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TYTHERINGTON QUARRY: 6 MILLION TONNES ADDITIONAL RESERVES

Environmental Statement: Chapter 9 Water Environment

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Environmental Statement: Chapter 9 Water Environment

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TABLES

9 WATER ENVIRONMENT

9.1 INTRODUCTION

9.1.1 This chapter reports the outcome of the assessment of likely significant effects arising from the Proposed Scheme upon the water environment. This chapter (and its associated figures and appendices) is intended to be read as part of the wider ES with particular reference to **Chapters 3: Description of Proposed Scheme**.

9.2 LIMITATIONS AND ASSUMPTIONS

9.2.1 The following limitations and assumptions are relevant to the assessment of the water environment:

- There remains some uncertainty regarding to what strata some of the Applicant's observation boreholes monitor. Borehole log information, together with analysis groundwater level hydrographs, contours and hydrochemical types have been used to establish the most plausible monitoring strata for each borehole.
- Water features categorised as 'wells' have been identified from Ordnance Survey maps (in addition to licensed or registered abstractions). Whilst their current status and purpose is unknown, they have been assumed in this study to still exist and to provide potable water.

9.3 POLICY AND LEGISLATIVE CONTEXT

9.3.1 This section identifies the legislation, planning policy and technical guidance that has informed the assessment of effects with respect to the water environment. Further information on policies relevant to the Proposed Scheme is provided in **Chapter 5: Planning policy overview** as well as in the accompanying Planning Statement.

LEGISLATIVE FRAMEWORK

9.3.2 Environmental legislation which is relevant to the life cycle of any large development and is relevant to the water environment have been considered in this assessment. The relevant legislation to the assessment of the effects on water environment receptors is as follows:

- Water Quality (Water Supply) Regulations 2016;
- The Water Environment (Water Framework Directive) (England and Wales) Regulations 2003;
- Water Act 2003;
- Water Resources (Environmental Impact Assessment) Regulations (England and Wales) 2003 (as amended);
- Groundwater Directive (2006/118/EC), as enacted into domestic law by the WFD[1] Regulations and Directions and EPR[2] Regulations;
- The EU Floods Directive (2007/60/EC), as enacted into domestic law by the Flood Risk Regulations 2009;

[1] WFD – Water Framework Directive
[2] EPR – Environmental Permitting Regulations

- Water Resources Act 1991 (Amendment) (England & Wales) Regulations 2009;
- Groundwater (England and Wales) Regulations 2009;
- Conservation of Habitats and Species Regulations 2010;
- Priority Substances Directive (2008/105/EC), as enacted into domestic law by the 2010 Directions listed above;
- Floods and Water Management Act 2010;
- River Basin Districts Typology, Standards and Groundwater threshold values (Water Framework Directive) (England and Wales) Directions 2010;
- Water Act 2014;
- Environmental Permitting (England and Wales) Regulations 2016 (as amended);
- Private Water Supplies (England) Regulations 2016;
- The Water Environment (Water Framework Directive) (England and Wales) Regulations 2017; and
- Conservation of Habitats and Species Regulations 2017.

9.3.3 A summary of the key legislative drivers is set out in **Table 9-1**.

Table 9-1 – Key legislative drivers relevant to the water environment assessment

Technical guidance document	Context
The Water and Environment (Water Framework Directive) (England and Wales) Regulations 2017[3]	Focuses on delivering an integrated approach to the protection and sustainable use of the water environment on a river basin scale.
Environmental Permitting (England and Wales) Regulations 2016 (Statutory Instrument (SI) 2016 No. 1154)[4]	Of relevance to surface water and drainage design due to infiltration to ground. The regulations include requirements for the prevention of hazardous substances entering groundwater and the control of non-hazardous pollutants to avoid pollution of groundwater (from revoked Groundwater (England and Wales) Regulations 2009).
The Water Resources Act 1991[5]	States that it is an offence to cause or knowing permit polluting, noxious, poisonous or any solid waste matter to enter controlled waters. The Act was revised by the *Water Act (2003)*[6], which sets out regulatory controls for water abstraction, discharge to water bodies, water impoundment and protection of water resources.
The Land Drainage Act 1991[7] and 1994[8]	Places responsibility for maintaining flows in watercourses on landowners and gives Local Authorities powers to serve a notice on

3 The Water Framework Directive (Standards and Classification) Directions (England and Wales) (2015), [online]. Available at: https://www.legislation.gov.uk/uksi/2015/1623/pdfs/uksiod_20151623_en_auto.pdf
4 The Environmental Permitting (England and Wales) Regulations 2016 together with subsequent amendments, [online]. Available at: https://www.legislation.gov.uk/uksi/2016/1154/pdfs/uksi_20161154_en.pdf
5 Water Resources Act 1991, [online]. Available at: https://www.legislation.gov.uk/ukpga/1991/57/contents
6 Water Act 2003, [online]. Available at: https://www.legislation.gov.uk/ukpga/2003/37/contents
7 Land Drainage Act 1991, [online]. Available at: https://www.legislation.gov.uk/ukpga/1991/59/contents
8 Land Drainage Act 1994, [online]. Available at: https://www.legislation.gov.uk/ukpga/1994/25/contents

Technical guidance document	Context
	landowners and to ensure works are carried out to maintain flow of watercourses.
The Flood Risk Regulations[9]	Published in December 2009, these transpose the EU Floods Directive into UK law.
The Flood and Water Management Act, 2010[10]	Sets out the Government's proposals to improve flood risk management, water quality and ensure water supplies are more secure. In December 2009, the Flood Risk Regulations were published, which transpose the EU Floods Directive into UK law, and these cover the flood issues from the Floods and Water Management Bill.

PLANNING POLICY

9.3.4 A summary of the relevant national and local planning policy is given in **Table 9-2**. The Planning Statement will cover the detail of actual policies.

Table 9-2 - Planning policy relevant to the Water Environment assessment

Policy	Policy context
National Policy:	
National Planning Policy Framework (NPPF) 2021[11] **Paragraph 153.**	NPPF Para 153 states that *"Plans should take a proactive approach to mitigating and adapting to climate change, taking into account the long-term implications for flood risk, coastal change, water supply".*
National Planning Policy Framework (NPPF) 2021[9] **Paragraph 174.**	NPPF Para 174 states that *"wherever possible, help to improve local environmental conditions such as air and water quality, taking into account relevant information such as river basin management plans."*
National Planning Practice Guidance, 2019 (NPPG)[12]	This sets out guidance regarding the need for and scope of assessments on the impact of developments on water quality. The water quality guidance was last updated in 2019, whilst the flood guidance was updated more recently in 2022.

9 The Flood Risk Regulations (2009). [online]. Available at: http://www.legislation.gov.uk/uksi/2009/3042/contents/made

10 The Flood and Water Management Act 2010, [online]. Available at: https://www.legislation.gov.uk/ukpga/2010/29/contents

11 Ministry of Housing, Communities & Local Government National Planning Policy Framework (NPPF) [online] available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1005759/NPPF_July_2021.pdf (Last accessed 17 August 2023)

12 Ministry of Housing, Communities & Local Government National Planning Practice Guidance (NPPG) Water supply, wastewater and water quality [online] available at: https://www.gov.uk/guidance/water-supply-wastewater-and-water-quality (Last accessed 17 August 2023)

Policy	Policy context
National Planning Practice Guidance, 2022 (NPPG)[13]	This sets out the guidance regarding how to take account of and address the risks associated with flooding in the planning process.
Local Policy:	
Minerals Local Plan for Gloucestershire (adopted March 2020)[14] **Policy DM04 Flood Risk**	Mineral development proposals will be permitted, where it can be demonstrated: • there will be no increase in the risk of flooding on site and elsewhere from all sources of flooding now and in the future; • wherever possible, flood risk reduction initiatives will be incorporated that will achieve a reduction in the risk of flooding overall; • appropriate measures will be put in place to manage and wherever possible, reduce surface water run-off including through the use of sustainable drainage systems (SuDS); • wherever possible, a net increase in flood water storage capacity will be achieved; • where applicable, flood flow routes will be improved such as through the removal of obstructions; • where applicable, there will be no detriment to the integrity of existing flood defences and that access to allow for their future maintenance or improvement will not be impeded • they accord with the policies contained in the River Severn, Severn Tidal Tributaries and Thames Catchment Flood Management Plans; and • any mineral processing plant, associated building(s), and / or equipment should be designed to remain operational, safe for users, and flood resilient during a flood event. Mineral development proposals will only be permitted in areas of flood risk (Flood Risk Zones 2, 3a or 3b) having taken into account climate change, where they have passed the Sequential Test and, where applicable, the Exception Test as set out in national policy. Mineral development proposals involving sand and gravel working along with water-compatible development158 may be appropriate within ‘Flood Risk Zone 3b’ or any identified ‘functional floodplain’, providing that: • there will be no net loss in flood storage and flood risk reduction measures (betterment opportunities) are provided where possible; • there will be no impediment to water flow routes; and

[13] Ministry of Housing, Communities & Local Government National Planning Practice Guidance (NPPG) Flood risk and coastal change [online] available at: https://www.gov.uk/guidance/flood-risk-and-coastal-change (Last accessed 17 August 2023)

[14] Gloucestershire County Council Minerals Local Plan [online] available at: https://www.gloucestershire.gov.uk/planning-and-environment/planning-policy/minerals/ (Last accessed 17 August 2023)

Policy	Policy context
	• any mineral processing plant, associated building(s), and / or equipment is designed to remain operational, safe for users, and flood resilient during a flood event. Mineral development proposals in areas of flood risk and where they exceed 1ha must be accompanied by a Flood Risk Assessment (FRA) that will shows how the risk of flooding on-site and elsewhere from all sources will not increase and, where possible could be reduced. The FRA must identify and assess the following: • all current and future sources of flooding, appropriately taking into account the anticipated impacts of climate change; • how flood risk on-site and elsewhere will be effectively managed for the lifetime of the proposal including during site restoration and aftercare; and • identify measures to prevent increased flood risk including through the use of sustainable drainage systems (SuDS) and compensatory works if any loss of flood storage capacity is expected to occur.
South Gloucestershire Local Plan Core Strategy (adopted December 2013)[15] **Policy CS1 High Quality Design**	As part of Policy CS1, development proposals will be required to take account of the South Gloucestershire Strategic Flood Risk Assessment and provide, where appropriate, measures to manage flood risk and prepare surface water management plans.
South Gloucestershire Local Plan Core Strategy **Policy CS32 Thornbury**	As part of Policy CS32, development plan document proposals will take account of the vision and partnership priorities for Thornbury, and will demonstrate through the preparation of appropriate Flood Risk Assessments, surface water management plans and drainage strategies, how flood risk will be managed.

9.3.5 In addition, this Chapter has been prepared in accordance with the Government's National Planning Practice Guidance (2020).

TECHNICAL GUIDANCE

9.3.6 A summary of the technical guidance for the water environment is given in **Table 9-3**.

[15] South Gloucestershire Local Plan Core Strategy (2006-2027) [online] available at: https://www.southglos.gov.uk/documents/cleanversionforinterimpublication2.pdf (Last accessed 17 August 2023)

Table 9-3 - Technical guidance relevant to the water environment assessment

Technical guidance document	Context
CIRIA (2001) C532: Control of water pollution from construction sites[16]	The guidance provides practical help for consultants and contractors on how to plan and manage construction projects to control water pollution.
CIRIA (2004) C624: Development and flood risk – guidance for the construction industry[17]	The document provides guidance on good practice in the assessment and management of flood risk as part of the development process.
CIRIA (2010) C688: Flood Resilience and resistance for critical infrastructure[18]	This document provides an overview of the regulatory framework for flood resilience and resistance in critical infrastructure and outlines the main issues now faced by organisations managing this infrastructure.
CIRIA (2006) C635: Designing for exceedance in urban drainage – good practice[19]	The guidance provides good practice advice to drainage engineers, regulators, planners and the construction industry on the design and management of urban sewerage and drainage systems to reduce the impacts from drainage exceedance.
CIRIA (2015) C741: Environmental good practice on site[20]	The guide is intended to be a reference and training aid which provides practical advice about managing construction on site to minimise environmental impacts.
CIRIA (2015) C753: The SuDS Manual[21]	The manual covers the planning, design, construction and maintenance of SuDS to assist with their effective implementation within both new and existing developments. Guidance is given on how to maximise amenity and biodiversity benefits while delivering the key objectives of managing flood risk and water quality.
Defra (2015) Sustainable Drainage Systems: Non-statutory technical standards for sustainable drainage systems[22]	The document sets out non-statutory technical standards for sustainable drainage systems. It is intended to be used in conjunction with the NPPF and NPPG.

[16] CIRIA (2001). C532: Control of water pollution from construction sites, [online]. Available at: http://www.ciria.org/ProductExcerpts/C532.aspx [Last accessed 17 August 2023]
[17] CIRIA (2004). C624: Development and flood risk – guidance for the construction industry, [online]. Available at: https://www.ciria.org/ItemDetail?iProductCode=C624 [Last accessed 17 August 2023]
[18] CIRIA (2010). C688: Flood Resilience and resistance for critical infrastructure, [online]. Available at: https://www.ciria.org/Resources/Free_publications/Flood_resilience.aspx [Last accessed]
[19] CIRIA (2006). C635: Designing for exceedance in urban drainage – good practice, [online]. Available at: https://www.ciria.org/Resources/Free_publications/SuDS_manual_C753.aspx [Last accessed]
[20] CIRIA (2015). C741: Environmental good practice on site, [online]. Available at: https://www.ciria.org/ItemDetail?iProductCode=C741D [Last accessed]
[21] CIRIA (2015). C753: The SuDS Manual, [online]. Available at: https://www.ciria.org/Resources/Free_publications/SuDS_manual_C753.aspx [Last accessed]
[22] Defra (2015). Sustainable Drainage Systems: Non-statutory technical standards for sustainable drainage systems, [online]. Available at: https://www.gov.uk/goverment/publications/sustainable-drainage-systems-non-statutory-technical-standards [Last accessed]

Technical guidance document	Context
West of England Partnership (2015) West of England Sustainable Drainage Developer Guide[23]	The guide signposts to existing policy and guidance to support the delivery of a sustainable approach to the drainage of new development in the West of England.
(WRc) (2012) Sewers for Adoption – A Design & Construction Guide for Developers: 7th Edition[24]	The guidance is intended for use by developers when planning, designing and constructing conventional foul and surface water gravity sewers and lateral drains for developments.

9.3.7 The chief custodian of the water environment is the Environment Agency (EA). The EA has a duty under the Water Resources Act 1991 to monitor and protect the quality of groundwater (Section 84) and to conserve its use for water resources (Section 19). It also has a duty (Section 16) to maintain and, where appropriate, enhance conservation of the surface water environment, which in many cases is dependent upon proper management of groundwater. Furthermore, it also must apply the principle of integrated groundwater protection and management as incorporated in the Water Framework Directive (WFD).

9.3.8 The EA's duties are set out in its strategy for Managing Water Abstraction (Environment Agency, 2021a). Under this strategy, River Basin Management Plans (RBMPs) provide the means by which the EA ensures that the requirements of the WFD are complied with. The Catchment Abstraction Management System (CAMS) is used to translate the RBMPs and the Water Abstraction Plan (Department for Food and Rural Affairs (Defra), 2021) into the licensing policy. As part of the CAMS process, the EA assesses the availability of both surface water and groundwater resources for abstraction using its Abstraction Licensing Strategies (ALSs). These determine how much water is available for abstraction on a catchment-by-catchment basis, based on the volume of water already licensed for abstraction and taking into account the requirements of the water environment. The Proposed Scheme lies within the Environment Agency's Bristol Avon and Little Avon Abstraction Licensing Strategies (ALS) area.

9.3.9 The EA applies these responsibilities not only in the use of its own powers, but also in seeking to influence the policies and decisions of others whose actions can affect the protection of surface water and groundwater. To this end, EA policy and general guidance relating to the water environment includes the following:

- Groundwater Protection [Online] (Environment Agency and Defra, 2017). Online groundwater protection guides covering requirements, permissions, risk assessments and controls (previously covered in the now withdrawn Groundwater Protection: Principles and Practice (GP3)), including:

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[23] West of England Partnership (2015). West of England Sustainable Drainage Developer Guide, [online]. Available at: https://www.bristol.gov.uk/documents/20182/34524/West+of+England+sustainable+drainage+developer+guide+section+1/864fe0d2-45bf-4240-95e2-a9d1962a0df9 [Last accessed]

[24] (WRc) (2012). Sewers for Adoption – A Design & Construction Guide for Developers: 7th Edition, [online]. Available at: http://sfa.wrcplc.co.uk/home.aspx [Last accessed]

- Environmental Permitting Guidance for Groundwater Activities (Defra, 2010);
- Protecting Our Water Soil and Air. A code of Good Agricultural Practice for farmers, growers and land managers (Defra, 2011);
- Prevent groundwater pollution from solvents ([Online] February 2016);
- Protect groundwater and prevent groundwater pollution ([Online] March 2017);
- Groundwater protection technical guidance ([Online] March 2017);
- Land contamination groundwater compliance points: quantitative risk assessments ([Online] March 2017);
- Groundwater risk assessment for your environmental permit ([Online] April 2018);
- Discharges to surface water and groundwater: environmental permits ([Online] May 2018); and
- Groundwater activity exclusions from environmental permits ([Online] July 2018).

- Hydrogeological impact appraisal for dewatering abstractions (2007); and
- Pollution Prevention Guidance Notes (PPGs, now discontinued), including:
  - PPG 1 Understanding your environmental responsibilities – good environmental practices (July 2013);
  - PPG 2 Above ground oil storage tanks (August 2011);
  - PPG 3 Use and design of oil separators in surface water drainage systems (April 2006);
  - PPG 4 Treatment and disposal of sewage where no foul sewer is available (July 2006);
  - PPG 5 Works and maintenance in, and near, water (October 2007);
  - PPG 6 Working at construction and demolition sites (March 2012);
  - PPG 8 Safe storage and disposal of used oils (February 2004);
  - PPG 21 Pollution incident response planning (March 2009); and
  - PPG 22 Dealing with spills (April 2011).

9.3.10 In executing its responsibilities with respect to groundwater, the EA acts in accordance with its published Approach to Groundwater Protection (2018). For its implementation, this approach partly relies on a hierarchy of protection zone maps (water protection zones, safeguard zones, source protection zones (SPZs) and vulnerability maps) that have been made public to allow the wide appreciation of groundwater protection issues. Position statements have also been derived by the EA that detail how it delivers government policy for groundwater and puts it into action with reference to key legislation, where it has freedom in the exercise of its powers and duties. The policy statements and the related maps and zones do not themselves have a statutory status. They instead form part of a consistent risk-based approach to decision-making with respect to the protection of groundwater.

9.3.11 With respect to quarrying activities of the type proposed here, the EA's 'Groundwater Resources' Position Statements N1 - N12 are of relevance. These statements seek to ensure that water resources and the water environment in the vicinity of the Proposed Scheme are managed and protected on a sustainable basis. With respect to protecting groundwater resources, Position Statement N5 states the following:

"*The Environment Agency will only authorise abstractions if it can be shown that*:

- *there will be no derogation of existing protected rights;*
- *there will be no unacceptable detriment to any groundwater-dependent environmental features such as rivers, lakes and wetlands;*

– *they can be managed so that they will not cause pollution;*
– *there will be no environmentally significant upward trends of pollutants through the intrusion of saline or polluted waters due to abstraction*."

9.3.12 Furthermore, Position Statement N7 states the requirement for an acceptable hydrogeological risk assessment (HRA), whilst Position Statement N11 states the following:

> *"For any proposal that would physically disturb aquifers, lower groundwater levels, or impede or intercept groundwater flow, the Environment Agency will seek to achieve equivalent protection for water resources and the related groundwater-dependent environment as if the effect were caused by a licensable abstraction."*

9.3.13 As mentioned earlier, the EA has published guidance (2007) on the evaluation of HIA from dewatering abstractions of the type proposed as part of Tytherington Quarry. The broad methodology is set out in a fourteen-step process, as outlined below:

- Step 1: Establish the regional water resource status;
- Step 2: Develop a conceptual model for the abstraction and the surrounding area;
- Step 3: Identify all potential water features that are susceptible to flow impacts;
- Step 4: Apportion the likely flow impacts to the water features;
- Step 5: Allow for the mitigating effects of any discharges, to arrive at net flow impacts;
- Step 6: Assess the significance of the net flow impacts;
- Step 7: Define the search area for drawdown impacts;
- Step 8: Identify all features in the search area that could be impacted by drawdown;
- Step 9: For all these features, predict the likely drawdown impacts;
- Step 10: Allow for the effects of measures taken to mitigate the drawdown impacts;
- Step 11: Assess the significance of the net drawdown impacts;
- Step 12: Assess the water quality impacts;
- Step 13: If necessary, redesign the mitigation measures to minimise the impacts; and
- Step 14: Develop a monitoring strategy.

9.3.14 This sequence of steps may seem onerous, but the process has a logical progression, and the steps impose some discipline on each appraisal. At the same time, the steps in the process are not prescriptive, and the level of effort expended on each step can be matched to the situation.

9.3.15 Other policy and general guidance relating to the water environment includes the following:

- Ministry for Agriculture, Fisheries and Food (MAFF): Good Practice Guide for Handling Soils (2000);
- Construction Industry Research and Information Association (CIRIA) Report C532: Control of Water Pollution from Construction Sites (2001);
- CIRIA Report C624: Development and Flood Risk – Guidance for the Construction Industry (2004);
- BS6031: Code of Practice for Earthworks (2009);
- Defra: Construction Code of Practice for the Sustainable Use of Soils on Construction Sites (2009);
- CIRIA Report C692: Environmental Good Practice on Site (2010); and
- Local and Regional Land Drainage Byelaws.

9.4 DATA GATHERING METHODOLOGY

STUDY AREA

9.4.1 Tytherington Quarry sits on top of three WFD river water bodies catchments but any effects on the water environment due to development activities are considered highly unlikely to extend over this large area. Therefore, a 4km search area, hereafter referred to as the 'Study Area', around the red line boundary of the 'extant planning permissions' area (**Figure 9.1**) is used on the basis that it is conservative and recognises that the hydrogeology of the area is complex and multi-layered. The same Study Area is used for both the surface water and the groundwater environment. It should certainly not be regarded as an indication that the Proposed Scheme is potentially impactful over a large area.

DESK STUDY

9.4.2 Sources of information used for the water environment assessment are listed in **Table 9-4**.

9.4.3 As set out in **Chapter 3**, the term Tytherington Quarry is used to refer to the extant quarrying operations being undertaken in Grovesend Quarry and Woodleaze Quarry (with all ongoing mineral extraction taking place from within the latter). Both quarries, together with the soil store area, are shown on **Figure 9.1** and fall within the extant planning permissions red line boundaries. Historically, minerals were also extracted from the now exhausted North Face Quarry to the north of Grovesend, which is also shown on the figure. This site has since been sold to a third party and is now occupied by a large quarry pond, which is included in the routine water level monitoring (as detailed in Section: Hydrogeology below) commissioned by the Applicant and being carried out around the three quarries, namely North Face, Grovesend and Woodleaze.

9.4.4 Whilst the Proposed Scheme only covers Grovesend and Woodleaze Quarries (including and the soil store area), all the three quarries need to be regarded for the water environment. Thus, as part of the water environment assessment, hereafter the term 'Tytherington Quarry Complex' ('Quarry Complex' for short) is used to refer to all three quarries, i.e. (from north to south) North Face Quarry, Grovesend Quarry and Woodleaze Quarry (including the soil store area). The red line boundary of the 'extant planning permissions' area is hereafter referred as 'the Site'.

Table 9-4 - Sources of desk study information

Source	Data
Bing Ordnance Survey (OS) Maps https://www.bing.com/maps/?cp=51.593194%7E-2.49582&lvl=14.5&style=s	Topography (elevation, relief, springs, wells)
Lidar DTM (1m resolution) OS 50 Terrain	Ground elevation
LandIS - Land Information System - Soilscapes soil types viewer https://www.landis.org.uk/soilscapes/	Soil types
Environment Agency records	Authorised and historic landfills

Source	Data
Permitted Waste Sites - Authorised Landfill Site Boundaries - data.gov.uk Permitted Waste Sites - Authorised Landfill Site Boundaries - data.gov.uk Historic Landfill Sites - data.gov.uk	
Met Office UK Climate averages https://www.metoffice.gov.uk/research/climate/maps-and-data/uk-climate-averages/gcj9q6c2v	Climate (rainfall, temperature, wind speed)
Centre for Ecology and Hydrology (CEH, 2018b) -National River Flow Archive On-line http://nrfa.ceh.ac.uk/	River flow and catchment descriptions
Stream flow data (15 min) from the Tytherington Quarry Complex hydrometric monitoring network at Owlsnest Farm Watercourse (applicant data)	Stream flow monitoring
Flow data from Environment Agency flow gauging stations	Stream flow monitoring
BGS Digital Mapping 1:50,000 BGS Geoindex Online https://www.bgs.ac.uk/geoindex/ BGS Lexicon of Named Rock Units http://www.bgs.ac.uk/lexicon	Geology (bedrock and superficial deposits geology) Stratigraphic and lithological information Borehole locations and scanned logs.
Aquifer properties: Allen et al (1997) and Jones (2000)	Hydrogeological characteristics
Various Tytherington Quarry site investigation reports focussing on geology and hydrogeology provided by applicant, see Table 9-8	Geology/hydrogeology
BGS Digital Mapping and MAGIC (2024)	Aquifer designation map
Monthly groundwater level data from the Tytherington Quarry Complex hydrometric monitoring network (applicant data)	Groundwater level data
Severn River Basin District River Basin Management Plan https://www.gov.uk/guidance/severn-river-basin-district-river-basin-management-plan-updated-2022	Groundwater quality
Groundwater samples from Entec (1998)	Groundwater quality

Source	Data
Environment Agency Water Information Management System (WIMS) Water quality data	Groundwater and surface water quality
Bristol Avon and North Somerset Streams WFD Management Area Abstraction Licensing Strategy https://www.gov.uk/government/publications/bristol-avon-and-north-somerset-abstraction-licensing-strategy Abstraction Licensing Strategy boundaries Cycle 2 - data.gov.uk	Abstraction Licensing Strategies
Multi-Agency Geographic Information for the Countryside (MAGIC, 2024) https://magic.defra.gov.uk/MagicMap.aspx	Conservation sites, groundwater vulnerability map, aquifer designation map, Groundwater Source Protection Zones (SPZs)
Open Government Data On-line (Open Government Data) https://data.gov.uk/dataset/72a149a2-1be7-441f-bc37-94a77f261e27/groundwater-dependent-terrestrial-ecosystems-england-only	Groundwater dependent terrestrial ecosystems
South Gloucestershire Council private water supply records	Private water supply abstractions
Environment Agency, 2024. Flood Map for Planning. https://flood-map-for-planning.service.gov.uk/ Environment Agency, 2024. Flood Map for long-term flood risk. Flood https://www.gov.uk/check-long-term-flood-risk	Flood Risk Assessment

SITE VISIT

9.4.5 A site visit to Tytherington Village to identify and observe the consent discharge location and downstream channel was conducted between 10:15 and 11:00 on 26 March 2024. The consent discharge location was identified to be at NGR ST 66995 88249 (also shown in **Figure 9.3**) beside Duck Street in Tytherington Village. The discharged water flows out of the culvert into a concrete square channel below the stone fence and flows in a southeast direction parallel to Duck Street.

9.4.6 The channel receiving the discharge from the Quarry Dewatering (**Figure 9.3**) runs parallel to Duck Street (on its southeastern side) and consists of a series of open channels and culverts. The sections of open channel range from 15m to 160m in length. After crossing under Walnut Field Street, the channel runs parallel to an agriculture field. At the end of the agricultural field and Duck Street, a residential property is located at the point of the final culvert. It is then understood that the channel daylights again in the agricultural fields to the southeast of Tytherington Village where the watercourse continues in a natural open channel before joining the Ladden Brook 1.3km southeast of Tytherington. This section was not visited as it was located on private land. The smallest of the culverts is that immediately downstream of the discharge point and has a cross-sectional area of around $0.06m^2$.

9.5 OVERALL BASELINE

CURRENT BASLINE

9.5.1 This section describes the current baseline environmental characteristics for the development site and surrounding areas within the Study Area, with reference to the water environment.

Location, landscape and topography

9.5.2 On a regional scale the Quarry Complex is situated between the Cotswold Hills in the east with heights reaching above 200 m and the Severn Estuary at sea level to the west.

9.5.3 The digital terrain model (DTM) for the wider area around the Quarry Complex is presented in **Figure 9.2**. This is based on Lidar DTM data (1 m resolution) and, for the Quarry Complex, on a survey from November 2022. The elevation contours from the survey are also shown in **Figure 9.3**.

9.5.4 The Quarry Complex is positioned on a southwest to northeast trending ridge and sits on top of three surface water catchments. As such the Quarry Complex coincides with a surface water divide between the rivers Severn (via Oldbury Naite Rhine catchment in the northwest and Tortworth Brook/Little Avon River catchment in the northeast), and the River Avon (via the Ladden Brook / River Frome catchment in the southeast).

9.5.5 The ridgeline, which hosts the Quarry Complex is broad linear and runs on a north-east to south-west axis at an elevation of ~100 m Above Ordnance Datum (m AOD). Descending, gently rolling, south-east facing slopes fall towards and contain the Tytherington Plain and Earthcott Vale to the east, which lie between ~50 to 65 m AOD. A small bluff forming Tytherington Hill lies between the settlement of Tytherington and the M5 motorway. In the subdued topography north and northwest of Chipping Sodbury, which encompasses the Quarry Complex the dipping limestones form a distinct escarpment (WRc, 1997).

Soils and land Use

9.5.6 The Land Information System (LandIS) - Soilscapes soil types viewer[25] indicates that the majority of the Study Area is hosts freely draining slightly acid but base-rich soils. The soils are freely draining and have a loamy texture. The soils drain to groundwater. The landcover is recorded as arable grassland containing base-rich pastures and deciduous woodlands.

9.5.7 Soils in the northwest corner and the southeast corner of the Study Area are composed of slowly permeable seasonably wet slightly acid but base-rich loamy and clayey soils. The soils here impede drainage and have a loamy and clayey texture. The soils drain to the stream network. The landcover within the Study Area is recorded as grassland and arable with some woodland, containing seasonally wet pastures and woodlands.

Landfills

9.5.8 There are no permitted waste or authorised landfill sites within the Study Area.

[25] Land Information System (LandIS) - Soilscapes soil types viewer (online). Available from https://www.landis.org.uk/soilscapes/

9.5.9 There are two historic landfill sites located within the Study Area (**Figure 9.12**), namely Greenhill Quarry and Westwinds. Greenhill Quarry Is located approximately 2.4km west of the Site boundary. The site operator is recorded as AJ Saunders and Company with first input of waste dated 31 December 1964 and the last recorded input as 31 July 1973. Westwinds is located 1km northwest of the Site boundary. The license holder is recorded as PM penny with the first input of waste recorded 30 September 1981 and the last recorded waste input as 31 December 1984. Waste is recorded as inert, industrial, commercial, and household. The license was surrendered on 27 September 1993.

Climate

9.5.10 The nearest weather station to the Site with data available on the Met Office UK Climate averages webpage is Filton in Gloucestershire (see small scale insert on **Figure 9.2**), which is located 9.4 km to the southwest of the Site. The local baseline climate data reflects the regional variables and is summarised within **Table 9-5**. Although data from the climate period 1991 to 2020 is now available, the baseline draws from 1981 – 2010 as more representative of current operations and aligns more closely to the baseline used in the UKCP18 future climate data. The average annual rainfall for Filton climate station over the period discussed above is 802 mm/a.

Table 9-5 – Baseline climate data 1981-2010[26]

1981-2010	Filton Station	District: Midlands	England
Mean monthly rainfall (mm)	802.14	792.75	849.79
Days of rainfall > 1mm (days per year)	125.91	130.46	133.01
Minimum Annual Temperature (°C)	7.04	5.63	5.85
Maximum Annual Temperature (°C)	14.21	13.41	13.46
Mean wind speed at 10m (knots)	8.44	7.94	8.44
Air Frost (days per year)	34.93	53.09	49.70

9.5.11 BCL (2023) gathered additional rainfall data from the Environment Agency Cromhall Sewage Treatment Works (STW) rain gauge No. 419923 (no data available for this on the Met Office UK Climate averages webpage). This rain gauge is located some 2km east-southeast of the Quarry Complex (NGR ST 6851 8939, see also small scale insert on **Figure 9.2**) and is considered in BCL (2023) as suitably reflective of the hydrometric conditions likely to be experienced at the Quarry Complex site. The average rainfall for this rain gauge over the period 1995 to 2023 amounts to 788.7 mm/a.

[26] Met Office UK Climate averages (online). Available from: https://www.metoffice.gov.uk/research/climate/maps-and-data/uk-climate-averages/gcj9q6c2v. (Accessed 04 March 2024).

9.5.12 WRc (1997) provides some additional more historic data. The authors refer to the Wessex Appendix (NRA, 1992) which states that more rain falls in the west of the Wessex region than in the east, and hilly areas attract more rain than low ground. Long term average for the Tytherington area is according to NRA (1992) between 750 mm/a and 800 mm/a (NRA, 1995 quoted in WRc, 1997). Average rainfall between 1916 and 1950 at former rain gauge in Tytherington (ST 668 884) was 883 mm/a. Potential evapotranspiration in the Wessex Region is approximately 500 to 550 mm/a on the Mendip hill to the southwest of Tytherington, this reduces to approximately 250 mm on the Salisbury plain. The level for Tytherington will lie between these values.

9.5.13 Additional climate details can be found in **Chapter 13: Climate Change – Climate Change Resilience** and **Chapter 14: Climate Change – Greenhouse Gas Emissions**.

Hydrology

Watercourses

9.5.14 OS mapping and data received from the Environment Agency and the Centre for Ecology and Hydrology National River Flow Archive have been used to characterise the baseline hydrology for the Study Area.

9.5.15 There are no natural watercourses within the Site. However, hydrologically the Site lies within the upstream catchments of the Tortworth Brook to the north-east, the Ladden Brook to the east and the Oldbury Naite Rhine to the west (**Figure 9.2**).

Tortworth Brook

9.5.16 Tortworth Brook is located ~2km northeast of the Site, and has a tributary located 2.5km northeast of the Site. The watercourse originates in Talbots End/Cromhall 4km north-east of the Site, from Talbots End it flows south and then west to Heath End, where the watercourse spans north joining the Litte Avon at a confluence east of Stone before discharging to the Severn Estuary.

Ladden Brook

9.5.17 The main Ladden Brook rises in the centre of Ladden Garden Village ~9km southeast of the Site, and flows to the northwest, before turning southwards flowing Ladden Brook (tributary to the Bristol Frome/Avon).

9.5.18 The course of the Ladden Brook and its south easterly headwaters mimics the strike of the strata which makes up the Coalpit Heath syncline (discussed in more detail in geology section), i.e. it flows NNW within Coal Measures (east of the synclinal axis), then bends around the axis into a SSW direction (west of the synclinal axis) flowing over initially Coal Measures and then Mercia Mudstone, i.e. it flows around a spur of harder rock formed by the Mangotsfield Sandstone in the core of the syncline.

