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Lye Valley Hydrogeological Impact Assessment

Oxford Local Plan 2042

Lye Valley SSSI – Hydrogeological Impact assessment

Background

The following study has been commissioned by Oxford City Council to better understand the complex hydrogeological environment that supports the Lye Valley Site of Special Scientific Interest (SSSI) and the potential impact mechanisms that could risk adverse effects to its functioning.

The study highlights that the SSSI is susceptible to several types of impact arising from new development coming forward in the wider surface water or groundwater catchment area, depending on where the development is located and/or what type of development is proposed. The study goes on to define a range of impact risk zones of varying scale in the surrounding area and recommends a range of tests that should be passed in order to satisfactorily demonstrate the development will have no adverse effect on the functioning of the SSSI. The various impact risk zones are highlighted for information on the proposals map which accompanies the Regulation 18 consultation.

What is the purpose of this study?

National Policy as set out in the National Planning Policy Framework is clear (para 193) that:

Development on land within or outside a Site of Special Scientific Interest, and which is likely to have an adverse effect on it (either individually or in combination with other developments), should not normally be permitted.

These requirements are embedded into the adopted Local Plan 2036 through policy G2 (Protection of biodiversity and geo-diversity); as well as policy RE4 (Sustainable and foul drainage, surface and groundwater flow).

The Regulation 18 first draft Local Plan 2042 meanwhile incorporates these requirements into draft policy G6 which states:

Development will not be permitted that would have an adverse effect on the integrity of the Oxford Meadows Special Area of Conservation (SAC) or an adverse effect on any Site of Special Scientific Interest (SSSI).

And also sets out that:

Within the groundwater catchment areas for the Oxford Meadows SAC, Lye Valley and New Marston Meadows SSSI's, development which could have negative hydrological impacts in *relation to surface and groundwater will need to demonstrate that these have been avoided, or mitigated where relevant, through use of appropriate measures such as infiltration methods (where geological conditions allow) and careful design of below ground works*.

Then going on to address requirements for determining adverse effects, stating that:

In determining the potential for adverse effects on ecology from a development, including where this relates to designated sites, applicants will need to demonstrate that they have considered information from various sources where relevant, including the site context and surrounding area; expert ecological advice, applicable Council Technical Advice Notes, as well as a review of relevant existing information where available, such as Natural England's Impact Risk Zones (IRZs).

The Lye Valley SSSI Hydrogeological Impact Assessment is intended to help provide additional clarity in how the SSSI functions and how to identify potential for adverse effects arising from a new development which could impact the particular characteristics of the Lye Valley. This additional guidance should help to better ensure applications meet the requirements of national policy and the policies of the current Local Plan 2036 and proposed Local Plan 2042 (which the Council is currently preparing), which ultimately seek to protect the special characteristics of this important designated site.

Next steps

It is envisioned that the study will form the basis of a new Technical Advice Note (TAN) which the Council is in the process of producing and will publish as soon as possible. As with other TANs supporting the Local Plan, this will provide additional practical guidance in how to meet the requirements of the Local Plan policies which, in this case, will include:

- advice on how to interpret the analysis and recommendations of the Lye Valley study;
- how to respond to the tests and what additional supporting information will be expected to demonstrate these tests have been passed; and
- guidance on potential design solutions and mitigation measures where necessary in order to avoid adverse effects.

The findings from the study and the guidance set out in the TAN may also support additional design requirements to be set out in any applicable Local Plan 2042 site allocations where these are located in proximity to the SSSI – which will be included in the Local Plan 2042 Regulation 19 consultation later in the year.

JBA consulting

Lye Valley SSSI

Hydrogeological Impact Assessment

Final

June 2025

Prepared for:
Oxford City Council

www.jbaconsulting.com

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Contract

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This report describes work commissioned by Oxford City Council by an instruction dated 20th July 2022. The Client's representative for the contract was Richard Wyatt of Oxford City Council. Parvaneh Aghajani and Alex Jones of JBA Consulting carried out this work.

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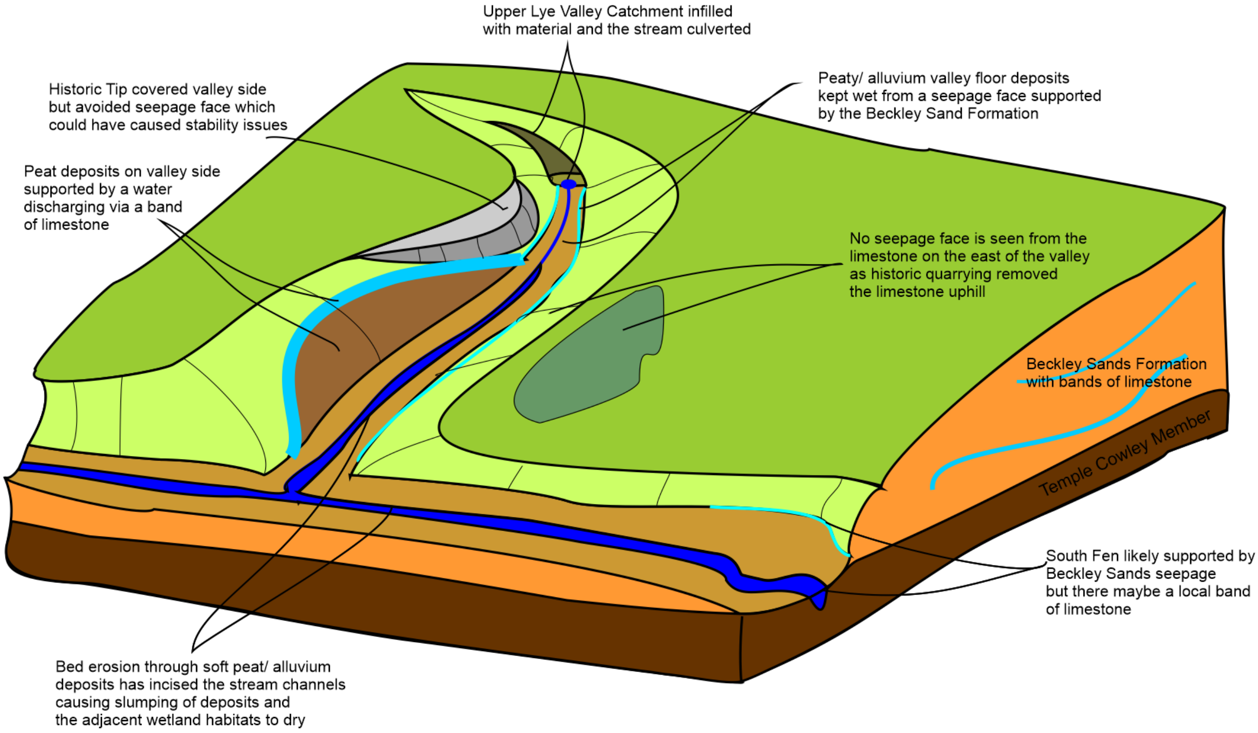
Assessment Approach

The Hydrogeological Impact Assessment was undertaken using a Source-Pathway-Receptor model as recommended by Environment Agency guidance[1]. The identification of potential environmental receptors within the SSSI has been undertaken through a review of baseline information and site walkovers by JBA specialists during monitoring borehole installation within the boundaries of the site (February 2023). The assessment involved the collection and interpretation of a wide range of data and information from published material, and monitoring data.

Conceptual Model of Lye Valley

The sources of data were used to develop a conceptual model of the SSSI. This synthesised the understanding of the mechanisms that supported the features of the SSSI.



Overview conceptual model.

[1] https://www.gov.uk/guidance/groundwater-risk-assessment-for-your-environmental-permit

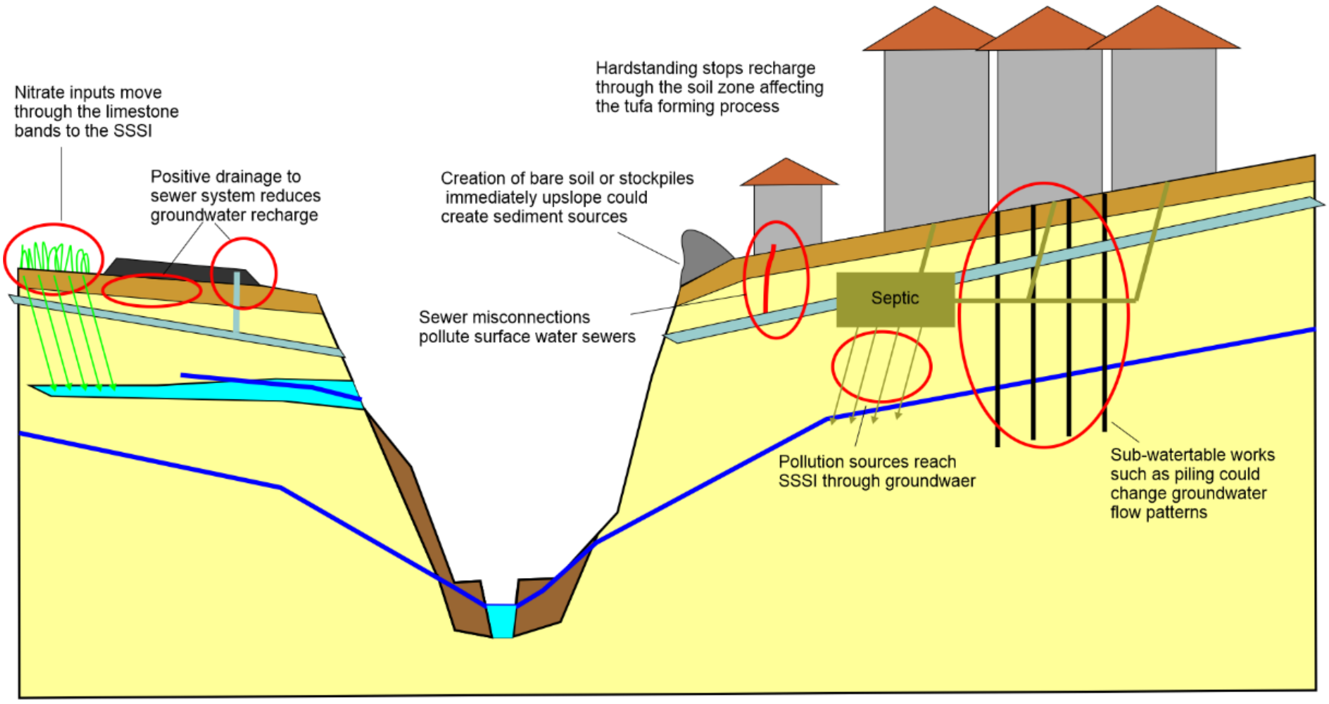
Impact Mechanisms and Zoning of the Catchment

Once the conceptual model was developed, it was possible to systematically outline impact mechanisms that could affect the SSSI. These are outlined in the table below.

Impact mechanisms.

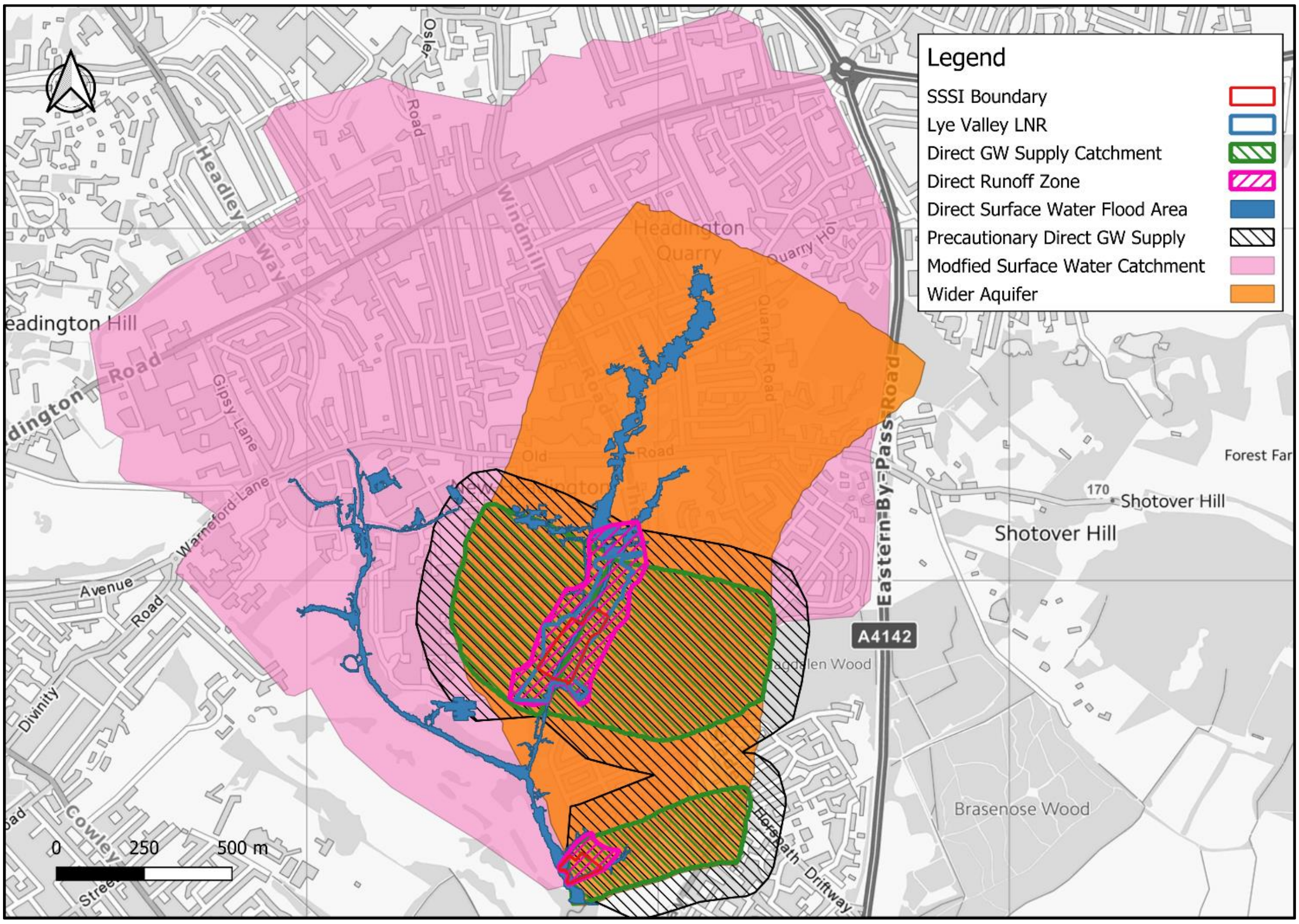
Category	Linkage	Discussion
Run-off	Pollution affected run-off	The SSSI lies in a valley. Direct run-off from the immediate surrounding slopes could bring in pollution.
Sewers and Streams	Pollution discharges from the sewer network to the watercourses	Pollution sources in the catchment could be transported to the SSSI via the surface water sewer network. There is some evidence of cloudy water discharging from certain outfalls (Webb 2016).
Sewers and Streams	Increases in peak flows in sewer network	This would exacerbate the issues with the incision of the channel through the soft valley floor wetland deposits.
Groundwater	Pollution to regional groundwater	Pollution that enters the groundwater within the boundaries of the groundwater catchment may reach the SSSI. Monitoring has shown that nitrate levels are relatively low in the sandstone system, likely due to denitrification processes.
Groundwater	Pollution to limestone bands	Due to the relatively quick pathway through the limestone bands, pollution can rapidly make its way to the sections of the SSSI supported by them. Elevated nitrate levels from these bands have been monitored.
Groundwater	Changes in groundwater chemistry - tufa formation	The tufa formation process is reliant on carbon dioxide being dissolved through the recharge process as water passes through the soil zone. The carbon dioxide makes the water more acidic (by forming carbonic acid) allowing more calcium carbonate to dissolve. Changes in land use could change the recharge process in the catchment.
Groundwater	Groundwater flow	Excavations, dewatering and piling could change groundwater discharges to the site. They could affect the regional groundwater flow through the Beckley

Category	Linkage	Discussion
		Sand Member, and the flows through the limestone bands that support the high-level seepage face and tufa springs.
Groundwater	Groundwater volumes	Reduction in recharge would reduce the groundwater flows entering the SSSI. The most sensitive areas for change would be the recharge area supporting the Lye Valley limestone band. Elsewhere in the wider catchment, changes in recharge would affect the regional water table level.



Impact conceptual model.

For each potential impact mechanism, zones were developed outlining, for example, where pollution to groundwater has a pathway to the SSSI. The figure below summaries all the zones identified.



Catchment Zones

Planning Guidance

Lye Valley is a SSSI and the lowland fen habitats within it are classified as irreplaceable habitats under the National Planning Policy Framework (NPPF). Paragraph 193 of the NPPF (accessed December 2024) indicates that schemes which have an adverse effect on a SSSI should not normally be permitted and/or schemes that lead to a deterioration of irreplaceable habitats should be refused unless there is a wholly exceptional reason, and a suitable compensation strategy exists. Based on this, robust planning guidance for each zone has been identified. The guidance consists of two main elements:

- A series of tests that are required to be passed for there to be no adverse effects on the SSSI or deterioration of the wider irreplaceable habitats.
- Examples of typical planning documents which could be used as evidence to support the test.

In addition to the main guidance, there is additional guidance for small-scale developments. This has been developed to screen where small-scale developments have the potential to adversely affect the SSSI and wider irreplaceable habitats and where they may be screened out due to lack of impact due to small scale.

1 Introduction

1.1 Introduction

Oxford City Council commissioned Jeremy Benn Associates Ltd. (JBA) to undertake a Hydrogeological Impact Assessment to assess the potential impacts of future development within the catchment of Lye Valley Site of Special Scientific Interest (SSSI) on the SSSI.

The objective of this assessment is to evaluate the potential for impacts to occur to the surrounding water environment that supports the SSSI, as a result of possible future residential and/or commercial development and advise on mitigation to prevent impacts. The assessment has been undertaken to support Oxford City Council in the development and implementation of their future Local Plan.

1.2 Assessment Approach

This Hydrogeological Impact Assessment has been undertaken using a Source-Pathway-Receptor model as recommended by Environment Agency guidance[2]. The identification of potential environmental receptors within the SSSI has been undertaken through a review of baseline information and site walkovers by JBA specialists during monitoring borehole installation within the boundaries of the site (February 2023). The assessment involves the collection and interpretation of a wide range of data and information from published material, and monitoring data. The sources of the potential impacts are identified through a review of the details of the Lye Valley SSSI. This has been undertaken in the context of local conditions regarding water resources near the site and includes review of information on topography, soils, historic activities undertaken within the catchment, geology, hydrology, hydrogeology, climate, and potential sources of contamination. The potential impacts are considered in the context of their: magnitude, spatial extent, frequency and timescale. The last stage is to identify whether there is an exposure pathway which may allow an effect to occur between source and receptor.

1.3 Limitations

The development of hydrogeological conceptualisations is an iterative process based on available information. The following are listed as key limitations in the conceptualisation process in this report:

- The water supply mechanisms that have been shown to supply the wetland in the area are dependent on complex geological structures. The number of borehole logs available to understand these structures is greater in the north of the site than in the south. This means that the detail of the conceptual model is greater there.

[2] https://www.gov.uk/guidance/groundwater-risk-assessment-for-your-environmental-permit

- A water level monitoring array was created. There were gaps in the record but an overall understanding of the ecohydrological conditions of the site were dependent on multiple complementary sources of information.
- In the wider catchment, those complex geologies mean that delineating groundwater catchments that supply the SSSI cannot be done precisely.

Where there are limitations in the conceptualisation and understanding of the wetland, this has led to conservative assumptions in the zoning and planning advice presented. Buffers to those zones have been created when appropriate and the advice associated with the zones have been created based on the precautionary principle.

1.4 Report Structure

The report has the following structure:

- Section 1 - Introduction summarising the aims of the study.
- Section 2 - Ecology of Lye Valley providing a description of the ecology of Lye Valley, the conditions it is dependent upon and its sensitivity to impacts.
- Section 3 - Environmental Baseline provides a physical environmental baseline describing the non-ecological features (topography, geology, hydrogeology, hydrology) of the site and surrounding study area.
- Section 4 - Eco-hydrological Conceptual Model describes the conditions that the ecological features are dependent upon using available baseline data.
- Section 5 - Impact Mechanisms describes the potential impact mechanisms that could affect the Lye Valley SSSI, and where in the catchment they might relate to.
- Section 6 - Planning Considerations - the impacts and zoning of impacts in the previous section are used as a basis for developing planning advice.
- Section 7 – Assessment Areas and relevant tests that are recommended as needing to be met for new development are set out.
- Section 8 – Conclusions.
- Appendices.

2 Ecology of Lye Valley

2.1 General

Lye Valley is a small wetland located within the Lye Brook and Boundary Brook catchments. Lye Valley North SSSI is located within Lye Valley LNR (see Figure 2-1) immediately adjacent to The Churchill Hospital, Oxford. The Lye Valley LNR contains a range of habitats including spring-fed lowland fen, a variety of ponds, and wet woodland with small representations of lowland calcareous grassland, wood pasture and parkland. The second unit of the SSSI, lies to the south and includes additional lowland fen, and woodland. Lye Valley has one of the best examples of a calcareous valley fen, a nationally rare habitat. The plant and animal species of the Lye Valley fen are thought to have lived there since they colonised the spring areas after the retreat of the last ice age perhaps 8,000 to 10,000 years ago.

The interest features of the Lye Valley SSSI (based on Natural England's SSSI citation) are summarised as follows:

- One of the best recorded examples of a calcareous valley fen in southern England;
- A high diversity of plant species (including mosses), many which are strongly associated with calcareous fens and are uncommon in southern Britain;
- A wide range of terrestrial and aquatic invertebrates; and
- A variety of birds including some associated with wetland habitats.

The ecology and habitats of the Lye Valley have been studied in detail previously by a number of authors, and the following sections summarise some of the habitat survey work completed to date.

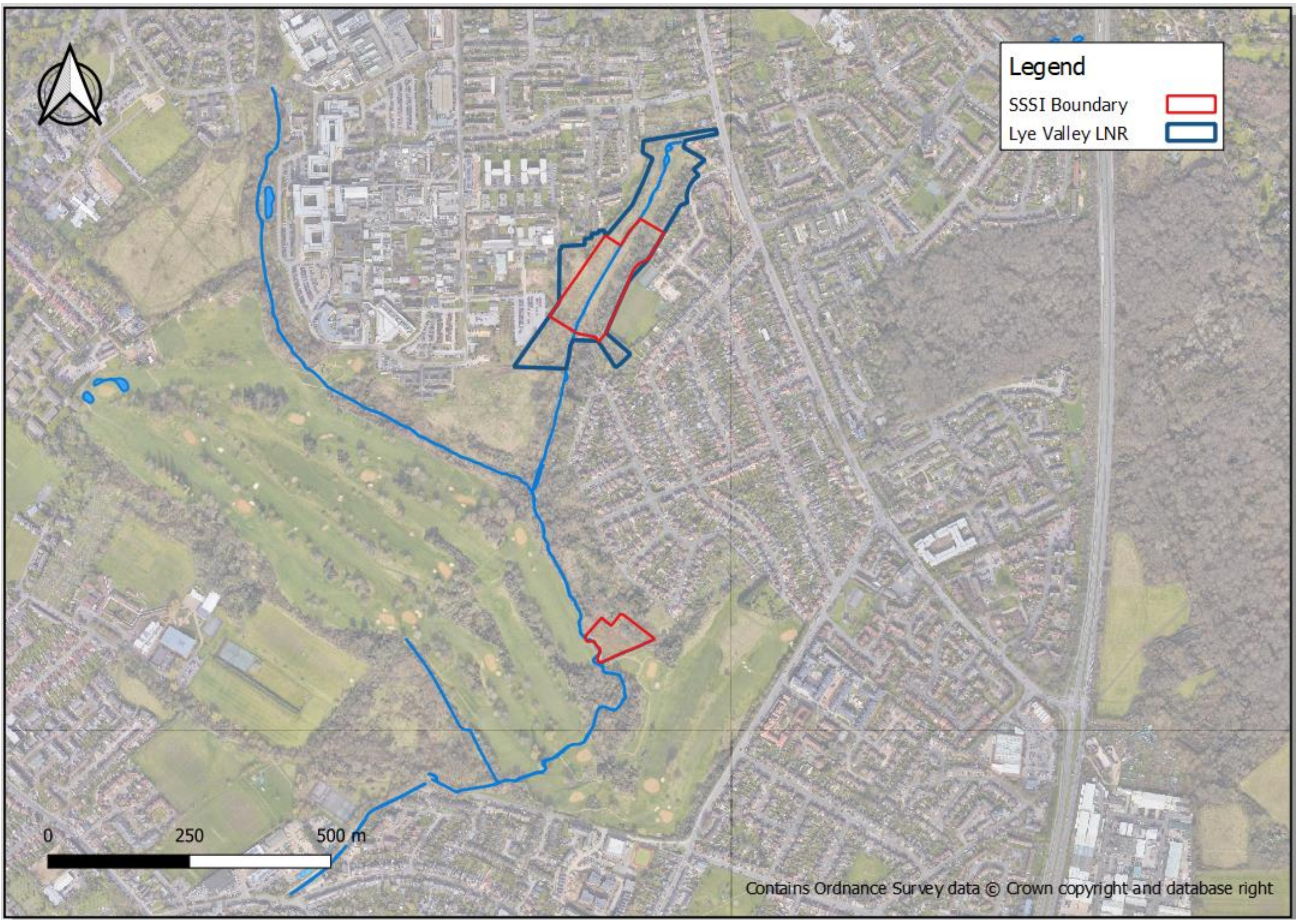


Figure 2-1: SSSI and LNR boundary.

2.2 Habitats

The following habitat information is summarised from Bows (2021) and Webb (2013a,b) and the National Vegetation Communities (NVC) are described in Rodwell (1991a,b, 1995). The alkaline fens of the Lye Valley represent the Annex 1 habitat '7230 Alkaline fens' which includes habitats with tufa or peat formation and a high water table with a calcareous, base-rich water supply. At a more detailed level, much of the most species-rich vegetation is, or has historically been, referable to the M13b *Schoenus nigricans-Juncus subnodulosus* mire, *Briza media-Pinguicula vulgaris* sub-community of the National Vegetation Classification (Rodwell, 1992).

Figure 2-2: The view of North Fen looking south, with M13b vegetation forming the paler central strip at the bottom of the valley.

Other areas undergoing restoration are referred to as a typical form of M22 *Juncus subnodulosus-Cirsium palustre* fen-meadow. Surrounding these communities are a range of other vegetation types, of which two communities with prominent Common Reed *Phragmites australis* are present, S4 *Phragmites australis* swamp and reedbeds and S26 *Phragmites australis-Urtica dioica* tall-herb fen. These are unrestored areas of ground with a high water table, where summer drying has allowed *Phragmites australis* to become dominant, possibly aided by fires. With the exception of pools, the other wetland plant community recorded from the site is the tall-herb vegetation, OV26 *Epilobium hirsutum* community. In places wet woodland has developed in areas of inundated ground, and the vegetation here is referable to W1 *Salix cinerea-Galium palustre* woodland and W2 *Salix cinerea-Betula pubescens-Phragmites australis* woodland, although only as small, fragmentary stands.

Figure 2-3: Common Reed and willows are still dominant in some areas of Lye Valley which have not been restored.

2.3 Sensitivity to Change

The ecohydrological guidelines (Wheeler et al., 2004) and the wetland framework for impact assessment (Wheeler et al., 2009) provide much useful information on the sensitivity of the key habitat, M13 *Schoenus nigricans-Juncus subnodulosus* mire, to changes. The following section presents a summary of this information.