9.5.19 The Tytherington Watercourse is a tributary of the Ladden Brook and rises in the centre of the Tytherington Village, ~1km east of the Site. The Tytherington Watercourse flows east before joining the Ladden Brook. As discussed under the site visit section, this watercourse consists of a series of open channels and culverts and receives the discharge from the Quarry Complex dewatering. Apart from the discharge point, **Figure 9.3** also shows a spring (SP02, discussed further below). Prior to the stream support of the discharge, it is understood that this spring would have fed the Tytherington Watercourse.

Oldbury Naite Rhine

9.5.20 A headwater of the Oldbury Naite Rhine lies ~400m to the north-west of the Site near Thornbury Village, and flows northwards before joining another tributary, turning westwards to then flow to the Severn Estuary at Oldbury Pill.

Flow gauging

9.5.21 There are no EA flow gauging stations on the Tortworth Brook, Ladden Brook or the Oldbury Naite Rhine, but only on downstream water bodies. The closest continuous EA flow gauging stations are located at Berkeley (Station ID 54088 - Little Avon at Berkeley Kennels) and Frampton Cotterel (Station 53026 - Frome (Bristol) at Frampton Cotterell). Both are well outside the Study Area (see small scale insert on **Figure 9.2**) but briefly discussed here.

9.5.22 The Berkeley station is located ~5.4km north of the Site on the Little Avon, a downstream water body of the Tortworth Brook and the Frampton Cotterell station is ~9.9km south of the Site on the River Frome, downstream of the Ladden Brook. Catchment information and long-term flow parameters of the two gauging stations are shown in **Table 9-6**.

Table 9-6 – River flows and catchment information

	54088 - Little Avon at Berkeley Kennels	53026 - Frome (Bristol) at Frampton Cotterell
NGR	ST682987	ST667822
Catchment area (km^2)	134	78.5
BFI (Base Flow Index)	0.55	0.4
Q10 flow (m^3/s)	2.552	2.532
Q95 flow (m^3/s)	0.233	0.089
Mean flow (m^3/s)	1.216	1.007
Flow record period	1979 - 2024	1978 - 2024
Mean Annual Rainfall (MAR, mm)	806	800
HER* (mean flow/catchment area) (mm/year)	268.18	404.54
HER as % Rainfall	35.8%	50.6%
Peak record flow (m^3/s)	Not available	17.65
Peak recorded flow date	Not available	20/01/1999

9.5.23 Flow gauging does form part of the Quarry Complex water monitoring and 15 min flow readings are collected in the ephemeral Owlsnest Farm Stream to the south of Tytherington Quarry since 2005. Details of these flows were reported in BCL (2023) as:

“*Flow conditions at the monitoring point are sensitive to volumetric and temporal variations in rainfall conditions (as would be expected for an ephemeral spring in limestone terrain). Flows are generally recorded at the monitoring point for 18-40% of the year, with the majority of flow occurring during six-month period October to March*”.

Geology

Geological overview

9.5.24 The Bristol and Gloucester district is one of the geologically most varied parts of Britain (Green,1992). WRc (1997) presents a useful overview of the regional geology around the Quarry Complex which is reproduced in this section. The Wessex geology consists of an older basement and younger cover. The basement rocks outcrop in a wide zone along the Bristol Channel.

9.5.25 As can be seen from the simplified geological map of the Tytherington area after WRc (1997) in **Figure 9.4** and also the British Geological Survey (BGS) 1:50k bedrock geology mapping (**Figure 9.5**) the Carboniferous Limestone of the Mendips and around Bristol are strongly folded and faulted. Over much of the Study Area, the cover rocks, which are largely of Permo-Triassic age, are flat lying or dip at very gently angles, typically 2 to 3°. Faults are common, usually parallel or at right angles to the main tectonic trends in the underlying basement.

9.5.26 The Quarry Complex is sited on the western flank of a north-south syncline with Carboniferous Limestone strata dipping generally to the southeast. The nose of a larger syncline, referred to in Green (1992) as ‘Coalpit Heath’ syncline and shown on **Figure 9.5**, lies ~3 km to the east (**Figures 9.4** and **9.5**) of the Site. The Wickhill Quarry (**Figure 9.4**), targeting the same limestones as the Site, lies on the opposite flank of the syncline with the strata dipping there to southwest (15 to 40°).

9.5.27 **Figures 9.4** and **9.5** show the syncline to be bisected by a major NNE-SSW fault (Berkeley Fault in Green, 1992) with the downthrow block to the east.

9.5.28 Haynes (1972) reviewed dip measurements at North Face Quarry and confirmed the existence of a smaller syncline with its nose in the northern part of North Face Quarry. This syncline is also apparent from the strata rockhead on both map figures and its synclinal axis has been added to **Figure 9.5**. This smaller fold sits as a subfold within the western limb of the larger Coalpit Heath syncline and with its axis being parallel to the latter. Owing to this subfold structure, strata dip at steeper angles of between 20 to 40° at Woodleaze and Grovesend Quarries (Figure 9.4) and at shallower angles to as low as 10° at North Face Quarry (Haynes, 1972).

9.5.29 Parallel to this subfold runs a second fault (referred to in Haynes (1972) as ‘Whitfield Fault’) of more limited longitudinal extent compared to the Berkeley Fault. The Whitfield Fault is identified on both geological map figures between the Quarry Complex and the village of Tytherington.

9.5.30 The limestone strata extracted from Quarry Complex comprise the Black Rock Dolomite/Limestone and Gully Oolite Formations. These are present in outcrop as northeast-southwest linear exposure, bounded to the northwest by the Lower Limestone Shale and to the southeast by the Clifton Down Mudstone.

Regional geology

9.5.31 The regional bedrock geology of the Study Area is mapped at rockhead on **Figure 9.5**, using the latest digital British Geological Survey (BGS) 1:50k bedrock geology mapping. This data is also presented in **Table 9-7** with additional information extracted from the BGS Lexicon of Named Rock Units (BGS, 2024b). The BGS LEX-RCS identifier is shown in both **Table 9-7** and **Figure 9.5** to better link the two. The older Bristol District solid and drift geology map (1:10,560 series has also been accessed online (BGS,1962)). The BGS aquifer designation (**Figure 9.8**) has been assigned in GIS to each strata of **Table 9-7** and added in the last table column.

Table 9-7 – Regional geological succession (BGS, 2024b) and aquifer designation

Era	Period	Stage	BGS nomenclature	Rock types	LEX-RCS identifier (Figure 9.5)	Regional thickness (m)	Aquifer designation
Mesozoic	Jurassic	Rhaetian	Blue Lias Formation	Limestone and mudstone, interbedded	BLI-LSMD	To c.140	Secondary A
				Mudstone	BLI-MDST		Secondary (undifferentiated)
				Mudstone and limestone, interbedded	BLI-MDLM		Secondary A
	Triassic		Penarth Group	Mudstone	PNG-MDST	0 to >12	Secondary (undifferentiated)
			Westbury Formation and Cotham Member (Undifferentiated)	Mudstone	WBCT-MDST	None recorded or not applicable	Secondary B
		Norian	Blue Anchor Formation	Mudstone	BAN-MDST	5 to 67.2	Secondary B
		Not defined	Mercia Mudstone Group (incl. Marginal Facies)	Mudstone	MMG-MDST	Thickness variation is considerable, ranging up to 1350 m in the Cheshire Basin.	Secondary B
				Conglomerate	MMMF-CONG	<1 to >100	Principal

Era	Period	Stage	BGS nomenclature	Rock types	LEX-RCS identifier (Figure 9.5)	Regional thickness (m)	Aquifer designation
				Mudstone, siltstone and sandstone	MMG-MDSS	Thickness variation is considerable, ranging up to 1350 m in the Cheshire Basin.	Secondary B
Palaeozoic	Carboniferous	Westphalian	Mangotsfield Member	Sandstone	MGF-SDST	450 to 580	Secondary A
				Mudstone, siltstone and sandstone	MGF-MDSS		Secondary A
			Downend Member	Mudstone	DN-MDST	120 to 660, typically 275	Secondary A
			South Wales Lower Coal Measures Formation and South Wales Middle Coal Measures Formation (Undifferentiated)	Sandstone	SWLMC-SDST	None recorded or not applicable	Secondary A
				Mudstone, siltstone and sandstone	SWLMC-MDSS	None recorded or not applicable	Secondary A
		Namurian	Marros Group	Sandstone	MARR-SDST	20 to 750	Secondary A
				Mudstone, siltstone and sandstone	MARR-MDSS		Secondary A
		Visean	Tanhouse Limestone	Limestone	TL-LMST	c.5	Principal
			Oxwich Head Limestone Formation	Limestone	OHL-LMST	125 to 183	Principal

Era	Period	Stage	BGS nomenclature	Rock types	LEX-RCS identifier (Figure 9.5)	Regional thickness (m)	Aquifer designation
				Limestone, ooidal	OHL-LMOOL		Principal
Palaeozoic			Clifton Down Limestone Formation	Limestone	CDL-LMST	137	Principal
			Cromhall Sandstone Formation[27]	Sandstone	CHSA-SDST	30	Principal
			Clifton Down Mudstone Formation	Dolomite-mudstone	CDM-DLMDST	60	Secondary A
			Gully Oolite Formation	Limestone, ooidal	GUO-LMOOL	19-83	Principal
		Tournaisian	Black Rock Limestone Subgroup	Dolostone	BRL-DOLO	104 to 158	Principal
				Limestone	BRL-LMST		Principal
				Mudstone and limestone, interbedded	AVO-MDLM	54 to 96	Secondary A

[27] Hanson (2009a and 2009b) differentiate between the 'Lower Cromhall Sandstone Formation' and the 'Middle Cromhall Sandstone Formation' with the Clifton Down Limestone in between. The BGS 50k bedrock geology map (Figure 9.5) shows the Clifton Down Limestone sandwiched between two sandstone layers, both being referred to on the map as 'Cromhall Sandstone'.

Era	Period	Stage	BGS nomenclature	Rock types	LEX-RCS identifier (Figure 9.5)	Regional thickness (m)	Aquifer designation
			Avon Group (previous name: Lower Limestone Shales)	Limestone	AVO-LMST		Principal
	Devonian	Famennian (Upper Old Red Sandstone)	Tintern Sandstone Formation	Sandstone	TSG-SDST	Up to 75	Secondary A
			Quartz Conglomerate Formation (Forest of Dean)	Sandstone and conglomerate, interbedded	QC-SCON	Up to 30	Secondary A
			Quartz Conglomerate Formation	Conglomerate and sandstone, interbedded	QTZC-COSD	None recorded or not applicable	Secondary A
	Silurian	Not Defined (Lower Old Red Sandstone)	Raglan Mudstone Formation	Siltstone and mudstone, interbedded	RG-SIMD	To c.800	Secondary A
		Not Defined	Brinkmarsh Beds	Mudstone, calcareous	BKM-CAMDST	None recorded or not applicable	Secondary B
				Limestone	BKM-LMST	None recorded or not applicable	Secondary A
				Sandstone, calcareous	BKM-CALSST	None recorded or not applicable	Secondary B
		Telychian	Tortworth Beds	Mudstone	TOB-MDST	c.61	Secondary B

Era	Period	Stage	BGS nomenclature	Rock types	LEX-RCS identifier (Figure 9.5)	Regional thickness (m)	Aquifer designation
			Damery Beds	Mudstone and sandstone, interbedded	DAB-MDSA	None recorded or not applicable	Secondary B

9.5.32 The area around Tytherington Quarry is largely covered by Triassic strata, except where it has eroded (Green,1992) to the west and east of the quarry following topographic highs and also to the north of the quarry. In these areas the older Palaeozoic strata is revealed, consisting from north to south of Silurian, Devonian and Carboniferous.

9.5.33 The Silurian rocks of the Damery Beds, Tortworth Beds and Brinkmarsh Beds found within the Study Area comprise according to Green (1992) shallow-water, arenaceous and argillaceous, marine sedimentary rocks with some limestone. They accumulated in the southern part of a wide, intermittently, but gently subsiding shelf region that separated the rapidly subsiding Welsh Basin to the north-west from a land area called the Midland Block that lay to the east and the south. The Raglan Mudstone Formation represents the uppermost Silurian strata and also forms part of the Lower Old Red Sandstone. Its depositional environment was a wide alluvial plain intersected by rivers of moderate to high sinuosity draining towards the south (Green, 1992).

9.5.34 The Devonian (Upper Old Red Sandstone, terrigenous sediment) is divided into the basal Quartz Conglomerate and the overlying Tintern Sandstone, composed predominantly of interbedded sandstone and conglomerate.

9.5.35 The Carboniferous period is divided into four epochs, namely the (from old to young, with rough equivalents in brackets, Toghill (2000)):

- Dinantian (Tournaisian and Visean in **Table 9-7**, Carboniferous Limestone);
- Namurian (Millstone Grit);
- Westphalian (Coal Measures); and
- Stephanian, which is not present in the Study Area.

9.5.36 By the end of the Devonian the Old Red Sandstone continent was invaded by marine transgressions. The British area was astride the equator and the shallow early Carboniferous seas were very warm and laid down shallow-water tropical carbonates (Toghill, 2000), which are represented in the Study Area as the Carboniferous Limestone. The latter includes the Black Rock Limestone Subgroup, the Gully Oolite Formation, and Clifton Down Limestone Formation which are being excavated at the Quarry Complex. At a later stage, these shallow seas were invaded by deltas formed by rivers flowing in from adjacent hight ground and the sandstones formed in these deltas became the Millstone Grits. The climate then became humid, and these deltas started to support swamps and tropical rain forest growths. The burial and decay of luxuriant vegetation led to the eventual formation of numerous coal seams and the formation of the Coal Measures. These are exposed in the southeast of the Study Area where they form the northwestern limb of the former coal pit of the Heath Syncline (Green, 1992).

9.5.37 Towards the end of the period the Varican orogeny caused the British areas to rise above sea level and a change from a humid to an arid climate which caused the formation of continental sediments of the Permo-Triassic. These consist of (from old to young, see **Table 9-7)** the:

- Bridgnorth Sandstone Formation (Perm);
- Sherwood Sandstone Group (Permo-Triassic);
- Mercia Mudstone Group;

- Blue Anchor Formation;
- Westbury Formation and Cotham Member; and
- Penarth Group.

9.5.38 Both, the Bridgnorth Sandstone Formation and the Sherwood Sandstone Group are absent in the Bristol-Mendip district (including the Study Area), where the Mercia Mudstone Group rocks have overstepped directly onto the Coal Measures and older rocks (Green, 1992). The desert type Mercia Mudstone Group change colour from reddish brown to green in the overlying Blue Anchor Formation, probably caused by iron oxides reduction within increased organic content (Toghill, 2000). The Blue Anchor Formation is followed by the Rhaetian Penarth Group, which indicates a change to marine conditions at the end of the Triassic (Toghill, 2000).

9.5.39 During the Jurassic the Mendips formed an island archipelago surrounded by warm, shallow seas. Away from the islands, the cyclical mudstones and limestones of the Blue Lias were deposited. Near to the islands where the water was shallowest, coarse-grained, littoral and sub-littoral sediments were deposited and these now occur around the flanks of the Mendips and in the Study Area (Entec, 2010).

Superficial deposits

9.5.40 Superficial deposits are sparsely distributed around the Study Area as can been seen from the digital BGS 1:50k superficial deposits geology mapping presented in **Figure 9.7**. Tidal flat deposits extent into the northwest of the Study Area along the un-named headwaters of the Oldbury Naite Rhine. Alluvium flanks the Ladden Brook over its entire length within the Study Area and is also present along parts of the un-named Tortworth Brook headwaters. There is a larger area of river terrace deposits bound to the north by a western un-named tributary of the Ladden Brook which reaches southwards beyond the second parallel Ladden Brook tributary. Head deposits are mapped to the northeast of the Site and partially along the Tortworth Brook headwaters. The BGS mapping shows no superficial deposits within or in the immediate vicinity of the site.

Local geology

9.5.41 Various site investigation reports, some of which present the findings from exploration boreholes for the various Tytherington Quarries, provide an additional refined understanding of the local geology. These are listed in **Table 9-8**.

Table 9-8 – Tytherington Quarries site investigation reports

Report reference	Report title	Investigation area and summary of scope
Haynes (1972)	Tytherington drilling survey	North Face Quarry: eight exploration boreholes ahead of development of northern part.
ARC Technical Department (1974)	Further investigations at Tytherington Quarry from June to November 1974.	North Face Quarry: one exploration boreholes ahead of quarry development.

Report reference	Report title	Investigation area and summary of scope
Entec (1998)	Site investigation at Tytherington Quarry	Covers installation of piezometers P1 to P6 around the three quarries.
ARC, undated	Scanned logs for Tytherington Quarry exploration boreholes, no associated report.	All three quarries and proposed quarry extension area to the southwest. Logs for a total of 32 Tytherington Quarry exploration boreholes (BH5 to 39), drilled between June 1972 and July 1989.
Hanson (2006)	Scanned logs for Woodleaze Quarry exploration trial pits, no associated report.	Southwestern part of Woodleaze Quarry. Logs for 25 exploration trial pits (0406/01 to 0406/25) from 2006 and location plan.
Hanson (2009a and 2009b)	Tytherington Quarry geological plan and three cross sections	One northwest-southeast section for each of the three Thrislington Quarries and geological plan.
GWP Consultants (2022a)	Core drilling in 2021-2022 in the proposed extension southwest of Woodleaze Quarry	Proposed quarry extension area to the southwest of Woodleaze Quarry: nine exploration boreholes
GWP Consultants (2022b)	Open hole drilling In August 2022 to test the overburden thickness in parts of the proposed extension area southwest of Woodleaze Quarry	Proposed quarry extension area to the southwest of Woodleaze Quarry: trial pits and shallow (<10m deep) boreholes to determine thickness of the Penarth Group.

9.5.42 A geological plan and three cross sections are reproduced from Hanson (2009a and 2009b) in **Figures 9.6a** and **9.6b**, respectively. These were produced by the engineering geologist of the applicant at the time as part of a geotechnical assessment. The map and sections show the general geological setting of the Tytherington Quarry Complex with one northwest-southeast cross section for each of the three quarries. It is understood that a combination of BGS maps, quarry outcrops, core drilling and trial pitting data were used to produce these schematic sections. The various exploration boreholes drilled as part of the investigations listed in **Table** 9-8 have been added to **Figure 9.6a**, grouped by drilling/investigation year.

9.5.43 The Clifton Down Limestone is sandwiched by two sandstone layers which are on the BGS geology map (**Figure 9.5**) both referred to as 'Cromhall Sandstone Formation'. However, the local geology map of **Figure 9.6a** differentiates these as 'Lower' and 'Middle Cromhall Sandstone Formation'.

9.5.44 The local bedrock map confirms the three Tytherington Quarries to be located on an outcrop of the Black Rock Limestone and the Black Rock Dolomite. For the two quarries to the southeast, the further south the quarry, the more additional younger strata is exposed south eastwards in down dip direction, i.e. the Grovesend Quarry extends south eastwards into the Gully Oolite and Clifton Down Mudstones and the southeast corner of Woodleaze Quarry, including the soil store area , extends further to close to the Cromhall Sandstone. The latter strata are overlain in the far southeast of the section by sediments of the Triassic Penarth Group.

9.5.45 The three cross sections show the dip of the strata to the southeast. A shallower dip in the North Face Quarry section compared to the two southern sections is apparent. In all three sections, the Black Rock Limestone is underlain by the Avon Group (former 'Lower Limestone Shales', interbedded mudstones and limestones) with a thickness of a few tens of metres, but question marks along the strata boundary imply uncertainties with regards to the actual thickness of this strata underneath the quarries. The local geological map shows the Quarry Complex to be bounded along its western and northern boundary by the underlying Avon Group.

9.5.46 The BGS nomenclature distinguishes within the Avon Group between an upper part made up of 'mudstone and limestone, interbedded' and a lower part of limestone (**Table 9-7**). However, according to the BGS bedrock map (**Figure 9.5**) the lower limestone dominated part of the Avon Group is only present north of the Quarry Complex, along the sub fold nose and also further away in the west, separated by a fault. Whereas it is absent along the northwestern boundary of the Quarry Complex, i.e. the upper mudstone/limestone part of the Avon Group is directly underlain by the Tintern Sandstone.

9.5.47 In the most southern section C, the Gulley Oolite is covered by the Clifton Down Mudstone with a thickness of approximately 50m. The latter is much thinner in the Grovesend Quarry section and, it does not feature at all in the North Face Quarry, i.e. it outcrops further southeast of the section line, as a result of the sub fold structure described above, leaving Black Rock Dolomite cropping out at the southeastern end of the section. The legend of **Figure 9.6a** does not make this spatial distinction, i.e. the Avon Group is specified with a limestone band at the base throughout.

9.5.48 The Devonian Tintern Sandstone Formation underneath the Avon Group outcrops in the northwest and further northeast of the Quarry Complex and forms a morphological scarp.

9.5.49 GWP (2022) presents and summarises logs for exploration boreholes which were drilled over the winter of 2021 and spring of 2022 in the proposed extension area to the southwest of Woodleaze Quarry (named as 2021-1 to 2021-9, implying year 2021 only, but marked as either 2021 crosses or 2022 diamonds reflecting their actual drilling year on **Figure 9.6a**). A total of nine cored boreholes with depths ranging between 60 and 216 m bGL were drilled, and in two boreholes 2021-8 and 2021-9 in the far southwest, piezometers were installed (named '8_21' and '9_21' and shown on **Figure 9.3**). Whilst the boreholes do not cover the current Quarry Complex, but the area to the adjacent southwest instead, the findings are considered very relevant to this report. The core recoveries achieved as part of the drilling are described in GWP (2022) as excellent which allowed the authors to provide very detailed borehole logs with the best lithology descriptions (including thicknesses) of all the reviewed reports (**Table 9-8**) for the strata relevant to the Quarry Complex. Hence the GWP (2022) geological sequence table is reproduced here as **Table 9-9**:

Table 9-9 - Intersected geological sequence listed from top (youngest) to base (oldest) derived from nine exploration boreholes from 2022 (after GWP, 2022)

Rock Unit	Description	Vertical thickness
Penarth Group (Rhaetic)	Dark grey to black, weak and fissile mudstones, in part represented by clay, with thin limestones. (Intersected in BH6).	c. 5m
Cromhall Sandstone	Pale yellow-brown to grey, fine grained sandstone, siltstone and sandy clay, thin conglomerate at base. (Intersected in BH9 only).	> 4m
Clifton Down Mudstone	Brown and grey-brown weak to moderately strong, massive mudstones, some calcareous, thickly interbedded with pale grey and brownish grey moderately strong to strong limestone and argillaceous limestone. Trace algal limestone. Local sedimentary breccias. Eroded base. (Full sequence intersected in BH9).	52m
Gully Oolite	Pale grey, strong and very strong, massive and homogenous fine grained oolitic limestones, becoming non-oolitic and weakly fossiliferous towards the base. Local trace pyrite. 50% of the top 10 m in BH7 is intruded by thick pegmatitic calcite veins. (Full sequence intersected in BH7 and BH8).	35m
	A 2.7 to 4.5m thick unit of moderately to strongly fossiliferous limestone (mostly crinoid ossicles and stems) identified as the Crinoid Sub-band at the base of the Gully Oolite. Sharp basal contact with the Black Rock Limestone. (BH7 and BH8).	
Black Rock Limestone	A variable sequence of pale to dark grey, mostly strong, fine grained massive and banded limestone and argillaceous limestone, often bioclastic and fossiliferous, commonly exhibiting suture stylolites, commonly cut by thin calcite veins, rarely with haematitic veinlets, very approximately sub-divided from top to base as follows: ~65m of pale grey, massive limestone, some weakly banded, weakly fossiliferous, often bioturbated or slumped, locally partially dolomitised.	155m

Rock Unit	Description	Vertical thickness
	~45m of grey, weakly banded and laminated limestone, in part with thin argillaceous units, mostly fossiliferous (crinoid, brachiopod, coral) with common coarse bioclastic grains. ~20m of grey, massive and weakly banded limestones, occasionally bioturbated, partly fossiliferous with coarse bioclastic grains, locally partially dolomitised. Includes a marker band of centimetric scale calcitic clasts identified in 5 boreholes. ~25m of pale to dark grey or black, banded and laminated limestone and argillaceous limestone, mostly fossiliferous (crinoid, brachiopod, coral) with abundant coarse bioclastic grains. Generally increasing proportion of argillaceous bands and lamellae down-hole, some bands tending to calcareous mudstone but rarely exceed 50mm thick. Some argillaceous lamellae have polished bedding planes or, rarely, slickensides. (Intersections in 8 boreholes, full sequence in BH7 and BH8).	
Lower Limestone Shale (=Avon Group)	Decimetric scale interbedded dark grey moderately strong, massive calcareous mudstones and pale grey, strong, massive or weakly banded limestones. Top of unit is placed at the top of the first calcareous mudstone (marked by trails of white, eroded crinoid debris). The calcareous mudstones become weak and friable when exposed to the air. (Intersections in 7 boreholes).	>15m

9.5.50 The local geological succession summarised in **Table 9-9** largely complies with the regional one from **Table 9-7**. It is however noted, that **Table 9-9**, unlike the regional stratigraphy, does not explicitly distinguish between an upper dolostone and a lower limestone. However, it records 'locally partially dolomitisation' for the upper 65m and a deeper 20m thick layer of the Black Rock Limestone.

9.5.51 The Avon Group (see further discussion below) has not been fully penetrated in any of the boreholes and hence its total thickness underneath the Quarry Complex remains uncertain. The summary logs in GWP (2022) describe it as interbedded calcareous mudstone and limestone (Lower Limestone Shale), with varying mudstone/limestone The maximum thickness of 14.8m was encountered in the 216m deep BH8. GWP (2022) placed the boundary between the Black Rock Limestone and the top of the Avon Group at "the top of the first intersected continuous calcareous mudstone unit that comprises decametric thick intervals of slightly fissile, moderately strong (when fresh, but quickly becomes weak and friable when exposed) mudstone with distinctive but widely spaced bedding-parallel trails of crinoid debris."

9.5.52 From the **Table 9-9** description of the Avon Group lithology it appears that the Avon Group Limestone (**Table 9-7**) was not encountered in any of the boreholes, either because it is not present in this area or because the boreholes did not reach deep enough to hit it. The former appears, based on **Figure 6.5** more likely.

9.5.53 As part of Haynes (1972), a total of eight exploration boreholes were drilled in summer 1972 ahead of the development of the northern part of North Face Quarry (black triangles labelled 1 to 6 in **Figure 9.6.a**). The objective of the drilling was to locate the boundary of the Black Rock Limestone and the Avon Group and also to assess if and how far future workings could be extended into the Avon Group. The geology encountered in the boreholes is summarised in **Table 9-10**.

Table 9-10 – Geology descriptions after Haynes (1972) from top to bottom

Formation	Horizon number	Lithological description	
Black Rock Limestone	1	Massive limestones	Occasional thin siltstone lenses and one persistent band of oolitic limestone.
Lower Limestone Shales (=Avon Group)	2	Alternating limestone and mudstone	Limestone dominant
	3		Mudstone dominant

9.5.54 Haynes (1972) reports that the massive limestones of the Black Rock Limestone Formation (Horizon 1 in **Table 9-10**) were seen to pass downwards into a sequence of alternating limestone and mudstone (Horizon 2, assigned to the upper encountered part of the Avon Group in **Table 9-10**) with the junction clearly marked by the first appearance of a thin band of black mudstone. In all cases this sequence is dominantly composed of limestone, with secondary partings and intermingling of black shaley mudstone The thickness of this horizon is variable from a minimum of some 7.3m (24ft) to a maximum of just over 15.2m (50ft). The base of this limestone/mudstone sequence is marked by the occurrence of thick black mudstone layers and there-after the strata become dominated by mudstone (Horizon 3 in **Table 9-10**, possibly where GWP (2022) placed the boundary between the Black Rock Limestone and the Avon Group, see discussion above), with only secondary developments of shelly limestone, i.e. Horizon 2 in **Table 9-10** is understood to be a transitional layer of significant thickness where both limestone and mudstone occur in alternating sequence. Haynes (1972) also found for this horizon from chemical analysis that the mudstone fraction contains high proportions of carbonate material, i.e. the mudstone is highly calcitic.

9.5.55 It is noted that the Avon Group Limestone (**Table 9-7)** was not encountered by the 1972 boreholes. This may be present at a greater depth or absent altogether.

9.5.56 The previously mentioned NNE-SSW trending 'Whitfield Fault' is shown on both the BGS geology map 1:10,560 (presented in Entec, 1998) and the BGS digital 1:50,000 GIS mapping (linear features). It bisects the Grovesend Quarry in its northeast corner and North Face Quarry along its northeastern edge. Haynes (1972) did not see, apart from minor disturbance in the northeast corner of the 'old quarry' (southern part of North Face Quarry), any geological or topographic evidence for the existence of such a major fault, and the drilling programme carried out as part of that study did not encounter any large-scale stratigraphic disturbance to support its occurrence. WRc (1997) on the other hand saw evidence of 'slick and sided structures with similar orientation' as the allegedly fault which were evident within the quarry (either North Face or Grovesend Quarry) during the WRc site visit at the time. The authors pointed out particularly a fault which bisects the North Face Quarry, the transfer distance being unknown, but appearing to be a large fault plate. The same fault is also shown on the local geology **Figure 9.6a** and Section B (**Figure 9.6b**) through the Grovesend Quarry, but there appear to be no exploration boreholes around to either support or dismiss the existence of the fault. The latter is not included in Section A (**Figure 9.6b**) in the south-eastern part of North Face Quarry, despite exploration boreholes close by on both sides of the fault (e.g. boreholes 15 and 16 from 1982).

9.5.57 By using the first appearance of the mudstone (Horizon 2/3 boundary from **Table 9-10**) as a marker zone, Haynes (1972) found that the dip of the Black Rock Limestone/Avon Group in the North Face Quarry follow similar trends to the regional fold structure, i.e. the dip exposed at the time in the western part of that quarry (west of BH8/1972) of 25° southeast was seen to swing around to a shallow 10° south in the north (south of BH6/1972), and further east to reach some 18° SSW (southeast of BH1/1972). Haynes (1972) therefore postulated that the overall structure appears to be part of a gently dipping syncline (i.e. the sub fold discussed above) with the edges dipping towards the centre. The authors observed that the change of dip direction is progressive and regular, which led them to conclude that this opposes the postulation of a major fault (i.e. the Whitfield Fault) through the centre the area.

9.5.58 A geological 3D model of the extent and thickness of Penarth Group sediments, and of overburden generally, using data from open hole drilling and from other sources is mentioned in GWP (2022b), but this only covers the proposed extension area and has not been reviewed as part of this study.

Hydrogeology

Aquifers

Aquifer designation and extent

9.5.59 The EA's aquifer designations reflect the importance of aquifers in terms of groundwater as a resource (drinking water supply), but also their role in supporting surface water flows and wetland ecosystems. The BGS aquifer designation map (**Figure 9.8**) shows the various aquifer types for the bedrock (MAGIC, 2024). The aquifer designations have been added for each BGS bedrock layer in **Table 9-7** in a separate column. In addition, the BGS 50k bedrock geology layer boundaries from **Figure 9.5** have been added on top of the aquifer designation polygons of **Figure 9.8**. Both was done to better understand how the various rock types are thought to behave in terms of hydrogeological units. The following text is written in order of aquifer designation, from Principal to Secondary (Undifferentiated). Not every single layer of **Table 9-7** is being discussed here. Instead, the focus is on the Principal Aquifers and some of the aquitards bounding them which are considered as relevant.

9.5.60 The Principal Aquifers within the Study Area have been extracted from **Table 9-7** and are listed separately in **Table 9-11**. Principal Aquifers are layers of rock that have high intergranular and/or fracture permeability (high level of water storage) which may support water supply and/or river base flow on a strategic scale. Strata that are in hydraulic continuity, and hence acting as a single aquifer are grouped together in **Table 9-11**, whereas where strata are separated from each other by less permeable strata in between this is marked by an 'xxx' entry.

Table 9-11 – Principal Aquifers in the Study Area

Period	BGS nomenclature	Rock types	LEX-RCS identifier (Figure 9.5)	Aquifer group
Triassic	Mercia Mudstone Group (Marginal Facies)	Conglomerate	MMMF-CONG	
		xxx		
Carboniferous	Tanhouse Limestone	Limestone	TL-LMST	Upper combined aquifer
	Oxwich Head Limestone Formation	Limestone	OHL-LMST	
		Limestone, ooidal	OHL-LMOOL	
	Cromhall Sandstone Formation	Sandstone	CHSA-SDST	
	Clifton Down Limestone Formation	Limestone	CDL-LMST	

	xxx			
	Gully Oolite Formation	Limestone, ooidal	GUO-LMOOL	Combined aquifer
	Black Rock Limestone Subgroup	Limestone	BRL-LMST	
		Dolostone	BRL-DOLO	
	xxx			
	Avon Group	Limestone	AVO-LMST	

9.5.61 The key Principal Aquifer within the Study Area comprises the Black Rock Limestone (both dolostone and limestone) and the Gully Oolite, which have in the past and continue to be extracted at the Quarry Complex. These three rock units are understood to act as one 'combined aquifer', and this is the term that is being used from hereon to refer to the three strata. This combined aquifer is bounded by the Avon Group (underneath: upper part of the Avon Group consisting of interbedded mudstone/limestone) and the Clifton Down Mudstone (above), both of which are classified as Secondary A Aquifers (**Table 9-7**). The mudstone/limestone part of the Avon Group separates the combined aquifer (above) from the lower limestone dominated part (where present) of the Avon Group, which is also classed as a Primary Aquifer (**Table 9-7**). It is worth noting that the Tintern Sandstone underneath is classified as a Secondary A aquifer, not as a Primary Aquifer (**Figure 9.8**).

9.5.62 The combined aquifer is separated by the Clifton Down Mudstone, from another aquifer group, comprising the Cromhall Sandstone, Clifton Down Limestone, Oxwich Head Limestone and Tanhouse Limestone. This aquifer group is referred in this report as 'upper combined aquifer'.

Table 9-12 – Avon Group dominant lithology and aquifer designation

Latest BGS description (Table 9-7)		Previous names (e.g. WRc 1997)	Additional information from Haynes (1972)	Aquifer designation
Avon Group	Mudstone and limestone, interbedded AVO-MDLM	Lower Limestone Shale	Alternating limestone and mudstone, with limestone dominant in upper part and mudstones in lower part.	Secondary A
	Limestone (AVO-LMST)	Lower Limestone Shale with limestone at the base	Not encountered in boreholes as presumably not deep enough or might be absent.	Principal

9.5.63 In the past, the Carboniferous Limestone of North Wessex was classified by the EA as a minor aquifer due to a lack of karst features, which elsewhere in the Bristol-Mendips meant these deposits were classed as major aquifers (WRc, 1997, NRA, 1992). This classification was supported by the fact that the Quarry Complex was at the time (and also at present) also not in a Source Protection Zone. However, the more recent Groundwater Vulnerability Map accessed via Magic (2024) maps the Groundwater Vulnerability as 'high' with 'soluble rock risk'. This is consistent with the later (current) aquifer designation which classifies the limestones of the Quarry Complex as Principal Aquifers.

9.5.64 As can be seen from **Table 9-7**, there are numerous Secondary A Aquifers in the Study Area, but only the upper part of the Avon Group (consisting of interbedded mudstone and limestone) and the Clifton Down Mudstone are discussed further below. Secondary A Aquifers comprise permeable layers capable of supporting local water supplies and in cases forming an important source of baseflow to rivers.