2.3.1 Water Levels

The water level is a key variable in maintaining species-rich M13 vegetation but Wheeler et al. (2004) note the variability of these in M13 stands across the country, instead highlighting the following general principles (See Figure 2-4):

- Most examples of M13 are characterised by winter water tables at or very close to the fen surface (-5 to +1 cm). However, the normal range of winter water tables is probably of little importance, except when associated with inundation.
- Good examples of M13 mostly occur in sites with visible surface water (but not inundated) or where water oozes from the soil underfoot during the summer months of a 'normal' (non-drought) year.
- Flushing by groundwater discharge is a feature of most 'high grade' M13 sites. Slopes prevent surface accumulation of water except in small shallow pools that probably experience considerable water throughput.
- Widespread inundation particularly in the summer, is likely to be damaging.

- The highest quality stands do not usually occur at sites where summer water tables are consistently c.10 cm below ground level.
- A long-term reduction of the summer water table beneath high quality stands of M13, to the extent that water no longer oozes underfoot in a non-drought summer, can be expected to result in some loss of botanical interest, as the habitat is dependent on saturated conditions.

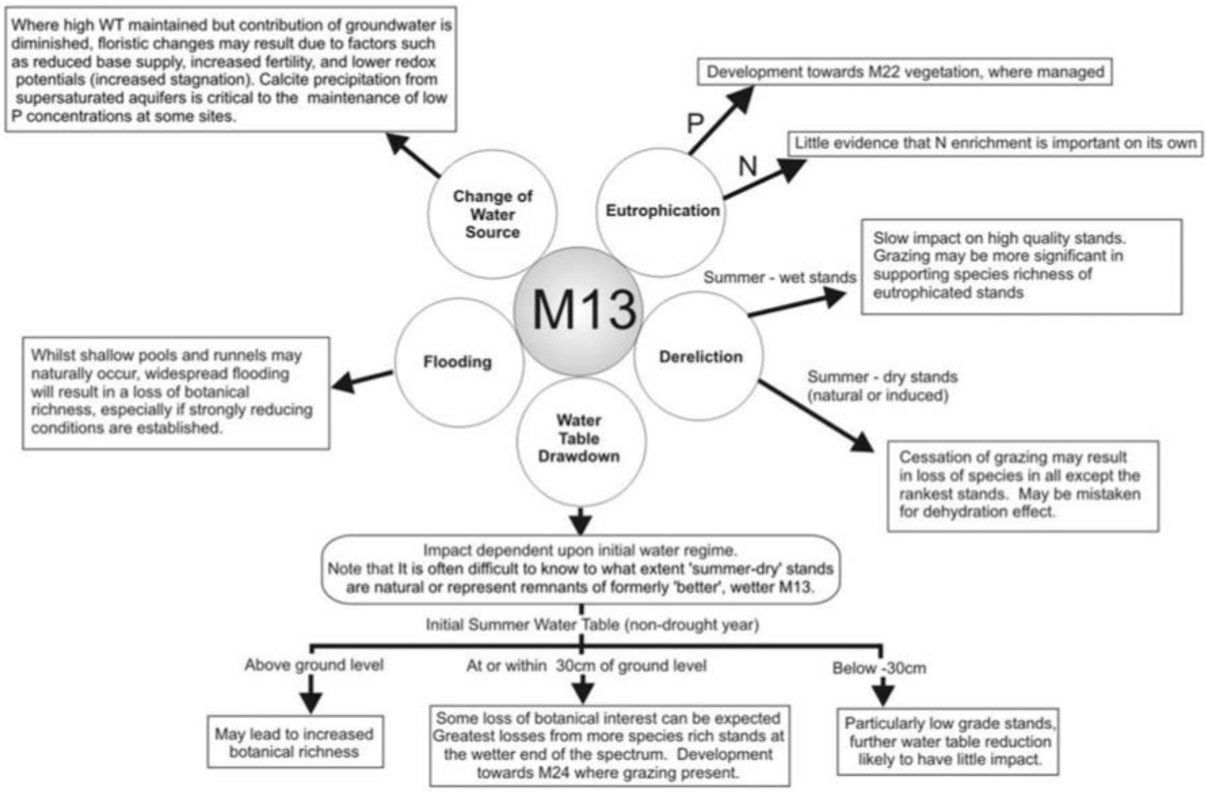


Figure 2-4: The possible effects of environmental change on stands of M13 (from Wheeler et al. 2004).

2.3.2 Nutrient Enrichment

Wheeler et al. (2009) note that stands of M13 are typically low-nutrient and low productivity ecosystems, with the best examples being flushed with oligotrophic water, particularly with very little phosphorous availability. Wheeler et al. suggest that nitrogen enrichment has little impact on its own, but phosphorus enrichment quickly leads to development of M22 vegetation. The effects of increased phosphorous can be masked by the calcium precipitate which binds available phosphorous, preventing a fertilisation effect. Details of nutrient thresholds are further discussed in Section 3.9.

2.3.3 Other Changes

The M13 vegetation is sensitive to other changes (Wheeler et al. 2009), notably it relies on a degree of vegetation removal to maintain the open conditions. This is often achieved by grazing, but in the Lye Valley is achieved to great effect by manual cutting. Botanical interest can also be lost if subject to deep flooding.

3 Environmental Baseline

3.1 Introduction

This section presents a summary of JBA's understanding of the environmental setting of the site and local area and in particular the physical site setting established through review of desk-based sources of information combined with a site inspection visit. The aim of this environmental baseline is to develop a detailed understanding of the environmental setting of the site and local area, including the climate, topography, hydrology, geology and hydrogeology.

The data used in the desk study were obtained from the following sources:

- Topography and general mapping:
  - OS Open Data, Terrain 50 DTM, LiDAR 1 and 2m DTM (EA Open Data);
  - Magic Map; and,
  - Aerial photography (Google Earth and Bing Maps).
- Geology and Soils:
  - British Geological Society (BGS) 1:50,000 Geology Map, Solid and Drift Edition, Sheet 237, Thame;
  - BGS digital geology mapping;
  - BGS online borehole database (BGS website);
  - BGS online Lexicon (BGS website); and
  - 1:250,000 soils mapping (Soil Survey of England and Wales, 1983).
  - Arkell, W.J. 1947. The Geology of Oxford, first edition. Oxford: Clarendon Press
- Hydrogeology:
  - British Geological Society (BGS) 1:100,000 Hydrogeology Map, Map number 7, South West Chilterns;
  - Aquifer classification (Environment Agency / Magic Map website);
  - Groundwater vulnerability (Environment Agency / Magic Map website);
  - Source Protection Zones (Environment Agency / Magic Map website);
  - Licensed abstractions (Environment Agency); and
  - Groundwater quality (Environment Agency website; ESI, 2006).
- References:
  - Adam Thomas Bows (2021), Assessing the biodiversity outcomes of Wild Oxford, an Alkaline fen ecosystem restoration project, MSc Dissertation
  - C Lambeth (2007), Hydrology Report for Lye Valley
  - The Lye Valley - A green space in Headington; Keith Frayn and Judy Webb 2013
  - AJ Sandels (1979), A study of the Plant Community of a Small Calcareous Fen, and the Implications for Conservation Management, Undergrad Report.
  - J Webb (2012), The Lye Valley

- JA Webb (2013a) Lye Valley SSSI North Fen Vegetation Transect investigation of the drying effect of brook bank erosion
- JA Webb (2013b) Lye Valley SSSI South Fen Vegetation Transect investigation of the drying effect of brook bank erosion
- Alkaline Fens & the Importance of the Lye Valley SSSI Fens within Oxfordshire and Nationally/Internationally; J A Webb 2014
- J A Webb (2016), FHT Citizen Science Water Quality Testing Results for Lye Valley LNR/LWS, including Lye Valley SSSI North Fen Unit 1 and Lye Brook, Oxford City
- JA Webb (2021) Peat and Carbon in the Lye Valley Fens;

3.2 SSSI and Study Area Delineation

This study is concerned with identifying potential impacts on the SSSI. Identifying a study area is therefore important in identifying potential impact mechanisms. Figure 3-1 identifies a catchment study area. It is based on three elements:

- The Surface water catchment based on LIDAR DTM topography (see Section 3.6),
- The Sewer network catchment (see Section 3.6.2),
- The Groundwater Catchment (see Section 3.8.6).

The three catchments are similar but have differences, so by combining and rationalising the shape, one study area has been developed.

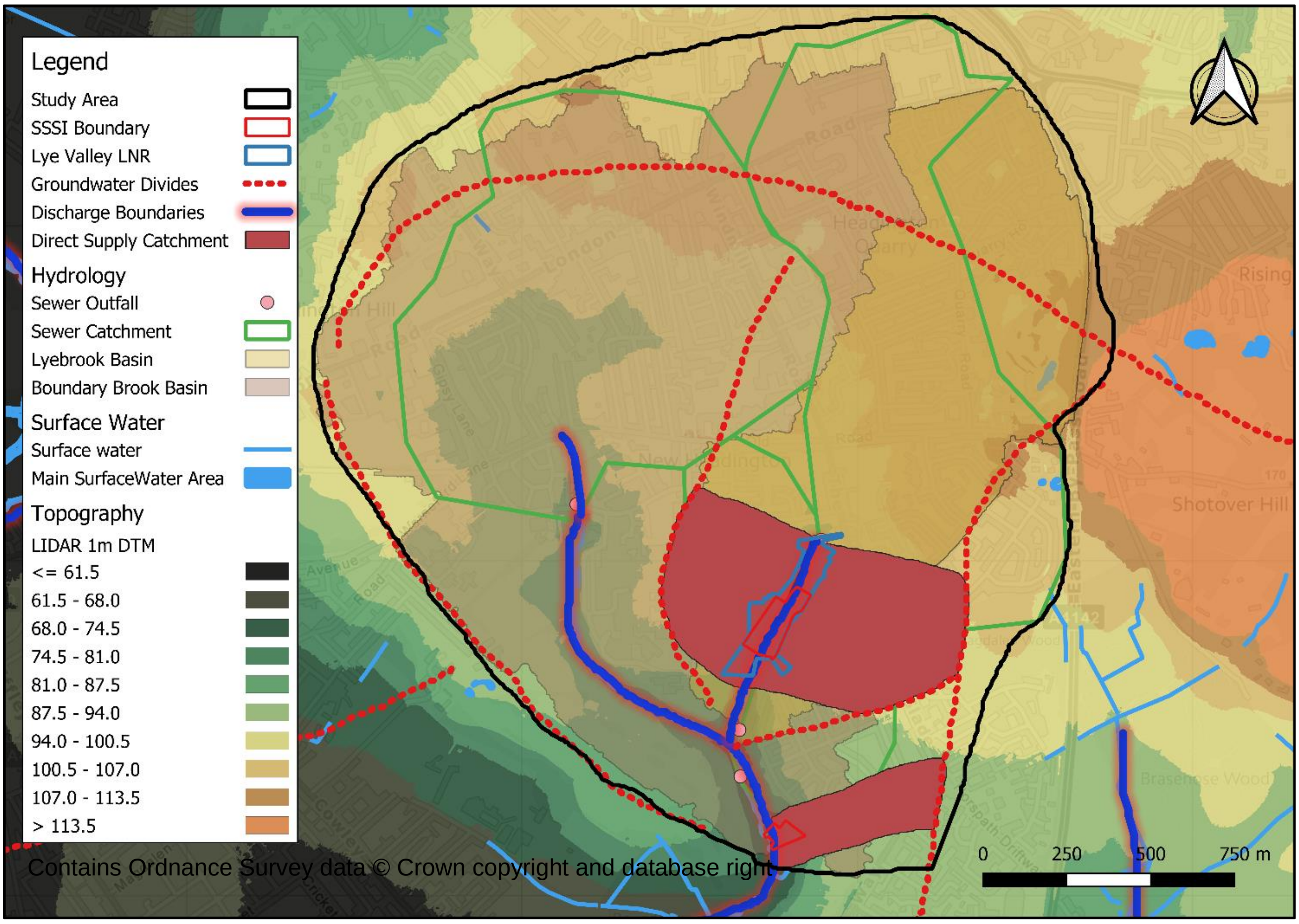


Figure 3-1: Study area.

3.3 Site Location and Topography

3.3.1 SSSI and Immediate Area

Lye Valley wetland is located within the Lye Brook and Boundary Brook catchments. Lye Valley North SSSI, formerly known as Bullingdon Bog, covers an area of 1.8 ha and is located within Lye Valley LNR immediately adjacent to The Churchill Hospital, Oxford. The site is approximately 3.5 km to the east of the centre of Oxford. Lye Valley South SSSI covers an area of 0.5 ha and is located approximately 250m downstream of the Lye Brook and Boundary Brook confluence at an approximate National Grid Reference of 454760 , 205180. The Lye Valley SSSI sites are illustrated in Figure 3-2. The SSSI consists of two units: the larger unit is in Lye Valley, with a smaller unit neighbouring Boundary Brook, known as South Fen.