9.5.65 Secondary B Aquifer comprise predominantly lower permeability layers which may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering.

9.5.66 The 'Secondary Undifferentiated Aquifer' classification is commonly used where it hasn't been able to attribute secondary A or B aquifer status and suggests that the strata has previously been designated as both Minor and Non-Aquifer in different locations due to the variable characteristics of the rock type.

9.5.67 Of the superficial deposits within the Study Area, the river terrace deposits and the alluvium are classified as Secondary A Aquifers. The head deposits to the north of the Quarry Complex are classified as a Secondary (undifferentiated) aquifer, i.e. lower permeability formations that may have local scale importance for water supply and river baseflow depending on localised features.

Avon Group (interbedded mudstone/limestone)

9.5.68 With the quarries being bordered to the west and north by the interbedded mudstone/limestone of the Avon Group, which are underlying the combined aquifer, the main groundwater flow is thought to be along the prevailing strata dip to the southeast. In fact, WRc (1997) argue that, presumably because of the mudstone component in the Avon Group and its position relative to the limestones (i.e. up-dip), flow to the north and west would not be expected.

9.5.69 By ruling out any groundwater flow to the north and west originating from the quarries, the conceptual model developed in WRc (1997) treats the Avon Group effectively as an aquitard. This understanding is also reflected in the layout of the current groundwater level monitoring network (see discussion below) which did not see the need for verifying the hydraulic role of the mudstone dominated part of the Avon Group by having additional monitoring boreholes beyond the Avon Group to the north and west, including within the underlying Tintern Sandstone.

9.5.70 However, the Avon Group (interbedded mudstone/limestone part) has in the meantime, probably due to its limestone components, been classified as a Secondary A aquifer. Therefore, the alleged effectiveness of this upper part as a potential hydraulic barrier and, with the Quarry Complex sitting at the head of three surface water catchments, the possibility of groundwater flow to the northwest and north needs to be reevaluated.

9.5.71 WRc (1997) does acknowledge that the presence of faulting may give rise to leakage pathways. Evidence of fault movements were according to WRC at the time clearly visible within the quarries, possibly providing routes for water movement. WRc (1997) thought the large fault between the quarries and Tytherington village to potentially have an important influence on groundwater flow patterns in the area, but WSP notes there is no actual data to verify this theory.

9.5.72 The Study Area of the Mendips Groundwater Conceptualisation report (Entec, 2010) only marginally misses out the Quarry Complex area in the northwest[28] but its findings are nevertheless considered to be relevant for this study. Entec (2010) states, based on groundwater level analysis around the Halecombe Quarry area (~6km west of Frome):

'*When levels in the limestone are low a steep hydraulic gradient is developed between the Old Red Sandstone and Carboniferous Limestone but it is unlikely that there is much flow down this gradient as the Old Red Sandstone is a poor aquifer and the intervening Avon Group (Lower Limestone Shales) is an aquitard.*'

9.5.73 Likewise, the Avon Group is also regarded as an aquitard in the Environmental Statement report (Wood, 2021) for the Westdown Quarry, which is just to the south of Halecombe Quarry.

9.5.74 Although the unit as a whole has been classified as a secondary aquifer, this does not mean that water could pass laterally through the unit, due to the presence of interbedded non-aquifer horizons. In fact, given the relatively steep strata dip (up to 40 degrees), recharge can enter the limestone layers of the upper part of the Avon Group and generate seasonal groundwater level fluctuations apparent in the hydrographs. But the more prominent mudstone bands are thought to be responsible for the hydraulic barrier behaviour between the aquifers it separates.

9.5.75 In summary, based on the above discussion, the concept of treating the upper interbedded mudstone/limestone part of the Avon Group as an aquitard and hence ruling out groundwater flow from the Quarry Complex north- and westwards is retained in this report.

Clifton Down Mudstone

9.5.76 Entec (2010) reports for the Broadfield Down area about uncertainties in the interpretation of the hydraulic behaviour of the Clifton Down Mudstone Formation, which is thought to be less permeable than the surrounding limestone formations. It is however noted that the Clifton Down Mudstone (like the Avon Group) is classified in the report in terms of 'qualitative behaviour in 4R' (Routing of Rainfall to Runoff and Recharge) as 'similar to clay'.

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[28] Maximum northing on Entec (2010) figures is 18500, whereas Study Area reaches south to as far as northing of 184000, i.e. only 100 m of overlap).

9.5.77 Whilst the Clifton Down Mudstone is classified as a Secondary A Aquifer (see above), WRc (1997) reported that '*the low angle of dip favours the development of extensive confined aquifers where permeable limestones are overlain by thick mudstone layers; e.g. the Black Rock Dolomite and Limestone are confined by the Cliffton Down Mudstone*'. The authors support this by referring to 48 m of encountered Clifton Mudstone in the log of a borehole drilled at Tytherington village (presumably for the Bristol Avon River Authority Borehole 020 / Tytherington 1 from 1972, NGR ST 6643 8823, in Tytherington village, see **Figure 9.3**). The log for this borehole (see **Appendix 9A**) shows the Clifton Mudstone was encountered between 48 and 96 m bGL and comprises predominantly calcilutite[29], which supports the idea if it acting as an aquitard. It is worth noting though, that WRc (1997) had recommended for the required monitoring network a borehole pair to the southeast of the Quarry Complex, comprising one borehole being screened in the combined aquifer and one in the Clifton Down Limestone in order to allow the verification of the alleged hydraulic barrier nature of the Clifton Down Mudstone in between (see further discussion on this in Section Groundwater levels).

9.5.78 A summary note titled 'Water resource problems related to mineral working in Wessex Region' (Stanton, 1991) claims for the period of c. 1960 - 1991 that 'dewatering of sub-water-table workings at Tytherington quarries reduces flow from springs in Tytherington village'. The one known village spring SP02 (**Figure 9.3**) is underlain by the Clifton Down Limestone. This observation would be explainable if the combined aquifer and the Clifton Down Limestone were at least in places hydraulically connected. The Whitfield Fault does not appear to have juxtaposed the two aquifers next to each other, which means that either a lithology change in the Clifton Down Mudstone (which would then allow layer cross flow) or (more likely) it might in places by bypassed. This could in theory be via streams (e.g. streams in the past flowing over less permeable Clifton Down Mudstone, then getting lost into permeable Clifton Down Limestone and subsequently re-emerging further downgradient as spring(s). The most plausible location of groundwater flow from the combined aquifer bypassing the Clifton Down Mudstone is just to the east of the Grovesend Quarry's northwestern corner where the Mercia Mudstone Group (Marginal Facies) conglomerate (Principal Aquifer) overlies directly the combined aquifer. This would also explain how the Tytherington Village spring (SP02 in **Figure 9.3**) got fed. This is discussed further below.

9.5.79 The lithology and thickness (52m) of this formation encountered during the drilling in the southwestern exploration area (**Table 9-9** and **Appendix 9A**) and the head differences between aquifers separated by this formation (see discussion below in section Groundwater levels) in the immediate vicinity of the Quarry Complex favours

[29] Calcilutite (also known as cementstone) is a type of limestone that is composed of predominantly, more than 50 percent, of either clay-size or both silt-size and clay-size detrital (transported) carbonate grains.

the Clifton Down Mudstone in the Study Area to act as an aquitard rather than a Secondary A Aquifer.

Aquifer parameters

9.5.80 WRc (1997) gathered from data of the Tytherington village borehole (020, location see **Figure 9.3**) pump test carried out in 1972:

- no yield between 0 to 50m, which corresponds to the Clifton Down Limestone and Lower Cromhall Sandstone (see **Appendix 9A**),
- 0.32m^3/h (70 gph) between 50 and 100m within the Clifton Down Mudstone; and
- 0.32m^3/h (70 gph) between 100-150m for the Gully Oolite and Black Rock Limestone strata[30].

9.5.81 ARC (1974) refers to an experimental sump pumping test that was instigated at North Face Quarry, and with the close co-operation of the Quarry Management and members of Bristol University a large amount of information had been gained from an otherwise routine dewatering procedure. The authors refer to a more detailed report which has not been made available to WSP, but the result of the test is reported as an estimate of permeability for the underlying Black Rock Limestone/Dolomite in excess of 2,000 galls/day/sq ft, which equates to a hydraulic conductivity of 98m/d (1.1 E-3 m/s).

9.5.82 Additional information about the pumping test described in ARC (1974) above is available in WRc (1997). According to this report, the pumping test using dye tracers was undertaken at the Tytherington Quarry by the University of Bristol. At that time the quarry had three sumps: Sump 1 in North Face and Sumps 2 and 3 in Grovesend Quarry. Seasonal variation in sump water levels were recorded. Pumping was only undertaken in Sump 1 in the summer to facilitate quarrying, Sump 2 was regularly pumped by a permanent installation and Sump 3 possessed a static water level. The pump test utilised three 'Halco' bores drilled to 100m (A), 70m (B), and 2m (C) respectively from the eastern rim of Sump 1. A red dye was injected into well A and a green dye into well B, immediately prior to the pumping test. A constant discharge test was undertaken in sump one at a rate of 20 l/s (1.7 Ml/d) for a period of 96 hours, inducing a drop of 14cm per day in the water level in Sump 1.

9.5.83 Pumping induced a groundwater gradient of 0.002, calculated flow velocities are of the order of 5 - 20 m/d. This equates to hydraulic conductivity of 100 m/s for the Black Rock Limestone/Dolomite aquifer (i.e. the same as recorded by ARC (1974) above.

9.5.84 WRc (1997) calculated on the assumption of a direct hydraulic connection of the quarry with the Tytherington spring an approximate travel time of 30 days. WSP suggests this to be a rather theoretical value given the hydraulic role of the Clifton Down Mudstone in between (see discussion above).

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[30] WSP notes, the fact that the obtained yield over borehole intervals of equal length (50m) for both the Clifton Down Mudstone and the combined aquifer would be the same, does not look plausible, but this is also how it is recorded for the pump test documented in **Appendix 9A**.

9.5.85 Entec (1998) carried out falling head tests for the six boreholes from the 1998 campaign. It is understood that the piezometer installations were carried out after the head tests, i.e. the head tests were performed in the open boreholes. Resulting hydraulic conductivities obtained range from 2.4 E-8 to 2.2E-6 m/s (2.1E-3 to 0.19 m/d). These values are very low and not considered as representative of the limestones as head tests only test a relatively narrow aquifer zone around the boreholes, i.e. they are representative of matrix scale conductivities. It appears the boreholes have not intersected any larger dissolution fissures or fractures, which control the wider flow pattern and will result in higher overall hydraulic conductivities, as demonstrated by the ARC (1974) sump pumping test.

9.5.86 According to Allen et al (1997) the matrix of the Carboniferous Limestone has very low values of permeability and is therefore an aquifer almost entirely by virtue of the secondary network of solution-enlarged fractures (commonly termed conduits.

9.5.87 The digital aquifer properties point data from the BGS aquifer properties database sitting behind the BGS Major and Minor Aquifer Properties Manuals (Allen et al., 1997 and Jones et al., 2000, respectively) present transmissivity values for the following two boreholes, namely the Thornberry Golf Centre borehole and the Game Farm borehole. The database does not contain any aquifer properties data within the Study Area for any of the Carboniferous Limestone strata.

9.5.88 The Thornberry Golf Centre borehole is located 3km west of the Site, on the Avon Group (limestone), underlain by the Tintern Sandstone Group. BGS borehole records (BGS, 2024a) indicate that the borehole (ST68SE40) has a depth of 64.3 m bGL. Permitted abstraction information provided by the EA suggests that this is abstracting from the Tintern Sandstone Group (see Water Resources - Abstractions) which is in line with the 'Upper Devonian' aquifer information provided for this borehole by Jones et al (2000). As such the borehole will be separated from the Quarry Complex by the mudstones of the Avon Group. One constant rate pumping test run over more than one day resulted in a transmissivity value of 32 m/d.

9.5.89 The Game Farm borehole is located 3 km south-east of the Site, on the Mercia Mudstone Group (mudstone, siltstone and sandstone), which has variable thickness. According to Jones et al (2000), this borehole targets the Merica Mudstone Group, presumably a sandstone or conglomerate horizon within it. BGS borehole records (BGS, 2024a) indicate that the Game Farm borehole (ST68NW58) has a depth of 37m bGL. One constant rate pumping test run over more less than one day resulted in a transmissivity value of 22 m/d.

Groundwater levels

Monitoring network

9.5.90 Back in 1997, Greenways, a division of ARC were looking to develop the North Face Quarry as a landfill for municipal solid waste, which in the end did not go ahead. As part of the planning application, WRc (1997) proposed a groundwater level monitoring network around the Quarry Complex to address the minimum monitoring requirements (time and coverage) that would be required before permission was granted. As part of this WRc recommended a total of seven monitoring boreholes (shown on **Figure 9.4**) as follows:

- Two boreholes to the southwest of Woodleaze Quarry to provide information on groundwater movement from the quarry through the limestone series to the west of the Whitfield Fault and south of the Quarry Complex.
- Two boreholes to the northeast of North Face Quarry on both sides of the Whitfield Fault to establish water levels in the Black Rock Limestone and Dolomite, to establish groundwater flow patterns in relation to pumped water level data; and to help establish whether the northern boundary of the quarry also forms a hydrogeological divide.
- Three boreholes (including one nested) parallel the railway line to establish groundwater movement between the quarry and the village.

9.5.91 All boreholes were to be screened within the Black Rock Limestone / Dolomite with the shallow piezometer of the nested borehole being screened in the Clifton Down Limestone to investigate the effectiveness of the Clifton Down Mudstone as a hydraulic barrier. In line with the WRc conceptual understanding of the Avon Group (AVO-MDLM) acting as a groundwater flow boundary, no monitoring boreholes were suggested to the west or north of the Quarry Complex.

9.5.92 Subsequently, Entec UK Ltd was commissioned by Greenways Waste Management to supervise drilling operations for a total of six piezometers (Entec, 1998). These got installed for the purpose of assessing the geology, groundwater conditions and groundwater quality in the area around North Face Quarry and to inform the landfill Planning Application. The location of these monitoring boreholes 1 to 6 is shown on **Figure 9.3** and on **Figure 9.6a** (the 1998 boreholes). It is noted that this monitoring network differs from the one recommended by WRc, i.e. it focusses (with the exception of borehole 5 in the south of Woodleaze Quarry) more on the vicinity of North Face Quarry, but it is understood from Entec (1998) that the network was realised following scoping discussions with the EA. The reasons behind the revised monitoring network are not documented in Entec (1998).

9.5.93 The borehole logs for the six piezometers, which also include the construction details (with the exception of borehole 1) are included in **Appendix 9B**. A rotary drilling rig was used in conjunction with a large compressor to enable for air flushing the arisings. Samples of these were collected at 1m intervals for the first ten metres of drilling and after that at 5m intervals These samples were used for logging geological strata change within each borehole, i.e. the borehole logs are not based on cored samples and the described method implies that strata boundaries and strata changes (e.g. between thin mudstone and limestone layers, as they are known to exist for the Avon Group) are unlikely to be captured in the logs. For example, the log for borehole 6 implies a 14.4m thick pure mudstone layer, whereas the findings from Haynes (1972) suggest an alternation of mudstone/limestone bands with the former potentially dominating the sequence to be much more likely.

9.5.94 Each borehole was typically advanced to a minimum depth of a further 10m after a water strike was encountered. Each location was equipped with 12 m of slotted HDPE pipe positioned from the base of the well upwards and plain pipe thereafter to the ground surface. As a consequence, some of the boreholes (1, 2, 6) might not be screened over the Black Rock Limestone / Dolomite, as was recommended in WRc (1997) but assumed to be the case so far (BCL, 2023, with the exception of BH6), but instead they may monitor different strata (or at least different lithologies), which adds uncertainty to any attempted groundwater level contours. But the latter is required in order to understand groundwater flow directions which forms the basis of any assessment of potential impacts of the Quarry Complex on any surrounding water features.

9.5.95 Following the drilling, each borehole got flushed, and a falling head test got carried out before each piezometer got installed. The borehole completion data is summarised in **Table 9-13**. This table presents information from Entec (1998), however, the geological layers recorded in the logs had not been assigned to any stratigraphic units by the authors and neither have the slotted sections, i.e. the monitoring strata for borehole are not recorded in the Entec report. This information is however considered to be vital for the ongoing analysis and WSP has therefore attempted to derive this information (see columns related to the depths for the slotted pipes (extracted from the borehole logs) and the rockhead information (from **Figure 9.5**) and column 'Installation comments' in **Table 9-13**.

Table 9-13 – Completion data for six 1998 monitoring boreholes

Piezo No	Easting	Northing	Datum m AOD	Drilling depth m bGL	Slotted pipe (m bGL)		Rockhead (BGS 50k bedrock map)	Installation comments
					from	to		
1	366992	188927	99.07	84.5	72.5	84.5	BRL-LMST	Screened over (presumably predominant- see uncertainties about borehole log inaccuracies in text) mudstone of either BRL or AVO. Hydrograph implies borehole probably not deep enough to reach AVO-MLDM (see discussion in text below).
2	366792	188970	99.29	74.5	62.5	74.5	BRL-LMST	Screened over (presumably predominant- see uncertainties about borehole log inaccuracies in text) mudstone of either BRL or AVO. Hydrograph suggests this borehole might be deep enough to reach AVO-MLDM (see discussion in text below).
3	366602	188685	85.87	71.0 (71.5 as of log)	56.0	68.0	BRL-DOLO	Screened over limestone (BRL?)
4	366090	188765	67.8	60.0 (63.0 as of log)	48.0	60.0	BRL-DOLO	Screened over limestone (BRL?)
5	365476	188188	95.86	84.5	72.5	84.5	BRL-DOLO	Screened over limestone (BRL?)
6	366824	189278	92.76	27.5			AVO-MDLM	Mudstone between 8.4 and 22.8 m bGL, i.e. over 14m, sandwiched by two limestone layers. Slotted pipe (12m?) location relative to geology not documented in Entec (1998). Given rock head is AVO-MDLM and based on hydrograph analysis this is likely to be screened in AVO-MDLM (in line with BCL (2023) understanding.

9.5.96 As is apparent from **Table 9-13** and the discussion in its last column, the information of rockhead, provided depths and hydrographs review (see detailed discussion further below) is thought to be of greater value than the too coarse lithology descriptions provided in the Entec (1998) borehole logs. On that basis the six monitoring boreholes are likely to monitor the following strata:

- Two of the six 1998 piezometers, namely piezometer 1 and 2 are screened over what is described in the borehole log as 'mudstone', so could be either of the Black Rock Limestone Formation or of the Avon Group. The hydrographs imply piezometer 1 to be likely screened in the combined aquifer and piezometer 2 in the Avon Group;
- Three piezometers, namely piezometers 3 to 5 are screened over limestone with their rockhead being the Black Rock Limestone/Dolomite, and these are likely to be screened over the combined aquifer; and
- For piezometer 6 there are no construction details provided in the Entec (1998) log. (if the '12 m of slotted HDPE pipe positioned from the base of borehole' rule specified in Entec (1998) got applied (albeit that was not the case for piezometers 3 and 4, see column 'drilling depth' compared to 'slotted to') the slotted pipe would cover 7.3m of mudstone on top of 4.7m of limestone, presumably of the Avon Group).

9.5.97 In accordance with Condition 27 of the extant principal planning consent (ref. NA/IDO/002/A), the Applicant has prepared a hydrometric monitoring scheme, which has been submitted and approved by the Mineral Planning Authority ("Scheme for the monitoring and investigation of hydrogeological characteristics of Tytherington Quarry"). The monitoring scheme requires preparation of annual monitoring reports. These reports (BCL, 2022 and 2023) have been prepared by BCL Consultant Hydrogeologists Limited to satisfy the reporting requirements for the Site, presenting all hydrometric monitoring data collected up to and including September 2023.

9.5.98 BCL (2023) utilises the six monitoring boreholes from 1998 (**Table 9-13**) plus additional ones listed in **Table 9-14**. The complete groundwater monitoring network is shown in **Figure 9.3**. Neither borehole log nor construction details are available for piezometer 7, but it is, based on its location and hydrograph response likely to monitor the combined aquifer.

Table 9-14 – Additional groundwater monitoring boreholes used in annual monitoring reports

Piezo No/ BH name	Installation date	Easting	Northing	Datum m AOD	Drilling Depth m bGL	Rockhead (BGS 50k bedrock map)	Installation comments
7	Not known. Based on numbering presumably between 1998 and 2021.	365234.8	188021.42	94.01	Not known	BRL_DOLO	Neither borehole log nor construction details available for this borehole. But based on rockhead and hydrograph review (see below) likely to be screened in combined aquifer.
8_21	26/11/2021 05/01/2022	365121	187706	89.4	216.1	PNG-MDST (above CDM-DLMDST)	Borehole log in GWP (2022a), and construction details from drillers log received separately. Screened over combined aquifer.
9_21	10/01/2022 - 13/01/2022	365054	187564	90.8	60.6	CHSA-SDST	Borehole log in GWP (2022a), construction details from separate drillers log ambiguous. Likely to be screened over either Cromhall Sandstone or upper part of Gully Oolite. Hydrograph implies piezometer likely to be installed in Cromhall Sandstone (see discussion in text below).
Farm Borehole	not known	365466	187898	96	>61	PNG-MDST (probably above CHSA-SDST)	Given its rockhead being Penarth Group, and the significant borehole depth of >61m suggests this borehole might have been drilled through ~52m of Clifton Down Mudstone to reach the upper part of the Gully Oolite.

Piezo No/ BH name	Installation date	Easting	Northing	Datum m AOD	Drilling Depth m bGL	Rockhead (BGS 50k bedrock map)	Installation comments
Ramsoak Well	not known	365742	188045	98.34		CHSA-SDST	This well was serving the now demolished Ramsoak Cottage (the foundations of which are under the soil store). It is very shallow (3 to 4m maximum depth?) and almost certainly in the Cromhall Sandstone. (applicant, Pers. Comm.)

9.5.99 The borehole logs for the two piezometers 8 and 9 from 2021/2022 are appended in GWP, 2022s (see **Appendix 9C**) but no construction details were provided. The following information to narrow down the likely screen locations for these two boreholes has been gathered from GWP (2022a):

- BH8 (216.1 m deep): Gully Oolite and Black Rock Limestone encountered between 11.4 and 201.3 m bGL. The drillers log provided separately by the applicant shows a 75 m long slotted section for this borehole between 50 and 125 m bGL, i.e. within the combined aquifer;
- BH9 (60.6 m deep): 4.3m thick Cromhall Sandstone is separated from the upper 1.3m of the Gully Oolite (in which the borehole terminated) by the 52m thick Clifton Down Mudstone. It would make hydrogeological sense to have the screened section in either the Cromhall Sandstone (upper aquifer) or in the Gully Oolite (lower section), but the actual location is not documented in GWP (2022). Based on the hydrographs analysis it seems more likely this piezometer has been screened in the Cromhall Sandstone. The drillers log separately provided by the applicant is ambiguous with regards to the depth and extent of the slotted section.

9.5.100 The following piezometers are according to BCL (2023) either temporarily or permanently out of use:

- Piezometer 1: there are access issues (fenced off within a solar farm compound, last reading from January 2015) and the authors suggest for access arrangements to be agreed with the relevant landowner to enable continued monitoring;
- Piezometer 4: this was located within the Grovesend Quarry void and lost in October 2004. Its contribution to hydrogeological setting data was seen by the authors as limited and hence it was not being replaced for the monitoring network; and
- Piezometer 6: this was located at Barmer's Land Farm but got recently removed (last reading from September 2023). The authors recommend for it to be replaced.

Groundwater level hydrographs

9.5.101 The Applicant provided WSP an updated version of the groundwater hydrographs presented in BCL (2023), updated to January 2024. This is reproduced in **Figure 9.9** and shows groundwater levels for the nine piezometers (1 to 9_21), the two monitoring points (Ramsoak Well, Farm Borehole) and sump/pond water levels for the three quarry water bodies (North Face Quarry, Grovesend Quarry and Woodleaze Quarry) since August 1998 to recent. All these monitoring locations are also shown in **Figure 9.3**. Under the existing monitoring scheme, groundwater level data is collected monthly.

9.5.102 Extraction of mineral was temporarily suspended between December 2012 and March 2019 and consequently, no offsite pumping of water was undertaken at the Quarry Complex and water levels were allowed to recover. This is reflected in the sump water levels in **Figure 9.9** as described below.

9.5.103 Abstracted water from both the North Face and Woodleaze areas currently is, and has historically (except for a slight alteration in the pump set up between 2019 and 2021) been, pumped to the Grovesend Sump. From the Grovesend Sump, water is pumped under EA consent No. 021407 to Tytherington Watercourse.

9.5.104 Quarrying activity at North Face Quarry is apparent by recorded lowered water levels over 1999 and 2000, with levels ranging from 23.8 to 34.5m AOD. This is followed by a data gap, but excavation is understood to have continued in this area, with recorded levels between June 2010 and July 2012 of 22.7 to 27.6m AOD. Since then, the initial steep and subsequently flatter rise in the water level demonstrates the effect of ceasing the dewatering in this quarry. From about 2019, the water level starts to flatten around 65 to 66m AOD, subject to some observed seasonality and this elevation interval is likely to mark the approximate final rebound level. A slight downward trend in the water level is apparent from mid-2020 which is thought to be related to the re-commencement of pumping at Woodleaze Quarry. Since early 2021, the North Face Quarry water levels have stabilised again between 63.4 and 66.2m AOD, i.e. at a slightly lower level as before and likely influenced by the ongoing abstraction at Woodleaze Quarry.

9.5.105 The water levels at Grovesed Quarry fluctuate up to December 2012 between 58.9 and 65.8m AOD with no trend or seasonality apparent. This is not surprising, given its role of only temporarily storing what was in the past dewatered at North Face and now at Woodleaze Quarry before it gets transferred to the Tytherington Watercourse discharge point. From July 2017 onwards, the Grovesend Quarry water levels are very similar to the North Face Quarry levels, including the rising trend, which implies a hydraulic connection via the limestone aquifer which holds both ponds. A marked step from 63.3 to 66.8m AOD of the Grovesend Quarry water level is apparent between May and June 2021. BCL (Pers. Comm., 2024) advised this jump was not due an increase in dewatering, but instead down to the quarry improving the efficiency of the pumping equipment from Woodleaze and hence rate of transfer from Woodleaze to Grovesend. The Woodleaze sump was not deepened until June/July 2022.

9.5.106 The first recorded water level at Woodleaze Quarry is from June 2010 and water levels remain relatively stable between 34.0 and 35.5m AOD until November 2012. The subsequent cessation of excavation activity is accompanied by the water level rebounding to as high as 63.7m AOD in March 2019, i.e. by approximately 28.5m over a period of 6.3 years. The subsequent commencement of the dewatering activity in this quarry has led to a water level decline over 4.7 years down to current 20.5m AOD (minimum of 18.5m AOD in August and November 2023).

9.5.107 The groundwater levels from the piezometers and boreholes have responded differently to the sump water levels with some having clearly been influenced whereas other have not. This is controlled mainly by proximity, and hydraulic connectivity between the relevant boreholes and the quarry sumps.

9.5.108 The two piezometers 2 and 6 (located to the east of North Face Quarry) and the Ramsoak Well (southeast of Woodleaze Quarry) all show seasonal fluctuations with no trend and none of them appears to be affected by the water level changes observed in the nearby quarry ponds (with the exception on piezometer 2, see below). Typical amplitudes of the groundwater levels are 10m, 5.4m and 3.2m, respectively. A reasonable correlation is noted between the P6 and Ramsoak Well (R^2=0.78). But whilst P6 is likely to be screened over Avon Group (**Table 9-13**) the latter is likely to be targeting the Cromhall Sandstone (**Table 9-14**). But the hydrographs of both imply them to be hydraulically isolated from the quarry ponds and hence the combined aquifer, i.e. the P6 hydrograph is thought to support the theory of the Avon Group mudstones preventing groundwater flow north and westwards from the Quarry Complex. Whilst the Ramsoak well hydrograph suggests the Clifton Down Mudstone to form an effective hydraulic barrier between the combined aquifer and the Cromhall Sandstone.

9.5.109 Piezometer 2 does show a reduction in amplitude from about 2016 onwards with later amplitudes being below 4 m. Given the closeness to North Face Quarry it is likely the water level of the latter has reached a level which might impose a dampening effect on the later piezometer 2 water levels. But that would imply that groundwater levels in this piezometer, unlike P6 and the Ramsoak Well above, would not be completely decoupled from the combined aquifer. There remains uncertainty to what aquifer P2 monitors (i.e. Avon Group or the combined aquifer).

9.5.110 The hydrographs of the three piezometers P5, P7, P8_21 and the Farm Borehole on the other hand look substantially different to the ones discussed above with much larger amplitudes. These four monitoring points are all located to the south of Woodleaze Quarry and their water levels are clearly influenced by the dewatering activity in the latter. The elevation of the groundwater highs has remained consistent over time, but the elevation of the groundwater level lows is influenced by the Woodleaze Quarry sump level. The groundwater levels of piezometer P7 for example fall, in the pre-mothballing phase (pre-2012) not below a water level which is just above the Woodleaze Quarry water level of ~34 m AOD. As the water level in the quarry is allowed to rise, so do the elevations of the groundwater lows for this borehole with regular lateral gradient reversals (i.e. quarry water level above borehole groundwater level) over these short dry periods. This effectively leads to a decrease in amplitude of piezometer 7 water levels from previously 50m to 30m in 2018/2019. With the dewatering recommencing in the quarry, the groundwater lows fall again, but not to as low as during the pre-mothballing phase. This pattern is also akin to the levels of the other three monitoring points. Whilst there is uncertainty over the actual construction details of these boreholes it is concluded from the hydrographs that they are hydraulically connected to the Woodleaze Quarry pond and hence they are likely to monitor the combined aquifer (which also hosts the quarry ponds).

9.5.111 Piezometer 1 is the most eastern monitoring point, and it is noted that its groundwater levels do not fall below 48.8 m AOD (possibly some blockage at this depth, as slotted pipe extends downwards to as far as 14.6 m AOD?). Its hydrograph is very similar to the one of piezometer 5 and had the piezometer level minima not been cut it would likely show a similar amplitude of approximately 40 m. The strong correlation between hydrographs of the two piezometers is also apparent from the regression coefficient R^2=86. This, and its comparison to the Woodleaze Quarry water levels means, that despite its deviant location (east instead of south of the Quarry Complex) it falls into the same category as piezometer 5 discussed above and it is therefore thought to monitor the combined aquifer.

9.5.112 Piezometer 3, also to the east of the Quarry Complex falls at least initially into the same category as boreholes 1 and 5. Its amplitude (showing seasonality) reaches initially over 20 m, but from 2013 onwards, once both North Face and Grovesend Quarry had recovered to a certain level, the piezometer 3 hydrograph loses its previously high amplitude and instead follows the gradual rise of both quarry lakes. The dragging down of level minima observed for the piezometer 5 category in response to the ongoing dewatering at Woodleaze Quarry is not apparent at piezometer 3, i.e. it appears to be more controlled by the two closer northern quarry sumps. But overall, it is thought to represent the combined aquifer.

9.5.113 Piezometer 4 was located in Grovesend Quarry (towards its northern edge) before it was lost in October 2004. Its amplitude shows seasonality and has a magnitude of approximately 15 m. It is thought to monitor the Black Rock Limestone and its amplitude might have been affected in a similar way by the dewatering going on at the time in North Face Quarry compared to the piezometer 5 boreholes in relation to Woodleaze Quarry, but there is not enough data to verify this. With this borehole no longer present for nearly 20 years it has not been included in the groundwater level contouring, but it is assumed it would have represented the combined aquifer.

9.5.114 The Piezometer 9_21 hydrograph shows compared to the other boreholes a relatively short record (first reading from December 2022). This borehole marks the most southern level monitoring point, its hydrograph shows an amplitude of only 1 m, and it correlates very well with the Ramsoak Well (R^2=0.94), and its hydrograph behaves very different to the closer piezometer 8. Like the Ramsoak Well it is not influenced by the Woodleaze Quarry dewatering. The borehole log suggests it could be installed in either the Cromhall Sandstone or the Gully Oolite, but in the absence of the actual construction details, the hydrograph implies it to be screened in the Cromhall Sandstone.

Groundwater level contours

9.5.115 Following the monitoring strata assignment to the various monitoring boreholes described above, the spatial pattern of the groundwater levels is analysed in this section and presented in **Figure 9.10**. This figure comprises four map panels which show the DTM (map A), groundwater level contours for high (map B) and low (map C) level periods, and a difference map between the two groundwater level maps for the area covered by the groundwater level monitoring network.

9.5.116 The point colours on maps B and C of **Figure 9.10** identify the assumed monitoring strata for each monitoring borehole, namely, from old to young, the Avon Group, the combined aquifer, and the Cromhall Sandstone. The groundwater level contours represent the combined aquifer, and consequently, the two Cromhall Sandstone and the two Avon Group boreholes have been excluded from the contouring, as both strata are thought to be hydraulically separated from the main aquifer. The top of the Avon Group is shown on both maps as a thick black line as it was treated for the contouring as a no flow boundary. The blue closed lines around each of the three quarries represent ground level contour lines from the quarry November 2022 survey with elevations close to the water levels recorded during 2023, i.e. these represent the approximate aerial extent of each quarry water body. All three are understood to be hydraulically connected to the combined aquifer and have hence been included in the contouring.

9.5.117 The contours of map B represent a high (using water level data from 20 April 2023) and map C a low groundwater level period (water level data from September 2023). Both periods were identified from hydrographs review and are fairly recent, i.e. with active dewatering at Woodleaze Quarry in place and close to its maximum drawdown level. This is apparent from the recorded water levels for this quarry of 21.5 m AOD (map B) and 20.0 m AOD (map C) for the two contouring periods, which compares to the minimum water level of 18.5 m AOD recorded in August and November 2023.

9.5.118 Apart from the three quarry water levels, monitoring data for both selected periods were also available for the main aquifer boreholes (from north to south) P3, P7, Farmhouse Borehole, and P8_21. No values from the two selected monitoring periods were available for both P1 and P5, hence infilled values, derived from correlation with P7 and/or hydrograph review, were used instead.

9.5.119 The groundwater flow pattern implied by the contours of maps B and C are overall quite similar, postulating:

- No groundwater flow to the north and west (reflected by the contours meeting the no flow boundary at 90 degrees angle);
- Groundwater flow to the southeast (down dip direction) and also to the southwest along layer strike direction, albeit across a narrower width;
- The water levels of the two northern quarries are likely to be close to having fully recovered with elevations above 65 m AOD (Grovesend Quarry) and at least 64.5 m AOD (North Face Quarry), see also hydrographs discussion above. The groundwater low caused by the dewatering in Woodleaze Quarry has resulted in a groundwater divide around it, i.e. groundwater flow is expected to contribute from all directions except for the no flow boundary along its north-western boundary.
- Based on the understanding of an expected down-dip groundwater flow (backed up by piezometer 1), and the fact that the piezometer 3 groundwater levels are almost always at least slightly above piezometer 1 and North Face Quarry water levels implies a groundwater divide between piezometer 1 and the North Face Quarry, as shown on both maps B and C.

9.5.120 The differences between the high and the low level period are mainly down to more pronounced differences (see also map D) in the levels of the four monitoring boreholes in the southwest, namely P7, P8_21 and Farm Borehole (with level differences of over 30 m) and also P5 (13.4 m difference). Significantly lower groundwater levels in the southwest (map C compared to map B) results in a significantly reduced lateral hydraulic gradient between these and the Woodleaze Quarry low point, marked by a wider spacing of the contours and a less pronounced groundwater divide in this area (this latter point also explains the greater dependency of low groundwater levels to the sump level which was discussed in the hydrographs section above). This means in the low-level period, less groundwater gets drawn into the quarry from the southwest and hence less water will contribute to the amount that needs to be dewatered (as would be expected during dryer periods). The opposite is true for the high-level period.

9.5.121 It should be noted that the contour maps discussed above, and related conclusions drawn from these, must be regarded with care. The main related uncertainties are listed below:

- The maps depend on the correctness of the assigned monitoring strata to each of the boreholes. Whilst the resulting monitoring strata/borehole mapping appears plausible, it won’t be definitive. The highest degree of uncertainty regarding monitoring strata assignment is currently seen for piezometer 2 (Avon Group or combined aquifer). The implications of piezometer 2 levels as discussed below;
- The contours are based on the assumption that the base of the composite aquifer/top of the Avon Group acts as no flow boundary. Whilst this is in line with the regional understanding, there is no local monitoring data from an underlying aquifer

(e.g. Tintern Sandstone or Avon Group Limestone) available to prove this theory. The piezometer 6 hydrograph which appears unaffected from water level changes in the quarry sumps does support the no flow boundary theory.

- Piezometers 1 and 5 are based on infilled data as no data were available for these points for the two selected monitoring periods;
- There are not enough data points to confirm groundwater flow directions in the south east and to allow mapping of the divides with more confidence. The current contours in the southeast are parallel to the general strike direction. An alternative interpretation could involve contours showing flows converging to a likely outlet just to the east of the Grovesend Quarry's northwestern corner where the Mercia Mudstone Group (Marginal Facies) conglomerate (Principal Aquifer) overlies directly the combined aquifer and hence could potentially provide a mechanism to bypass the Clifton Down Mudstone. However, further analysis done on Figure 9.11 suggests the conglomerate does not extend to sufficient depth below ground to allow the transfer of water in the manner described above, at least not for current groundwater levels monitored in the combined aquifer. This may however have been a factor historically when groundwater levels were likely to be higher underneath the Site.

9.5.122 Despite these uncertainties and limitations, it is thought that the available data have been interpreted in a robust way and the presented resulting groundwater flow pattern makes overall conceptual sense.

Vertical hydraulic gradients

9.5.123 Piezometer 2 has been excluded from the contouring above as it is thought to represent the Avon Group rather than the composite aquifer. This piezometer is located in a recharge zone which implies a vertical hydraulic downward gradient. However, in the current contour maps it is with groundwater heads of >=80.0 m AOD well above the groundwater levels of the composite aquifer (below 70 m AOD) implied by the contours. Based on this, it is likely that a neighbouring piezometer installed in the composite aquifer would monitor levels above 80 m AOD (i.e. resulting in the expected vertical hydraulic downward gradient). This would lead in the contour maps to a more pronounced divide between North Face Quarry and the southeast with larger groundwater highs along the divide compared to the current contour versions shown in maps B and C. The same is true if piezometer 2 was to represent the combined aquifer.

9.5.124 A vertical hydraulic downward gradient is also expected at the Ramsoak Well (recharge area) between the Cromhall Sandstone and the composite aquifer. This is reflected in the contours of both maps B and C, i.e. it makes conceptual sense.

9.5.125 Piezometer P9_21 is located less than 50 m to the east of Owlsnest Farm Watercourse and could as such mark in theory a discharge zone (implying vertical hydraulic upward gradient). The nearest composite aquifer piezometer 8_21 is >150 m to the northeast / upgradient, which is too far away to verify this for the entire groundwater level spectrum. The hydrographs (and also **Figure 9.10**, map C) show piezometer 9_21 levels to be significantly higher than for piezometer 8_21, which implies a vertical hydraulic downward gradient and hence not a discharge zone. However, at higher groundwater level periods the piezometer 8_21 levels do exceed piezometer 9_21 levels (see e.g. **Figure 9.10**, map B: 0.8 m head difference), but the two boreholes are too far apart to conclude whether the high levels could lead to a temporary gradient reversal at piezometer 9_21 and hence mark a discharge zone.

Groundwater – surface water interaction

9.5.126 WRc (1997) report that the Black Rock Dolomite and Limestone are regarded in the Tytherington area as an important aquifer that supplies baseflows to the tributaries of the River Frome. Looking at **Figure 9.2** implies the only relevant tributary which is likely to receive baseflow from the combined aquifer is the Ladden Brook and its western contributories. It is noted that the Ladden Brook and its southeasterly headwaters mimic the strike of the strata making up the Coalpit Heath syncline, supported by tributaries flowing in a more downdip direction and thus likely to be supported by baseflow from the aquifer units they cross. Where the Ladden Brook flows over the Mercia Mudstone, mainly between Tytherington Quarry and the Coalpit Heath synclinal axis, it is likely to be hydraulically disconnected from any underlying aquifers.

9.5.127 The water level monitoring scheme described above was extended in February 2005 to also include flow monitoring of a stream to the southwest of the Quarry Complex (BCL, 2023). This ephemeral feature (un-named on OS map) is referred to in BCL (2023) as the "Owlsnest Farm Watercourse" (**Figure 9.3**, close to piezometers 8_21 and 9_21) after a nearby farm. The stream originates approximately 450 m to the southwest of Woodleaze Quarry within the Gully Oolite (i.e. potentially supported by baseflow) and initially flows in a south westerly direction, prior to bending south-eastwards in strata dip direction and entering an incised valley. Further downstream, it passes over the applicant's monitoring weir (**Figure 9.3**) and flows onwards through a large culvert beneath the M4 motorway.

9.5.128 Further upstream of the Owlsnest Farm Watercourse two drains are noted. The longer drain runs parallel to the Avon Group / Black Rock Limestone boundary (**Figure 9.5**, south westwards covered by the Penarth Group) and its likely designed to capture surface water run off coming from the northwest (Avon Group and Penarth Group). From the drains low point, a second drain leads south-eastwards in down dip direction. As soon as it hits the Black Rock / Gully Oolite boundary, it terminates, suggesting any captured runoff is likely to get lost into the latter aquifer. A projection of this drain south-eastwards connects with the origin of the Owlsnest Farm Watercourse, i.e. basically with a losing section in between the two surface water features.

9.5.129 The key findings of the BCL (2023) flow data analysis are presented here. The flow data for the period February 2005 to September 2023 are presented in graphical form as daily average flows in BCL (2023). An assessment of the number of No Flow Days (days when there has been no flow recorded at the monitoring point) has been undertaken to allow comparison between the fourteen full hydrometric years that have been completed since the monitoring point was installed.

9.5.130 BCL (2023) conclude the flow conditions at the monitoring point are sensitive to volumetric and temporal variations in rainfall conditions (as would be expected for an ephemeral spring in limestone terrain). Flows are generally recorded at the monitoring point for 18 to 40% of the year, with the majority of flow occurring during the six-month period October to March (flow for 29 to 89% of the period). Flows during the remainder of the year are normally very low (flow for between 0 and 23% of the period).

9.5.131 Comparing the monitored groundwater level range recoded for piezometer 8_21 (combined aquifer) with the close by DTM elevation of the Owlsnest Farm Watercourse suggests baseflow contribution from the combined aquifer to be unlikely, see Table 9-15. This is consistent with the BCL (2023) findings which suggest the stream to be rather fed by rainfall and surface water runoff as opposed to baseflow.

9.5.132 In contrast, for the Owlsnest Farm Watercourse section further downstream which runs over Cromhall Sandstone and making use of the nearby piezometer 9_21, the numbers presented in **Table 9-15** imply baseflow from that aquifer to be plausible. A continuous baseflow component supporting the stream is certainly not apparent in the flow monitoring point further downstream, which could mean, any gained baseflow in the stream section close to 9_21 is likely to get lost further downstream, e.g. along passage over the Clifton Down Limestone. BCL (Pers. Comm., 2024) provided some further background on this based on their observations in the field as follows. The stream can flow for the reach upstream of 8_21 and even P7 during extreme wet periods and high groundwater levels. From around April onwards the entire water course (including downstream of the motorway culvert) dries up. The soils comprising the fields around the stream are very poor draining and contribute a significant volume to overall flows as runoff during extended wet periods.

Table 9-15 – Piezometer groundwater level comparison with Owlsnest Farm Watercourse DTM elevation

Piezometer information				Piezometer-watercourse distance (m)	Watercourse information		
Piezometer	Monitoring strata	Datum	Groundwater level range (m AOD)		DTM (1m) elevation (m AOD)	Underlying geology	Conclusion regarding potential for baseflow
8_21	Combined aquifer	89.4	54.2 to 86.3	~25	87.6	Clifton Down Mudstone	Groundwater heads in combined aquifer below stream elevation and confined by CDM. No baseflow contribution expected for this stream section.
9_21	Cromhall Sandstone	90.8	84.8 to 85.7	~30	84.4	Cromhall Sandstone	Cromhall Sandstone groundwater levels could potentially be intercepted by stream bed for this section and hence result in baseflow contribution.

9.5.133 The OS 50k map shows a straight 200m long drain which runs in a northwest - southeast direction, ending approximately 30 m to the northwest of Woodleaze Quarry. The DTM (map A of **Figure 9.10**) and geological map (map D of **Figure 9.10**) shows it to originate in the northwest within the Tintern Sandstone, then running over Avon Group rockhead (likely to provide surface runoff but less likely to contribute significant baseflow given its lithology) and terminating within Black Rock Limestone, where any drain water presumably gets lost into the more permeable aquifer. This implies groundwater levels in the Tintern Sandstone (topographically higher than Black Rock outcrop area), are both, likely to be higher compared to the Black Rock and also hydraulically separated from the latter by the Avon Group in between.

BCL (Pers. Comm., 2024) advised that they had examined this feature in the past and it has been shown to be dry, but accumulating water during wet periods from runoff. Accumulating water seems to infiltrate as described above as opposed to making it downstream to the Owlsnest Stream.

9.5.134 Tytherington Watercourse presumably emerged in pre-quarrying days, i.e. under naturalised conditions from SP02. As discussed above, it is possible that this spring was fed by baseflow originating in the combined aquifer at the Quarry Complex, which bypasses the Clifton Down Mudstone where the Mercia Mudstone Group conglomerate directly overlies the combined aquifer, just to the east of the Grovesend Quarry's northeast corner (see **Figure 9.5** and **Figure 9.8**, with the latter figure showing the continuation of Principal Aquifers south eastwards, cutting through the Clifton Down Mudstone. See also **Figure 9.11**). This flow path is however currently not available with the monitored combined aquifer groundwater levels near the Site being lower than the conglomerate base. An alternative mechanism to feed the spring could be via rainfall infiltrating the conglomerate and emerging downstream, which would not involve any hydraulic connection between the spring and the combined aquifer.

Karst

9.5.135 EA (2007) defines karst and its implication for the hydrogeology and the HIA approach as follows:

"Karst comprise dissolutional features such as conduits, caves, sinkholes, and closed depressions which can develop in any soluble rock type, including carbonate rocks such as limestones and dolomites, and evaporites such as gypsum, anhydrite and halite. Such dissolutional features give an aquifer karstic properties, and the assumptions built into many models and analytical equations (that the aquifer is homogeneous and isotropic, for example) break down. There is far greater uncertainty when predicting impacts or interpreting monitoring data in karstic aquifers, and a slightly different approach to HIA may be required.

In terms of hydrogeology, flow in karstic systems can strictly speaking no longer be described using Darcy's Law (which applies only to laminar flow) and conventional approaches to groundwater flow modelling can become inappropriate."

9.5.136 It is therefore briefly discussed in this section whether karstic behaviour is likely to be expected in the Study Area or not.

9.5.137 Whilst Green (1992) wites of deposits filling fissures in karst areas and palaeo-caves in the Carboniferous Limestone in general and it reports of evidence of karstification and micritisation specifically in the Weston area of the Gully Oolite, indicating subaerial exposure of the strata before deposition of the Clifton Down Mudstone, this is not mentioned for the area further north, including the Study Area.

9.5.138 Entec (2010) describes the Gully Oolite in its generic description (Figure 2.3b stratigraphic column table) as 'oolitic limestone capped by palaeokarst surface covered by thin green/red clay palaeosol'. On the BGS Geosure Risk of Kart Feature Development Classifications map (risk classes ranging from A = lowest to E = highest risk) presented in Entec (2010), the Carboniferous Limestone in the north which is closest to the Quarry Complex is classified as risk class B, which means: '*soluble rocks are present within the ground. Few dissolution features are likely to be present. Potential for difficult ground conditions or localised subsidence are at a level where they need not be considered except in exceptional circumstances*'.

9.5.139 WRc (1997) mentions the karstic nature of the Carboniferous Limestone in general and states that, although it is not as pronounced in the Tytherington area, karst features are evident within the quarry. The basement rocks, including the limestones targeted at the Quarry Complex were compacted and recrystallised at the time of folding, so that much of their natural porosity was lost. According to WRc (1997) those limestones have subsequently been karstified by dissolution from subaerial weathering.

9.5.140 The karst features that WRc identified during their site visit in all three Tytherington Quarries are summarised as follows:

- A particularly large feature, moving down strata, which has been removed from the second bench level in the northeast corner of Woodleaze quarry; and
- Other small features (apparently infilled with recent material rather than Triassic) were visible in the North Face Quarry at 65 to 70 m AOD.

9.5.141 WRc (1997) go however on to ague the fact that no turbidity [as of elevated suspended solids which can originate from quarries, typically in the absence of settling ponds prior to water transfer/discharge] problems have been reported at Tytherington Watercourse even during initial quarrying, and before significant dewatering. This indicates to the authors that there are no direct karstic connections between the two sites. WRc also noted that there was obvious seepage in the Clifton Down Mudstones in Woodleaze Quarry. The authors also observed bedding planes within the quarry limestones are well developed and almost certainly act as small conduits in the lower benches.

9.5.142 GWP (2022) encountered 1 m wide voids during drilling at 53 m bGL (BH 2021-3) and 141 m bGL (2021-8), the authors made no references to karstic features.

9.5.143 Despite the uncertainties around the groundwater level contours, it appears that observed levels can be explained by assuming Darcy behaviour and because of this, together with the relatively low karst risk from the regional studies and WRc findings discussed above, it is, that karst is not an issue assumed for the Study Area.

Groundwater quality

9.5.144 Entec (1998) report that water samples were collected from five of the six 1998 boreholes (Table 9-13, no. 1 was dry) and also from the North Face Quarry sump. The report states that 'on completion of each monitoring well the boreholes were air flushed for half an hour for well development' and that a sample would be collected at the end of this period. This implies samples were taken from the readily installed piezometers as expected and not from the open boreholes. Determinands included major ions and some heavy metals. Since Entec (1998) is a factual report, the results have not been analysed or interpreted, but the report notes that some of the groundwater sample results show evidence of being affected (despite the well development described above) by drilling.

9.5.145 The Entec (1998) water samples are presented in **Figure 9.13** on a piper chart. More sample rounds would be required to derive more robust conclusions, but the following can be seen at this stage:

- The North Face Quarry (NFQ) sample and the P3 sample are both of Ca-Mg-HCO3 type which is to be expected for groundwater in dolomitised limestones, as at least in parts applies to the combined aquifer.
- The P5 sample has a very high ion balance error, which typically is down to incorrect alkalinity. By using a more plausible alkalinity this moves the sample in the type diamond closer to the NFQ and the P3 sample, as would be expected, given they all represent the combined aquifer.
- P6, which is likely to be screened in the Avon Group is also of Ca-Mg-HCO3 type, but with less Mg. I.e. its groundwater type, at least for this one sample differs from the cluster of the samples discussed above.
- The P2 sample, is of Na-HCO3 type, i.e. very different to P6 and the combined aquifer samples which is not understood. The same applies to P4 (mixed type) which would be expected to be of Ca-Mg-HCO3 type like the other combined aquifer samples.

9.5.146 Other than this initial one-off sampling round it is understood that no further groundwater quality monitoring has been carried out at or around the Quarry Complex and it is not part of the routine hydrometric monitoring scheme described above.

9.5.147 WRc (1997) states, based on karstic features being evident within the Quarry Complex, that if circumstances are unfavourable pollutants can be quickly transferred from any potential source of spillage deep underground. But as described above there appears to be currently no evidence of karstic behaviour in the groundwater flow patterns.

Hydrogeological conceptual model

9.5.148 The conceptual model has been developed in the above sections. This is presented in **Figure 9.11** and explained below.

9.5.149 The Quarry Complex, comprising the two historic quarries (North Face and Grovesend) and the current active Woodleaze Quarry sits on top of hill. Based on topography only groundwater flow would be expected to follow the geomorphology, i.e. south-eastwards and north-westwards. However, the groundwater flow pattern is complicated by the underlying complex geology (involves both folding and faulting) and the alternation between aquifers and aquitards. The groundwater flow pattern is also influenced by the ongoing dewatering activity. Given the Quarry Complex marks a topographic high between the even higher Cotswold Hills in the east and the Severn Estuary in the west, it acts as a recharge zone.

9.5.150 The upper part of the Avon Group (interbedded mudstone/limestone) is regarded as an aquitard. It hydraulically separates the lower part of the Avon Group (limestone, Principal Aquifer) where present, or the Tintern Sandstone below from the combined aquifer (Black Rock Limestone (both dolostone and limestone) and the Gully Oolite) above. As such it is believed to act as a no flow boundary, i.e. it prevents groundwater flowing north-westwards. Given the relatively steep strata dip (up to 40 degrees), recharge can enter the limestone layers of the upper part of the Avon Group and generate seasonal groundwater level fluctuations, but the more prominent mudstone bands are responsible for the hydraulic barrier behaviour between the aquifers it separates.

9.5.151 The Clifton Down Mudstone is also regarded as an aquitard. It hydraulically separatees the combined aquifer underneath from the Cromhall Sandstone, Clifton Down Limestone, Oxwich Head Limestone and Tanhouse Limestone (upper combined aquifer) above. It is anticipated to act as a no flow boundary where it is present.

9.5.152 From groundwater level analysis (both spatial and temporal) the following is understood for the combined aquifer:

- The surface water bodies of all three quarries sit in the combined aquifer and are therefore hydraulically connected to the aquifer;
- There is a depression cone around the Woodleaze Quarry sump (annual pumping averages of between 1.2 and 3.5 Ml/d during active dewatering) at currently as low as 18.5 m AOD.
- Groundwater contours imply a closed groundwater divide around it, except for the no flow boundary along the north-western boundary of the quarry.
- Groundwater levels in the Avon Group and in the Cromhall Sandstone (subject to uncertainties in the piezometer monitoring strata) appear to behave independently from levels in the combined aquifer (including the quarry lake levels) which supports the theory of both, the upper part of the Avon Group and the Clifton Down Mudstone acting as aquitards.
- Groundwater within the combined aquifer on the other side of / outside the divide is likely to flow:
  - To the southwest, along strata strike direction. However, groundwater levels are thought to be not high enough, at least in the combined aquifer, to provide any meaningful baseflow to the Owlsnest Farm Watercourse (also confirmed by flow gauging / rainfall data analysis, BCL, 2023).
  - To the southeast, along strata dip direction. However, given the steep dip, the combined aquifer is expected to get soon confined under the Clifton Down Mudstone, and the latter is thought to prevent actual upward flow, even further in the southeast in the presumed discharge zone underneath the Ladden Brook.
  - Possibly to the northeast of piezometer P1 along strata strike direction, but there are no monitoring boreholes to verify this. However, a northeast-southwest trending fault approximately 1.2 km to the northeast of the Site, which juxtaposes the combined aquifer and the upper combined aquifer next to each other is noted. This could potentially act as an additional outlet for combined aquifer groundwater, and hence allow groundwater flow through the upper combined aquifer to the southeast

9.5.153 The Ladden Brook valley mimics the softer rocks of the Coalpit Heath syncline and flows around the more resistant Mangotsfield Member Sandstone in the syncline core. The valley marks the morphological low between the highs of the western limb (where the Quarry Complex sits) and the eastern limb (which hosts for example Wickhill Quarry). Both surface water run-off, following the topography, and lateral groundwater flow in the underlying aquifers, following the strata dip, are oriented towards the Ladden Brook valley, which is expected to represent a discharge zone, i.e. vertical hydraulic gradients are expected to be upwards in this area. However, the Avon Group is thought to prevent actual upward flow from the combined aquifer to support the Ladden Brook with baseflow and the same is likely to be true for the Mercia Mudstone Group mudstones separating the stream from the upper combined aquifer. Therefore, groundwater in the deeply buried combined aquifer is thought to be heavily confined in this area with groundwater to be rather static.

9.5.154 Stanton (1991) claims that dewatering of the Quarry Complex has in the past reduced flow from springs in Tytherington village. The only known spring SP2 in **Figure 9.11** is likely to no longer exist. Currently, the combined aquifer groundwater levels (influenced by dewatering) are too low to support a potential spring at location SP2 with a ground elevation of 68.1 m AOD. Current Cromhall Sandstone groundwater levels recorded close to the Site would be high enough, but at the same time do not respond to quarry dewatering despite being much closer to the quarry than the spring location. This implies, that if the spring was supported by the Cromhall Sandstone, it would not be impacted by dewatering activity occurring in the combined aquifer.

9.5.155 The Triassic Mercia Mudstone Group conglomerate (Principal Aquifer) unconformably overlies the Carboniferous to the southeast of North Face Quarry and provides the fill of a dry valley structure. Its outcrop shape, the geomorphology and the fact of a surface watercourse emerging further down to the southeast along the valley axis implies that this valley feature will at some stage (historically, presumably under pre-quarrying/naturalised conditions) have acted as a drain for surface runoff from the hill and presumably have connected with the present Tytherington Watercourse.

9.5.156 This conglomerate deposit is noted to overly both, the combined and the upper combined aquifer by ‘bridging’ over the Clifton Down Mudstone, i.e. the latter could in theory, if groundwater levels in the combined aquifer are high enough be bypassed. The contact elevation between the combined aquifer and the conglomerate is, according to the DTM as low as 76.2 m AOD, which means it is higher than the current maximum combined aquifer groundwater levels (e.g. 67.4 m AOD at piezometer 3). Hence, this flow path can be ruled out for the current situation, i.e. a spring located at SP02 would not be fed by the combined aquifer via this route. It is however conceivable, that this groundwater flow path might have been active under pre-quarrying conditions and thus have provided baseflow for any village springs. This flow mechanism would explain the Stanton (1991) claim, but at the same time, it implies that any further lowering of the quarry water table would have no further impact. In the absence of historic spring flow rates, it is difficult to rank the importance of the conglomerate feature.

9.5.157 Any potential loss to spring flow in the past would have resulted in a baseflow reduction in Tytherington Watercourse further downstream. The consented discharge point just to the north of SP02 does compensate for this by supporting the watercourse.

9.5.158 Alternatively, SP02 could be fed via rainfall infiltrating the conglomerate and emerging downstream, which would not involve any hydraulic connection between the spring and the combined aquifer.

9.5.159 The licensed abstraction AB03 just to the southeast of Tytherington Village is associated with farming (annual licenced volume <0.1 Ml/d, Table 9-25). Its depth is not recorded, according to Environment Agency records it is targeting the Carboniferous Limestone, which could be either of the combined aquifers. Given the low licensed volume, the farming purpose and its rockhead (Mercia Mudstone Group conglomerate) the borehole is not expected to be deep enough to target the combined aquifer and hence, being hydraulically isolated from it by the Avon Group the borehole is not expected to be impacted from current and future planned (as part of the Proposed Scheme) dewatering activities at the Site.

9.5.160 The water types of the one-off sample round from 1998 (Entec, 1998) shows piezometer samples 6, 3, 5 and the North Face Quarry sample to be of Ca-Mg-HCO_3 type, which makes conceptual sense given the limestone environment with partial dolomitisation. The Mg component in P6 is lower than in the other samples mentioned above, potentially implying different groundwater types between the Avon Group and the combined aquifer. For the piezometer 4 sample the combined aquifer type as of Ca-Mg-HCO3 would have been expected but the actual sample is of mixed type. The piezometer 2 sample was expected to be similar to piezometer 6, but instead it shows a unique type of Na-HCO3. More data would be required to draw more robust conclusions as to what water types the various strata are likely to produce and the findings from just the one sampling round need to be treated with care.

9.5.161 Based on regional findings (Entec, 2010), local observations from WRc (1997) and the fact that the groundwater levels can be contoured in a way that applies Darcy's Law (as of continuous flow within aquifers) karst is not seen as an issue for the Carboniferous Limestones within the Study Area.

Aquatic Environment

Conservation sites

9.5.162 There are three statutory designated sites within the Study Area which are all Sites of Special Scientific Interest (SSSI) (Magic Maps, 2024), namely Tytherington Quarry SSSI, Buckover Road Cutting SSSI and Brinkmarsh Quarry SSSI (**Figure 9.12**).

9.5.163 Tytherington Quarry SSSI is located north of the northern site boundary, within North Face Quarry. Buckover Road Cutting SSSI is located 1.7km north of the Site, along the A38. Brinkmarsh Quarry SSSI is located 2.8km north of the Site. All these SSSIs are designated due to being geological exposures. These are unlikely to be water dependent, which is supported by the fact that none of the three sites features in the Open Government online data[31] set of groundwater dependent terrestrial ecosystems (GWDTEs).

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[31] Open Government Data On-line - Groundwater dependent terrestrial ecosystems (online). Available from https://data.gov.uk/dataset/72a149a2-1be7-441f-bc37-94a77f261e27/groundwater-dependent-terrestrial-ecosystems-england-only

Surface water run-off

9.5.164 In terms of surface water run-off, the quarry's plant area comprises a hard surface of compacted crushed aggregate or surfaced with asphalt laid to a fall, consequently runoff is collected and channelled through an oil intercept prior to entering the Site's approved discharge consent easement in the existing lagoon in Grovesend Quarry, prior to transfer and discharge via the consented discharge point within Tytherington Village.

Ponds and lakes

9.5.165 There are no surface water bodies (lakes/ponds) located within the Site, other than the quarry sumps in each the Grovesend Quarry and Woodleaze Quarry, which both form part of the quarry water management scheme. These are also visible on recent aerial imagery. In addition, during the aquatic habitats survey, an ephemeral pond was identified within the soil store area . At the time of survey, the pond was dry, and it is assumed that this dries out yearly and that it would not support a fish, invertebrate or amphibian assemblage of any value.

9.5.166 Several maps were reviewed to identify water features within the Study Area, including 1:25k scale OS Mapping, OS Open Map Local and Bing Maps. Numerous ponds and one lake ('The Lake'- PO157) were identified and these are shown in **Figure 9.12** (PO001 to PO157).

Springs

9.5.167 Within the Study Area, one spring source (SP01) was identified from 1:25k scale OS Mapping and the second spring has been discussed above and is located in Tytherington Village (SP02). These are mapped on **Figures 9.3** and **9.12** (SP01 and SP02).

9.5.168 SP1 is located 570 m north-east of the Site, within woodland (Cleve Wood) close to its western edge. WRc (1997) point out for this spring, that it appears to rise off the Lower Limestone Shales (=Avon Group), but the BGS mapping (**Figure 9.5**) suggests it to be located on the Raglan Mudstone Formation (Silurian), but in any case, separated from Quarry Complex by the Avon Group. The spring is therefore unlikely to be affected by quarry dewatering. WRc (1997) concluded it is probably derived from surface run off rather than being groundwater fed. BCL (Pers. Comm., 2024) have also looked at this feature in the past and found it to be dry, with water only being identified some distance downstream east of Thornbury. This supports the idea of the feature to be more related to focussed runoff from adjacent land.

9.5.169 WRc (1997) mentions a "source of the spring marked at Tytherington (NGR 669 882, Figure 2 in WRc, 1997) and subsequently culverted as the Tytherington Watercourse, but reports this could not be identified by WRc during a site visit. This spring is also not mapped on the 25k OS map and hence is not discussed further in this report.

9.5.170 As discussed above, Stanton (1991) claims that the Quarry Complex dewatering activity has in the past reduced flow of the village spring SP02.

9.5.171 WRc (1997) refer to the Lower Bristol Avon Catchment Management Plan (NRA 1995) which states that the sub water table quarries at Tytherington have dried up natural springs feeding the Ladden Brook, although these have been replaced by "dewatering pumpage", or, as WSP interprets this by discharging the water gained from dewatering at the consented discharge point (**Figure 9.3**) to support the Ladden Brook.

9.5.172 As discussed above, SP02 might, whilst not currently but potentially in the past have been fed by baseflow originating in the combined aquifer at the Quarry Complex, and subsequently bypassing the Clifton Down Mudstone where the Mercia Mudstone Group conglomerate directly overlies the combined aquifer. It is also possible that SP02 could be fed via rainfall infiltrating the conglomerate and emerging downstream, which would not involve any hydraulic connection between the spring and the combined aquifer.

Wells

9.5.173 Fourteen wells were identified from 1:25k scale OS Mapping within the Study Area. These are mapped on **Figure 9.12** (WL01 to WL14). None of the wells identified correlate with Environment Agency Licenced Abstractions or Private Water Supplies which are discussed later in the "Water Resources – Abstractions" section of this chapter. None of the wells identified correlate with the BGS GeoIndex Borehole Records. A summary of the wells is provided in **Table 9-16**.

Table 9-16 – Summary of wells

Figure reference	Location in relation to site	NGR	Rockhead geology	Aquifer Designation
WL01	2.2km west	ST6305588490	Blue Anchor Formation (mudstone)	Secondary B
WL02	3.3km west	ST6193587878	Penarth group (mudstone)	Secondary (undifferentiated)
WL03	2.9km west	ST6243587795	Blue Anchor Formation (mudstone)	Secondary B
WL04	2.7km south	ST6555285222	Penarth group (mudstone)	Secondary (undifferentiated)
WL05	2.7km south	ST6572685228	Penarth group (mudstone)	Secondary (undifferentiated)
WL06	2.8km east	ST6921488376	South Wales Lower Coal Measures Formation And South Wales Middle Coal Measures Formation (Undifferentiated) (mudstone and sandstone)	Secondary A
WL07	1.7km north-east	ST6705690221	Tintern Sandstone Formation (sandstone)	Secondary A
WL08	0.5km north	ST6588589540	Tintern Sandstone Formation (sandstone)	Secondary A

Figure reference	Location in relation to site	NGR	Rockhead geology	Aquifer Designation
WL09	0.8km north	ST6550489863	Raglan Mudstone Formation (siltstone and mudstone, interbedded)	Secondary A
WL10	2.7km north	ST6669391421	Raglan Mudstone Formation (siltstone and mudstone, interbedded)	Secondary A
WL11	2.7km north	ST6708791309	Raglan Mudstone Formation (siltstone and mudstone, interbedded)	Secondary A
WL12	2.5km north-west	ST6341590179	Raglan Mudstone Formation (siltstone and mudstone, interbedded)	Secondary A
WL13	4km north-east	ST6931891424	Clifton Down Limestone Formation (limestone)	Principal
WL14	3.7km north-east	ST6969190342	Cromhall Sandstone Formation (sandstone)	Principal

Water quality

9.5.174 There are twelve water quality sampling locations from the EA WIMS within the Study Area. These are shown on **Figure 9.14** and are listed in **Table 9-17**.

9.5.175 The sample locations consist of:

- One freshwater (Tortworth Brook in the northeast of the Study Area);
- Two groundwater boreholes (Game farm, Latteridge to the south and Thornbury golf centre to the west of the Site); and
- Nine trade or sewage discharge points.

Table 9-17 - Water Quality sampling locations

Location			Monitoring date		Distance from Site
Name	ID	Type	First	Last	
Tytherington Quarry pumped discharge	SW-Z2050126	Trade Discharges – Process Effluent – Water Company (wastewater)	2000	2013	On site
Wyevale Garden Centre	SW-62023001	Sewage & Trade Combined – Unspecified	2016	2018	1.1km north
White Horse Inn	SW-62023005	Sewage Discharges – Final/Treated Effluent – Not Water Company	2015	2015	1.7km north
Former limeworks site Itchington serving 18 domestic properties	SW-63020050	Sewage Discharges – Final/Treated Effluent – Not Water Company	2008	2008	700m south
Game farm, Latteridge	SW-6002GW13	Groundwater – Borehole	2004	2024	3km south east
Cromhall STW Tortworth Brook	SW-B3160103	Sewage Discharges – Final/Treated Effluent – Water Company	2000	2020	2.3km north east
Cromhall STW new	SW-63160103	Sewage Discharges – Final/Treated Effluent – Water Company	2021	2024	2.3km north east
Alveston STW	SW-B0050203	Sewage Discharges – Final/Treated Effluent – Water Company	2000	2024	3.4km south west
Thornbury golf centre	SW-6420GW01	Groundwater – Borehole	2008	2023	3.0km west
Westwing Girls School, Thornbury	SW-B0010790	Sewage Discharges – Final/Treated Effluent – Not Water Company	2001	2015	3.5km north-west
Eastwood Park training centre	SW-B3150103	Sewage Discharges – Final/Treated Effluent – Not Water Company	2000	2018	3.8km north
Tortworth Brook abbot-side	SW-B3160109	Freshwater – Rivers	2000	2017	4.0km north-east

Groundwater quality

9.5.176 The Thornberry Golf Centre borehole (Tintern Sandstone Group, 3km west of the Site) has already been introduced in **Section: Aquifer parameters**. The water quality analysis for this borehole includes fifteen samples from May 2008 to August 2023. Samples were routinely tested for inorganics, organics and major ions. Metals, dissolved metals, pesticides, herbicides and PFAS were tested irregularly. PFAS, herbicides and pesticides were generally recorded below the limit of detection; although carbendazim was recorded above the detection limit in 2009 and 2012. A summary of the groundwater quality results is detailed in **Table 9-18**.

Table 9-18 - Groundwater quality summary of Thornbury Golf Centre (SW-6420GW01)

Determinand	Unit	No of samples		Concentrations		
		Total	>LOD*	Min	Max	Average
Alkalinity to pH 4.5 as CaCO3	mg/l	12	12	250	392	333.3
Ammoniacal Nitrogen as N	mg/l	12	2	0.032	0.035	0.0
Carbon, Organic, Dissolved as C (DOC)	mg/l	10	10	0.49	1.17	0.8
Calcium, dissolved	mg/l	4	4	76	107	90.0
Cadmium, dissolved	µg/l	4	0	<LOD	<LOD	<LOD
Conductivity at 25 C	µs/cm	12	12	617	817	727.0
Nitrogen, Total Oxidised as N	mg/l	12	12	1.06	3.48	2.3
Nitrate as N	mg/l	12	12	1.06	3.48	2.3
Nitrite as N	mg/l	12	2	0.01	0.0102	0.0
Oxygen, Dissolved, % Saturation	%	12	12	20	86.4	62.9
Orthophosphate, reactive as P	mg/l	12	1	0.011	0.011	0.0
pH		7	7	7.26	7.7	7.5
Temperature of Water	°C	12	12	11.1	13	12.1
Hardness, Total as CaCO3	mg/l	10	10	313	442	389.3
Sulphate, Dissolved as SO4	mg/l	4	4	32.3	40	35.0
Chloride	mg/l	12	12	12	24.9	18.4
Sodium	mg/l	6	6	7.23	13.1	9.4
Potassium	mg/l	6	6	1.65	6.45	3.3

Determinand	Unit	No of samples		Concentrations		
		Total	>LOD*	Min	Max	Average
Bicarbonate as HCO3	mg/l	9	9	318	478	416.9
Magnesium, Dissolved	mg/l	4	4	37	42.4	39.4
Zinc, Dissolved	µg/l	4	4	0.82	3.95	2.5

*LOD = limit of detection

9.5.177 The Game Farm borehole (Mercia Mudstone Group, 3km southeast of the Site) has already been introduced in **Section: Aquifer parameters**. The water quality analysis for this borehole includes 39 samples from February 2004 to March 2024. Samples were routinely tested for inorganics, organics and major ions. Metals, dissolved metals, pesticides, herbicides and PFAS were tested irregularly. PFAS and pesticides were recorded below the limit of detection. A summary of the groundwater quality results is outlined in **Table 9-19**.