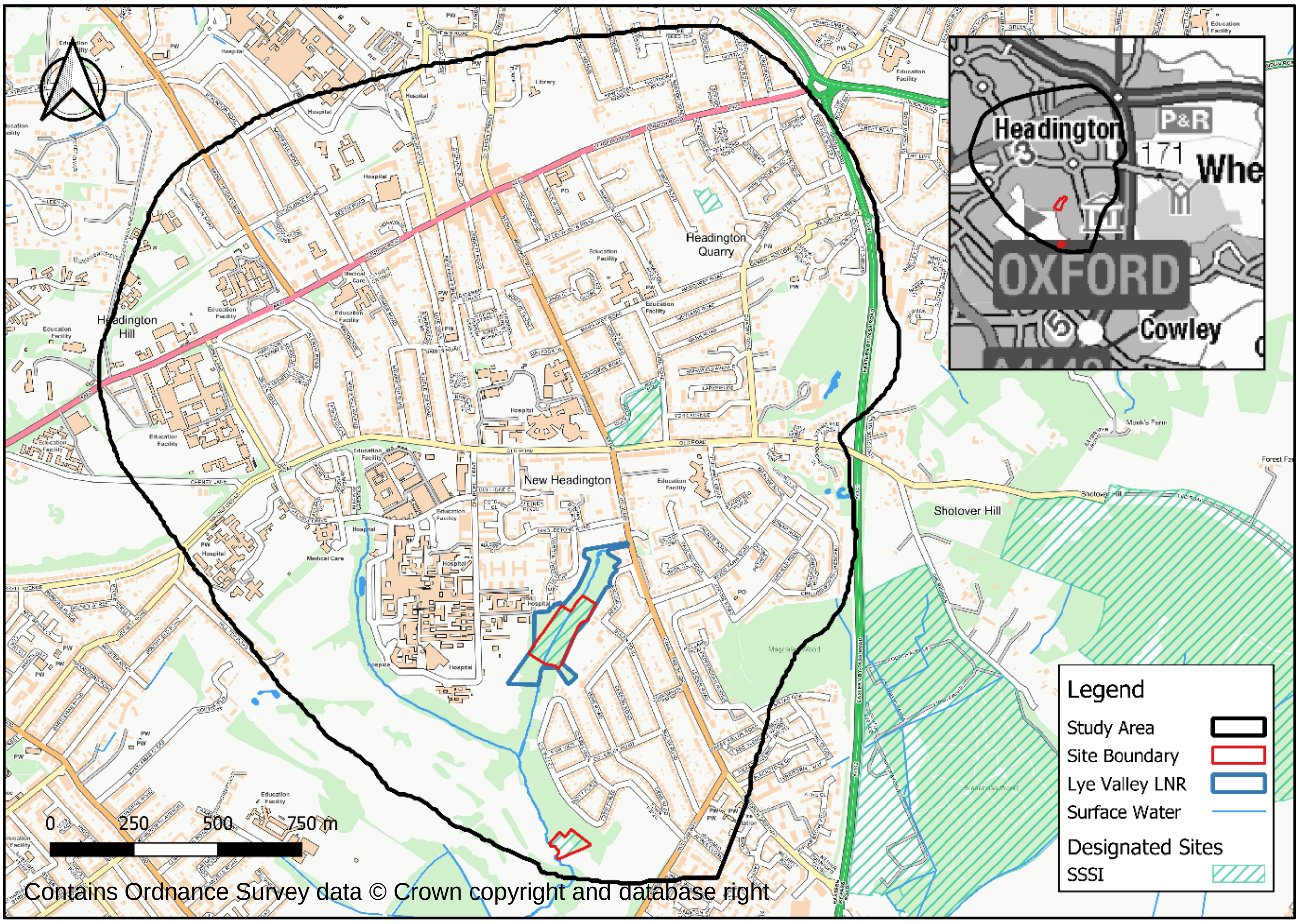


Figure 3-2: Site location.

The topography of the study area and site is shown in Figure 3-3.

The study area covers the top of the Boundary Brook catchment. The highest area is along the eastern boundary at around 110mAOD. The study area has two main valleys, the one containing Boundary Brook and the other one occupied by the Lye Brook, which forms its tributary.

The elevation varies across the Lye Valley SSSI (North) from 79mAOD in the south-west to 95mAOD in the north-east. In Lye Valley SSSI (South) ground elevation varies from 69mAOD in the west to 78mAOD in the east. In the wider area, ground levels generally fall towards the River Thames to the south-west.

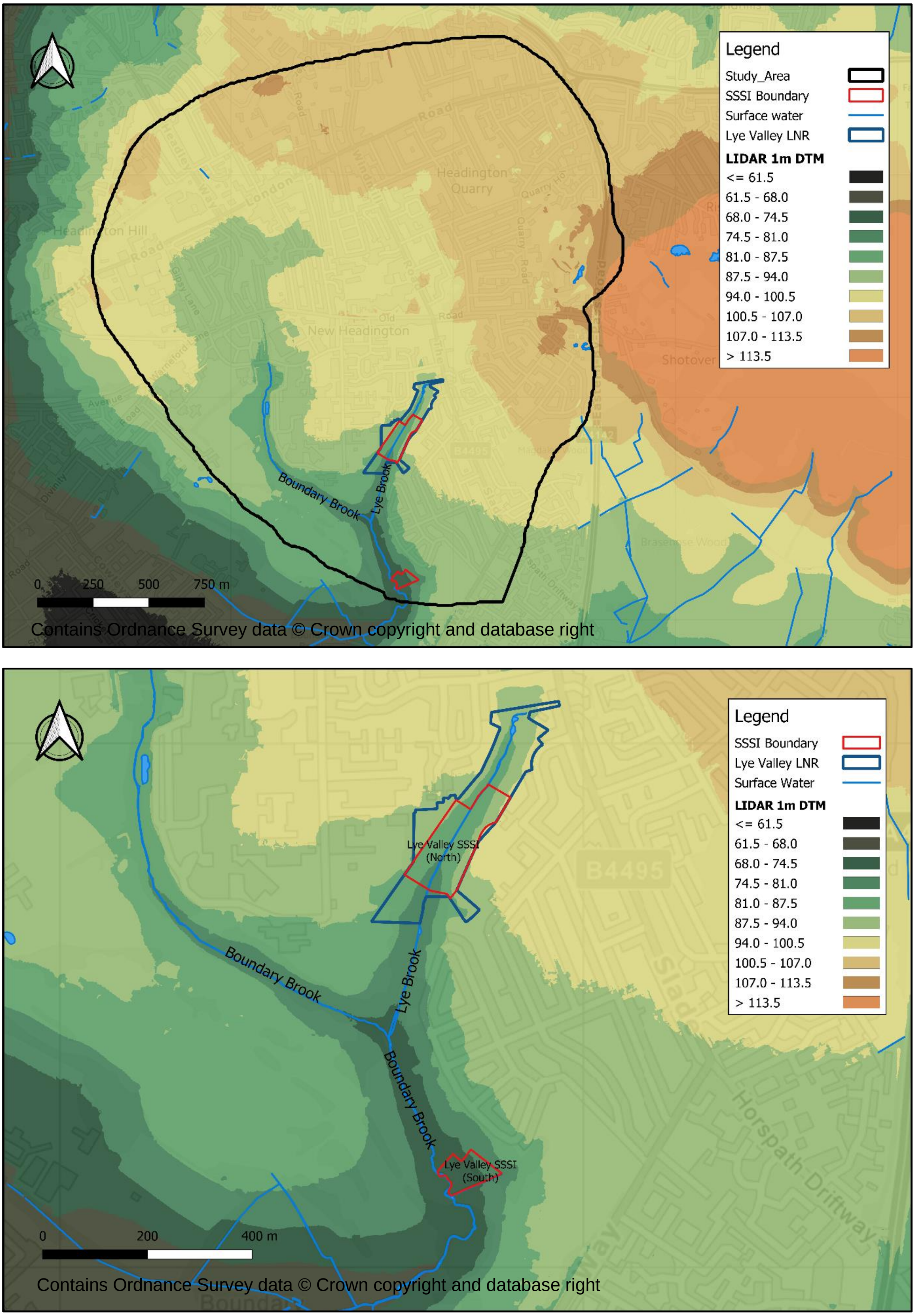


Figure 3-3: Topography.

3.3.2 Study Area Topography and Land Use

The upstream catchment of the Lye Valley SSSI is largely urbanised, comprising predominantly residential developments, with the Churchill Hospital lying on the high ground between Boundary Brook and Lye Valley (see Figure 3-4).

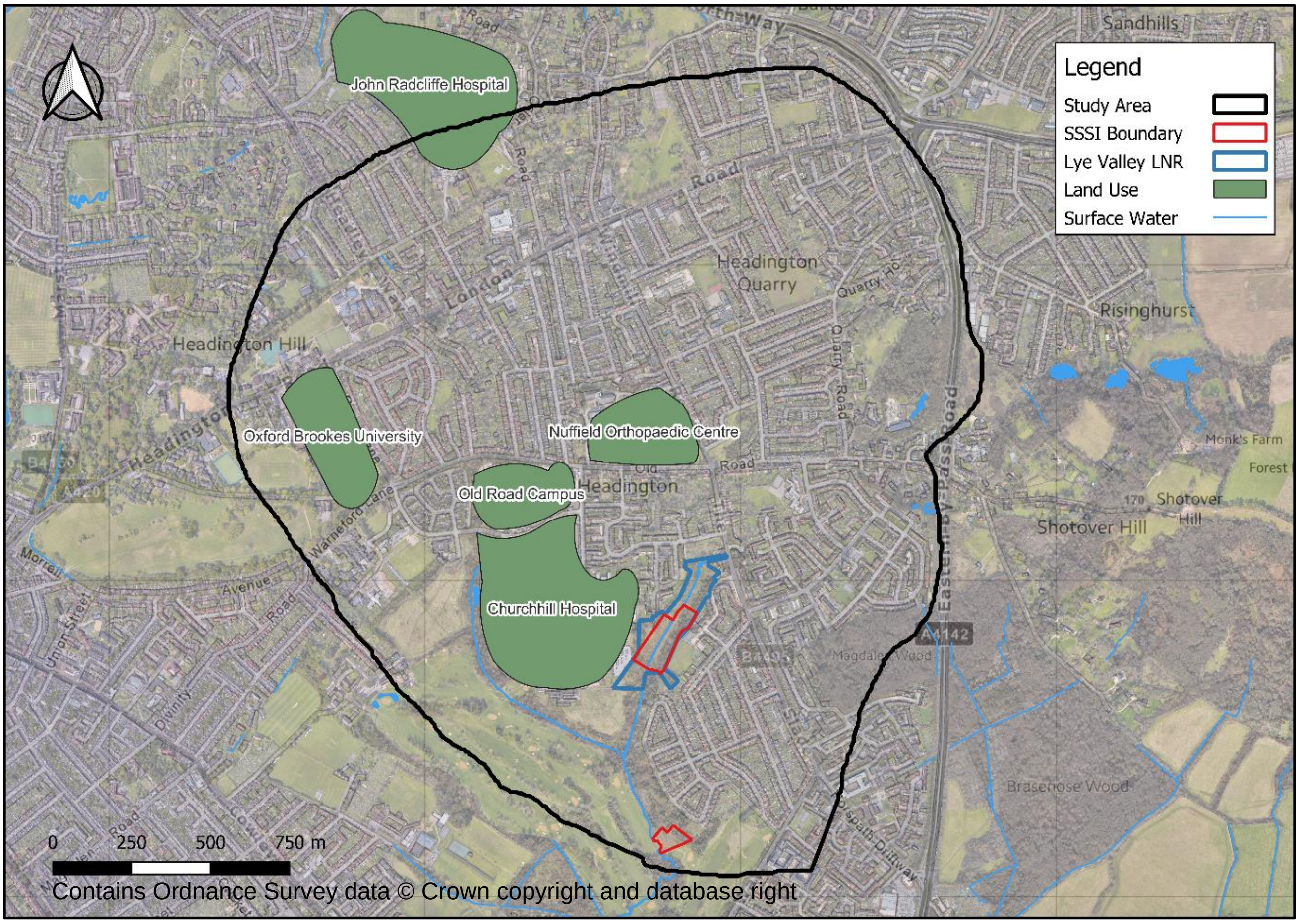


Figure 3-4: Notable land uses in the study area.

3.3.3 Catchment Development

Figure 3-5 provides a summary of how the study area has developed since the end of the 19th Century and is based on available historical Ordnance Survey maps. It is not fully comprehensive (e.g. the initial Second World War phase of the Churchill Hospital occurred between available maps) but presents a reliable summary of how the catchment developed from a predominately rural area to highly urbanised over the course of a few decades. The main phase of development was in the inter war years and through the 1950s and 1960s.

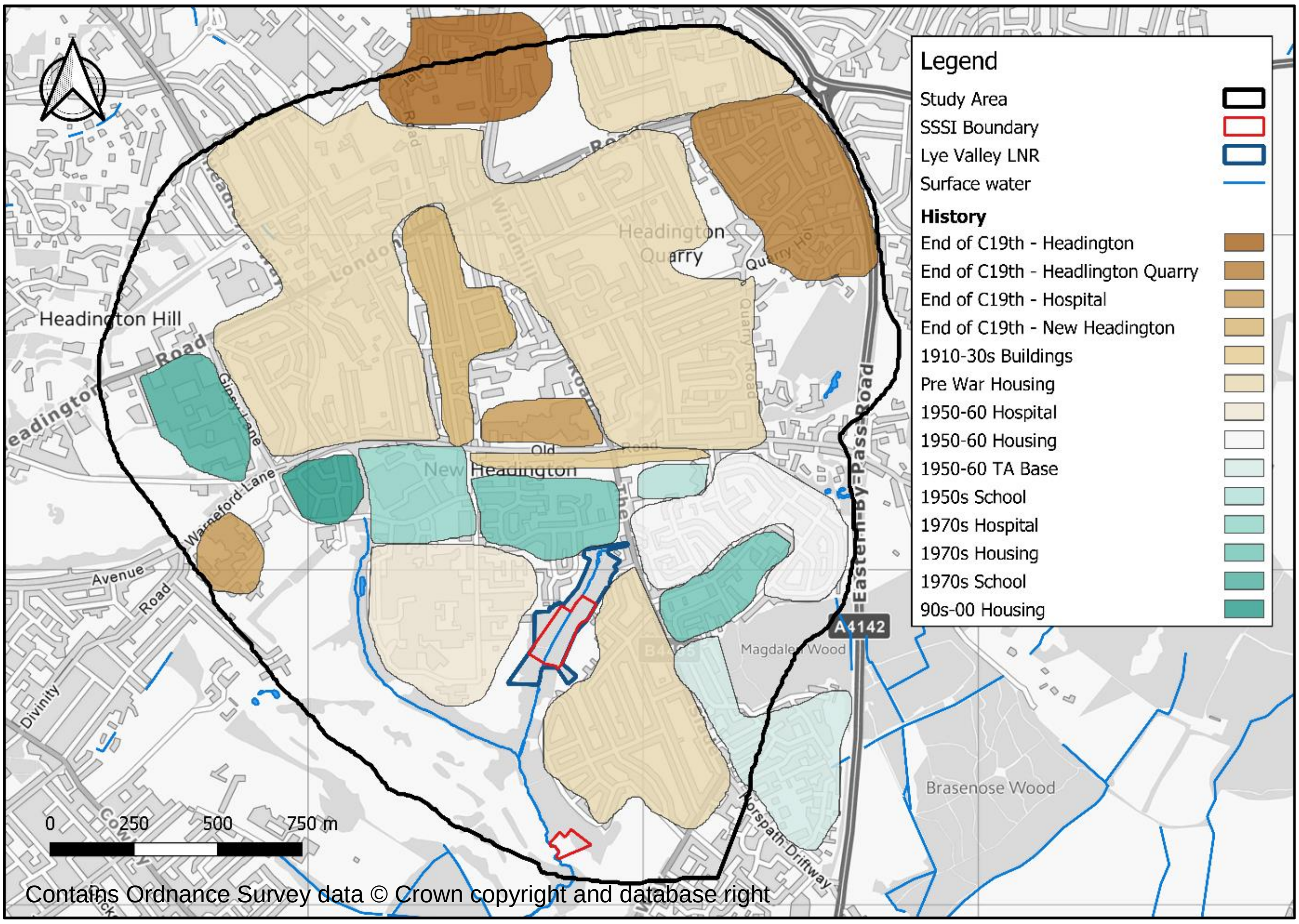


Figure 3-5: Catchment development summary.