Table 9-19 - Groundwater quality summary of Game Farm, Latteridge (SW-6002GW13)

Determinand	Unit	No of samples		Concentrations		
		Total	>LOD	Min	Max	Average
Alkalinity to pH 4.5 as CaCO3	mg/l	39	39	291	435	361.1
Ammoniacal Nitrogen as N	mg/l	39	3	0.302	0.65	0.46
DOC	mg/l	30	30	0.59	3.7	1.74
Calcium, dissolved	mg/l	18	18	51	115	88.7
Cadmium, dissolved	µg/l	17	1	0.0106	0.0106	0.01
Conductivity at 25 C	µS/cm	32	32	448	1128	945.4
Nitrogen, Total Oxidised as N	mg/l	39	37	0.5	8.2	1.7
Nitrate as N	mg/l	39	39	0.196	8.2	1.6
Nitrite as N	mg/l	39	7	0.0041	0.05	0.01
Oxygen, Dissolved, % Saturation	%	39	39	8.7	97.4	49.2
Orthophosphate, reactive as P	mg/l	39	11	0.012	0.05	0.02
pH		26	26	7.23	7.85	7.5
Temperature of Water	°C	39	39	4.45	17.4	10.1
Hardness, Total as CaCO3	mg/l	33	33	243	446	380.8
Sulphate, Dissolved as SO4	mg/l	11	11	80.8	165	115.8

Determinand	Unit	No of samples		Concentrations		
		Total	>LOD	Min	Max	Average
Chloride	mg/l	39	39	28.5	83	40.5
Sodium	mg/l	30	30	18.6	150	46.6
Potassium	mg/l	30	30	1.79	12	5.0
Bicarbonate as HCO3	mg/l	23	23	355	478	436.4
Magnesium	mg/l	30	30	28	42.7	34.0
Zinc, Dissolved	µg/l	17	17	2.84	19.2	11.8

9.5.178 The groundwater monitoring results have been plotted on a Piper diagram to determine the groundwater type, based on concentrations of specific major ions. The Piper plot is presented in (**Figure 9.13**). A summary of the groundwater types is outlined in **Table 9-20**.

9.5.179 There are four samples available for Thornbury Golf centre. There were 11 samples available for Game Farm, Latteridge. However, five of these samples were removed due to having ionic balances exceeding ±5%.

9.5.180 The groundwater type of the Game Farm borehole is variable. There does not appear to be any correlation for this change, annually or seasonally. Groundwater levels were not recorded so cannot be reviewed to determine possible correlation. The four samples from the Thornbury Golf centre borehole on the other hand are consistently of Ca-Mg-HCO3 type.

Table 9-20 – Groundwater type analysis

Monitoring Point	No. of samples	Sampling date	Water Type	Ionic balance %
Game Farm, Latteridge (SW-6002GW13)	6	16 Mar 2016	Ca-Mg-HCO3	-3.87
		19 Sep 2016	Mg-HC03	-3.03
		13 Sep 2017	Mixed type (Na-K-HCO3)	-0.16
		20 Nov 2018	Mixed (Na-K-HCO3)	-0.87
		8 Oct 2019	Ca-Mg-HCO3	-3.74
		6 Sep 2022	Mixed (Na-K-HCO3)	-0.89
Thornbury Golf Centre (SW-6420GW01)	4	17 Jul 2017	Ca-Mg-HCO3	1.93
		24 Sep 2018	Ca-Mg-HCO3	1.19
		29 Aug 2019	Ca-Mg-HCO3	-0.78
		25 Aug 2023	Ca-Mg-HCO3	0.75

Surface water quality

9.5.181 In terms of surface water quality, there is one EA surface water quality sampling location within the Study Area. This is Tortworth Brook - Abbot Side (SW-B3160109), located approximately 3.3km north-east of the Site and part of the Severn Lower Vale Operational Catchment. This sampling location is downstream of several discharge points, including Cromhall Water Treatment Works (sewage), RMC Aggregates (Quartzite Quarry- trade effluent), St Andrews Church (sewage), and Jubilee Lane Pumping Station (sewage).

9.5.182 The water quality analysis includes 197 samples from January 2000 to May 2017. Samples were routinely tested for inorganics, organics, major ions and zinc. A summary of the groundwater quality results is set out in **Table 9-21**.

Table 9-21 - Groundwater Quality Summary of Tort Brook- Abbot Side (SW-B3160109)

Determinand	Unit	No of samples		Concentrations		
		Total	>LOD*	Min	Max	Average
Alkalinity to pH 4.5 as CaCO3	mg/l	138	145	<LOD	355	251
Ammoniacal Nitrogen as N	mg/l	157	102	0.03	3.59	0.15
Calcium	mg/l	38	47	<LOD	130	86.2
Conductivity at 25 C	µs/cm	70	80	<LOD	996	658.5
Nitrogen, Total Oxidised as N	mg/l	197	197	2.55	19.5	7.8
Nitrate as N	mg/l	197	197	2.53	19.5	7.8
Nitrite as N	mg/l	197	197	0.0043	0.193	0.04
Oxygen, Dissolved, % Saturation	%	156	157	<LOD	107.3	80.5
Orthophosphate, reactive as P	mg/l	145	147	<LOD	1.88	0.51
pH		157	157	7.1	8.19	7.7
Temperature of Water	°C	157	157	4.7	17.82	10.8
Hardness, Total as CaCO3	mg/l	38	47	<LOD	382	265.6
Potassium	mg/l	54	65	<LOD	12.1	6.7
Magnesium	mg/l	38	47	<LOD	24.3	12.2
Zinc	µg/l	157	157	12.6	103	39.0

Water Framework Directive

9.5.183 River Basin Management Plans (RBMPs) have been drawn up by the EA for the ten river basin districts in England and Wales as a requirement of the WFD. The plans for England have been developed by the EA through consultations with organisations and individuals. The plans are designed to protect and improve the quality of the water environment, providing information on what needs to be done to tackle water issues, i.e. measures to improve water quality in rivers, lakes, estuaries, coasts and in groundwater. The Study Area includes the Tortworth Brook, Ladden Brook[32], and the Oldbury Naite Rhine which are covered by the RBMP for the Severn River Basin District.

9.5.184 WFD water bodies are separately categorised into surface water body, and groundwater water body management units as described below.

9.5.185 In relation to surface water bodies, River Basin Districts are dived into Management Catchments, which are further divided into Operational Catchments, within which there are sub-catchment water bodies. The Study Area is located within the Avon Bristol and Somerset North Streams Management Catchment and contains the following sub-catchment surface water bodies:

- Oldbury Naite Rhine (GB109054026670);
- Tortworth Brook – source to confluence of River Little Avon (GB109054026590); and
- Ladden Brook – source to confluence of River Frome (Bristol) (GB109053027590).

9.5.186 In relation to groundwater bodies, the Study Area is located within the Severn England groundwater management catchment and contains the following Operational Catchments:

- Carboniferous Limestone – Alveston;
- Avonmouth Merica Mudstone; and
- Bristol Triassic.

9.5.187 A summary of the local WFD water bodies and their associated status, based on the 2021 WFD classification, Cycle 3 for surface water and on the 2019, Cycle 3 for groundwater is presented in **Table 9-22** and **Table 9-23** respectively.

[32] Ladden Brook is spelt 'Laddon' according to WFD classification, but 'Ladden' in OS 25k map, i.e. 'e' instead of 'o'. The OS 'Ladden' spelling is used throughout in this chapter.

Table 9-22 - Summary of local WFD River Water bodies

Water Body ID / Management catchment	Water Body type	Status	Supporting Elements, less than Good Status / Potential	Issues Preventing the Attainment of Good Status
Oldbury Naite Rhine (GB109054026670) / Avon Bristol and Somerset North Streams	River	Moderate Status (2022): Moderate Ecological status, Chemical 'Does Not Require Assessment' – classified as Fail in 2019	Macrophytes and Phytobenthos Combined Phosphate	Phosphate – poor livestock management – diffuse source Phosphate – poor nutrient management – diffuse source Phosphate – septic tanks – diffuse source Macrophytes and Phytobenthos Combined – private sewage treatment - diffuse source Macrophytes and Phytobenthos Combined – suspect data Perfluorooctane sulphonate (PFOS) -unknown (pending investigation) Fish – flood protection structures – physical modification Fish – natural conditions Polybrominated diphenyl ethers (PBDE) - measures delivered to address reason, awaiting recovery Mercury and Its Compounds - measures delivered to address reason, awaiting recovery
Laddon Bk – source to conf R Frome (Brist) Water Body GB109053027590) / Avon Bristol and Somerset North Streams	River	Poor status (2022): Poor ecological status, Chemical 'Does Not Require Assessment' – classified as Fail in 2019	Fish Macrophytes and Phytobenthos Combined Phosphate	Fish – poor soil management – diffuse source Macrophytes and Phytobenthos Combined - poor livestock management – diffuse source Phosphate – poor nutrient management – diffuse source Fish - land drainage - operational management - physical modification

Water Body ID / Management catchment	Water Body type	Status	Supporting Elements, less than Good Status / Potential	Issues Preventing the Attainment of Good Status
				Macrophytes and Phytobenthos Combined - Flood protection structures – physical modification Mercury and Its Compounds - measures delivered to address reason, awaiting recovery Polybrominated diphenyl ethers (PBDE) - measures delivered to address reason, awaiting recovery Macrophytes and Phytobenthos Combined- Suspect data
Tortworth Bk - source to conf R Little Avon (GB109054026590)	River	Moderate Status (2022): Moderate Ecological status, Chemical 'Does Not Require Assessment' – classified as Fail in 2019	Macrophytes and Phytobenthos Combined	Phosphate – poor nutrient management – diffuse source Macrophytes and Phytobenthos Combined – poor nutrient management – diffuse source Macrophytes and Phytobenthos Combined – sewage discharge (continuous) – point source Phosphate - sewage discharge (continuous) – point source Mercury and Its Compounds - measures delivered to address reason, awaiting recovery Polybrominated diphenyl ethers (PBDE) - measures delivered to address reason, awaiting recovery

https://environment.data.gov.uk/catchment-planning/ManagementCatchment/3005

Table 9-23 - Summary of local WFD groundwater bodies and their associated status

WFD Water Body	Carboniferous Limestone – Alveston	Avonmouth Merica Mudstone	Bristol Triassic
Water body Identifier	GB40901G806200	GB40902G303100	GB40902G804800
Management Catchment	Severn England GW	Severn England GW	Severn England GW
Operational Catchment	Carboniferous Limestone – Alveston	Avonmouth Merica Mudstone	Bristol Triassic
Quantitative status	Poor	Good	Good
Chemical (GW) status	Good	Poor	Good
Overall current (2019) status	Poor	Poor	Good
Reasons for not achieving Good Status	Quantitative Water Balance = poor, no further reasons provided	Chemical Dependent Surface Water Body Status and General Chemical Test = poor, no further reasons provided	N/A

https://environment.data.gov.uk/catchment-planning/ManagementCatchment/1011

9.5.187.1 Water resources

Abstractions

9.5.188 The EA and SGC were contacted to obtain information on licensed abstractions and registered Private Water Supplies (PWS) respectively within the Study Area.

9.5.189 The EA identified three licensed abstractions and SGC identified seven PWS.

9.5.190 The three licensed abstractions are all for groundwater sources and the respective borehole points are shown on **Figure 9.14**, labelled as AB01 to AB03. Additional details for these three abstractions can be found in **Table 9-24**.

9.5.191 In terms of recent actual volumes, the following information was obtained for the three abstractions:

- Borehole at Park Mill Farm (AB01) recorded 11,817 m^3/day (11.8 Ml/d) between September 2020 and September 2021.
- Borehole at Mill Farm (AB03), Tytherington, has no readings available.
- Thornbury Golf Centre (AB02) has no correct readings available since 2019.

9.5.192 It should be noted that the Thornbury Golf Centre abstraction borehole is also part of the EA WIMS water quality database (see **Section: Water Quality**).

9.5.193 Additional information on BGS (2024a) for the actual boreholes is only available for Thornbury Golf Centre (as discussed above), but not for the other two boreholes.

Table 9-24 - Licensed abstractions within the Study Area

Figure Reference	Permit Name (Permit number)	Location relative to Site	Aquifer	Purpose & license conditions	Licensed volumes			
					Hourly m³/h	Daily m³/d	Annual m³/y	Instantaneous l/s
AB01	Borehole at Park Mill Farm (18/54/020/G//R01)	3.5km northwest	Mercia Mudstone	General Farming & Domestic (All year abstraction)	2.3	55	20,075	N/A
AB02	Thornbury Golf Centre (18/54/020/G/294)	3km west	Tintern Sandstone Group	Spray Irrigation – Storage (April to September)	6.0	136	20,455	1.66
AB03	Borehole at Mill Farm Tytherington (17/53/002/G/080)	1.2km east	Carboniferous Limestone	General Farming & Domestic (All year abstraction)	2.77	40	11,000	N/A

9.5.194 Monthly returns information was also requested for the sites. It was noted that there is no data held for “Borehole at Park Mill Farm”, as the license to abstract is <100m3/day. Likewise, “Borehole at Mill Farm, Tytherington” has only partial data for pre-2008 since the license to abstract is also <100m3/day.

9.5.195 There are a total of 12 PWS within the Study Area and these are shown on **Figure 9.14**, labelled as GA01 to GA12. The consist of:

- Three springs, namely, from north to south, GA08, GA01, and GA07;
- Two wells, namely, from north to south, GA06 and GA05; and
- Seven boreholes, namely, GA03, GA02, GA04, GA09, GA10, GA11, and GA12. The latter six of the locations are represented by on point only on **Figure 9.14**, as they were provided with identical grid references. These commercial abstractions are likely to be associated with farms and dwellings in Milbury Heath.

9.5.196 Further details of the PWS are presented in **Table 9-26**.

9.5.197 The EA and South Gloucestershire Council were contacted to obtain information on licensed abstractions and registered Private Water Supplies (PWS) respectively within the Study Area.

9.5.198 The EA identified three licensed abstractions and South Gloucestershire Council identified seven PWS.

9.5.199 The three licensed abstractions are all for groundwater sources and the respective borehole points are shown on **Figure 9.14**, labelled as AB01 to AB03. Additional details for these three abstractions can be found in **Table 9-25**.

9.5.200 In terms of recent actual volumes the following information was obtained for the three abstractions:

- Borehole at Park Mill Farm (AB01) recorded 11,817 m^3/day (11.8 Ml/d) between September 2020 and September 2021.
- Borehole at Mill Farm (AB03), Tytherington, has no readings available.
- Thornbury Golf Centre (AB02) has no correct readings available since 2019.

9.5.201 It should be noted that the Thornbury Golf Centre abstraction borehole is also part of the EA WIMS water quality database (see Section Water Quality).

9.5.202 Additional information on BGS (2024a) for the actual boreholes is only available for Thornbury Golf Centre (already discussed above), but not for the other two boreholes.

Table 9-25 - Licensed abstractions within the Study Area

Figure Reference	Permit Name (Permit number)	Location relative to Site	Aquifer	Purpose & license conditions	Licensed volumes			
					Hourly m^3/h	Daily m^3/d	Annual m^3/y	Instantaneous l/s
AB01	Borehole at Park Mill Farm (18/54/020/G//R01)	3.5km north-west	Mercia Mudstone	General Farming & Domestic (All year abstraction)	2.3	55	20,075	N/A
AB02	Thornbury Golf Centre (18/54/020/G/294)	3km west	Tintern Sandstone Group	Spray Irrigation – Storage (April to September)	6.0	136	20,455	1.66
AB03	Borehole at Mill Farm Tytherington (17/53/002/G/080)	1.2km east	Carboniferous Limestone	General Farming & Domestic (All year abstraction)	2.77	40	11,000	N/A

Table 9-26 - Private water supplies within the Study Area

Figure Reference	Address	Source	Class	Class Description	Rockhead (Figure 9.5)	Location in relation to the Site	Additional comments
GA01	Buckover Farm, Falfield	Spring	SPD	Single Dwelling	Raglan Mudstone Formation	2.1km north	The water features mapping identified a pond within this area.
GA07	Armstrong Way, Thornbury	Spring	-	No longer used	Tintern Sandstone Formation	1.6km northwest	
GA08	Park Farmhouse, Butt Lane, Thornbury	Spring	-	-	Mercia Mudstone Group	3.1km northwest	
GA05	Huntly Farm Patch, Elm Lane, Rangeworthy	Well	SPD	Single Dwelling	Mangotsfield Member - sandstone	3.7km southeast	
GA06	Yew Tree House, Whitfield, Falfield	Well	-	No longer used	Tortworth Beds - mudstone	3km northeast	The water features mapping identified two ponds within this area and a well 400m southwest.
GA02	Lodge Farm Milbury Health	Borehole	Reg 9	Commercial	Tintern Sandstone Formation	1.2km northeast	No information for Milbury Health boreholes available in BGS (2024a).
GA04	Trapp House Milbury Heath						
GA09	Wagon House, Milbury Heath						
GA10	Stable Cottage, Milbury Heath						

Figure Reference	Address	Source	Class	Class Description	Rockhead (Figure 9.5)	Location in relation to the Site	Additional comments
GA11	Lodge Field Barn, Lodge Farm, Milbury Heath						
GA12	Lodge Farm Annex, Lodge Farm, Milbury Heath						
GA03	Dairy Cottage, Milbury Heath	Borehole	Reg 9	Commercial	Tintern Sandstone Formation	1.2km northeast	

Discharges

9.5.203 Regarding foul water, sewerage from mess and toilet facilities are contained within a sealed cess pit and prevented from discharging to either surface water or groundwaters.

9.5.204 The EA has records for sixty consented discharges within the Study Area, although some contain multiple permit numbers. Details are provided in **Table 9-27-** and **Figure 9.14**.

Table 9-27 - Consented discharges within the Study Area

Site name	Permit number	Discharge category	NGR	Location in relation to the Site
Tytherington Road Nursery	SW/EPRKB3799NW /001	Sewage-Farms (not house)/Crop + Animal Rearing/Plant Nursery	ST6559688988	200m west
Tytherington Quarry (within Grovesend Quarry)	SW/021407/001	Trade-Mineral/Gravel Extraction/Quarrying	ST6600088700	On site
Tytherington Quarry (discharge point in Tytherington Village, not included in EA data)	021407	Trade-Mineral/Gravel Extraction/Quarrying	ST66898832	700m east
Dobbies Garden Centre Thornbury	SW/103214/001	Sewage and Trade combined-Shop incl. Garden Centre/Retail Trade (not Motor Vehicle)	ST6630090040	1.1km north
Black Horse, Gravesend Road	SW/010972/001 and /002	Sewage-Storm Tank/CSO on Sewerage Network (water company)	ST6436089950	1.8km north-west
Former Limeworks Site	SW/102193/001 and /002	Sewage-Domestic property (multiple) (incl. farm houses)	ST6573787241	700m south
Former Limeworks Site	SW/101507/001	Sewage-Domestic property (multiple) (incl. farm houses)	ST6571087180	700m south
White Horse Inn	SW/EPRAP3428XX/ 001	Sewage-Food+Beverage Services/Cafe/Restaurant/Pub	ST6640590400	1.1km north

Site name	Permit number	Discharge category	NGR	Location in relation to the Site
8 Properties at The Street	SW/EPRDB3699EQ/001	Sewage-Domestic property (multiple) (incl. farm houses)	ST6389188039	1.7km west
The Farmhouse	SW/011918/001	Sewage-Domestic property (multiple) (incl. farm houses)	ST6349089260	2.2km west
Knapp Farm	SW/102874/001	Sewage-Domestic property (single) (incl. farm house)	ST6556090920	1.6km north-west
Scarlets Land	SW/103695/001	Sewage-Sport, Amusement+Recreation/Golf Club/Gym/Theme Pk/Spa	ST6746090000	1.2km north-east
Hope Manor Farm	SW/102950/001	Sewage-Kennel/Dry Cleaning/Hairdresser/Other Personal Services	ST6769089950	1.8km north-east
Thornbury Lawn Tennis Club	SW/010507/001	Sewage-Sport, Amusement+Recreation/Golf Club/Gym/Theme Pk/Spa	ST6323089830	2.7km north-west
2 Brinkmarsh Cottages	SW/EPRJB3290WY/001	Sewage-Domestic property (single) (incl. farm house)	ST6753290645	1.8m north-east
Alveston Down	SW/010693/001	Sewage-Undefined or Other	ST6290088000	1.7km west
Ash Lodge Farm(Bristol)	SW/020162/001	Trade-Farms (not house)/Crop + Animal Rearing/Plant Nursery	ST6410086500	2.1km south-west
The Old School House	SW/101193/001	Sewage-Domestic property (single) (incl. farm house)	ST6553085970	2.0km south

Site name	Permit number	Discharge category	NGR	Location in relation to the Site
Park Farm	SW/013160/001	Sewage-Domestic property (multiple) (incl. farm houses)	ST6405091470	3.2km north-west
Cromhall Water Recycling Centre	SW/010029/001 **to** /005	Sewage-WwTW/Sewage Treatment Works (water company)	ST6851989392	2.0km east
The Old School House	SW/021233/001	Sewage-Domestic property (single) (incl. farm house)	ST6540085700	2.2km south
Mead Farm	SW/020080/001	Trade-Farms (not house)/Crop + Animal Rearing/Plant Nursery	ST6800091000	2.3km north-east
The Grange	SW/102196/001	Sewage-Domestic property (single) (incl. farm house)	ST6505485586	2.4km south
The Grange	SW/102196/002	Sewage-Domestic property (single) (incl. farm house)	ST6505485586	2.4km south
Bagstone Ps	SW/010691/001	Sewage-Pumping Station on Sewerage Network (water company)	ST6860087700	2.4km east
Maypole Barn And Morton Maypole	SW/011699/001 and /002	Sewage-Domestic property (multiple) (incl. farm houses)	ST6438092000	4.0km north-west
Kyneton House	SW/012857/001 and /002	Sewage-Education/Nursery/School/College/Uni/Training Venue	ST6217089760	3.7km north-west
Alveston Wastewater Treatment Works	SW/010002/001 to /008	Sewage-WwTW/Sewage Treatment Works (water company)	ST6237087380	3.0km south-west

Site name	Permit number	Discharge category	NGR	Location in relation to the Site
Iron Acton Substation	SW/102181/001	Sewage-Sub-station/Electricity/Gas/Air Conditioning Supply	ST6687085680	2.5km south-east
Whitehouse Farm	SW/100529/001	Sewage-Domestic property (multiple) (incl. farm houses)	ST6534085370	2.6km south
Iron Acton 275Kv Substation	SW/102182/001	Trade-Sub-station/Electricity/Gas/Air Conditioning Supply	ST6689085650	2.5km south-east
Woodbine Cottage St Retrofit Kit	SW/EPRZB3893DC/001	Sewage-Domestic property (single) (incl. farm house)	ST6567185221	2.7km south
Wesleyan Chapel	SW/102470/001	Sewage-Domestic property (single) (incl. farm house)	ST6578085180	2.7km south
Whitehouse Farm	SW/021036/001	Trade-Farms (not house)/Crop + Animal Rearing/Plant Nursery	ST6910087900	2.0km east
Whitehouse Farm	SW/021037/001	Sewage-Farms (not house)/Crop + Animal Rearing/Plant Nursery	ST6910087900	2.0km east
Elm Tree Cottage	SW/010985/001 and /002	Sewage-Storm Tank/CSO on Sewerage Network (water company)	ST6890087170	3.0km south-east
Jubilee Lane Ps	SW/103286/001	Sewage-Pumping Station on Sewerage Network (water company)	ST6942089510	2.9km east
Bagstone Court Farm	SW/020352/001	Trade-Domestic property (multiple) (incl. farm houses)	ST6900086910	3.2km south-east

Site name	Permit number	Discharge category	NGR	Location in relation to the Site
Bagstone Court Farm	SW/020353/001	Sewage-Domestic property (multiple) (incl. farm houses)	ST6900086910	3.2km south-east
Green Farm	SW/101697/001 and /002	Sewage-Domestic property (multiple) (incl. farm houses)	ST6630084420	3.5km south
Rangeworthy Ps	SW/010679/001	Sewage-Pumping Station on Sewerage Network (water company)	ST6940086100	4.0km south-east
Rangeworthy Ps	SW/103233/001	Sewage-Pumping Station on Sewerage Network (water company)	ST6940086100	4.0km south-east
Latteridge Road Ps	SW/010688/001	Trade-Pumping Station on Sewerage Network (water company)	ST6749084420	3.9km south-east
Latteridge Road Ps	SW/102906/001	Sewage-Pumping Station on Sewerage Network (water company)	ST6749084420	3.9km south-east
RCM Aggregates	SW/101343/001	Mineral/Gravel Extraction/Quarrying	ST6923090450	3.4km north-east
Trench Arch at St. Andrews Church	SW/EPRVP3720GP/001	Sewage - not water company	ST6922290490	3.4km north-east
Eastwood Park Conference Centre	SW/013197/001	Sewage - not water company	ST6791092020	3.7km north-east

Site name	Permit number	Discharge category	NGR	Location in relation to the Site
1 Yew Tree Farm	SW/021675/001	Farms (not house)/Crop + Animal Rearing/Plant Nursery	ST6471092740	3.9km north-west
Wixoldbury Farm	SW/021038/001 and SW/021039/001	Domestic property (single) (incl. farm house)	ST7010087400	4.0km east
Firing Close Farm (Wotton-U-Edge)	SW/021131/001	Farms (not house)/Crop + Animal Rearing/Plant Nursery	ST7000087000	4.0km east

9.5.205 **Table 9-27** includes the EA consent Tytherington Quarry, No. SW/021407/001 under which water is pumped from the active Woodleaze Quarry via the Grovesend Quarry sump to the Tytherington Watercourse (see also discussion under **Section: Site Visit** and **Figure 9.3**). The quarry operates under a discharge consent which came into effect on 11 July 1987. Under this consent, the water accumulating in the quarry void is permitted to be discharged at the discharge location NGR ST 6689 8832 (**Figure 9.3**). The following conditions are imposed as part of the extant principal planning consent (ref. NA/IDO/002/A):

- The nature of the discharge shall be that of effluent from quarry working, the composition shall be such that the pH shall be ≥6 but ≤9, suspended solids shall be ≤60mg/l and fats, oil and grease shall be ≤10mg/l;
- The temperature shall be ambient;
- The volume shall be no more than 6,820m/day; and
- The rate cannot exceed 79 l/s (6.8 Ml/d) (4,736l/min as stated in discharge consent document).

Catchment Abstrction Management Strategy (CAMS)

9.5.206 The Site lies within the EA's Bristol Avon and Little Avon Abstraction Licensing Strategies (ALS) area[33].

9.5.207 The Bristol Avon River has a large catchment area of approximately 2,220 km^2, encompassing the major cities of Bristol and Bath. The primary river flows south then west for approximately 134km from its source upstream of Malmesbury, through gentle rural landscapes and towns such as Bradford-on-Avon, before flowing through the Clifton Gorge to Avonmouth, and into the Severn Estuary. The Little Avon CAMS area stretches along the coast from Sharpness in the north, to Avonmouth in the southwest and inland to include the towns of Wotton-under-Edge, Thornbury, and Berkeley. The Little Avon rises at Horton, on the edge of the Cotswold escarpment at a height of approximately 170m AOD (EA, 2012).

9.5.208 The CAMS report indicates that, within the Study Area, water is available for licensing with availability 95% of the time. The water resources availability for the surface water bodies closest to the Site are:

9.5.209 The Upper Little Avon (AP 13), outside the Study Area, is located 7km north-east of the Site. After taking into account a Hands Off Flow (HoF) of 5 Ml/d, there is a further 5 Ml/day available for licensing.

9.5.210 The Lower Little Avon (AP14), outside of the Study Area, is located approximately 10.7km north of the Site. There is a Minimal Residual Flow restriction to protect very low flows, resulting in 0.6 Ml/d being available for licensing.

9.5.211 Groundwater Management Units (GWMUs) are assigned to the groundwater bodies (Principal Aquifers) for the purposes of local groundwater availability assessment in ALSs. The Bristol, Avon and Somerset ALS suggests that the licensing strategy that it sets out applies to both surface water and groundwater applications, and that where groundwater abstractions directly impact on surface

[33] Bristol Avon and North Somerset abstraction licensing strategy [online] Available at: https://www.gov.uk/government/publications/bristol-avon-and-north-somerset-abstraction-licensing-strategy

water flows a Hands off Level (HoL) condition may be applied to the abstraction to provide a groundwater level below which an abstractor is required to reduce or stop abstraction.

Flood Risk

9.5.212 A Flood Risk Assessment (FRA) has been produced separately, as a stand-alone document, and the baseline flood risk with respect to the Site is summarised below.

Historic flooding

9.5.213 Historic flood mapping[34] has been obtained from the EA. It shows that the nearest recorded historic flood occurred ~1.1 km south of the Site and was related to fluvial flooding of a minor portion of a small watercourse near Itchington. There are no records of historical flooding at the Site. This does not categorically prove that the Site has never been flooded in the past, simply that no flooding has been recorded.

Surface water flood risk

9.5.214 The outer margins of the Site effectively form a watershed, such that the quarry void has no notable upslope area. As such, there is minimal surface water run-on to the Site and surface water flood risk at the Site is associated with the accumulation and pathways of rainfall draining to the void base.

9.5.215 The EA Flood Map for Planning for Surface Water Flood Risk, presented in FRA Figure 3.2, gives an indication of the broad areas likely to be at risk of surface water flooding at present, i.e. areas where surface water would be expected to flow or pond. According to this, the Site area consists of mostly very low risk of surface water flooding (0.1% AEP). However, there are areas of low to high flood risk (0.1% to >3.3% AEP) associated with the topographic low points within and around the Woodleaze and Grovesend Quarry voids and the preferential flow paths associated with the haul roads. There are also areas of ponding below the permitter bund on the eastern boundary of Woodleaze Quarry, which appears to form a small cut against the M5 motorway. There is also a notable area on the southern boundary of the Woodleaze Quarry adjacent to the soil store area boundary which then drains across the agricultural fields to the southwest, and then into a minor watercourse, namely the Owlsnest Farm Watercourse, which flows into the Ladden Brook. This area of mapped flood risk (underlain at the time by mudstone of the Penarth Group, **Figure 9.5**) is no longer present, since this area of land has now been worked as an extension to the Woodleaze Quarry. All current flood risk within the Grovesend Quarry void will not change as no changes in operation within this area are proposed.

9.5.216 The EA Climate Change Allowances[35] for the Avon Bristol and North Somerset Streams Management Catchment, states that the upper end forecast for increase in rainfall intensity is 40% for the period 2022 to 2060 (covering Phases 1 to 3 and progressive restoration phase) and 45% for the period 2061 to 2125 (covering the restoration phase). This could exacerbate surface water flood

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[34] Environment Agency Historic Flood Map [online] Available at: https://www.data.gov.uk/dataset/76292bec-7d8b-43e8-9c98-02734fd89c81/historic-flood-map (Last accessed 10 April 2024)

[35] Environment Agency Climate Change Allowances [online] Available at: https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances (Last accessed 10 April 2024)

risk in the lowest elevation areas of the quarry, in the absence of an appropriate surface water drainage strategy. The quarry excavation works are projected to end around 2032 provided work starts by 2025.

9.5.217 **Working Phase:** The quarrying operations will impact the ground levels across the proposed scheme, both in terms of excavation which will deepen the ground elevations as well as the placement of materials which will increase ground elevations. Such activities provide the potential to affect surface water flood risks across the Site. The soil store area provides a potential source of surface runoff when being stripped, and this may need to be mitigated and managed. The development of bare and compact land associated with the limestone extraction, haul roads and overburdened storage mounds and bunds, all have the potential to increase the overall extent of less permeable areas within the proposed scheme. These increases will slightly increase the peak runoff rates and volumes; however, runoff will be captured in the base of the quarry void, and dissipate to ground, or require pumping to the sump in the Grovesend Quarry. If the rate of required Site discharge changed, this could therefore result in an increase in flood risk to any low-lying development within Tytherington Village beside the watercourse that receives dewatering flows. However, it is understood that the Proposed Scheme will lead to no appreciable increase above the current ‘with-quarrying baseline’ dewatering discharge rates.

9.5.218 Minor adjustments to the screening bund will result in negligible changes to runoff quantity owing to the overall increase in the void area, reducing the area of land that drains off-site.

9.5.219 **Restoration Phase:** With the restoration of the soil store area to grassland with a mosaic of small ponds, this will in the long term reduce runoff to the new restoration lagoon in the Woodleaze Quarry. The soil store area provides a potential source of surface runoff when infilled and reprofiled during restoration. Reprofiling will direct runoff into the remaining quarry void since if unmitigated, these could lead to an increase in off-site surface water flood risk.

Groundwater flood risk

9.5.220 Groundwater flooding occurs as a result of water issuing to the surface from the underlying aquifers. This tends to occur after long periods of sustained high rainfall, with areas most at risk being situated on permeable geology, which is low-lying compared to the local water table, and where no watercourse is available to drain the water away.

9.5.221 The Strategic Flood Risk Assessment (SFRA) states that the vast majority within South Gloucestershire is considered at low risk of groundwater flooding. However, as the Site is located over bedrock classified as a Principal Aquifer, a risk of groundwater flooding could exist. Under baseline conditions any emergence of rising groundwater is likely to be contained within the Woodleaze Quarry void and managed by dewatering and via consented discharge, thus not posing any risk to potential flood risk receptors.

9.5.222 **Working phase:** There is the potential for groundwater flood risk if quarry works are undertaken below the water table or if quarry works influence the depth of the water table, in the absence of appropriate flood risk mitigation measures. Considering that the Woodleaze Quarry is proposed to be deepened to a maximum of -40 m AOD, there is a potential risk of groundwater flooding. Groundwater ingress, as is currently occurring, will be contained within the sump at the base of the Woodleaze Quarry void and when required, pumped to the Grovesend Quarry attenuation sump from where it can be discharged off site via the consented discharge. There is no planned change to the manner in which groundwater dewatering is to be handled. It is normal for quarry operations to be subject to groundwater ingress and dewatering operations and thus it is anticipated that operators of the quarry will be fully engaged with the dewatering process such that groundwater flooding would be managed and actively addressed/reacted to as necessary to ensure the risk to Site is dealt with appropriately. As such, the risk of groundwater flooding detrimental to extraction operations during the working phase is considered low.