3.4 Other Designated Sites

There are two other SSSIs within the study area (Figure 3-6):

- Rock Edge SSSI; and
- Magdalen Quarry SSSI.

These are both geological SSSIs with their citation descriptions presented in the boxes below. These sites are not designated for ecological reasons, and therefore no assessment is made of the potential for hydrogeological changes to impact the habitats within these sites.

Rock Edge SSSI Citation Description
This geologically important site exposes an Upper Jurassic coral-rich limestone known as the Coral Rag, believed to be approximately 145 million years old. The study of the rock sequence at Rock Edge (or Crossroads) Quarry has provided valuable information which has enabled geologists to partially reconstruct the geography of 145 million years ago, when much of the area that is now Oxfordshire was covered by a warm, shallow sea. Similar conditions to those found in the Bahama Banks today are believed to have existed at the time. At Rock Edge the Coral Rag is rich in fossil remains, derived from corals reefs that formed in the ancient shelf sea. Close examination reveals the presence

Rock Edge SSSI Citation Description
of two types of limestone, reflecting the close proximity of the reef margin. One variety consists primarily of coarse fragments broken off the reef, whilst the other is finer grained, representing the lime sand accumulating on the sea bed a short distance from the reef. Actual in situ reefs were previously visible in quarries located a few metres to the south. The study of this crucial site has helped to demonstrate the existence of the so-called 'Headington reef' in this area during Upper Jurassic times. https://designatedsites.naturalengland.org.uk/PDFsForWeb/Citation/1000185.pdf

Magdalen Quarry Citation Description
The classic geological site exposes three important rock units (Beckley Sand, Shell Pebble Bed and the Wheatley Limestone) approximately 145 million years old (Upper Jurassic age). The study of the rock sequence at Magdalen Quarry has provided valuable information which has enabled geologists to partially reconstruct the geography of Upper Jurassic times, when much of the area that is now Oxfordshire was covered by a warm, shallow sea. Similar conditions to those found in the Bahama Banks today are believed to have existed at the time. Most importantly, the rock units at this site indicate the presence of a reef structure in this area, formed by growth on the sea bed of an upstanding mound of lime-secreting, marine organisms, such as corals. The proximity of the reef is indicated by the rapid changes in thickness and composition of some of the rock layers, reflecting the importance of the reef as an active source of sedimentary debris. The uppermost unit, the Wheatley limestone, represents a deposit accumulating along the northern flank of the reef. The site is therefore of major importance in the geographical reconstruction of this ancient sea. Furthermore, the presence of fossil ammonites, and more specifically *Cardioceras densiplicatum*, is important in enabling the deposits to be accurately placed within the Upper Jurassic rock succession. https://designatedsites.naturalengland.org.uk/PDFsForWeb/Citation/1002889.pdf

There are no Special Areas of Conservation (SAC) or Special Protection Areas (SPA) within the catchment.

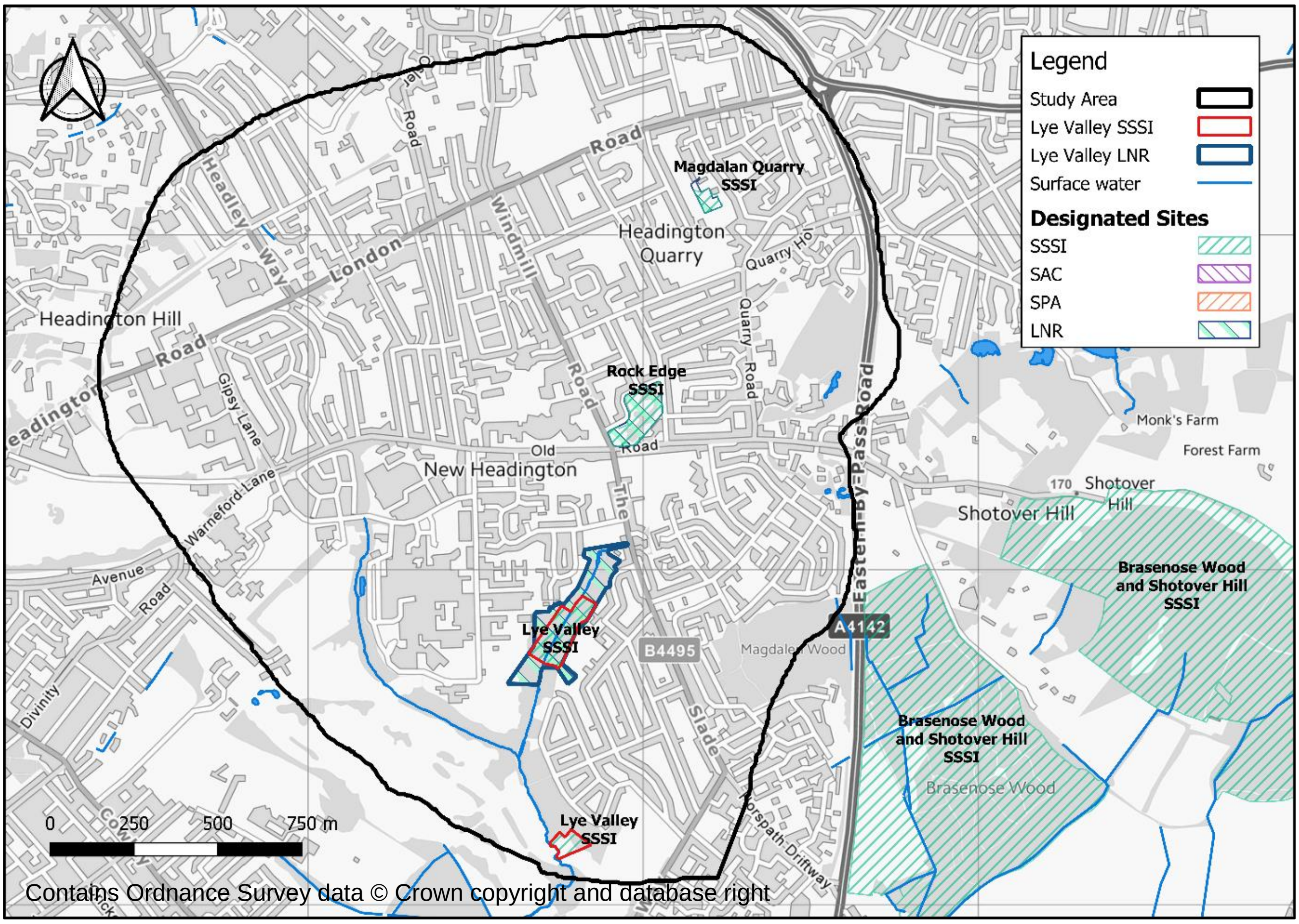


Figure 3-6: Designated sites.

3.5 Catchment and Climate

The Flood Estimation Handbook (FEH)[3] catchment descriptors have been assessed for the Boundary Brook local catchment (NGR 454800 , 205100). This gives the Standard Percentage Runoff (SPR) near the site as being 50%. The SPR is the percentage of rainfall responsible for the short-term increase in river flow during and/or following a rainfall event.

The Baseflow Index (BFI) for the site is 0.26. This is the proportion of total streamflow made up of baseflow (mostly groundwater input). This suggests that around a quarter of the flow of the local watercourses is made up of groundwater baseflow. This is relatively low for a sandstone and limestone dominated catchment.

The BFI was also obtained for a small stream north of Baywater Brook through Wick Copse (NGR 454650, 209100). This lies on the same geology but is a rural catchment. The BFI for this catchment was identified as 0.76, which is significantly higher than for the Boundary Brook catchment. This suggests that baseflow/groundwater inputs into Boundary Brook maybe around three times less than they were before urbanisation. Groundwater

[3] https://www.ceh.ac.uk/our-science/projects/flood-estimation-handbook?gad_source=1&gclid=CjwKCAjwhvi0BhA4EiwAX25uj28k_UILAXxEdqm4C_lqRKq1W7ffNj2tPqM2TK_P47xucOSG_25cgBoCy4kQAvD_BwE

monitoring presented in Section 3.8.4, however suggest that groundwater inputs are still sufficient to maintain high and stable groundwater levels on site. The SPR for the Wick Copse catchment is 12.54%, showing that there is much less run-off in the rural catchment too.

The FEH also includes long-term average rainfall data for catchments in the UK. For this catchment the Standard Annual Average Rainfall (SAAR) is 635 mm/yr for the period 1961 - 1990 and 648 mm/yr for the period 1941 - 1970.

3.6 Surface water

3.6.1 Study Area Rivers

The study area is within the Boundary Brook catchment, which is a small tributary of the River Thames. The two main watercourses are Boundary Brook and Lye Brook, shown in Figure 3-7. The catchments shown in the figure are based on GIS analysis of topography.

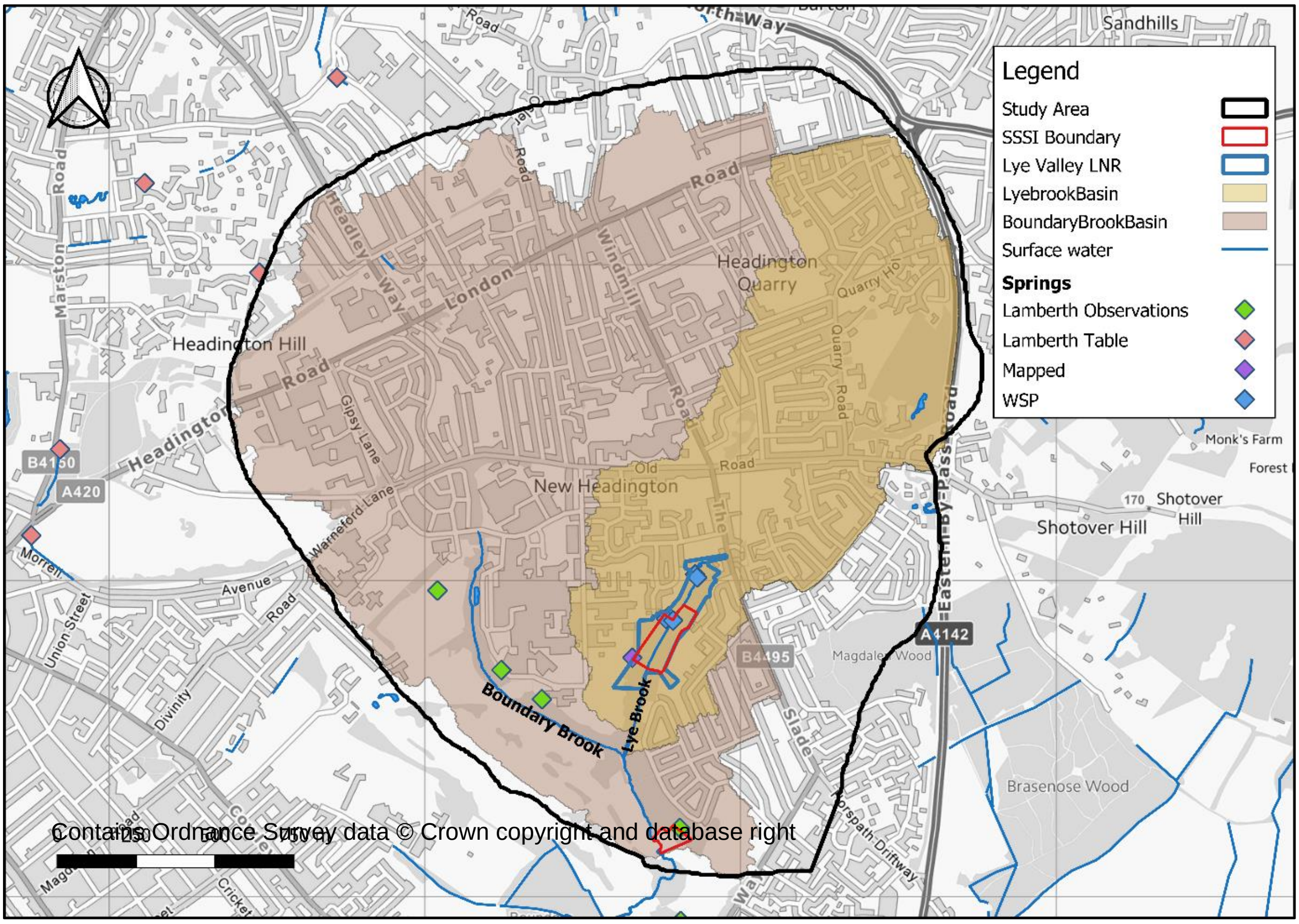


Figure 3-7: Water features.

The Boundary Brook starts to the north of the White Horse pub, probably near the boundary stone (boundary between Oxford and Headington) on Woodlands Road. The Brook runs underground in a southerly direction past the west side of the White Horse, cutting under part of Headley Way.

It continues south along the west side of the Churchill Hospital, and a large balancing pond/lake near the Oxford Cancer Centre which is designed to collect surplus storm water running off the built-up Churchill site.

The brook then turns south-east and runs along the edge of the golf course and then down to meet the Lye Brook in the Lye Valley Nature Reserve (see Figure 3-8). The brook then runs south-east through the golf course and then south west, emerging in Barracks Lane at the bottom of the hill. It continues all the way through the south side of Meadow Lane Nature Park and enters the River Thames approximately 2.5 km downstream of Lye Valley.