9.5.223 **Restoration Phase:** Restoration of the Woodleaze Quarry to a lagoon with a base elevation of -40m AOD suggest that groundwater ingress into the base of the quarry will occur and is expected to equilibrate with natural groundwater levels at the anticipated rest mean water level of 68-70 m AOD. Dewatering of the Woodleaze Quarry was paused between December 2012 and March 2019 (BCL. 2023), and the water level within the void was left to recover. The Woodleaze Quarry water level subsequently rose to as high as 63.7 m AOD before dewatering re-commenced. There are no reports of flooding of the surrounding land associated with this period of settlement.

Off-site discharge of dewatered surface water runoff and groundwater

9.5.224 The principal component of the discharge is made up of the dewatering volume from Woodleaze Quarry (from groundwater and surface water contributions). With the proposed deepening of Woodleaze Quarry (and minor additional contributions from the south-eastern extension of the void into the soil store area, slightly increasing the area of the open quarry void). There is expected to be no appreciable increase above the current 'with-quarrying baseline' volume of water requiring dewatering in order to prevent flooding in the base of the Woodleaze Quarry. Therefore, it is considered that there will be no increase in potential flood risk to downstream receptors located within Tytherington Village.

9.5.225 Potential receptors of flood risk in Tytherington Village are several residential buildings along Duck Street. Of particular concern, based on the EA Surface Water Flood Risk Map, is a residential building between Duck Street and Walnut Field Street (Building 1, FRA Figure 3.5, for street names see FRA Figure 3.4). Additionally, a significant area of surface water flood risk is located at the southeast end of Duck Street where it becomes Sidcot Lane (Buildings 2 to 4). This was outlined in the SFRA as a point of high flood risk in Tytherington Village. The residential gardens around this area, despite being already land at risk, are identified as potential receptors, as this area would receive all flood water that would flow down Duck Street.

9.5.226 Based on the LiDAR, it is evident that the residential land and buildings to the northeast of Duck Street are on higher ground, while the residential land and buildings to the southeast are on lower land (FRA Table 3.3), which becomes progressively lower with distance to the south. The majority of residential buildings are outside the surface water flood areas, with the exception being the four buildings marked on FRA Figure 3.5, on the land at the boundary between Duck Street and Walnut Field Street, and in the area where Duck Street becomes Sidcot Lane. Using the LiDAR, the elevations of the bank top of the channel, the land beside each receptor building, and land at the edge of the surface water flood risk areas for the 3.3%, 1.0% and 0.1% AEP events.

PREDICTED FUTURE BASELINE

9.5.227 Some of the baseline conditions outlined in **Section 9.5** may change even if the Proposed Scheme was not to go ahead, for the following reasons:

- Climate Change: The concept of climate change is well documented, the main implication for the United Kingdom appears to be more rainfall seasonality, with wetter winters and drier summers. This will, of course, have implications for river flows and groundwater levels, although these effects are difficult to quantify at present;
- Changes in the location and rate of surface and groundwater abstractions in the area: These could vary over time, and increased understanding of the groundwater flow regime may result in changes to the aquifer status and SPZ designations; and
- Groundwater recovery: It is anticipated that groundwater levels at the Site will rise again and equilibrate within the Woodleaze Quarry restoration lake (**Figure 3.4**). The restoration plan assumes that water would rebound at 68 to 70 m AOD in line with the permitted restoration scheme. It is understood that this rebound level figure is based on what happened when the water levels were allowed to rebound when the quarry operations ceased prior to dewatering and recommencement of operations (**Figure 9.9**). However, the following is noted:
  - Whilst the hydrographs of the ponds in both North Face Quarry and Grovesend Quarry appear to have reached equilibrium for the hydraulic situation at the time, this was not the case for Woodleaze Quarry, i.e. by the time the dewatering recommenced back in March 2019, its water level was still rising.
  - During the future restoration phase with no more dewatering, the amount of water that would previously have been discharged off the site (between 1.2 to 3.5 Ml/d) will subsequently be used to fill up the quarry void, and also replenish storage in the combined aquifer. But once this process is completed, this excess water still has to go somewhere.
  - A possible scenario is it might trigger additional groundwater level rises in the combined aquifer, until it reaches the suggested outlet point elevation in the area where the Mercia Mudstone Group Conglomerate directly overlies the combined aquifer. This could then revitalise former flow paths that existed under naturalised conditions, by effectively by-passing the Clifton Down Mudstone horizonal flow barrier and thus enabling baseflow to the southeast.
  - Alternatively, or potentially in parallel, the excess water could escape along strike directions, i.e. in northeasterly and/or south westerly direction.
    - In the absence of monitoring data, groundwater flow in the combined aquifer to the northeast for the current situation is uncertain. If it happens during and after the restoration phase this could potentially lead to south-eastwards groundwater flow where the northeast-southwest trending fault (~1.2 km to the northeast of the Site) has potentially created a hydraulic connection between the combined aquifer and the upper combined aquifer.
    - As a consequence of additional south-westwards groundwater flow within the combined aquifer, this might result for it to start providing baseflow to the Owlsnest Farm Watercourse. This additional stream flow might get lost further downstream or it might lead to an increase in flow being recorded in the ongoing monitoring. An extended groundwater level monitoring network is expected to verify these potential changes to the groundwater flow regime.

9.6 CONSULTATION

9.6.1 The assessment has been informed by consultation responses and ongoing stakeholder engagement. An overview of the approach to consultation is provided in **Section 2.4** of **Chapter 2: Approach to Environment Impact Assessment**.

SCOPING

9.6.2 A Scoping Opinion was issued by South Gloucestershire Council (SGC) on 18 January 2024. A summary of the relevant response received in the Scoping Opinion in relation to the water environment and confirmation of how these have been addressed within the assessment to date is presented in **Table 9-28**.

Table 9-28 - Summary of issues raised during consultation regarding Water Environment

Issue raised	Consultee	Response and how considered in this chapter	Section Ref
In their pre application advice SGC identified the need for an FRA to deal with surface water runoff from the site. The surface water drainage strategy should also have consideration to pollution control measures. The Lead Local Flood Authority (LLFA) request that as well as an FRA, a 'comprehensive' Surface Water Drainage Strategy' will also need to be submitted.	SGC, LLFA	The FRA has been carried out to ensure that there is no increase in flood risk to and from the Site, and drainage calculations have been provided to satisfy the requirement of achieving greenfield runoff rates. A summary of the findings of the assessment is also presented within the assessment section of this chapter.	Section 9.5 and FRA (Appendix 9D)
SCG point out in the context of Groundwater Protection / Contaminated Land that if historic use of the site may have caused contamination, then National Planning Policy Framework (NPPF) paragraph 109 states that the planning system should contribute to and enhance the natural and local environment by preventing both new and existing development from contributing to or being put at risk from unacceptable levels of water pollution.	SGC	Quarry water management, pollution prevention and accident response protocols, and monitoring is in place to prevent the Site from contributing to or being put at risk from unacceptable levels of water pollution.	Section 9.7
National Highways request that the Proposed Scheme must not lead to any surface water flooding on the SRN carriageway; and no new connections are permitted to National Highways' drainage network. In the case of an existing 'permitted' connection, this can only be retained if there is no land use change.	National Highways	Given that under the proposed scheme there is to be no changes to the earth bund which boarders Tytherington Quarry adjacent to the M5, the proposed scheme will not increase runoff towards the M5.	Section 9.5 and FRA (Appendix 9D)
SGC stated that pollution prevention safeguards are implemented during construction phase. These should cover: ▪ The use of plant and machinery	SGC	The proposed scheme will implement pollution prevention and accident response protocols during construction. These measures will prevent the Site from contributing to or being put at risk from unacceptable levels of water pollution.	Section 9.7

Issue raised	Consultee	Response and how considered in this chapter	Section Ref
▪ Oils/chemicals and materials ▪ The use and routing of plant and vehicles ▪ The location and form of work and storage areas and compounds ▪ The control and removal of spoil and waste			

9.7 ENVIRONMENTAL MEASURES INCOPORATED INTO THE PROPOSED SCHEME

9.7.1 A range of environmental measures have been embedded into the Proposed Scheme as outlined in **Chapter 3 (Section 3.3)**. **Table 9-29** outlines how these embedded measures will influence the water environment assessment.

Table 9-29 - Summary of the embedded environmental measures and how they influence the water environment assessment

Receptor	Change and effects	Embedded measure and influence on assessment
Watercourses	Quarry excavation and dewatering could lead to a decline in river flow and associated water quality (through reduced dilution in local watercourses that are in hydraulic continuity with the aquifer).	Quarry water management and monitoring.
	Site activities could result in the release of pollutants and the subsequent contamination of groundwater base flow to watercourses.	Pollution prevention, accident response protocols and monitoring.
	Any contaminated site discharge to surface water could result in a deterioration in the water quality in receiving and downstream watercourses.	Quarry water management, pollution prevention and accident response protocols, and monitoring.
	Quarry excavation and dewatering could lead to a decline in river flow in local watercourses that are in hydraulic continuity with the Proposed Scheme , leading to a deterioration in watercourse morphology.	Any discharge to surface water, especially that with a high sediment content, could result in a deterioration in watercourse morphology.
	Any discharge to surface water, especially that with a high sediment content, could result in a deterioration in watercourse morphology.	Quarry water management.
	Site restoration could increase off-site runoff and restrict recharge, leading to an increase in runoff-derived surface water flows and a decline in groundwater baseflow in watercourses, also with consequent changes in water quality and watercourse morphology.	Appropriate site restoration.
	Site restoration could result in the leaching of contaminants from the backfill material, leading in turn to a deterioration in water quality within watercourses.	Appropriate site restoration.
WFD water bodies	Quarry excavation, dewatering and site activities could result in the decline in river	Quarry water management and monitoring.

Receptor	Change and effects	Embedded measure and influence on assessment
	flows and water quality (through reduced dilution in local watercourses that are in hydraulic continuity with the aquifer), leading to a deterioration in WFD status of surface water bodies.	
	Site activities could result in the release of pollutants and the subsequent contamination of groundwater base flow to watercourses, leading to a deterioration in WFD status of surface water bodies.	Pollution prevention, accident response protocols and groundwater monitoring.
	Any contaminated site discharge to surface water could result in a deterioration in the water quality in receiving and downstream watercourses, leading to a deterioration in WFD status of surface water bodies.	Recharge of water back to the aquifer, quarry water management, pollution prevention and accident response protocols, and monitoring.
	Quarry excavation and dewatering could lead to a decline in river flow in local watercourses that are in hydraulic continuity with the Proposed Scheme , leading to a deterioration in watercourse morphology.	Recharge of water back to the aquifer, quarry water management and monitoring.
	Any discharge to surface water, especially that with a high sediment content, could result in a deterioration in watercourse morphology.	Quarry water management.
	Site restoration could increase off-site runoff and restrict recharge, leading to an increase in runoff-derived surface water flows and a decline in groundwater baseflow in watercourses, also with consequent changes in water quality and watercourse morphology, and resulting in a deterioration in WFD status of surface water bodies.	Appropriate site restoration.
	Site restoration could result in the leaching of contaminants from the backfill material, leading in turn to a deterioration in water quality within watercourses and resulting in a deterioration in WFD status of surface water bodies.	Appropriate site restoration.
	Quarry dewatering could lead to a decline in groundwater levels, and a subsequent deterioration in WFD status of groundwater bodies.	Quarry water management and monitoring.
	Quarry dewatering could lead to a decline in groundwater levels, and a subsequent deterioration in groundwater quality as a	Quarry water management and monitoring.

Receptor	Change and effects	Embedded measure and influence on assessment
	result of induced leakage from landfills, resulting in a deterioration in groundwater quality and the WFD status of groundwater bodies.	
	Site activities could result in the release of pollutants and the subsequent contamination of groundwater, and a subsequent deterioration in WFD status of groundwater bodies.	Pollution prevention, accident response protocols and monitoring.
	Site restoration could restrict recharge, leading to a decline in groundwater levels, and a subsequent deterioration in WFD status of groundwater bodies	Appropriate site restoration.
	Site restoration could result in the leaching of contaminants from the backfill material, leading in turn to a deterioration in groundwater quality and the WFD status of groundwater bodies.	Appropriate site restoration.
Aquifer	Quarry dewatering could lead to a decline in groundwater levels, and a subsequent loss of aquifer resource.	Quarry water management and monitoring.
	Site activities could result in the release of pollutants and the subsequent contamination of groundwater.	Pollution prevention, accident response protocols and monitoring.
	Site restoration could restrict recharge, leading to a decline in groundwater levels, and a subsequent loss of aquifer resource.	Appropriate site restoration.
	Site restoration could result in the leaching of contaminants from backfill material, leading in turn to a deterioration in groundwater quality.	Appropriate site restoration.
Conditions supporting Conservation Sites[36]	Quarry dewatering could lead to a decline in surface water flows and groundwater levels in the vicinity of conservation sites.	Quarry water management and monitoring.

[36] Note: This chapter examines potential changes arising from the development on the water environment supporting conservation sites, not the conservation sites themselves, which is instead a matter for the Biodiversity chapter (Chapter 10).

Receptor	Change and effects	Embedded measure and influence on assessment
	Site activities could result in the release of pollutants and the subsequent contamination of groundwater in the vicinity of conservation sites.	Pollution prevention, accident response protocols and monitoring
	Site restoration could increase off-site runoff and restrict recharge, leading to an increase in runoff-derived surface water flows and a decline in groundwater levels in the vicinity of conservation sites.	Appropriate site restoration
	Site restoration could result in the leaching of contaminants from backfill material, leading in turn to a deterioration in water quality within watercourses and aquifers that are in hydraulic continuity with conservation sites.	Appropriate site restoration
Springs	Quarry dewatering could lead to a decline in groundwater levels, and a subsequent decline in spring yield and associated water quality.	Recharge of water back to the aquifer, quarry water management and monitoring.
	Site activities could result in the release of pollutants and the subsequent contamination of groundwater, leading in turn to a deterioration in spring water quality.	Pollution prevention, accident response protocols and monitoring.
	Site restoration could restrict recharge, leading to a decline in groundwater levels, and a subsequent decline in spring yield and associated water quality.	Appropriate site restoration.
	Site restoration could result in the leaching of contaminants from backfill material, leading in turn to a deterioration in spring water quality.	Appropriate site restoration.
Water bodies	Quarry dewatering could lead to a decline in water levels and associated water quality through reduced dilution within ponds that are in hydraulic contact with the aquifer.	Quarry water management and monitoring.
	Site activities could result in the release of pollutants and the subsequent contamination of groundwater base flow to these water bodies.	Pollution prevention, accident response protocols and monitoring.
	Site restoration could restrict recharge, leading to a decline in groundwater and associated water body levels.	Appropriate site restoration.

Receptor	Change and effects	Embedded measure and influence on assessment
	Site restoration could result in the leaching of contaminants from backfill material, leading in turn to a deterioration in water quality within aquifers and associated water body levels.	Appropriate site restoration.
Licensed abstractions and PWS	Quarry dewatering could lead to a decline in groundwater levels, and a subsequent decline in yield and associated abstraction water quality.	Quarry water management and monitoring.
	Site activities could result in the release of pollutants and the subsequent contamination of groundwater, leading in turn to a deterioration in abstraction water quality.	Pollution prevention, accident response protocols and monitoring.
	Site restoration could restrict recharge, leading to a decline in groundwater levels, and a subsequent decline in abstraction yield and associated water quality.	Appropriate site restoration.
	Site restoration could result in the leaching of contaminants from the backfill material, leading in turn to a deterioration in abstraction water quality.	Appropriate site restoration.
Humans, property and infrastructure (flood risk)	Any site discharge could increase surface flows and result in increased flooding in the immediate vicinity of receiving and downstream watercourses.	Quarry water management, and emergency flood response plan.
	Creation of bare/compacted land increasing surface water run-off rates, volumes and pathways.	Quarry water management and monitoring.
	Site restoration could increase off-site runoff, leading to an increase in runoff-derived surface water flows and flooding risk.	Appropriate site restoration.

9.7.2 Environmental measures are used to describe those measures which have been embedded into the Proposed Scheme. The water environmental measures which have been embedded into the Proposed Scheme, including relevant industry good practice measures, are set out below, and **Section 9.15** outlines how they will be secured and implemented as part of the development.

QUARRY WATER MANAGEMENT

9.7.3 The current extraction depth at Woodleaze Quarry is approximately 18.5 mAOD (based on November 2023 sump water levels), which compares to the current permitted extraction depth of

25 m BOD (i.e. below OD) and a proposed maximum extraction depth of 40 m BOD which is to be reached in Phase 2, i.e. the Proposed Scheme involves a deepening of an additional 15 m.

9.7.4 The proposed excavations will continue to be below the water table and consequently, dewatering will also continue to be required to facilitate dry working and safe site conditions. Mitigation may therefore also be required with respect to the potential aquifer derogation. Whilst this will continue to result in a vertical hydraulic upward gradient, an actual upward flow of water from the underlying Avon Group Limestone and/or Tintern Sandstone into the combined aquifer is ruled out, given the postulated aquitard behaviour of the Avon Group (interbedded mudstone/limestones) in-between.

9.7.5 Dewatering volumes depend on the amount of rainfall and the respective dewatering depth. Between 1994 and 2023, dewatering has amounted to annual averages of between 1.2 and 3.5 Ml/d (with paused dewatering phase excluded). If a similar amount of rainfall was to fall, slightly higher dewatering volumes would be expected, given the gradual planned deepening of Woodleaze Quarry.

9.7.6 During the development phases, surface water runoff from the void will be captured and together with direct rainfall and intercepted groundwater transferred over from the Woodleaze Quarry will be collected in the Grovesend Quarry sump in the first instance, which also acts as a settlement lagoon. From there water will be pumped as under the extant water management scheme and under the extant EA consent No. 021407 to Tytherington Watercourse.

9.7.7 Tytherington is an active quarry and thus the quarry void already exists and receives both direct rainfall and runoff from minor areas adjacent to the lip of the quarry. The Proposed Scheme will mean that a small area to the south of Woodleaze void is excavated and temporarily drains into the void. The FRA has estimated the additional volume of water which may drain into the quarry void and will be captured within the base of the Woodleaze void and controlled by the extant water management scheme. Following appropriate treatment any excess waters will be pumped and discharged to the Tytherington watercourse in accordance with the terms of Tytherington's extant permitted EA discharge consent (Discharge consent 021407). Discharge rates to the Tytherington Watercourse are controlled to an agreed daily average consent limit (6820 m^3/d). The discharge consent also specifies the required water quality levels for discharge, which are a pH between 6 and 9, suspended solids less than or equal to 60mg/l and fats oil and grease shall be less than or equal to 10mg/l.

9.7.8 In the context of runoff draining to the void for management by the existing quarry dewatering system, these minimal increases (due to inclusion of climate change allowances) in runoff rates during the operational phase to the void are considered negligible.

9.7.9 Appropriate consideration of drainage routes would be given to ensure all runoff flows are captured by the Site water management system and routed to the excavation void and settlement/storage lagoon.

Monitoring

9.7.10 The specification of the following monitoring and any subsequent remedial actions would be the subject of a Mitigation and Monitoring Strategy (MMS).

Private water supplies and licensed abstractions

9.7.11 The licensed abstraction borehole at Mill Farm (AB03, 17/53/002/G/080), Tytherington just to the southeast of Tytherington Village is associated with farming. It is recommended tyring to obtain more details about this borehole (e.g. borehole log, construction details, targeted aquifer, borehole depth, rest- and pump water levels, etc.) by liaising with the farmer. It is also recommended to carry out some water sampling and apply groundwater typing.

9.7.12 It would make sense for the identified wells found on OS maps that feature in **Table 9-37** to establish in a site visit as part of a water features survey whether they still exist and if yes, whether they are still being used and for what purposes.

Springs

9.7.13 Stanton (1991) talks of springs (i.e. plural) in Tytherington village for which he believed that dewatering of sub-water-table workings at Tytherington quarries had reduced flow for the period of c. 1960 – 1991. These are likely to no longer exist. However, a desk study, involving the review of historic maps and a subsequent spring survey in the village is recommended to be carried out to confirm the current state of these springs, including SP02. Knowing the location of these former springs will be of use to understand historic groundwater flow patterns. Should any springs still be found to exist in the village, then these should be included in the existing monitoring scheme to record their estimated flow rates over time.

Groundwater level monitoring

9.7.14 The monthly collection of groundwater level data as part of the extant monitoring scheme (BCL, 2023) for the existing applicants monitoring network is recommended to continue with a monthly data collection frequency.

9.7.15 Access issues for piezometer 1 should be resolved to make sure this location is retained for future monitoring rounds.

9.7.16 A replacement piezometer at or near the previous piezometer 6 should be installed. It is suggested to drill the borehole through the upper Avon Group interbedded mudstone/limestone and screen the piezometer within the lower Avon Group Limestone, or, if not present the Tintern Sandstone. This will allow to verify the effectiveness of the Avon Group mudstones as a hydraulic barrier.

9.7.17 An additional borehole group is recommended between current piezometer 3 and the spring SP02 location. This group should consist of three piezometers screened in (from deepest to shallowest):

- Gully Oolite (to represent the combined aquifer);
- Clifton Down Limestone; and
- Mercia Mudstone Group conglomerate.

9.7.18 This will allow:

- Verification of the effectiveness of the Clifton Down Mudstone as a hydraulic barrier. This is in line with what WRc (1997) suggested at the time;
- Understanding of the relationship/degree of hydraulic connectivity between the three aquifers; and
- Monitoring whether the Mercia Mudstone Group conglomerate, especially when water levels will be allowed to rise again following restoration can channel groundwater from the combined aquifer across the Clifton Down Mudstone into the younger two aquifers.

9.7.19 A piezometer to the northwest of the Woodleaze Quarry is recommended to be drilled and installed into the Tintern Sandstone to verify the anticipated hydraulic barrier character of the Avon Group interbedded mudstone/limestone.

9.7.20 The Conceptual Model (**Figure 9.11**) suggests horizontal flow within the combined aquifer along strike to be likely, both to the northwest and to the southeast.

- A new piezometer approximately 500 m to the west of P8_21 is suggested;
- Two new piezometers approximately 1 km to the northeast of current piezometer P1, along the NE-SW trending fault which juxtaposes the combined aquifer and the Cromhall Sandstone/Clifton Down Limestone. One borehole on each side of the fault, the northwestern one screened in the combined aquifer, the southeastern one in the Clifton Down Limestone. The former will help to verify potential groundwater flow form the Quarry Complex to the northwest and the information from both to establish hydraulic connections between both aquifers in this area where the Clifton Down Mudstone is missing.

9.7.21 All new boreholes should be cored to allow both, the preparation of detailed logs, including piezometer construction details, and a robust stratigraphy assignment to the encountered geological layers and crucially the screened sections. If a new piezometer 6 replacement borehole is located near the 1998 location, its log can then also be used to verify the stratigraphy interpretation of the old borehole. Any new boreholes should be included in the monitoring scheme with monthly monitoring rounds.

9.7.22 The main objective of the level monitoring would be to better understand the groundwater flow pattern around the Quarry Complex, to identify any changes in the groundwater regime due to the quarrying and/or restoration phase water level rises, and also excessively high groundwater levels that could in theory result in groundwater flooding further downgradient, and to trigger remedial action as appropriate.

9.7.23 Once water levels are allowed to rise again during the restoration phase, there is the possibility that some of the flow paths which historically are likely to have fed the springs in Tytherington village get reactivated. This could in theory lead to local groundwater flooding issues. Additional boreholes might be required to monitor this, depending on the outcome of the proposed spring survey (see above).

9.7.24 Groundwater quality sampling is recommended to be run on a quarterly basis and the major ion concentrations should be used to establish groundwater types and monitor if/how they changes over the development phases and during the restoration phase.

Stream flow monitoring

9.7.25 The hydrogeological assessment has indicated that there may be a potential impact on the streamflow of the Owlsnest Farm Watercourse, which rises and flows to the southwest of the Woodleaze Quarry. As such, the surface water monitoring program which has been monitoring the flows within this ephemeral stream since 2005 should continue through the working phase and following restoration.

Appropriate Site Restoration

9.7.26 Following restoration, surface water and groundwater entering the Woodleaze void will be contained within the newly formed restoration lagoon. The screen bank within the soil store area will be profiled in a way to promote the drainage of surface water towards the Woodleaze restoration lagoon. Surface water runoff from the restored areas of the soil store area will drain towards and be captured by the Woodleaze restoration lagoon. The proportion of land draining to the void and away from the void will at restoration match the proportions at present, albeit the rate of runoff will be elevated slightly due to the effects of climate change on rainfall intensity. However, given the area of land in question the potential for flood risk to be increased by these minor changes to runoff are considered to be negligible.

9.7.27 In relation to the restoration lagoon in the Woodleaze void, appropriate consideration of drainage routes would be given to ensure all runoff flows are captured by the Site water management system and routed to the restoration lagoon.

9.7.28 As noted in **Section 9.5** groundwater levels at the site could potentially rise post-restoration over the long term. Based on level monitoring results obtained over the six years with no dewatering, a rebound water level at Woodleaze Quarry between 68 to 70 m AOD is anticipated. The top quarry level would remain at 95 m AOD and hence the restoration lake levels would remain within the wider quarry void, which is to remain inaccessible to the general public following restoration. If groundwater levels rise above maximum levels being currently monitored, more groundwater is expected to flow along strike within the combined aquifer in both directions, i.e. to the northeast and the southwest and this needs to be monitored (see proposed additional piezometers above). A further groundwater level rise could also potentially reactive the flow path via the identified Mercia Mudstone Group conglomerate valley filling and lead to increased groundwater flow into the upper combined aquifer, and thus increased groundwater flow south-eastwards towards Tytherington Village.

9.7.29 At this stage no further flood risk management measures are considered necessary to address groundwater flood risks. The need for a formal spill structure to safely convey any excess flows will be reviewed if quarry pond and groundwater level monitoring undertaken during quarry operations as part of routine groundwater monitoring (including the proposed borehole group to the southeast of the Site) indicates that post-restoration groundwater levels would reach the spill elevation sufficiently frequently that a formal spill structure would be necessary.

9.8 SCOPE OF THE ASSESSMENT

9.8.1 This section presents information relating to the current scope of the assessment rather than the scope as set out in the Scoping Report in that it takes account of the comments received in the Scoping Opinion and ongoing stakeholder engagement, notably with the EA.

9.8.2 Based on available data, and consultation with the EA and SGC as the Lead Local Flood Authority (LLFA), the assessment will achieve the following:

- Further develop the baseline description of the hydrology and hydrogeology in the Tytherington Quarry area;
- Consider the potential effects of the Tytherington Quarry proposals on surface water and groundwater; and
- Consider mitigation measures required to address these and other water-related concerns.

9.8.3 In accordance with existing requirements, a stand-alone Flood Risk Assessment (FRA) has also been prepared and submitted.

THE PROPOSED SCHEME

Spatial scope

9.8.4 The spatial scope of the assessment of the water environment covers the area of the Proposed Scheme contained within the extant planning permission red line boundaries, together with the Zones of Influence (ZoIs) that have formed the basis of the study area described in **Section 9.4**.

9.8.5 Following the gathering of all relevant data, this section identifies potential hydrogeological and hydrological and flood risk receptors of quarrying related effects within the Study Area which has been defined in **Section 9.4** as the area 4 km around the Site. Effects on the Water environment due to the Proposed Scheme are unlikely to extend beyond the scope of these areas.

Temporal scope

9.8.6 The temporal scope of the water environment assessment is consistent with the period over which the Proposed Scheme would be carried out and therefore covers the planned 18-year operational lifecycle period from 2025 to 2042 as described in **Chapter 3 Description of the Development**.

POTENTIAL RECEPTORS

9.8.7 The hydrogeological conceptual model developed in the Baseline section (**Section 9.5**) assumes for the Avon Group (interbedded mud- and limestones) to act as a flow barrier. As such, receptors potentially depending on groundwater, which are located to the north or west of this presumed aquitard have been discarded. These potential receptors are summarised in **Table 9-30** and shown on **Figures 9.12** and **9.14**.

9.8.8 The following receptors have been discarded and are not discussed further:

- Two SSSIs;
- One watercourse;
- Two licensed abstractions;
- Eleven registered private water supplies;
- One spring;
- Six wells; and
- 37 ponds.

Table 9-30 - Receptors scoped out from the water environment assessment based on their location relative to the Avon Group

Receptor category	Ref Number/ receptor name (where applicable)	NGR	Location relative to the Site	Rockhead geology (where applicable)
SSSI	Buckover Road Cutting	ST 666 906	1.7km north	Tintern Sandstone Formation (sandstone)
	Brinkmarsh Quarry	ST 674 912	2.8km north	Brinkmarsh Beds (limestone)
Watercourse	Oldbury Naite Rhine (and tributaries)	ST 654 892	Headwaters 470m northwest	Variable
Licensed abstraction (groundwater)	AB01: Park Mill Farm Borehole	ST 62981 90952	3.5km northwest	Aquifer: Mercia Mudstone
	AB02: Thornbury Golf Centre	ST 62628 28894	3km west	Aquifer: Tintern Sandstone Group
Registered private water supply: spring	GA01: Buckover Farm	ST 66500 91000	2.1km north	Raglan Mudstone Formation (siltstone and mudstone, interbedded)
	GA07: Armstrong Way (no longer used)	ST 64000 89300	1.6km northwest	Tintern Sandstone Formation (sandstone)
	GA08: Park Farmhouse	ST 63832 91441	3.1km northwest	Mercia Mudstone Group (marginal Facies, conglomerate)
Registered private water supply: well	GA06: Yew Tree House (no longer used)	ST 67500 91500	3km northeast	Tortworth Beds (mudstone)

Receptor category	Ref Number/ receptor name (where applicable)	NGR	Location relative to the Site	Rockhead geology (where applicable)
Registered private water supply: borehole	GA02: Lodge Farm	ST 66538 90013	1.2km northeast	Tintern Sandstone Formation (sandstone)
	GA04: Trapp House	"	"	"
	GA09: Wagon House	"	"	"
	GA10: Stable Cottage	"	"	"
	GA11: Lodge Field Barn	"	"	"
	GA12: Lodge Farm	"	"	"
	GA03: Dairy Cottage	ST 66500 90000	1.2km northeast	Tintern Sandstone Formation (sandstone)
Spring	SP01	ST 65539 89453	590m northwest	Raglan Mudstone Formation (siltstone and mudstone, interbedded)
Well	WL07	ST 67056 90221	1.7km northeast	Tintern Sandstone Formation (sandstone)
	WL08	ST 65886 89541	600m north	Tintern Sandstone Formation (sandstone)
	WL09	ST 65504 89863	980m northwest	Raglan Mudstone Formation (siltstone and mudstone, interbedded)

Receptor category	Ref Number/ receptor name (where applicable)	NGR	Location relative to the Site	Rockhead geology (where applicable)
	WL10	ST 66693 91421	2.6km northeast	Raglan Mudstone Formation (siltstone and mudstone, interbedded)
	WL11	ST 67088 91309	2.7km northeast	Raglan Mudstone Formation (siltstone and mudstone, interbedded)
	WL12	ST 63416 90179	2.7km northwest	Raglan Mudstone Formation (siltstone and mudstone, interbedded)
Pond	PO001	ST 62534 88883	2.8km west	Avon Group (mudstone and limestone, interbedded)
	PO002	ST 62602 88896	2.8km west	Avon Group (mudstone and limestone, interbedded)
	PO003	ST 62787 88943	2.6km west	Avon Group (mudstone and limestone, interbedded)
	PO004	ST 61641 88674	3.7km west	Avon Group (mudstone and limestone, interbedded)
	PO005	ST 62101 89548	3.5km west	Tintern Sandstone Formation (sandstone)
	PO006	ST 62428 88879	2.9km west	Avon Group (mudstone and limestone, interbedded)
	PO011	ST 62986 89041	2.4km west	Avon Group (mudstone and limestone, interbedded)
	PO092	ST 67776 89690	1.6km north-east	Avon Group (mudstone and limestone, interbedded)
	PO093	ST 66640 89288	0.6km north	Avon Group (mudstone and limestone, interbedded)
	PO094	ST 66699 89244	0.6km north	Avon Group (mudstone and limestone, interbedded)
	PO104	ST 65928 89559	0.6km north	Tintern Sandstone Formation (sandstone)
	PO105	ST 65189 88680	0.3km north-west	Tintern Sandstone Formation (sandstone)

Receptor category	Ref Number/ receptor name (where applicable)	NGR	Location relative to the Site	Rockhead geology (where applicable)
	PO107	ST 65674 90087	1.0km north	Raglan Mudstone Formation (siltstone and mudstone, interbedded)
	PO108	ST 65809 90262	1.2km north	Raglan Mudstone Formation (siltstone and mudstone, interbedded)
	PO109	ST 65488 90311	1.2km north	Raglan Mudstone Formation (siltstone and mudstone, interbedded)
	PO110	ST 66525 90967	2.2km north	Raglan Mudstone Formation (siltstone and mudstone, interbedded)
	PO111	ST 65866 90934	2.2km north	Raglan Mudstone Formation (siltstone and mudstone, interbedded)
	PO112	ST 65039 90843	2.0km north-west	Raglan Mudstone Formation (siltstone and mudstone, interbedded)
	PO113	ST 64980 91473	2.5km north-west	Mercia Mudstone Group (marginal Facies, conglomerate)
	PO116	ST 67280 91447	2.9km north	Brinkmarsh Beds (limestone)
	PO117	ST 63418 89843	2.3km north-west	Tintern Sandstone Formation (sandstone)
	PO118	ST 63271 90492	2.8km north-west	Mercia Mudstone Group (marginal Facies, conglomerate)
	PO129	ST 67568 89572	1.4km north-east	Tintern Sandstone Formation (sandstone)
	PO132	ST 63037 91120	3.3km north-west	Mercia Mudstone Group (marginal Facies, conglomerate)

Receptor category	Ref Number/ receptor name (where applicable)	NGR	Location relative to the Site	Rockhead geology (where applicable)
	PO133	ST 63397 91473	3.4km north-west	Mercia Mudstone Group (marginal Facies, conglomerate)
	PO134	ST 63818 91261	3.0km north-west	Mercia Mudstone Group (mudstone)
	PO135	ST 63475 89228	2.1km west	Tintern Sandstone Formation (sandstone)
	PO141	ST 67127 91839	3.1km north	Penarth Group (mudstone)
	PO142	ST 63968 91602	3.1km north-west	Mercia Mudstone Group (marginal Facies, conglomerate)
	PO143	ST 63963 91624	3.1km north-west	Mercia Mudstone Group (marginal Facies, conglomerate)
	PO144	ST 63828 91272	3.0km north-west	Mercia Mudstone Group (mudstone)
	PO145	ST 63808 91251	3.0km north-west	Mercia Mudstone Group (mudstone)
	PO146	ST 63802 91229	3.0km north-west	Mercia Mudstone Group (mudstone)
	PO151	ST 65143 90449	1.5km north-west	Raglan Mudstone Formation (siltstone and mudstone, interbedded)
	PO154	ST 61604 89400	3.0km west	Mercia Mudstone Group (mudstone)
	PO155	ST 62136 90441	3.7km north-west	Raglan Mudstone Formation (siltstone and mudstone, interbedded)
	PO156	ST 62291 91058	3.8km north-west	Mercia Mudstone Group (mudstone)

9.8.9 The remaining potential hydrological and hydrogeological receptors of quarrying related effects are summarised as follows:

- One SSSI, namely Tytherington Quarry SSSI;
- Two watercourses, namely the Ladden Brook and the un-named tributary (originating in Cromhall) of the Tortworth Brook;
- Two WFD surface water bodies, namely the Laddon Bk – source to confluence River Frome, and the Tortworth Brook - source to confluence River Little Avon;
- Three WFT groundwater bodies, namely Carboniferous Limestone – Alveston, Avonmouth Merica Mudstone, and Bristol Triassic;
- One licensed groundwater abstraction, namely Mill Farm Borehole (AB03);
- One registered private water supply, namely Huntly Farm (GA05);
- One non-registered spring (SP02 in Tytherington Village);
- Eight wells;
- One lake called ‘The Lake’ (PO157, north of Townwell);
- A total of 119 ponds (see **Appendix 9D**);and
- Four properties, within areas prone to flooding.

9.8.10 The potential receptors within each receptor category are listed in **Table 9-31**, with the exception of the ponds, which are detailed in **Appendix 9D**.

Table 9-31 – Potential receptors included in the water environment assessment

Receptor category	Ref Number/ receptor name (where applicable)	NGR	Location relative to the Site	Rockhead geology (where applicable)
SSSI	Tytherington Quarry	ST 662 888	<20m, within North Face Quarry	Black Rock Limestone/Dolomite
Watercourse	Ladden Brook	ST 67884 87426	2.1km southeast	Variable
	un-named tributary (originating in Cromhall) of the Tortworth Brook	ST 68689 89483	2.5km northeast	Variable
WFD surface water body	Oldbury Naite Rhine	ST 6400 9050	Contains most of the Site	Variable
	Laddon Bk – source to conf R Frome	ST 6814 8703	Contains southeastern part of the Site	Variable
	Tortworth Bk - source to conf R Little Avon	ST 6869 8948	Immediately northeast of the Site (contains North Face Quarry)	Variable
WFD groundwater body	Carboniferous Limestone – Alveston (GB40901G806200)	ST 6675 8893	Contains entire Site	Aquifer: Carboniferous Limestone
	Avonmouth Merica Mudstone (GB40902G303100)	ST 6576 9065	420m northeast	Aquifer: Merica Mudstone Group

Receptor category	Ref Number/ receptor name (where applicable)	NGR	Location relative to the Site	Rockhead geology (where applicable)
	Bristol Triassic (GB40902G804800)	ST 6814 8703	170m southeast	Aquifer: Triassic
Licensed abstraction (groundwater)	AB03: Mill Farm Borehole (17/53/002/G/080)	ST 67318 18800	1.2km east	Aquifer: Carboniferous Limestone
Private water supply: well	GA05: Huntly Farm	ST 68400 85400	3.7km southeast	Mangotsfield Member (sandstone)
Lake	PO157: The Lake	ST 69012 91689	4.0km northeast	Black Rock Limestone Subgroup (dolostone)
Spring	SP02	ST 66897 88190	850m southeast	Mercia Mudstone Group (marginal Facies, conglomerate)
Well	WL01	ST 63056 88490	2.3km west	Blue Anchor Formation (mudstone)
	WL02	ST 61935 87878	3.5km west	Penarth Group (mudstone)
	WL03	ST 62435 87795	3.0km west	Blue Anchor Formation (mudstone)
	WL04	ST 65552 85222	2.7km south	Penarth Group (mudstone)
	WL05	ST 65727 85229	2.7km south	Penarth Group (mudstone)
	WL06	ST 69214 88377	3.1km east	South Wales Lower Coal Measures Formation and South Wales Middle Coal Measures Formation (undifferentiated, mudstone, siltstone and sandstone)
	WL13	ST 69319 91425	4.0km northeast	Clifton Down Limestone Formation (limestone)
	WL14	ST 69692 90343	3.8km northeast	Cromhall Sandstone Formation (sandstone)

Receptor category	Ref Number/ receptor name (where applicable)	NGR	Location relative to the Site	Rockhead geology (where applicable)
Properties at risk of flooding	FRR1: Building #1	ST 67040 88180		
	FRR2: Building #2	ST 67261 88085		
	FRR3: Building #3	ST 67281 88107		
	FRR4: Building #4	ST 67266 88143		

POTENTIALLY SIGNIFICANT EFFECTS

9.8.11 The potential significant effects relating to the Proposed Scheme which are subject to further assessment in this chapter are summarised below:

- Potential effects on conditions supporting conservation sites as a result of quarry dewatering leading to a decline in surface water flows and groundwater levels; site activities resulting in the release of pollutants and the subsequent contamination of groundwater; and site restoration leading to an increase in runoff-derived surface flows and a decline in groundwater levels, and leaching of contaminants from backfill.
- Potential effects on watercourses as a result of quarry excavation and dewatering leading to a decline in flow, water quality (through reduced dilution) and morphology; site activities resulting in the release of pollutants and the subsequent contamination of groundwater base flow to watercourses; contaminated and silt-laden site discharges to surface water causing deterioration in the water quality and morphology; and site restoration leading to an increase in runoff-derived surface water flows and a decline in groundwater base flow, also with consequent changes in water quality and watercourse morphology, and leaching of contaminants from backfill, leading to a deterioration in water quality.
- In the **FRA** potential flood risk effects were identified for humans, property and infrastructure as a result of the consented discharge increasing surface flows in the Tytherington Watercourse.
- Potential effects on groundwater licensed abstractions and PWS as a result of quarry dewatering leading to a decline in water levels and a subsequent decline in abstraction yield and associated water quality; site activities resulting in the release of pollutants and the subsequent contamination of abstraction water; and site restoration restricting recharge, leading to a decline in groundwater levels and abstraction yields, and also resulting in the leaching of contaminants from the backfill material and a deterioration in abstraction water quality.
- Potential effects on springs as a result of quarry dewatering leading to a decline in water levels and a subsequent decline in spring yield and associated water quality; site activities resulting in the release of pollutants and the subsequent contamination of spring water; and site restoration restricting recharge, leading to a decline in groundwater levels and spring yield, and resulting in the leaching of contaminants from the backfill material and a deterioration in spring water quality.
- Potential effects on WFD surface water bodies and other ponds/lakes as a result of quarry excavation and dewatering by way of a decline in river flow, water quality (through reduced dilution) and morphology; site activities resulting in the release of pollutants and the subsequent contamination of groundwater base flow to watercourses; contaminated and silt-laden site discharges to surface water causing deterioration in the water quality and morphology; and site restoration leading to an increase in runoff-derived surface water flows and a decline in groundwater base flow, also with consequent changes in water quality and watercourse morphology, and leaching of contaminants from backfill, leading to a deterioration in water quality.
- Potential effects on WFD groundwater bodies as a result of quarry dewatering leading to a decline in groundwater levels; site activities resulting in the release of pollutants and the subsequent contamination of groundwater; and site restoration restricting recharge, leading to a decline in groundwater levels, and resulting in the leaching of contaminants from the backfill material.

9.8.11.1 Effects scoped-in to the assessment

9.8.12 Water environment receptors that have been taken forward for further assessment are summarised in **Table 9-31** and **Appendix 9D** (only ponds which are underlain by either Principal or Secondary A Aquifer, i.e. a total of 43 ponds).

9.8.12.1 Effects scoped-out of the assessment

9.8.13 The receptors that have been scoped out based on their location relative to the Avon Group are summarised in **Table 9-30**.

9.8.14 The following additional receptors have been scoped out from being subject to further assessment because the potential effects are not considered likely to be significant:

- A total of 76 ponds which are underlain by a Secondary (either B or undifferentiated) Aquifer (see last column in table of **Appendix 9D**) as these are not thought to be hydraulically disconnected from the Carboniferous Limestone aquifers.

9.9 ASSESSMENT METHODOLOGY

9.9.1 The generic project-wide approach to the assessment methodology is set out in **Chapter 4**, and specifically in Sections 4.5 to 4.7. However, whilst this has informed the approach that has been used in this water environment assessment, it is necessary to set out how this methodology has been applied, and adapted as appropriate, to address the specific needs of this water environment assessment.

9.9.2 METHODOLOGY FOR PREDICTION OF EFFECTS

9.9.3 The method and criteria used to determine value, magnitude and significance of effect is described in this section.

9.9.4 Value of hydrological and hydrogeological water features is normally related to the importance of the surface water or groundwater feature that might be at risk from effects. **Table 9-32** provides a summary of the criteria used in the assessment of water feature value.

Table 9-32 - Summary of value of hydrological, hydrogeological and flood risk receptors

Value	Criteria	Receptor category*	Examples
Very High	Features with a very high yield, quality or rarity with little potential for substitution.	Aquatic environment	Conditions supporting a site with an international conservation designation (Special Area of Conservation (SAC), Special Protection Area (SPA), Ramsar site), where the designation is based specifically on aquatic features. WFD surface water body with overall High status. WFD surface water body with High status for morphology.
	Water use supporting human health and economic activity at a regional scale.	Water use	Regionally important public surface water or groundwater supply (and associated catchment/GWMU) or permitted discharge.
	Features with a very high vulnerability to flooding.	Flood risk	Land use type defined as 'Essential Infrastructure' (i.e. critical national infrastructure, such as essential transport and utility infrastructure) and 'Highly Vulnerable' (e.g.

Value	Criteria	Receptor category*	Examples
			police/ambulance stations that are required to operate during flooding, mobile homes intended for permanent residential use) in the NPPF flood risk vulnerability classification.
High	Features with a high yield, quality or rarity, with a limited potential for substitution.	Aquatic environment	Conditions supporting a site with a national conservation designation (e.g. SSSI, National Nature Reserve (NNR)), where the designation is based specifically on aquatic features. WFD surface water body (or part thereof) with overall 'Good' status/potential. WFD groundwater body (or part thereof) with overall 'Good' status.
	High quality watercourse morphology	Watercourse morphology	A watercourse in natural equilibrium and exhibiting a natural range of fluvial processes and morphological features, with little or no modification or anthropogenic influence.
	Water use supporting human health and economic activity at a local scale.	Water use	Local public surface water and groundwater supply (and associated catchment/GWMU) or permitted discharge. Licensed non-public surface water and groundwater supply abstraction (and associated groundwater catchment) which is relatively large relative to available resource, or where raw water quality is a critical issue, e.g. industrial process water, or permitted discharge.
	Features with a high vulnerability to flooding.	Flood risk	Land use type defined as 'More Vulnerable' in the NPPF flood risk vulnerability classification (e.g. hospitals and health centres, educational institutions, most types of residential development).
Medium	Features with a moderate yield, quality or rarity, with some potential for substitution.	Aquatic environment	Conditions supporting a site with a local conservation designation (e.g. LNR, County Wildlife Site (CWS)), where the designation is based specifically on aquatic features, or an undesignated but highly/moderately water-dependent ecosystem, including an LWS and a GWDTE. WFD surface water body (or part thereof) with overall Moderate or lower status/potential. Groundwater body (or part thereof) with overall Poor status.

Value	Criteria	Receptor category*	Examples
	Medium quality watercourse morphology	Watercourse morphology	A watercourse showing signs of modification and recovery to a natural equilibrium, and currently exhibiting a limited range of fluvial processes and morphological features affected by modification or anthropogenic influence.
	Water use supporting human health and economic activity at household/individual business scale.	Water use	Licensed non-public surface water and groundwater supply abstraction (and associated catchment/ GWMU), which is relatively small relative to available resource, or where raw water quality is not critical, e.g. cooling water, spray irrigation, mineral washing or permitted discharge. Unlicensed potable surface water and groundwater abstraction (and associated catchment) e.g. private domestic water supply, well, spring or permitted discharge.
	Features with a moderate to low vulnerability to flooding.	Flood risk	Land use type defined as 'Less Vulnerable' in the NPPF flood risk vulnerability classification (e.g. most types of business premises).
Low	Commonplace features with low yield or quality with good potential for substitution.	Aquatic environment	Conditions supporting an undesignated and low water-dependent ecosystem, including a LWS, GWDTE and pond. Non-reportable WFD surface water or groundwater body (or part thereof), or non-WFD water body.
	Low quality watercourse morphology	Watercourse morphology	A highly modified watercourse changed by channel modification or other anthropogenic pressures, currently exhibiting no active flow processes or morphological diversity.
	Water use does not support human health, and of only limited economic benefit.	Water use	Unlicensed non-potable surface water and groundwater abstraction (and associated catchment) e.g. livestock supply.
	Features that are resilient to flooding.	Flood risk	Land use type defined as 'Water-compatible development' in the NPPF flood risk vulnerability classification and undeveloped land (e.g. flood control infrastructure; water transmission infrastructure).

9.9.5 Assessment of the value of all the potential receptors identified in **Table 9-31** and using the criteria provided in **Table 9-32** is detailed in **Table 9-33**.

Table 9-33 - Assessment of value of potential hydrological, hydrogeological and flood risk receptors

Ref Number (where applicable)	Receptor	NGR	Value	Rationale
Conservation sites (SSSIs)				
	Tytherington Quarry	ST 662 888	Low	Designation base on SSSI being geological exposure, i.e. not based specifically on aquatic features.
Watercourses				
	Ladden Brook	ST 67884 87426	Medium	Part of WFD overall Poor status surface water body
	un-named tributary (originating in Cromhall) of the Tortworth Brook	ST 68689 89483	Medium	Part of WFD overall Medium status surface water body
WFD River Water bodies				
	Ladden Brook – source to conf R Frome (Brist, GB109053027590)	ST 6814 8703	Medium	WFD overall Poor status surface water body
	Tortworth Bk - source to conf R Little Avon (GB109054026590)	ST 6869 8948	Medium	Part of WFD overall Medium status surface water body
WFD Groundwater bodies				
	Carboniferous Limestone – Alveston (GB40901G806200)	ST 6675 8893	Medium	WFD overall Poor status groundwater body
	Avonmouth Merica Mudstone (GB40902G303100)	ST 6576 9065	Medium	WFD overall Poor status groundwater body

Ref Number (where applicable)	Receptor	NGR	Value	Rationale
	Bristol Triassic (GB40902G804800)	ST 6814 8703	High	WFD overall Good status groundwater body
Licensed abstraction (groundwater)				
	AB03: Mill Farm Borehole (17/53/002/G/080)	ST 67318 18800	High	Licensed non public abstraction where the water quality is critical (domestic use)
Private water supplies (wells)				
	GA05: Huntly Farm	ST 68400 85400	Medium	Unlicensed but registered and potentially potable groundwater abstraction.
Lakes				
	PO157: The Lake	ST 69012 91689	Low	Lake, as of undesignated and low water-dependent ecosystem.
Ponds				
	A total of 43 ponds as of (locations see **Figure 9.14**, NGRs see **Appendix 9D**): PO007, PO010, PO012, PO013, PO014, PO018, PO026, PO042, PO070, PO073, PO074, PO075, PO076, PO077, PO078, PO079, PO082, PO084, PO089, PO090, PO091, PO095, PO096, PO097, PO099, PO100, PO101, PO102, PO103, PO123, PO124, PO126, PO130, PO131, PO137, PO138, PO139, PO140, PO148, PO149, PO150, PO152, PO153		Low	Ponds, as of undesignated and low water-dependent ecosystem.
Springs				

Ref Number (where applicable)	Receptor	NGR	Value	Rationale
	SP02	ST 66897 88190	Low	Unlicensed spring, not being used for potable water. Note: this spring (location from WRc (1997) map) is likely to no longer exist.
Wells (from OS maps)				
	WL01	ST 63056 88490	Medium	Unlicensed and un-registered but potentially potable groundwater abstraction.
	WL02	ST 61935 87878	Medium	Unlicensed and un-registered but potentially potable groundwater abstraction.
	WL03	ST 62435 87795	Medium	Unlicensed and un-registered but potentially potable groundwater abstraction.
	WL04	ST 65552 85222	Medium	Unlicensed and un-registered but potentially potable groundwater abstraction.
	WL05	ST 65727 85229	Medium	Unlicensed and un-registered but potentially potable groundwater abstraction.
	WL06	ST 69214 88377	Medium	Unlicensed and un-registered but potentially potable groundwater abstraction.
	WL13	ST 69319 91425	Medium	Unlicensed and un-registered but potentially potable groundwater abstraction.
	WL14	ST 69692 90343	Medium	Unlicensed and un-registered but potentially potable groundwater abstraction.
Humans, properties, and infrastructure within areas at risk of flooding				

Ref Number (where applicable)	Receptor	NGR	Value	Rationale
FRR1	Building #1	ST	High	Land use type defined as 'More vulnerable' in the NPPF flood risk vulnerability classification
FRR2	Building #2	ST	High	Land use type defined as 'More vulnerable' in the NPPF flood risk vulnerability classification
FRR3	Building #3	ST	High	Land use type defined as 'More vulnerable' in the NPPF flood risk vulnerability classification
FRR4	Building #4	ST	High	Land use type defined as 'More vulnerable' in the NPPF flood risk vulnerability classification

9.9.6 The magnitude of change on water features is independent of the value of the feature, and its assessment is qualitative and relies on professional judgment. **Table 9-34** provides examples of how various levels of change have been determined with respect to water features.

Table 9-34 - Summary of hydrological, hydrogeological and flood risk magnitude of change

Magnitude	Criteria	Receptor category*	Example**
High	Results in major change to feature, of sufficient magnitude to affect its use/integrity.	Aquatic environment	Deterioration in river flow regime, morphology or water quality, leading to sustained, permanent or long-term breach of relevant conservation objectives (COs) or non-temporary downgrading (deterioration) of WFD surface water body status (including downgrading of individual WFD elements), or resulting in the inability of the surface water body to attain Good status in line with the measures identified in the RBMP. Deterioration in groundwater levels, flows or water quality, leading to non-temporary downgrading of WFD groundwater body status, or the inability of the groundwater body to attain Good status in line with the measures identified in the RBMP.
		Watercourse morphology	Loss or extensive damage to geomorphological habitat and processes due to extensive modification and/or fine sediment input. Replacement of a large extent of the natural bed and/or banks with artificial material. Extensive change to channel planform.
		Water use	Complete or severely reduced water availability and/or quality, compromising the ability of water users to abstract.
		Flood risk	Change in flood risk resulting in potential loss of life or major damage to the property or infrastructure.
Medium	Results in noticeable change to feature, of sufficient magnitude to affect its use/integrity in some circumstances.	Aquatic environment	Deterioration in river flow regime, morphology or water quality, leading to periodic, short-term and reversible breaches of relevant COs, or potential temporary downgrading of surface water body status (including potential temporary downgrading of individual WFD elements), although not affecting the ability of the surface water body to achieve future WFD objectives.

Magnitude	Criteria	Receptor category*	Example**
			Deterioration in groundwater levels, flows or water quality, leading to potential temporary downgrading of WFD groundwater body status, although not affecting the ability of the groundwater body to achieve future WFD objectives.
		Watercourse morphology	Partial loss or damage to geomorphological habitat and processes due to modifications and/or fine sediment input. Replacement of the natural bed and/or banks with artificial material (total length is more than 3% of water body length).
		Water use	Moderate reduction in water availability and/or quality, which may compromise the ability of the water user to abstract on a temporary basis or for limited periods, with no longer-term impact on the purpose for which the water is used.
		Flood risk	Change in flood risk resulting in potential for moderate damage to the property or infrastructure.
Low	Results in minor change to feature, with insufficient magnitude to affect its use/integrity in most circumstances.	Aquatic environment	Measurable impact on river flow regime, morphology or water quality, but remaining generally within COs, and with no short-term or permanent change to WFD surface water body status (of overall status or element status). Measurable impact on groundwater levels, flows or water quality, but with no short-term or permanent downgrading of WFD groundwater body status.
		Watercourse morphology	Slight change or deviation from baseline conditions, or partial loss or damage or improvement/ gain to in channel habitat and geomorphological processes due to modifications and/or fine sediment input.

Magnitude	Criteria	Receptor category*	Example**
		Water use	Minor reduction in water availability and/or quality, but unlikely to affect the ability of a water user to abstract.
		Flood risk	Change in flood risk resulting in potential for minor damage to property or infrastructure.
Negligible	Results in little or no change to feature, with insufficient magnitude to affect its use/integrity	Aquatic environment	None or very slight change in river flow regime or surface water quality and no consequences in terms of COs or WFD surface water body status. None or very slight change in groundwater levels or groundwater quality, and no consequences in terms of WFD groundwater status.
		Watercourse morphology	Very slight change from surface water baseline conditions, approximating to a ‘no change’ situation.
		Water use	None, or very slight change in water availability or quality and no change in ability of the water user to exercise licenced rights or continue with small private abstraction.
		Flood risk	Increased frequency of flood flows, but which does not pose an increased risk to property or infrastructure.

*The watercourse morphology receptor type is only relevant when ‘in-channel’ works are proposed.

**For the purposes of this assessment of change, relevant WFD elements for surface water body classification include:

- all biological quality elements e.g. fish, macrophytes, invertebrates;
- all physio-chemical quality elements e.g. dissolved oxygen, phosphate;
- hydromorphological supporting elements;
- Priority Hazardous Substances;
- Priority Substances;
- Specific Pollutants; and

- for Artificial and Heavily Modified Water Bodies, the WFD mitigation measures assessment.

For the purposes of this assessment of change, relevant WFD characteristics for groundwater body classification are quantity (groundwater level regime) and chemistry (conductivity and source of pollutants), as determined by the following tests:

- Water balance (quantitative);
- Drinking Water Protection Areas (chemical);
- General Quality Assessment (chemical);
- Saline and other intrusions (quantitative and chemical);
- Surface water (quantitative and chemical); and
- Groundwater Dependent Terrestrial Ecosystems (GWDTEs) (quantitative and chemical).

9.9.7 SIGNIFICANT EVALUATION METHODOLOGY

9.9.8 The significance level attributed to each effect has been assessed based on the sensitivity/value of the affected receptor(s) and the magnitude of change arising from the Proposed Scheme, as well as a number of other factors that are outlined in more detail in **Chapter 4: Approach to EIA**. The sensitivity of the affected receptor is assessed on a scale of high, medium, low, and negligible, and the magnitude of change is assessed on a scale of large, medium, small, negligible and no change, as set out in **Chapter 4: Approach to EIA**.

Effect Significance

9.9.9 The following terms have been used to define the significance of the effects identified and apply to both beneficial and adverse effects:

- **Major effect**: where the Proposed Scheme could be expected to have a substantial improvement or deterioration on;
- **Moderate effect**: where the Proposed Scheme could be expected to have a noticeable improvement or deterioration on receptors;
- **Minor effect**: where the Proposed Scheme could be expected to result in a perceptible improvement or deterioration on receptors; and
- **Negligible**: where no discernible improvement or deterioration is expected as a result of the Proposed Scheme on receptors, including instances where no change is confirmed.

9.9.10 As set out in **Chapter 4: Approach to EIA**, effects that are classified as **minor or above** are considered to be **significant**. Effects classified as below minor are considered to be **not significant**.

9.10 ASSESSMENT OF WATER ENVIRONMENT EFFECTS

CONDITIONS SUPPORTING CONSERVATION SITES

9.10.1 This chapter examines potential changes due to the Proposed Scheme on the water environment supporting conservation sites, not the conservation sites themselves, which are instead a matter for the ES Biodiversity chapter (**Chapter 10**).

9.10.2 Based on the water environment baseline presented in **Section 9.5**, **Section 9.9** identified potential effects due to the Proposed Scheme on conditions supporting one conservation site within the Study Area as requiring consideration as part of the EIA. The potential effects that were identified relate to site activities resulting in the release of pollutants and the subsequent contamination of groundwater.

WATERCOURSES

9.10.3 Based on the water environment baseline presented in **Section 9.5**, **Section 9.9** identified potential effects due to the Proposed Scheme at Tytherington Quarry on the Ladden Brook watercourse and the un-named tributary (originating in Cromhall) of the Tortworth Brook. The potential effects relate to quarry excavation were identified as: dewatering leading to a decline in river flow, water quality (through reduced dilution) and morphology; site activities resulting in the release of pollutants and the subsequent contamination of groundwater base flow to watercourses; contaminated and silt-laden site discharge to surface water causing a deterioration in the water quality and morphology; and site restoration leading to an increase in runoff-derived surface water flows and a decline in groundwater baseflow. These could also lead to changes in water quality and watercourse morphology, and leaching of contaminants from backfill, leading to a deterioration in water quality.

Ladden Brook

9.10.4 Given that the Ladden Brook watercourse lies within a surface water body with a current overall poor WFD status, the Ladden Brook watercourse has been assigned a medium sensitivity value (Table 9-33).

9.10.5 The Ladden Brook is underlain by at least 4m thick (based no BGS geoindex borehole logs) Mercia Mudstone Group (mudstone, siltstone and sandstone) and this, together with the Clifton Down Mudstone aquitard is thought to hydraulically separate it from the combined aquifer. On that basis, the anticipated effectiveness of the embedded environmental measures and regulated by the extant discharge consent license (**Section 9.5**) means that the magnitude of effect on the watercourse with respect to quarry excavation and dewatering (river flow and quality), and site restoration (river flow and quality) is considered negligeable (**Table 9-37**).

Un-named tributary (originating in Cromhall) of the Tortworth Brook

9.10.6 Given that this Tortworth Brook triburary lies within a surface water body with a current overall poor WFD status, it has been assigned a medium sensitivity value (**Table 9-33**).

9.10.7 The stream starts to the west of Heath End to flow northwards and subsequently traverses strata of the upper combined aquifer which are likely to provide baseflow. However, due to the hydraulic barrier effect of the underlying Clifton Down Mudstone, the magnitude of effect on the watercourse with respect to quarry excavation and dewatering (river flow and quality), and site restoration (river flow and quality) is considered negligeable to low (**Table 9-37**).

WFD RIVER WATER BODIES

9.10.8 Based on the water environment baseline presented in **Section 9.5**, **Section 9.9** identified potential effects due to the Proposed Scheme at Tytherington Quarry on the Ladden Brook from Source to Confluence with River Frome (Bristol) WFD surface water body requiring consideration as part of this EIA.

9.10.9 The potential effects on WFD surface water bodies related to quarry dewatering were identified as: dewatering site and site restoration activities leading to contaminated site discharge; a decline in water levels and flows and water quality and a deterioration in WFD status of those water bodies.

9.10.9.1 Ladden Brook from Source to Confluence with River Frome (Bristol) (GB109053027590)

9.10.10 This river water body is of poor overall status (**Table 9-22**) and is therefore considered of medium sensitivity value (**Table 9-32**).

9.10.11 Despite the proximity of this water body to the Proposed Scheme at Tytherington Quarry, the anticipated effectiveness of the embedded environmental measures (**Section 9.13**) means that the magnitude of effect on the surface water body as a whole with respect to the quarry excavation and dewatering (river flow and water quality) is low to medium. The magnitude of change from site discharge (water quality) and site restoration (river flow and water quality) is negligible (**Table 9-34**).

9.10.12 On this basis, the level of effect on these surface water bodies is considered negligible and not significant (**Table 9-37**).

Tortworth Bk - source to conf R Little Avon (GB109054026590)

9.10.13 This river water body is of poor overall status (**Table 9-22**) and is therefore considered of medium sensitivity value (**Table 9-32**).

9.10.14 Despite the proximity of this water body to the Proposed Scheme at Tytherington Quarry, the anticipated effectiveness of the embedded environmental measures (**Section 9.13**) means that the magnitude of effect on the surface water body as a whole with respect to the quarry excavation and dewatering (river flow and water quality) is low to medium. The magnitude of change from site discharge (water quality) and site restoration (river flow and water quality) is considered negligible (**Table 9-34**).

9.10.15 On this basis, the level of effect on these surface water bodies is considered negligible and not significant (**Table 9-37**).

WFD GROUNDWATER BODIES

9.10.16 For the WFD groundwater bodies the potential effects relate to: a deterioration in WFD status through quarry dewatering leading to a decline in groundwater levels; deterioration in groundwater quality; site activities resulting in the release of pollutants and the subsequent contamination of groundwater, and site restoration restricting recharge, leading to a decline in groundwater levels and the leaching of contaminants from the backfill material resulting in a deterioration in groundwater quality.

Carboniferous Limestone – Alveston (GB40901G806200)

9.10.17 The Site overlies this groundwater body which is at Poor overall status (**Table 9-23**) and, therefore, is considered of medium sensitivity value (**Table 9-32**).

9.10.18 Despite the water body including the combined aquifer beneath the Site, the anticipated effectiveness of the embedded environmental measures (**Section 9.15**, including **Table 9-38**) means that the magnitude of effect on the groundwater water body as a whole with respect to the quarry excavation and dewatering (groundwater levels and water quality) is low. The magnitude of change from site activities (groundwater quality) and site restoration (groundwater levels and water quality) is considered negligible (**Table 9-34**).

9.10.19 On this basis, the level of effect on this groundwater body is considered negligible and not significant (**Table** 9-37).

Avonmouth Merica Mudstone (GB40902G303100)

9.10.20 The Site overlies this groundwater body which is at Poor overall status (**Table 9-23**) and is therefore considered of medium sensitivity value (**Table 9-32**).

9.10.21 This groundwater body is thought to be hydraulically separated from the combined aquifer. Therefore, the anticipated effectiveness of the embedded environmental measures (**Section 9.15**, including **Table 9-38**) means that the magnitude of effect on the groundwater water body as a whole with respect to the quarry excavation and dewatering (groundwater levels and water quality) is low. The magnitude of change from site activities (groundwater quality) and site restoration (groundwater levels and water quality) is considered negligible (**Table 9-34**).

9.10.22 On this basis, the level of effect on this groundwater body is considered negligible and not significant (**Table 9-37**).

Bristol Triassic (GB40902G804800)

9.10.23 The Site overlies this groundwater body which is at Good overall status (**Table 9-23)** and, therefore, is considered of high sensitivity value (**Table 9-32**).

9.10.24 This water body includes the Mercia Mudstone conglomerate aquifer close to the Site to the southeast. The groundwater body as a whole is hydraulically separated from the Stie by the Clifton Down Mudstone (potential flow path discussed in **Section 9.5** via Mercia Mudstone conglomerate not active). Therefore, the anticipated effectiveness of the embedded environmental measures (**Section 9.15**, including **Table 9-38**) means that the magnitude of effect on the groundwater water body as a whole with respect to the quarry excavation and dewatering (groundwater levels and water quality) is low. The magnitude of change from site activities (groundwater quality) and site restoration (groundwater levels and water quality) is considered negligible (**Table 9-34**).

9.10.25 On this basis, the level of effect on this groundwater body is considered negligible and not significant (**Table 9-37**).

LICENSED ABSTRACTIONS AND REGISTERED PWS

9.10.26 Based on the water environment baseline presented in **Section 9.5**, **Section 9.9** identified potential effects due to the Proposed Scheme at the Site on one licensed abstraction and one registered PWS within the Study Area as requiring consideration as part of the EIA. The potential effects that were identified relate to: quarry dewatering leading to a decline in water levels and a subsequent decline in abstraction yield and associated water quality; a deterioration in abstraction water quality as a result of reduced dilution; site activities resulting in the release of pollutants and the subsequent contamination of abstraction water; and site restoration restricting recharge, leading to a decline in water levels and abstraction yields and leaching of contaminants from the backfill material resulting in deterioration in abstraction water quality.

Mill Farm Borehole (AB03, 17/53/002/G/080)

9.10.27 This licensed groundwater abstraction to the southeast of the Site is considered to be of high sensitivity value (**Table 9-32**).

9.10.28 It is thought to be hydraulically separated from the combined aquifer by the Clifton Down Mudstone, and, together with the anticipated effectiveness of the embedded environmental measures (**Section 9.13**, including **Table 9-33**) means that the magnitude of effect on the abstraction with respect to the quarry dewatering (groundwater levels and water quality) is low. The magnitude of effect from site activities (water quality) and site restoration (groundwater levels and water quality) is considered negligible (**Table 9-34**).

9.10.29 On this basis, the level of effect on these two this abstraction is considered negligible and not significant (**Table 9-37**).

Huntly Farm (GA05)

9.10.30 This distant registered PWS groundwater abstraction to the southeast of the Site is considered to be of medium sensitivity value (**Table 9-32**).

9.10.31 It is thought to be hydraulically separated from the combined aquifer both by the Ladden Brook discharge zone (marks groundwater divide) and by the Clifton Down Mudstone. This means that the magnitude of effect on the abstraction with respect to the quarry dewatering (groundwater levels and water quality) is low. The magnitude of effect from site activities (water quality) and site restoration (groundwater levels and water quality) is considered negligible (**Table 9-34**).

9.10.32 On this basis, the level of effect on this abstraction is considered negligible and not significant (**Table 9-37**).

WELLS

9.10.33 The wells in this section have been gathered from OS maps. None of these are licensed or registered PWS which means their current status, i.e. whether they still exist and/or active, is not known.

9.10.34 The wells are considered to be of medium sensitivity value (**Table 9-32**).

Group of wells WL01, WL02, and WL03

9.10.35 These distant wells to the southwest of the Site sit within Triassic strata but are likely to be targeting the combined aquifer. Whilst offset by a northeast-southwest trending fault against the Site, the wells could potentially be hydraulically connected to the Site. However, the anticipated effectiveness of the embedded environmental measures (**Section 9.13**, including **Table 9-33**) means that the magnitude of effect on the potential abstractions with respect to the quarry dewatering (groundwater levels and water quality) is low. The magnitude of effect from site activities (water quality) and site restoration (groundwater levels and water quality) is considered negligible (**Table 9-34**).

9.10.36 On this basis, the level of effect on these potential abstractions is considered negligible and not significant (**Table 9-37**).

Group of wells WL04, WL05, WL06, WL13, and WL14

9.10.37 These are mostly distant wells to the southwest to northwest of the Site. They are hydraulically separated from combined aquifer by the Avon Group aquitard and other low permeability strata. Therefore, the anticipated effectiveness of the embedded environmental measures (**Section 9.13**, including **Table 9-33)** means that the magnitude of effect on the potential abstractions with respect to the quarry dewatering (groundwater levels and water quality) is low. The magnitude of effect from site activities (water quality) and site restoration (groundwater levels and water quality) is considered negligible (**Table 9-34**).

9.10.38 On this basis, the level of effect on these potential abstractions is considered negligible and not significant (**Table 9-37**).

SPRINGS

9.10.39 Based on the water environment baseline presented in **Section 9.5**, **Section 9.9** identified potential effects due to the Proposed Scheme at the Site on one spring within the Study Area as requiring consideration as part of the EIA. The potential effects were identified as: quarry dewatering leading to a decline in water levels and a subsequent decline in spring yield and associated water quality; a deterioration in spring water quality as a result of reduced dilution; site activities resulting in the release of pollutants and the subsequent contamination of spring water; and site restoration restricting recharge, leading to a decline in groundwater levels, and spring yield, and leaching of contaminants from the backfill material resulting in a deterioration in spring water quality.

Spring SO02 in Tytherington Village

9.10.40 This spring located in Tytherington Village may no longer exist but is being assessed here. It is considered to be of low value (**Table 9-32**).

9.10.41 The spring is thought to be hydraulically separated from the Site by the Clifton Down Mudstone aquitard. A potential alternative flow path via the Mercia Mudstone Group conglomerate it thought to be currently deactivated and the spring ground elevation is higher than the current combined aquifer groundwater level highs, implying it won't be affected from dewatering activities at the Site. This could potentially change during the restoration phase.