Figure 3-8: The Boundary Brook leaving the Churchill Hospital area and running down to the Lye Valley, where it is joined by the Lye Brook[4].

Lye Valley North SSSI is located within the Lye Brook catchment, which is a tributary of Boundary Brook. The upper reaches of the Lye Brook are culverted but discharge in a channel at the northern end of the LNR.

Lye Brook is fed by a number of different sources. This includes the springs of the Lye Valley (from both sides of the valley), surface water run-off from surrounding land

[4] Boundary Brook, Headington

(allotments to the north, residential to the east and west), and highway drainage from the B4495/The Slade which discharges into the stream at the northern extent of the Lye Valley.

There are no gauging stations along Boundary Brook or Lye Brook, and therefore no long-term flow records are available.

3.6.1.1 Nature of the Watercourse through the SSSI

The Lye Brook enters the top of the Lye Valley and passes through a series of attenuation ponds. Figure 3-9 shows the main water features along the Lye Valley.

Figure 3-9: Main water features along the Lye Valley.

The channel is incised and has cut through the soft peats and clays in the base of the valley to reach hard deposits beneath. Lambeth (2007) identifies a storm in 1979 that caused much of the incision and provides a long section of the bed profile (see Figure 3-10). Figure 3-11 is taken from a survey conducted in December 1978, at this time a circa 1m high knickpoint was located halfway up the SSSI. The knickpoint shows how far up the SSSI, the ditch erosion had reached at that point. It is possible that the 1979 storm, then allowed the knickpoint to move rapidly upstream.

The increased urbanisation (reflected in the change in the SPR - see Section 3.5), is likely to have made the stream more flashy, i.e. higher flows (and therefore more erosive) in response to rainfall than the original naturalised conditions prior to urbanisation within the catchment.

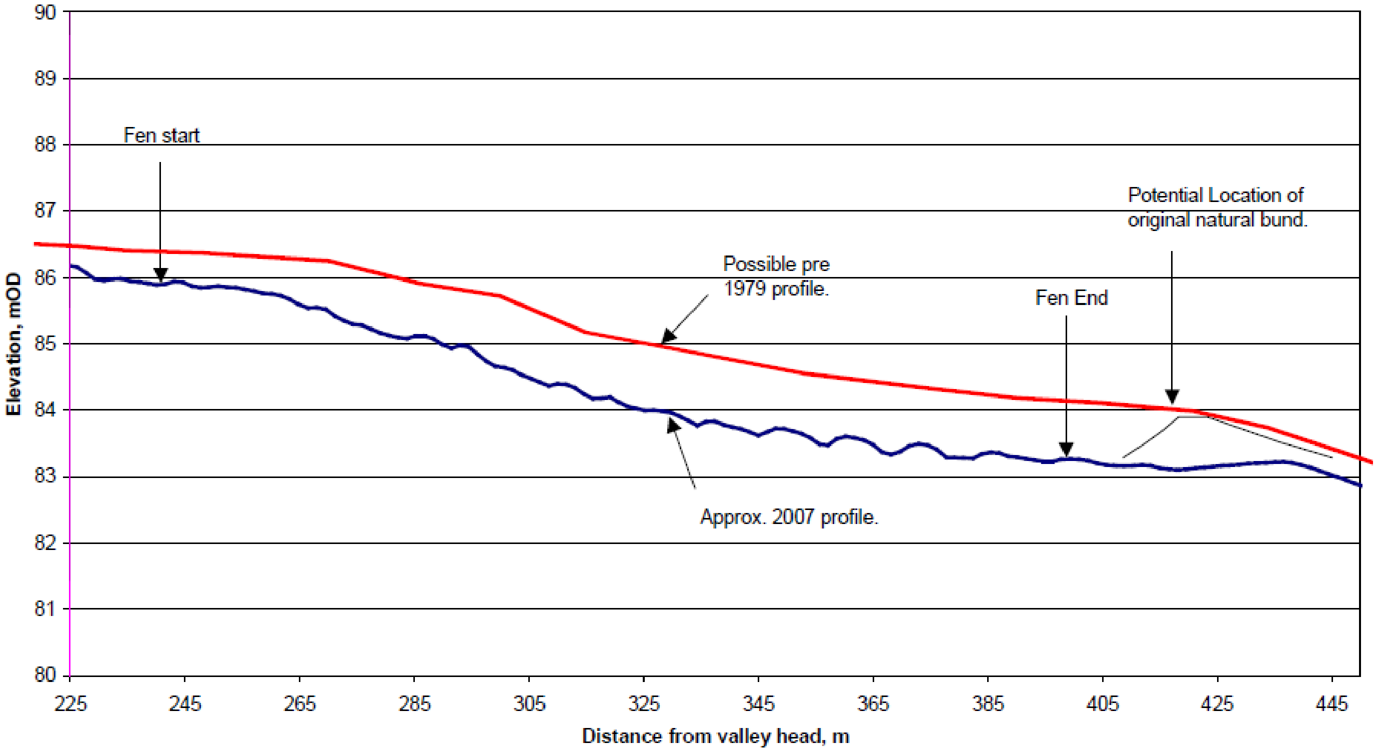


Figure 3-10: Approximate Lye Valley North SSSI stream bed (from Lambeth 2007).

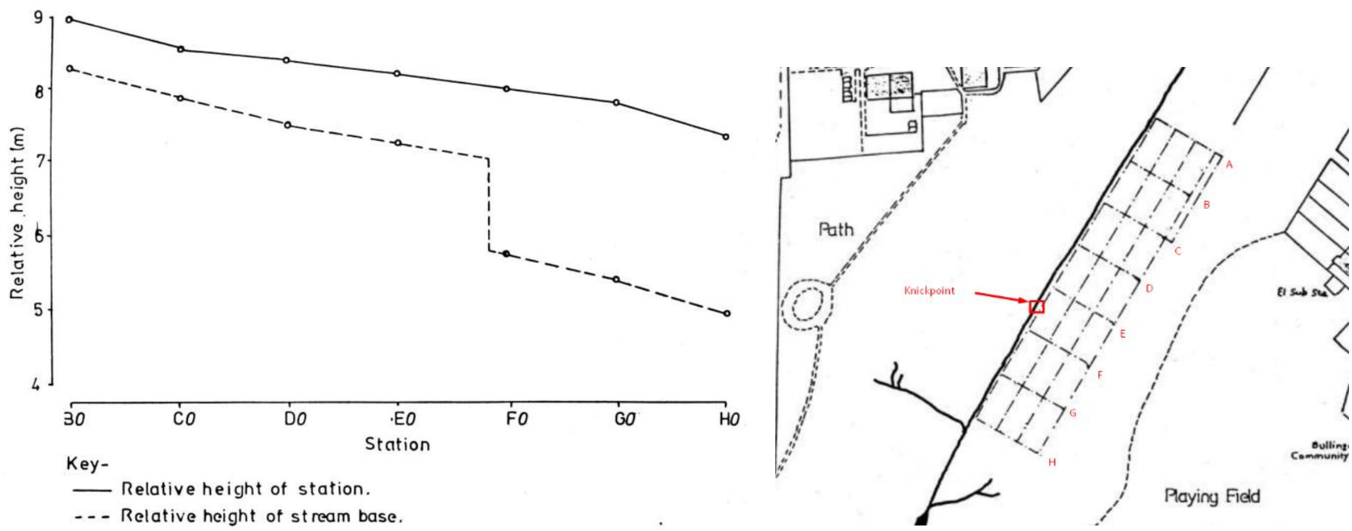


Figure 3-11: Long profile and location of Knickpoint in December 1978 (modified from Sandel 1979).

An article on the Headington Heritage website[5] shows the nature of the stream in 1914 compared to today (see Figure 3-12). It shows how the watercourse at that time was much smaller than today. The stream in this historic condition would have provided the low energy environment that allowed the soft peats and clays of the valley floor to be deposited.

Figure 3-12: Lye Brook in 1914 and 2020 from Headington Heritage with the map showing the line of sight.

On the JBA November 2023 site visit, restoration works by the Friends of Lye Valley were observed, including repairs to the bank and leaky debris dams along the length. Slumping of the peat in the valley floor adjacent to the incised stream could also be observed (see Figure 3-13).

[5] https://headingtonheritage.wordpress.com/the-lye-taunt-in-colour/

Figure 3-13: Evidence of slumping.

The erosion of local watercourse also extends down Boundary Brook. Figure 3-14 shows the brook at the beginning of the 20th century, with Figure 3-15 showing erosion today. Webb (2013) estimates that the brook has incised by 1-1.78m.

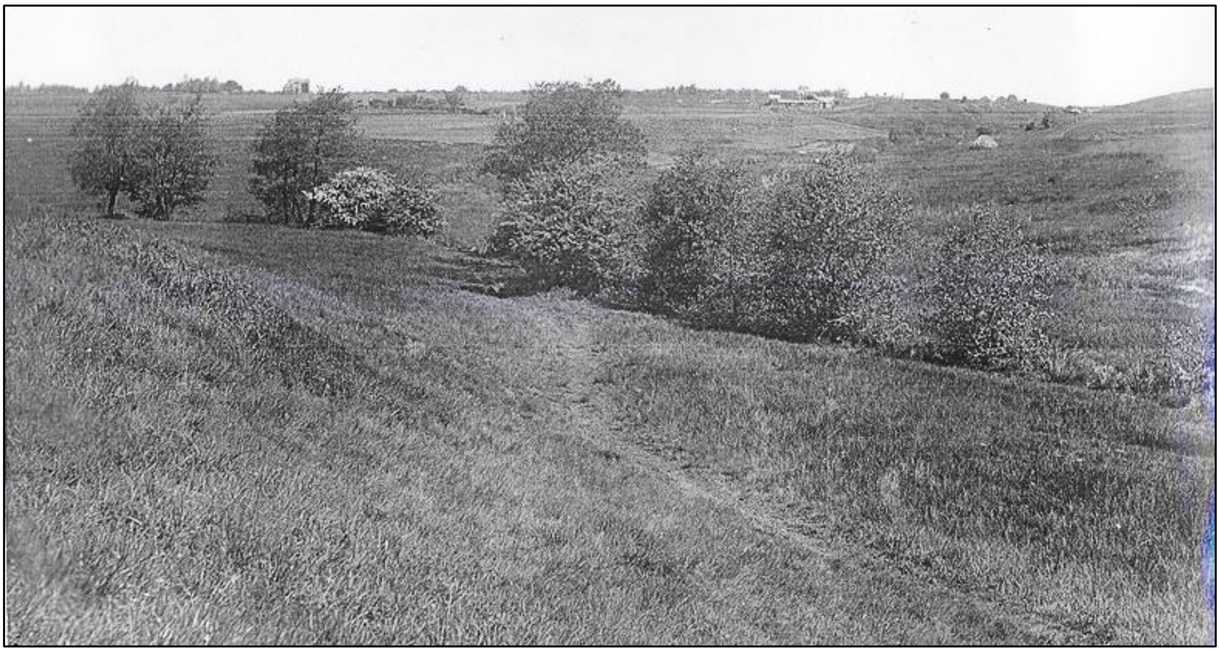


Figure 3-14: Boundary Brook with Lye Valley in the background from the early 20th Century[6].

Figure 3-15: Erosion of Boundary Brook from Webb (2013).

6 https://en.wikipedia.org/wiki/File:Boundary_Brookand_Lye_Valley.jpg

3.6.2 Sewer Network

Figure 3-16 shows the surface water sewer network and the main outfalls in the study area. Not shown on the figure are private surface water sewers which appear to include those on the hospital campus. The catchments shown provide an approximate indication of which sewers discharge to which outfall, however some sections of sewers have two potential outfalls.

It is also of note that foul sewers run down the Lye valley, these are however a separate system. Observations of pollution from surface water sewer outfalls (see Section 3.9.6) may represent misconnections in the system.

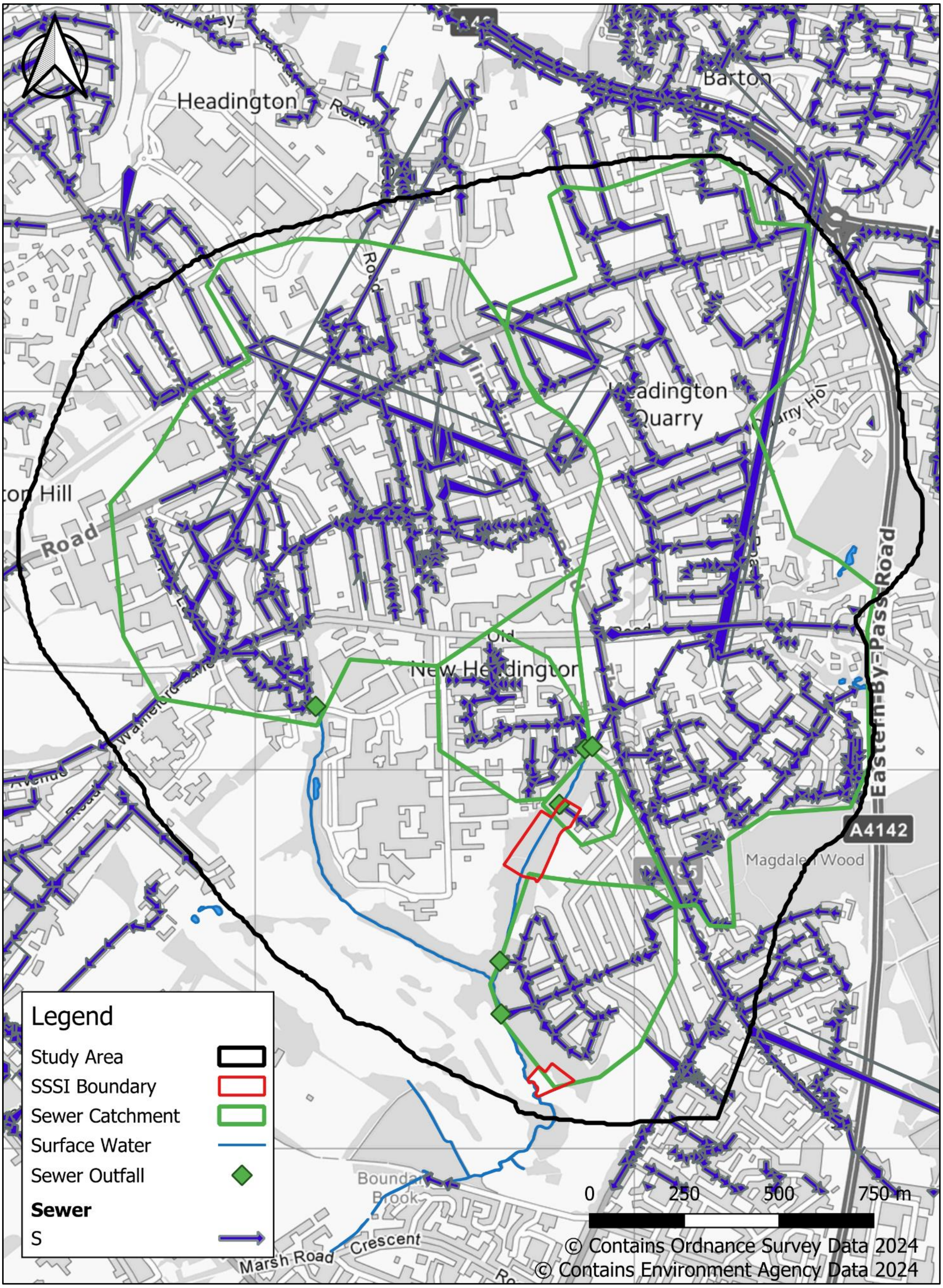


Figure 3-16: Surface water sewer network.