9.10.42 The anticipated effectiveness of the embedded environmental measures (**Section 9.13**, including **Table 9-38**), means that the magnitude of effect on this spring with respect to the quarry dewatering (groundwater levels and surface water flows) is low. The magnitude of change from site activities (water quality) and site restoration (surface water flows, groundwater levels and water quality) is considered negligible (**Table 9-34**).

9.10.43 On this basis, the level of effect on the Seven Springs is considered negligible to minor and not significant (**Table 9-37**).

WATER BODIES (PONDS AND LAKES)

9.10.44 Based on the water environment baseline presented in Section 9.5, Section 9.9 identified potential effects due to the Proposed Scheme at the Site on 44 water bodies (43 ponds and one lake) within the Study Area as requiring consideration as part of the EIA. The potential effects that were identified relate to: quarry dewatering leading to a decline in water levels and a subsequent decline in spring yield and associated water quality; a deterioration in water body quality as a result of reduced dilution; site activities resulting in the release of pollutants and the subsequent contamination of the water body; and site restoration restricting recharge, leading to a decline in groundwater levels and water body yield and leaching of contaminants from the backfill material resulting in deterioration in water body quality.

Group 1: North Face Quarry pond (PO152)

9.10.45 This water body immediately to north of the Site within North Face Quarry is fed by the combined aquifer and thus, connected to Woodleaze Quarry, albeit separated by a groundwater divide. It also lies within the WFD Carboniferous Limestone (Alveston) groundwater body and is considered to be of low sensitivity value (**Table** 9-32).

9.10.46 The anticipated effectiveness of the embedded environmental measures (**Section 9.13**, including **Table 9-38**), means that the magnitude of effect on this water body with respect to the quarry dewatering (surface water flows, groundwater levels and water quality) is low. The magnitude of effect from site activities (water quality) and site restoration (surface water flows, groundwater levels and water quality) is medium (**Table 9-34**).

9.10.47 On this basis, the level of effect on each of the identified water bodies is considered negligible and not significant (**Table 9-37**).

Group 2: PO007, PO010 and PO126

9.10.48 The water bodies of this group to the southwest of the Site are sit within the WFD Carboniferous Limestone (Alveston) groundwater body and are each considered to be of low sensitivity value (**Table 9-32**).

9.10.49 They sit in the upper combined aquifer (with only PO010 being underlain by additional Triassic strata) along strata strike and hence are thought to be hydraulically separated from the Site by Clifton Down Mudstone aquitard.

9.10.50 The anticipated effectiveness of the embedded environmental measures (**Section 9.13**, including **Table 9-38**), means that the magnitude of effect on these water bodies with respect to the quarry dewatering (surface water flows, groundwater levels and water quality) is low. The magnitude of effect from site activities (water quality) and site restoration (surface water flows, groundwater levels and water quality) is considered negligible (**Table** 9-34).

9.10.51 On this basis, the level of effect on each of the identified water bodies is considered negligible and not significant (**Table 9-37**).

Group 3: PO070, PO073, PO074, PO075, PO076, PO077, PO078, PO079, PO084, PO137, PO138, PO149, and PO153

9.10.52 The water bodies of this group to the far southeast of the Site are sit within the WFD Bristol Triassic groundwater body but are each considered to be of low sensitivity value (Table **9-32**).

9.10.53 All these water bodies are distant to the southeast of the Site with Laddon Brook (seen as groundwater divide) in between.

9.10.54 The anticipated effectiveness of the embedded environmental measures (**Section 9.13**, including **Table 9-38**), means that the magnitude of effect on these water bodies with respect to the quarry dewatering (surface water flows, groundwater levels and water quality) is low. The magnitude of effect from site activities (water quality) and site restoration (surface water flows, groundwater levels and water quality) is considered negligible (**Table** 9-34).

9.10.55 On this basis, the level of effect on each of the identified water bodies is considered negligible and not significant (**Table 9-37)**.

Group 4: PO089, PO090, PO091, PO130, PO131, PO140 and PO157 (The Lake)

9.10.56 The water bodies of this group in the far distance of the Site to the northeast either sit within the WFD Bristol Triassic or the Carboniferous Limestone (Alveston) groundwater body, but are each considered to be of low sensitivity value (**Table 9-32**).

9.10.57 All these water bodies are close to the Tortworth Brook tributary, and they are thought to be hydraulically separated from Site by the Clifton Down Mudstone aquitard.

9.10.58 The anticipated effectiveness of the embedded environmental measures (**Section 9.13**, including **Table 9-38**), means that the magnitude of effect on these water bodies with respect to the quarry dewatering (surface water flows, groundwater levels and water quality) is low. The magnitude of effect from site activities (water quality) and site restoration (surface water flows, groundwater levels and water quality) is considered negligible (**Table** 9-34).

9.10.59 On this basis, the level of effect on each of the identified water bodies is considered negligible and not significant (**Table 9-37**).

Group 5: PO082, PO095, PO096, PO097, PO099, PO100, PO101, PO102, PO103, PO139 and PO150

9.10.60 The water bodies of this group to nearer to southeast of the Site are sit within the all within the WFD Bristol Triassic groundwater body, with only one exception (WFD Carboniferous Limestone (Alveston) groundwater body) but are each considered to be of low sensitivity value (**Table 9-32)**.

9.10.61 They are all hydraulically separated from the Site by the Clifton Down Mudstone aquitard.

9.10.62 The anticipated effectiveness of the embedded environmental measures (**Section 9.13**, including **Table 9-38**), means that the magnitude of effect on these water bodies with respect to the quarry dewatering (surface water flows, groundwater levels and water quality) is low. The magnitude of effect from site activities (water quality) and site restoration (surface water flows, groundwater levels and water quality) is considered negligible (**Table** 9-34).

9.10.63 On this basis, the level of effect on each of the identified water bodies is considered negligible and not significant (**Table 9-37**).

Group 6: PO012, PO013, PO014, PO018, PO026, PO042, PO123, PO124, and PO148

9.10.64 The water bodies of this group in the far distance of the Site to the southwest do not sit in either the WFD Bristol Triassic or the Carboniferous Limestone (Alveston) groundwater body, and are each considered to be of low sensitivity value (**Table 9-32**).

9.10.65 To the southwest of the Site in strata strike direction, all these water bodies are underlain by Jurassic strata (likely to include the Blue Lias Mudstone (aquitard)) and are also thought to be hydraulically separated from the Site by the Clifton Down Mudstone.

9.10.66 The anticipated effectiveness of the embedded environmental measures (**Section 9.13**, including **Table 9-38**), means that the magnitude of effect on these water bodies with respect to the quarry dewatering (surface water flows, groundwater levels and water quality) is low. The magnitude of effect from site activities (water quality) and site restoration (surface water flows, groundwater levels and water quality) is considered negligible (**Table** 9-34).

9.10.67 On this basis, the level of effect on each of the identified water bodies is considered negligible and not significant (**Table 9-37**).

9.10.68 HUMANS, PROPERTIES AND INFRASTRUCTURE WITHIN AREAS OF FLOODING

9.10.69 Based on the FRA and water environment baseline presented in **Section 9.5**, identified potential effects due to the Proposed Scheme at Tytherington Quarry on four properties, together with their human occupiers and users (FRR1 -FRR4), within the Study Area as requiring consideration as part of the EIA.

9.10.70 The four identified receptors comprise of land uses defined as ‘More vulnerable’ in the NPPF classification and are therefore considered to be of high sensitivity value respectively (Table 9-32).

9.10.71 Given the effectiveness of the embedded environmental measures (**Section 9.13**), the magnitude of effect on these flood risk receptors is considered negligible (**Table 9-37**).

9.10.72 On this basis, the level of effect on these flood risk receptors is considered negligible and not significant.

9.11 ASSESSMENT OF CUMULATIVE EFFECTS

9.11.1 **Chapter 15: Cumulative Effects** considers three similar developments in the assessment of cumulative effects which are listed and assessed in **Table 9-35**. All of them are more than 4km away from the Site, i.e. outside the Study Area. Nevertheless, a cumulative effects assessment has been carried out for these identified developments and has found no significant cumulative effect.

Table 9-35 - Cumulative effects assessment for the water environment

Project / development	Location relative to Site	Planning status	Potential impact and assessment
Chipping Sodbury Quarry	~8km southeast	Active	The potential impacts identified in **Section 9.8** and **Section 9.10** are not thought to be relevant as a result of the construction, operation and restoration activities which, whilst in similar geological strata as the Site, this quarry is located on the opposite eastern limb of the Coalpit Heath syncline as the Site. Based on this and the additional assumption that the ongoing mitigation and monitoring strategies being employed at Chipping Sodbury Quarry will ensure that there are no significant cumulative changes in water quantity and quality for the potential receptors identified in **Section 9.8** of this chapter.
Wickwar Quarry	~6km northeast	Active	The potential impacts identified in **Section 9.8** and **Section 9.10** are not thought to be relevant as a result of the construction, operation and restoration activities which, whilst in similar geological strata as the Site, this quarry is located on the opposite eastern limb of the Coalpit Heath syncline as the Site. Based on this and the additional assumption that the ongoing mitigation and monitoring strategies being employed at Wickwar Quarry will ensure that there are no significant cumulative changes in water quantity and quality for the potential receptors identified in **Section 9.8** of this chapter.
Cromhall Quarry	~5km northeast	Dormant	The potential impacts identified in **Section 9.8** and **Section 9.10** are not thought to be relevant as a result of the construction, operation and restoration activities which, whilst in similar geological strata as the Site, this quarry is located on the opposite eastern limb of the Coalpit Heath syncline as the Site. Based on this and the additional assumption that any future mitigation and monitoring strategies to be employed at Cromhall Quarry once work recommences there will ensure that there are no significant cumulative changes in water quantity and quality for the potential receptors identified in **Section 9.8** of this chapter.

9.12 ASSESSMENT OF IN-COMBINATION CLIMATE IMPACTS

9.12.1 The In-combination Climate Change Impacts (ICCI) assessment considers the extent to which climate change exacerbates or ameliorates the potential effects identified for the water environment.

9.12.2 The ICCI assessment presented has been informed by the future baseline presented within **Chapter 13**: **Climate Resilience**. The ICCI uses the topic specific assessment methodologies and professional judgement to assess likelihood and magnitude of the impacts, with the combined consideration of future climate trends and impacts.

Table 9-36 - In-Combination Climate Change Impacts (ICCI) related to water environment

Hazard	Potential impacts of Climate Change	Mitigation
Decrease in summer precipitation (i.e. drier summers)	This can result in: ▪ reduced river flows; ▪ lowered groundwater levels; and ▪ reduced yields in downgradient wells/ groundwater abstractions, which may require replacement boreholes at different locations.	No additional mitigation measures required.
Increase in winter precipitation (i.e. wetter winters)	This can result in: ▪ Surface water flooding; and ▪ Groundwater flooding	No additional mitigation measures required.

9.13 MITIGATION AND ENHANCEMENT MEASURES

9.13.1 Opportunities to mitigate potential adverse effects have already been incorporated within the development or are imposed through a number of existing regulatory controls. The Proposed Scheme with these measures and controls in place has been subject to assessment. No other measures are proposed as mitigation in relation to the effects that are identified in this chapter. The principles of good practice mitigation during the operational phases will be applied to the Proposed Scheme as set out in **Section 9.15**.

9.14 CONCLUSIONS OF SIGNIFICANCE EVALUATION

9.14.1 The following table provides a summary of the conclusions about the significance of the predicted water environment effects that have been subject to assessment in this ES.

Table 9-37 - Summary of significance of predicted water environment effects

Receptor	Effects	Sensitivity/ importance/value of receptor	Magnitude of change	Significance	Summary rationale
Conservation sites (SSSIs)					
Tytherington Quarry	Site activities resulting in the release of pollutants and the subsequent contamination of groundwater in the vicinity of conservation sites.	Low	Negligible	Negligible	Successful implementation of measures including quarry water management, monitoring and flow augmentation.
Watercourses					
Ladden Brook	Quarry excavation and dewatering could lead to a decline in river flow and associated water quality (through reduced dilution in local watercourses that are in hydraulic continuity with the aquifer).	Medium	Negligible	Negligible	Successful implementation of measures including quarry water management and monitoring.
	Any discharge to surface water, especially that with a high sediment content, could result in a deterioration in watercourse morphology.	Medium	Negligible	Negligible	Successful implementation of measures including quarry water management, pollution prevention and discharge consent compliance.
	Site restoration could increase off-site runoff and restrict recharge, leading to an increase in runoff-derived surface water flows and a decline in groundwater	Medium	Negligible	Negligible	Appropriate site restoration.

Receptor	Effects	Sensitivity/ importance/value of receptor	Magnitude of change	Significance	Summary rationale
	baseflow in watercourses, also with consequent changes in water quality and watercourse morphology.				
	Site restoration could result in the leaching of contaminants from the backfill material, leading in turn to a deterioration in water quality within watercourses.	Medium	Negligible	Negligible	Appropriate site restoration.
Un-named tributary (originating in Cromhall) of the Tortworth Brook	Quarry excavation and dewatering could lead to a decline in river flow and associated water quality (through reduced dilution in local watercourses that are in hydraulic continuity with the aquifer).	Medium	Negligible	Negligible	Successful implementation of measures including quarry water management and monitoring.
	Site activities could result in the release of pollutants and the subsequent contamination of groundwater base flow to watercourses.	Medium	Negligible	Negligible	Successful implementation of measures including pollution prevention, accident response protocols and monitoring.
	Site restoration could increase off-site runoff and restrict recharge, leading to an increase in runoff-derived surface water flows and a decline in groundwater baseflow in watercourses, also	Medium	Negligible	Negligible	Appropriate site restoration.

Receptor	Effects	Sensitivity/ importance/value of receptor	Magnitude of change	Significance	Summary rationale
	with consequent changes in water quality and watercourse morphology.				
	Site restoration could result in the leaching of contaminants from the backfill material, leading in turn to a deterioration in water quality within watercourses.	Medium	Negligible	Negligible	Appropriate site restoration.
WFD River Water Bodies					
Ladden Brook from source to confluence of River Frome (Bristol) (GB109053027590)	Quarry excavation, dewatering and site activities could result in the decline in river flows and water quality (through reduced dilution in local watercourses that are in hydraulic continuity with the aquifer), leading to a deterioration in WFD status of surface water bodies.	Medium	Negligible	Negligible	Successful implementation of measures including quarry water management and monitoring.
	Any contaminated site discharge to surface water could result in a deterioration in the water quality in receiving and downstream watercourses, leading to a deterioration in WFD status of surface water bodies.	Medium	Negligible	Negligible	Successful implementation of measures including quarry water management, pollution prevention and discharge consent compliance.

Receptor	Effects	Sensitivity/ importance/value of receptor	Magnitude of change	Significance	Summary rationale
	Quarry excavation and dewatering could lead to a decline in river flow in local watercourses that are in hydraulic continuity with the Proposed Scheme , leading to a deterioration in watercourse morphology.	Medium	Negligible	Negligible	Successful implementation of measures including quarry water management and monitoring.
	Any discharge to surface water, especially that with a high sediment content, could result in a deterioration in watercourse morphology.	Medium	Negligible	Negligible	Successful implementation of measures including quarry water management and discharge consent compliance.
	Site restoration could increase off-site runoff and restrict recharge, leading to an increase in runoff-derived surface water flows and a decline in groundwater baseflow in watercourses, also with consequent changes in water quality and watercourse morphology, and resulting in a deterioration in WFD status of surface water bodies.	Medium	Negligible	Negligible	Successful implementation of site restoration protocols.
	Site restoration could result in the leaching of contaminants from the backfill material, leading in turn to a deterioration in water quality within	Medium	Negligible	Negligible	Successful implementation of site restoration protocols.

Receptor	Effects	Sensitivity/ importance/value of receptor	Magnitude of change	Significance	Summary rationale
	watercourses and resulting in a deterioration in WFD status of surface water bodies.				
Tortworth Bk - source to conf R Little Avon (GB109054026590)	Quarry excavation, dewatering and site activities could result in the decline in river flows and water quality (through reduced dilution in local watercourses that are in hydraulic continuity with the aquifer), leading to a deterioration in WFD status of surface water bodies.	Medium	Negligible	Negligible	Successful implementation of measures including quarry water management, pollution prevention and discharge consent compliance.
	Any contaminated site discharge to surface water could result in a deterioration in the water quality in receiving and downstream watercourses, leading to a deterioration in WFD status of surface water bodies.	Medium	Negligible	Negligible	Successful implementation of measures including quarry water management, pollution prevention and discharge consent compliance.
	Quarry excavation and dewatering could lead to a decline in river flow in local watercourses that are in hydraulic continuity with the Proposed Scheme , leading to a deterioration in watercourse morphology.	Medium	Negligible	Negligible	Successful implementation of measures including quarry water management and monitoring.
	Site restoration could increase off-site runoff and restrict	Medium	Negligible	Negligible	Successful implementation of site restoration protocols.

Receptor	Effects	Sensitivity/ importance/value of receptor	Magnitude of change	Significance	Summary rationale
	recharge, leading to an increase in runoff-derived surface water flows and a decline in groundwater baseflow in watercourses, also with consequent changes in water quality and watercourse morphology, and resulting in a deterioration in WFD status of surface water bodies.				
	Site restoration could result in the leaching of contaminants from the backfill material, leading in turn to a deterioration in water quality within watercourses and resulting in a deterioration in WFD status of surface water bodies.	Medium	Negligible	Negligible	Successful implementation of site restoration protocols.
WFD Groundwater bodies					
Carboniferous Limestone – Alveston (GB40901G806200)	Quarry dewatering could lead to a decline in groundwater levels, and a subsequent deterioration in WFD status of groundwater bodies.	Medium	Negligible	Negligible	Quarry water management and monitoring.
	Site activities could result in the release of pollutants and the subsequent contamination of groundwater, and a subsequent deterioration in WFD status of groundwater bodies.	Medium	Negligible	Negligible	Pollution prevention, accident response protocols and monitoring.

Receptor	Effects	Sensitivity/ importance/value of receptor	Magnitude of change	Significance	Summary rationale
	Site restoration could restrict recharge, leading to a decline in groundwater levels, and a subsequent deterioration in WFD status of groundwater bodies	Medium	Negligible	Negligible	Successful implementation of site restoration protocols.
	Site restoration could result in the leaching of contaminants from the backfill material, leading in turn to a deterioration in groundwater quality and the WFD status of groundwater bodies.	Medium	Negligible	Negligible	Successful implementation of site restoration protocols.
Avonmouth Merica Mudstone (GB40902G303100)	Quarry dewatering could lead to a decline in groundwater levels, and a subsequent deterioration in WFD status of groundwater bodies.	Medium	Negligible	Negligible	Quarry water management and monitoring.
	Site activities could result in the release of pollutants and the subsequent contamination of groundwater, and a subsequent deterioration in WFD status of groundwater bodies.	Medium	Negligible	Negligible	Pollution prevention, accident response protocols and monitoring.
	Site restoration could restrict recharge, leading to a decline in groundwater levels, and a subsequent deterioration in	Medium	Negligible	Negligible	Successful implementation of site restoration protocols.

Receptor	Effects	Sensitivity/ importance/value of receptor	Magnitude of change	Significance	Summary rationale
	WFD status of groundwater bodies				
	Site restoration could result in the leaching of contaminants from the backfill material, leading in turn to a deterioration in groundwater quality and the WFD status of groundwater bodies.	Medium	Negligible	Negligible	Successful implementation of site restoration protocols.
Bristol Triassic (GB40902G804800)	Quarry dewatering could lead to a decline in groundwater levels, and a subsequent deterioration in WFD status of groundwater bodies.	High	Negligible	Negligible	Quarry water management and monitoring.
	Site activities could result in the release of pollutants and the subsequent contamination of groundwater, and a subsequent deterioration in WFD status of groundwater bodies.	High	Negligible	Negligible	Pollution prevention, accident response protocols and monitoring.
	Site restoration could restrict recharge, leading to a decline in groundwater levels, and a subsequent deterioration in WFD status of groundwater bodies	High	Negligible	Negligible	Successful implementation of site restoration protocols.
	Site restoration could result in the leaching of contaminants from the backfill material,	High	Negligible	Negligible	Successful implementation of site restoration protocols.

Receptor	Effects	Sensitivity/ importance/value of receptor	Magnitude of change	Significance	Summary rationale
	leading in turn to a deterioration in groundwater quality and the WFD status of groundwater bodies.				
Licensed abstraction (groundwater)					
AB03: Mill Farm Borehole (17/53/002/G/080)	Quarry dewatering could lead to a decline in groundwater levels, and a subsequent decline in yield and associated abstraction water quality.	High	Negligible	Negligible	Hydraulically separated from combined aquifer by Clifton Down Mudstone. Successful implementation of measures including quarry water management and monitoring.
	Site activities could result in the release of pollutants and the subsequent contamination of groundwater, leading in turn to a deterioration in abstraction water quality.	High	Negligible	Negligible	Hydraulically separated from combined aquifer by Clifton Down Mudstone. Successful implementation of measures including quarry water management and monitoring.
	Site restoration could restrict recharge, leading to a decline in groundwater levels, and a subsequent decline in abstraction yield and associated water quality.	High	Negligible	Negligible	Hydraulically separated from combined aquifer by Clifton Down Mudstone. Successful implementation of site restoration protocols.
	Site restoration could result in the leaching of contaminants from the backfill material, leading in turn to a deterioration in abstraction water quality.	High	Negligible	Negligible	Hydraulically separated from combined aquifer by Clifton Down Mudstone.

Receptor	Effects	Sensitivity/ importance/value of receptor	Magnitude of change	Significance	Summary rationale
					Successful implementation of site restoration protocols.
Private water supplies (wells)					
GA05: Huntly Farm	Quarry dewatering could lead to a decline in groundwater levels, and a subsequent decline in yield and associated abstraction water quality.	Medium	Negligible	Negligible	Beyond Ladden Brook divide, distant and hydraulically separated from combined aquifer by Clifton Down Mudstone and other low permeability strata. Successful implementation of measures including quarry water management and monitoring.
	Site activities could result in the release of pollutants and the subsequent contamination of groundwater, leading in turn to a deterioration in abstraction water quality.	Medium	Negligible	Negligible	Beyond Ladden Brook divide, distant and hydraulically separated from combined aquifer by the Clifton Down Mudstone and other low permeability strata. Successful implementation of measures including quarry water management and monitoring.
	Site restoration could restrict recharge, leading to a decline in groundwater levels, and a subsequent decline in abstraction yield and associated water quality.	Medium	Negligible	Negligible	Beyond Ladden Brook divide, distant and hydraulically separated from combined aquifer by the Clifton Down Mudstone and other low permeability strata. Successful implementation of site restoration protocols.

Receptor	Effects	Sensitivity/ importance/value of receptor	Magnitude of change	Significance	Summary rationale
	Site restoration could result in the leaching of contaminants from the backfill material, leading in turn to a deterioration in abstraction water quality.	Medium	Negligible	Negligible	Beyond Ladden Brook divide, distant and hydraulically separated from combined aquifer by the Clifton Down Mudstone and other low permeability strata. Successful implementation of site restoration protocols
Ponds and lake					
Grp1 (1): PO152 North Face Quarry pond	Quarry dewatering could lead to a decline in water levels and associated water quality through reduced dilution within ponds that are in hydraulic contact with the aquifer.	Low	Medium	Negligible	North Face Quarry water body is close to the Site and sits in combined aquifer, i.e. hydraulically commented. Successful implementation of measures including quarry water management and monitoring.
	Site activities could result in the release of pollutants and the subsequent contamination of groundwater base flow to these water bodies.	Low	Negligible	Negligible	Woodleaze Quarry sump downgradient of North Face Quarry water body. Successful implementation of measures including pollution prevention and accident response protocols and monitoring.
	Site restoration could restrict recharge, leading to a decline in groundwater and associated water body levels.	Low	Negligible	Negligible	North Face Quarry water body is close to the Site and also sits in combined aquifer, i.e. hydraulically commented.

Receptor	Effects	Sensitivity/ importance/value of receptor	Magnitude of change	Significance	Summary rationale
					Successful implementation of site restoration protocols.
	Site restoration could result in the leaching of contaminants from backfill material, leading in turn to a deterioration in water quality within aquifers and associated water body levels.	Low	Negligible	Negligible	North Face Quarry water body is close to the Site and also sits in combined aquifer, i.e. hydraulically commented. Successful implementation of site restoration protocols.
Grp2 (3): PO007, PO010, PO126	Quarry dewatering could lead to a decline in water levels and associated water quality through reduced dilution within ponds that are in hydraulic contact with the aquifer.	Low	Negligible	Negligible	Ponds sit in upper combined aquifer (only PO10 underlain by Triassic strata) to the southwest of Site, i.e. along strata strike and hence hydraulically separated by Clifton Down Mudstone aquitard. Successful implementation of measures including quarry water management and monitoring.
	Site activities could result in the release of pollutants and the subsequent contamination of groundwater base flow to these water bodies.	Low	Negligible	Negligible	See hydrogeology description above. Successful implementation of measures including pollution prevention and accident response protocols and monitoring.
	Site restoration could restrict recharge, leading to a decline in groundwater and associated water body levels.	Low	Negligible	Negligible	See hydrogeology description above. Successful implementation of site restoration protocols.

Receptor	Effects	Sensitivity/ importance/value of receptor	Magnitude of change	Significance	Summary rationale
	Site restoration could result in the leaching of contaminants from backfill material, leading in turn to a deterioration in water quality within aquifers and associated water body levels.	Low	Negligible	Negligible	See hydrogeology description above. Successful implementation of site restoration protocols.
Grp3 (13): PO070, PO073, PO074, PO075, PO076, PO077, PO078, PO079, PO084, PO137, PO138, PO149, PO153	Quarry dewatering could lead to a decline in water levels and associated water quality through reduced dilution within ponds that are in hydraulic contact with the aquifer.	Low	Negligible	Negligible	All features distant to the east of the Site with Laddon Brook (seen as groundwater divide) in between. Successful implementation of measures including quarry water management and monitoring.
	Site activities could result in the release of pollutants and the subsequent contamination of groundwater base flow to these water bodies.	Low	Negligible	Negligible	See hydrogeology description above. Successful implementation of measures including pollution prevention and accident response protocols and monitoring.
	Site restoration could restrict recharge, leading to a decline in groundwater and associated water body levels.	Low	Negligible	Negligible	See hydrogeology description above. Successful implementation of site restoration protocols.
	Site restoration could result in the leaching of contaminants from backfill material, leading in turn to a deterioration in water quality within aquifers and associated water body levels.	Low	Negligible	Negligible	See hydrogeology description above. Successful implementation of site restoration protocols.

Receptor	Effects	Sensitivity/ importance/value of receptor	Magnitude of change	Significance	Summary rationale
Grp4 (7): PO089, PO090, PO091, PO130, PO131, PO140, PO157: The Lake	Quarry dewatering could lead to a decline in water levels and associated water quality through reduced dilution within ponds that are in hydraulic contact with the aquifer.	Low	Negligible	Negligible	All features along Tortworth Brook tributary hydraulically separated from Site by Clifton Down Mudstone aquitard. Successful implementation of measures including quarry water management and monitoring.
	Site activities could result in the release of pollutants and the subsequent contamination of groundwater base flow to these water bodies.	Low	Negligible	Negligible	See hydrogeology description above. Successful implementation of measures including pollution prevention and accident response protocols and monitoring.
	Site restoration could restrict recharge, leading to a decline in groundwater and associated water body levels.	Low	Negligible	Negligible	See hydrogeology description above. Successful implementation of site restoration protocols.
	Site restoration could result in the leaching of contaminants from backfill material, leading in turn to a deterioration in water quality within aquifers and associated water body levels.	Low	Negligible	Negligible	See hydrogeology description above. Successful implementation of site restoration protocols.
Grp5 (11): PO082, PO095, PO096, PO097, PO099, PO100, PO101, PO102, PO103, PO139, PO150	Quarry dewatering could lead to a decline in water levels and associated water quality through reduced dilution within	Low	Negligible	Negligible	Hydraulically separated from Site by Clifton Down Mudstone aquitard.

Receptor	Effects	Sensitivity/ importance/value of receptor	Magnitude of change	Significance	Summary rationale
	ponds that are in hydraulic contact with the aquifer.				Successful implementation of measures including quarry water management and monitoring.
	Site activities could result in the release of pollutants and the subsequent contamination of groundwater base flow to these water bodies.	Low	Negligible	Negligible	See hydrogeology description above. Successful implementation of measures including pollution prevention and accident response protocols and monitoring.
	Site restoration could restrict recharge, leading to a decline in groundwater and associated water body levels.	Low	Negligible	Negligible	See hydrogeology description above. Successful implementation of site restoration protocols.
	Site restoration could result in the leaching of contaminants from backfill material, leading in turn to a deterioration in water quality within aquifers and associated water body levels.	Low	Negligible	Negligible	See hydrogeology description above. Successful implementation of site restoration protocols.
Grp 6: (9): PO012, PO013, PO014, PO018, PO026, PO042, PO123, PO124, PO148	Quarry dewatering could lead to a decline in water levels and associated water quality through reduced dilution within ponds that are in hydraulic contact with the aquifer.	Low	Negligible	Negligible	To the southwest of the Site in strata strike direction, all features underlain by Jurassic strata (likely to include the Blue Lias Mudstone (aquitard)) and likely to be hydraulically separated from the Site by the Clifton Down Mudstone.

Receptor	Effects	Sensitivity/ importance/value of receptor	Magnitude of change	Significance	Summary rationale
					Successful implementation of measures including quarry water management and monitoring.
	Site activities could result in the release of pollutants and the subsequent contamination of groundwater base flow to these water bodies.	Low	Negligible	Negligible	See hydrogeology description above. Successful implementation of measures including pollution prevention and accident response protocols and monitoring.
	Site restoration could restrict recharge, leading to a decline in groundwater and associated water body levels.	Low	Negligible	Negligible	See hydrogeology description above. Successful implementation of site restoration protocols.
	Site restoration could result in the leaching of contaminants from backfill material, leading in turn to a deterioration in water quality within aquifers and associated water body levels.	Low	Negligible	Negligible	See hydrogeology description above. Successful implementation of site restoration protocols.
Springs					
SP02	Quarry dewatering could lead to a decline in groundwater levels, and a subsequent decline in spring yield and associated water quality.	Low	Negligible	Negligible	Hydraulically separated from Site by Clifton Down Mudstone aquitard, potential alternative flow path via Mercia Mudstone Group conglomerate currently deactivated and spring ground elevation higher

Receptor	Effects	Sensitivity/ importance/value of receptor	Magnitude of change	Significance	Summary rationale
					than current combined aquifer groundwater level highs. Successful implementation of measures including quarry water management and monitoring.
	Site activities could result in the release of pollutants and the subsequent contamination of groundwater, leading in turn to a deterioration in spring water quality.	Low	Negligible	Negligible	See hydrogeology description above. Successful implementation of measures including pollution prevention and accident response protocols and monitoring.
	Site restoration could restrict recharge, leading to a decline in groundwater levels, and a subsequent decline in spring yield and associated water quality.	Low	Negligible	Negligible	Hydraulically separated from Site by Clifton Down Mudstone aquitard. Potential alternative flow path via Mercia Mudstone Group conglomerate could get reactivated but required groundwater level rise in combined aquifer unlikely to be large enough to make this happen. Successful implementation of site restoration protocols.
	Site restoration could result in the leaching of contaminants from backfill material, leading in turn to a deterioration in spring water quality.	Low	Negligible	Negligible	See hydrogeology description above. Successful implementation of site restoration protocols.
Wells (from OS maps)					

Receptor	Effects	Sensitivity/ importance/value of receptor	Magnitude of change	Significance	Summary rationale
WL01, WL02, WL03	Quarry dewatering could lead to a decline in groundwater levels, and a subsequent decline in yield and associated abstraction water quality.	Medium	Negligible	Negligible	These distant wells sit within Triassic strata but are likely to be targeting the combined aquifer. Whilst offset by a NE-SW trending fault against the Site, the wells could potentially be hydraulically connected to the Site. Successful implementation of measures including quarry water management and monitoring.
	Site activities could result in the release of pollutants and the subsequent contamination of groundwater, leading in turn to a deterioration in abstraction water quality.	Medium	Negligible	Negligible	Hydrogeological setting as above. Successful implementation of measures including quarry water management and monitoring.
	Site restoration could restrict recharge, leading to a decline in groundwater levels, and a subsequent decline in abstraction yield and associated water quality.	Medium	Negligible	Negligible	Hydrogeological setting as above. Successful implementation of site restoration protocols.
	Site restoration could result in the leaching of contaminants from the backfill material, leading in turn to a deterioration in abstraction water quality.	Medium	Negligible	Negligible	Hydrogeological setting as above. Successful implementation of site restoration protocols.
WL04, WL05, WL06, WL13, WL14	Quarry dewatering could lead to a decline in groundwater levels,	Medium	Negligible	Negligible	Mostly distant and hydraulically separated from combined aquifer

Receptor	Effects	Sensitivity/ importance/value of receptor	Magnitude of change	Significance	Summary rationale
	and a subsequent decline in yield and associated abstraction water quality.				by Avon Group and other low permeability strata. Successful implementation of measures including quarry water management and monitoring.
	Site activities could result in the release of pollutants and the subsequent contamination of groundwater, leading in turn to a deterioration in abstraction water quality.	Medium	Negligible	Negligible	Distant and hydraulically separated from combined aquifer by Avon Group and other low permeability strata. Successful implementation of measures including quarry water management and monitoring.
	Site restoration could restrict recharge, leading to a decline in groundwater levels, and a subsequent decline in abstraction yield and associated water quality.	Medium	Negligible	Negligible	Distant and hydraulically separated from combined aquifer by Avon Group and other low permeability strata. Successful implementation of site restoration protocols.
	Site restoration could result in the leaching of contaminants from the backfill material, leading in turn to a deterioration in abstraction water quality.	Medium	Negligible	Negligible	Distant and hydraulically separated from combined aquifer by Avon Group and other low permeability strata. Successful implementation of site restoration protocols.
Flood Risk Receptors: Humans, properties and infrastructure within areas of flooding					

Receptor	Effects	Sensitivity/ importance/value of receptor	Magnitude of change	Significance	Summary rationale
Domestic Properties downstream of the discharge location along Duck Street in Tytherington Village (FRR1, FRR2, FRR3, & FRR4)	Increases in site discharge associated with the deepening of Woodleaze Quarry could increase surface flows within the discharge channel and result in increased flooding in the immediate vicinity.	High	Negligible	Negligible	Successful implementation of measures including appropriate quarry water management and monitoring

9.15 IMPLEMENTATION OF ENVIRONMENTAL MEASURES

9.15.1 **Table 9-38** describes the environmental measures embedded within the Proposed Scheme and the means by which they will be implemented, i.e. they will have been secured through the planning conditions.

Table 9-38 - Implementation of environmental measures

Environmental measure / mitigation	Responsibility for implementation	Compliance mechanism
Quarry water management	Developer/ Contractor	Compliance with appropriate planning conditions and the terms of any Environment Agency abstraction licence and discharge consent.
Pollution prevention and accident response	Developer/Contractor	Compliance with appropriate planning conditions.
Monitoring (including groundwater, surface water level monitoring and water supply monitoring)	Developer/Contractor	Compliance with appropriate planning conditions.
Appropriate restoration	Developer/Contractor	Compliance with appropriate planning conditions.

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