3.6.3 Modified Surface Water Catchment

Figure 3-17 presents the current surface water catchment. It takes the catchments derived from topography shown in Figure 3-7 and modifies it based on the influence of the sewer drainage system. In some areas, this slightly increases the size of the catchments, in others it reduces it.

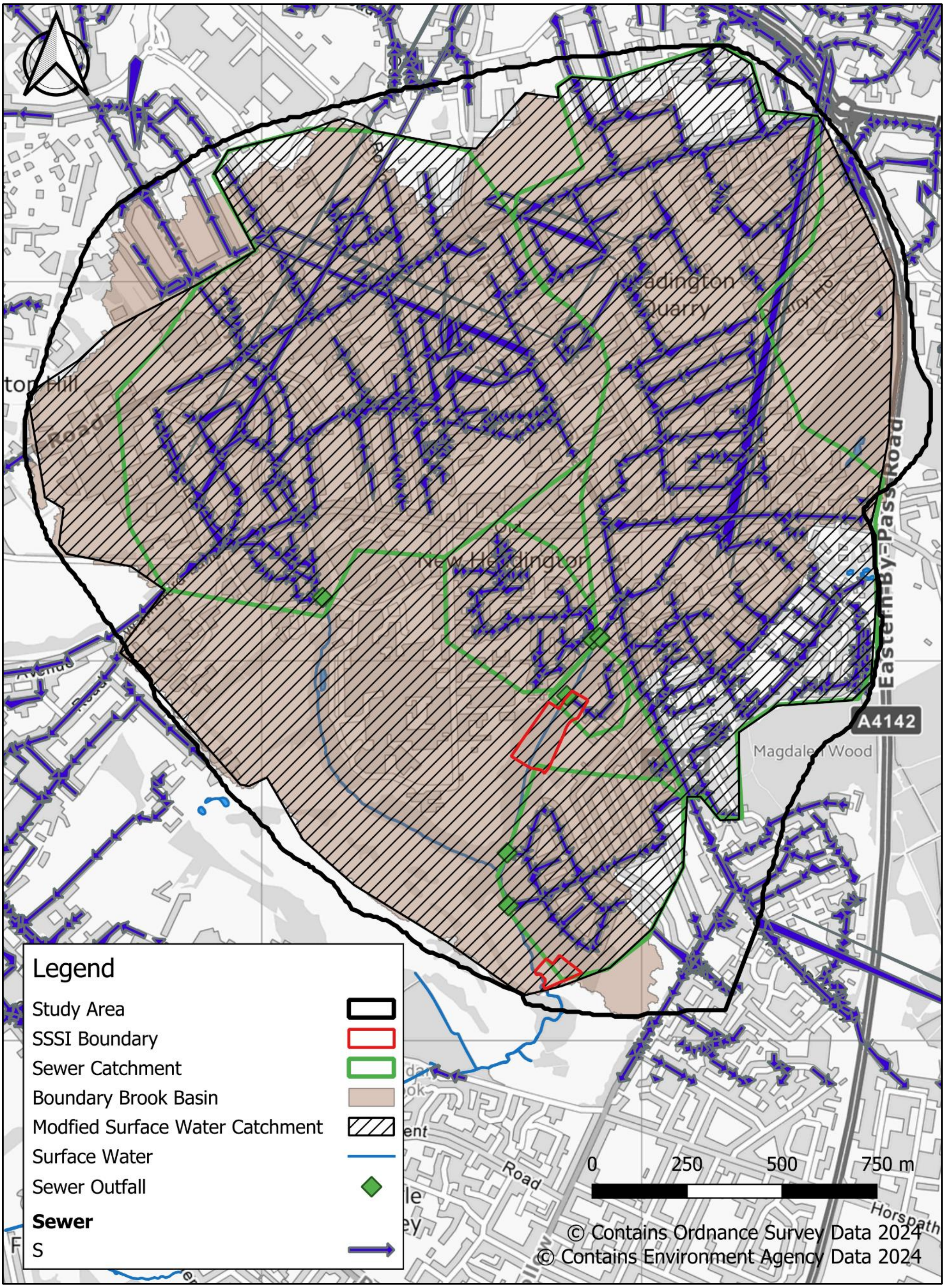


Figure 3-17: Modified surface water catchment.

3.6.4 Flooding

The risk of flooding has been reviewed using the https://check-long-term-flood-risk.service.gov.uk/ website. Figure 3-18 shows surface water flood risk and Figure 3-19 shows risk of flooding from rivers. Parts of the catchment above the SSSI are subject to surface water flooding (risk varying from low to high), with fluvial flooding being mainly limited to the valley floors (but high in those areas) with some extra flood risk to the north of old road.

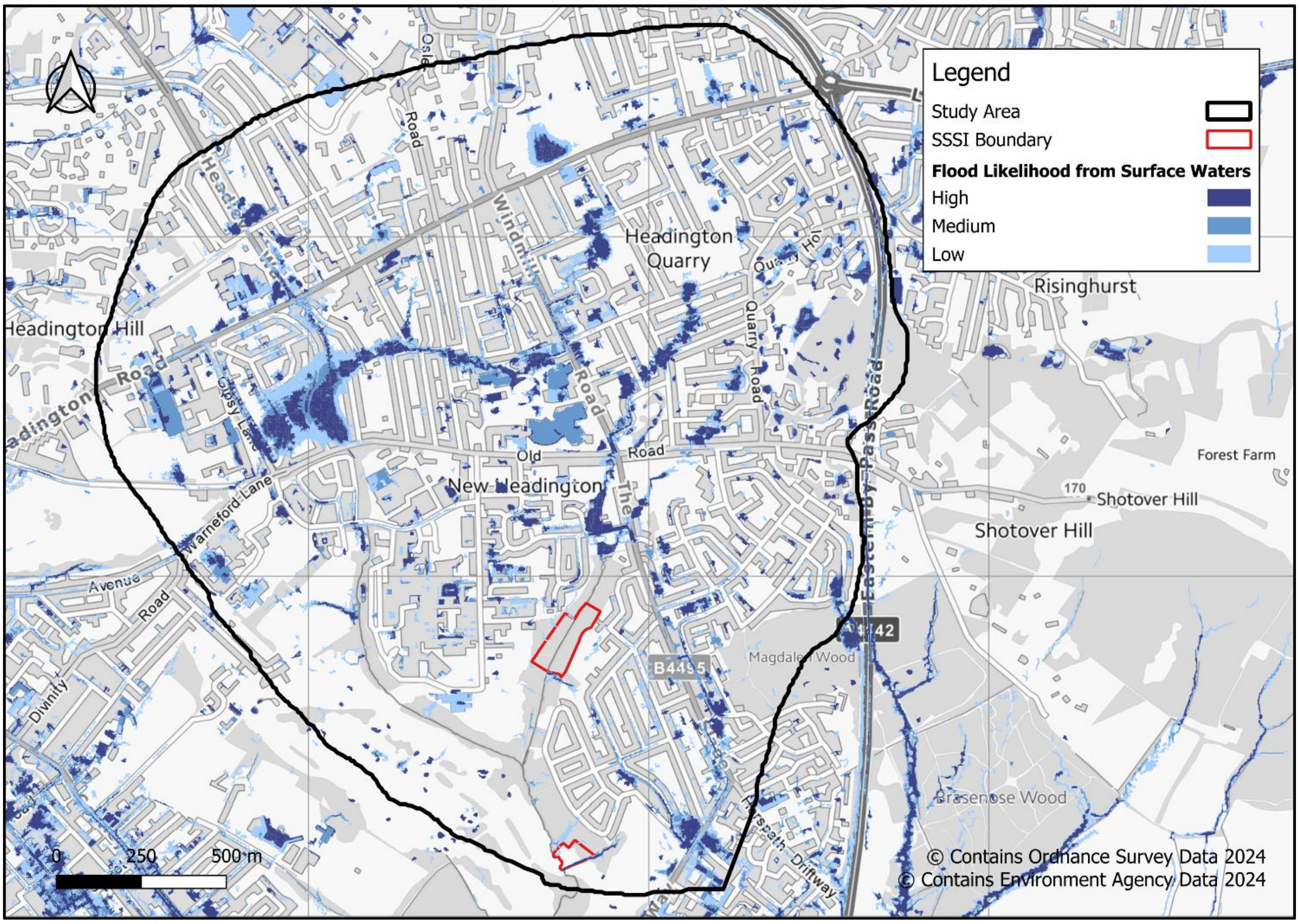


Figure 3-18: Risk of flooding from surface waters.

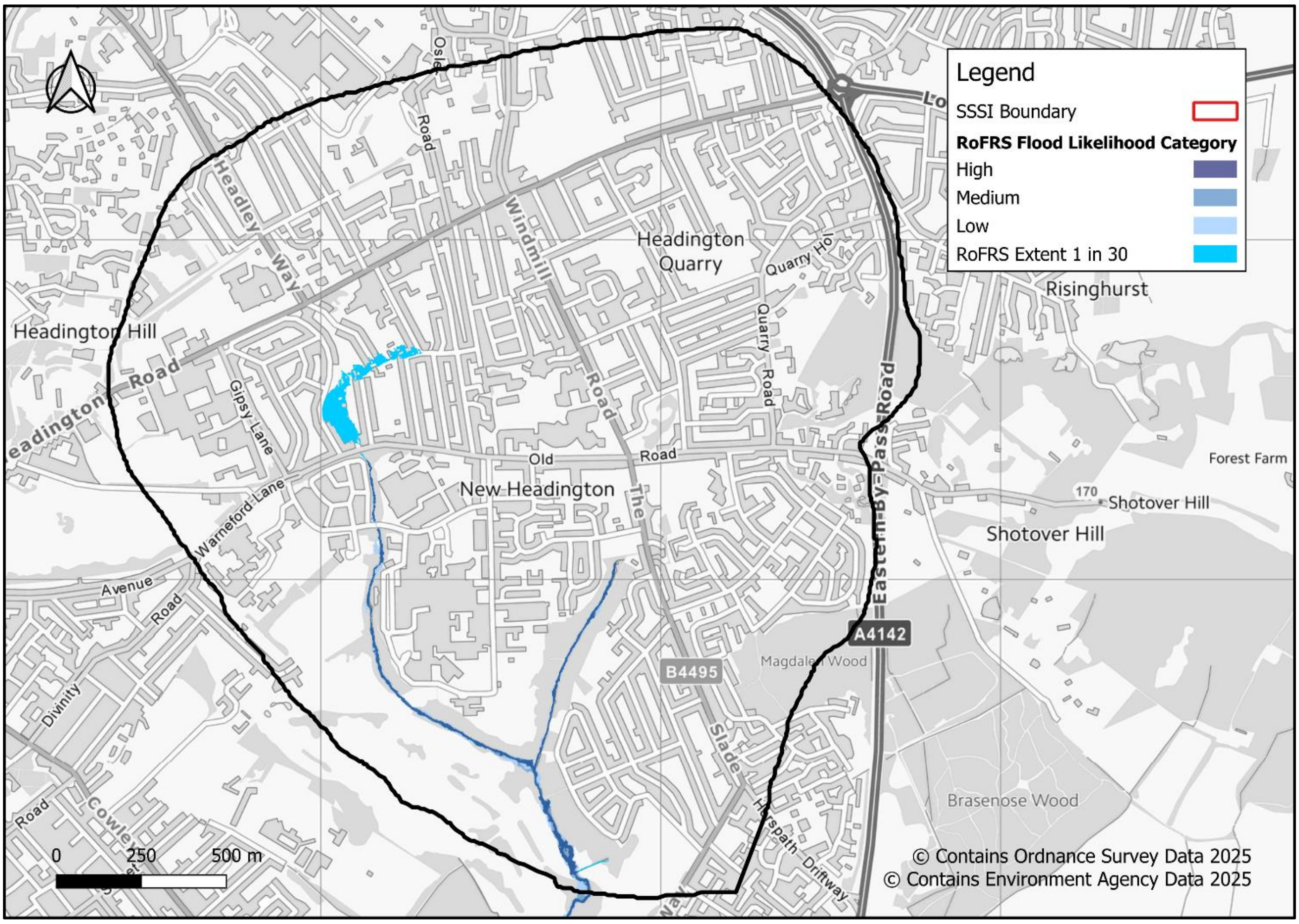


Figure 3-19: Risk of flooding from rivers and seas with 3.3 percent annual chance (defended).

3.7 Geology

3.7.1 Overview

Information on the soils and geology of the site and surrounding area has been derived from 1:50,000 BGS mapping (50k Solid and Drift, Sheet 237, Thames), BGS online borehole archive and ground investigation conducted by WSP in January 2018 (Appendix C). The geology underlying the Lye Valley is summarised in Table 3-1.

Table 3-1: Geology underlying the Lye Valley.

Age	Group	Unit	Description	Thickness
Quaternary	Superficial deposits	Topsoil/ Made Ground	Soft dark grey/brown sandy slightly organic clay with occasional rock and brick fragments	0-3.25m**
Quaternary	Superficial deposits	Alluvium	Clay, silt, sand and gravel; Normally soft to firm consolidated, compressible silty clay, but can contain layers of silt, sand, peat and basal gravel. A stronger, desiccated surface zone may be present.	Circa 1 - 1.5m****
Quaternary	Superficial deposits	Head	Clay, silt, sand and gravel; Poorly sorted and poorly stratified, angular rock debris and/or clayey hillwash and soil creep, mantling a hillslope and deposited by solifluction and gelifluction processes.	No data available
Quaternary	Superficial deposits	Peat	Peat; A partially decomposed mass of semi-carbonized vegetation which has grown under waterlogged, anaerobic conditions, usually in bogs or swamps.	0-1.25m**
Upper Jurassic (Oxfordian)	Bedrock	Ampthill Clay Formation	Grey mudstone with sporadic bands of limestone nodules.	15-23m***

Age	Group	Unit	Description	Thickness
Upper Jurassic (Oxfordian)	Bedrock	Wheatley Limestone (Corallian Group)	Shell-fragment and coralline limestone; Shell-fragmental, biosparite grainstones interbedded with shell-fragmental marls, locally with rubbly coralliferous limestone with marls of the 'Coral Rag' facies.	0-26m***
Upper Jurassic (Oxfordian)	Bedrock	Beckley Sand (Corallian Group)	Sand and calcareous sandstone; A grey, weathering brown to yellow, quartzose, fine- to medium-grained Sand in the east, becoming coarser in the west, with calcareous sandstone beds and doggers, and thin, sandy, shelly bioclastic limestone beds. It is moderately fossiliferous, containing bivalves and ammonites.	0-25m***
Upper Jurassic (Oxfordian)	Bedrock	Temple Cowley (Corallian Group)	Fine-grained sandstone, sands and siltstone; Fine-grained silty sands, calcareous sandstones and clayey silts and siltstones, commonly thinly or ripple bedded, may show pronounced bioturbation.	0-12m***

Notes
* Site Investigation (2018)
** BGS online Lexicon of Named Rock Units
*** BGS (British Geological Survey), 1994. Thames. England & Wales Sheet 237. Solid & Drift Geology Map, 1:50,000 Series
**** Depth of incised channel in Lye Valley

3.7.2 Soil

Soil classification by the Soil Landscapes Online Viewer (DEFRA, 2022) have classified the study as containing freely draining, slightly acid, loamy soil which drains to local groundwater and watercourses in the area underlain by the Beckley Sand Member. The upstream catchment of Lye Brook has been classified as shallow, freely draining, lime-rich soil over limestone and drains to groundwater where the Wheatley Limestone is present.

3.7.3 Made Ground

Made Ground refers to lithology that is made up of artificial material, or the reworking of natural material used to create a new landform. Made Ground is likely to be limited to areas of historic and present residential and agricultural buildings, where the ground may have been prepared for construction. The larger areas of Made Ground in the study area are shown in Figure 3-20.

3.7.4 Made Ground within Lye Valley

Based on historic ground investigation data, together with LIDAR data, Made Ground is known to be present and associated with a tip along the northwest edge of the Lye Valley. The emplacement of Made Ground next to Warren Crescent is thought to have occurred around 1970 (see Figure 3-21) (note this is not mapped by the BGS). The tip avoids the main seepage face from a limestone band (see Section 3.7.7.1). Placement of tipped material on the seepage face may have been deliberately avoided as it would cause stability issues (i.e. tipping on a wet slope would have been more prone to slumping and collapse).

Upstream of the Lye Valley LNR, the stream is culverted. Review of the LIDAR topography suggests that some of the valley floor here has been infilled.

3.7.5 Superficial Deposits

The superficial geology consists of units deposited within the Quaternary Period. Those deposited within the study area, as mapped by the BGS, are shown in Figure 3-20. Peat and alluvium are mapped in the valley floor. BGS borehole records and available borehole records show that there are very limited superficial deposits elsewhere in the study area.

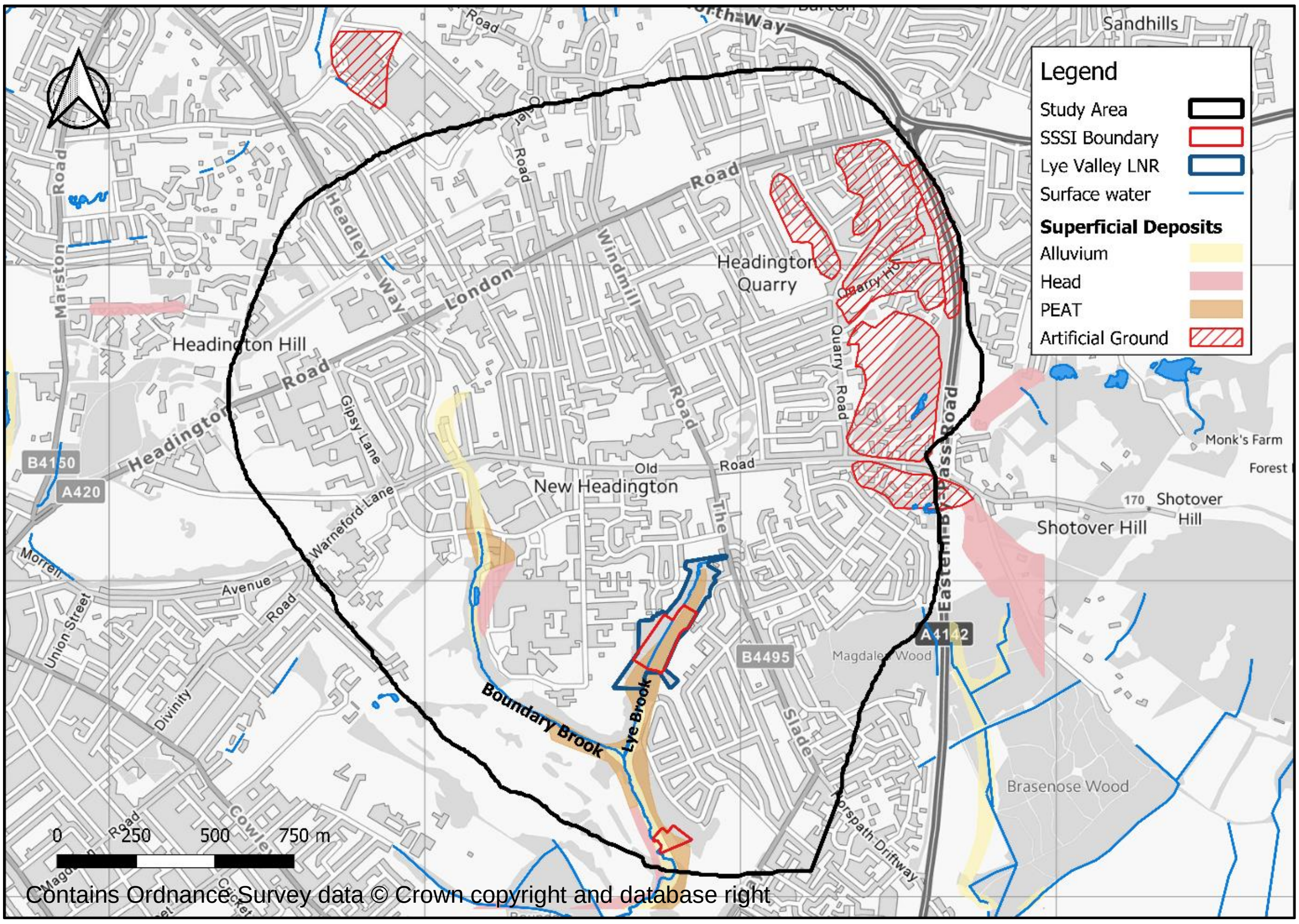


Figure 3-20: Superficial deposits.

3.7.6 Deposits within the SSSI

Figure 3-21 shows the extent of superficial deposits on site based on a range of sources including the site walk-over and monitoring dipwell logs. There appears to be two main areas of superficial deposits:

- Valley floor deposits comprising a mixture of peats and alluvial clays:
- Valley side deposits also comprising a mixture of peat and clays with identifiable seepage faces beneath.

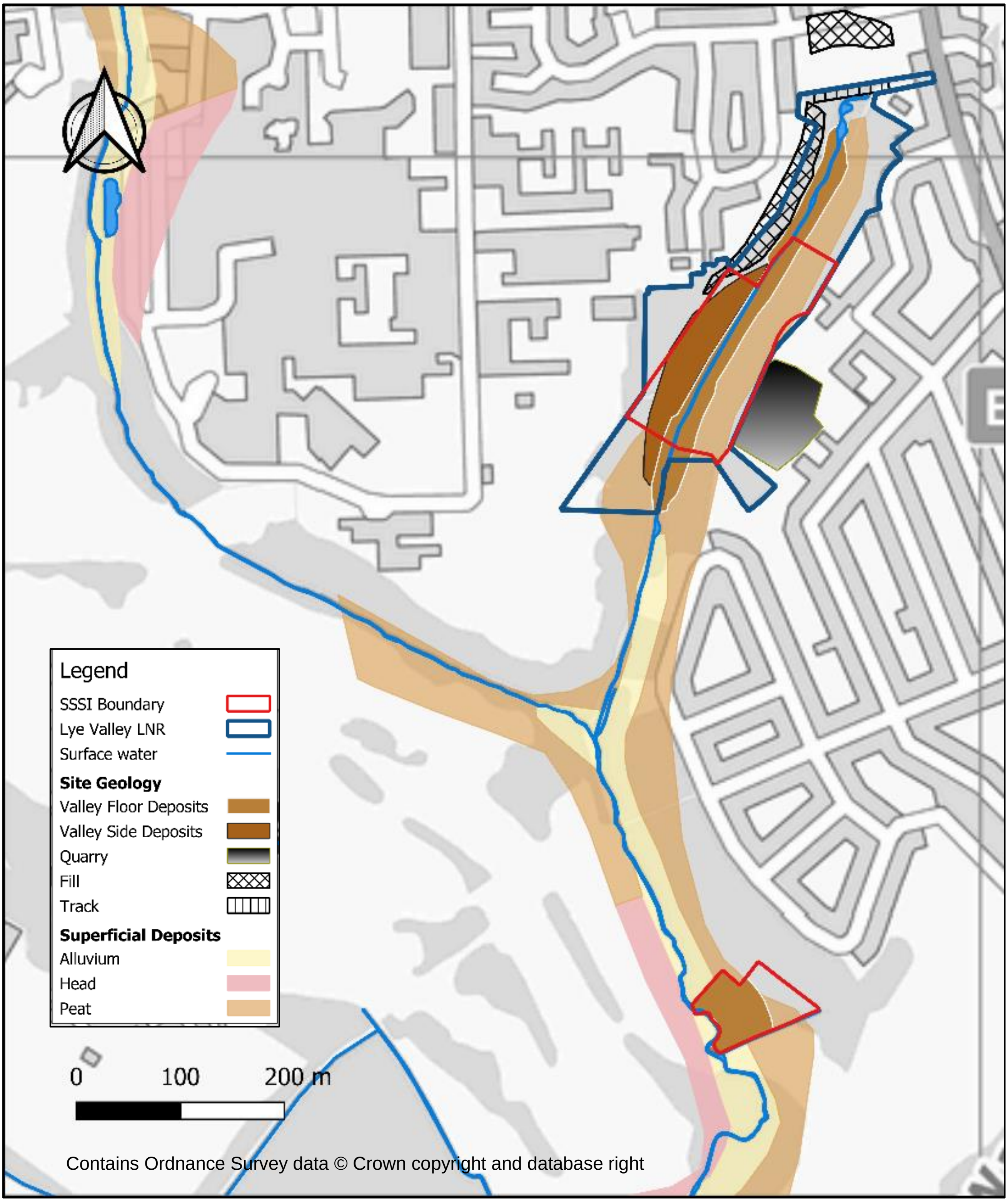


Figure 3-21: Superficial deposits and Made Ground in Lye Valley.

At the South Fen, hand augering by JBA identified that the valley floor comprises a mixture of sands, silts and clays. The surface deposits of the valley floor were organic rich but only around 20cm thick at the auger locations and therefore too thin to be considered as peat (which needs to be of 40cm thick to be defined as peat in England).

3.7.7 Bedrock Geology

The bedrock geology at the site and study area is shown in Figure 3-22. The mapping shows that the bedrock underlying the site comprises largely of strata forming the Corallian Group overlain by the Ampthill Clay Formation. The Ampthill Clay Formation consists of 5-23m thick grey mudstone with sporadic bands of limestone nodules.

The Corallian Group formed is Oxfordian Age (Upper Jurassic), is approximately 100m thick and comprises a complex succession of interdigitating limestones, marls, sandstones, sands, siltstones, silts, spiculites and mudstones. Within the Corallian Group there are the following units:

- Wheatley Limestone Member (0-26m) - including "Coral Rag", shell-fragment and coralline limestone
- Littlemore Member (0-12m) - marl and limestone
- Oakley Member (0-5m) - marl and limestone
- Beckley Sand Member (0-25m) - sand and calcareous sandstone
- Arngrove Spiculite Member (0-5m) - siliceous spiculitic sandstone
- Temple Cowley Member (0-12m) - fine-grained sandstones, sands and siltstones

The topographic highs within the Boundary Brook catchment are mapped as the Wheatley Limestone member. Borehole records show that the bedrock surrounding Lye Valley SSSI is the Beckley Sand Member. Available borehole logs report the member to be a fine-grained, clay/silty sandstone.

Underlying the Beckley Sand Member and exposed beneath the channels of Lye Brook and Boundary brook is the Temple Cowley Member.

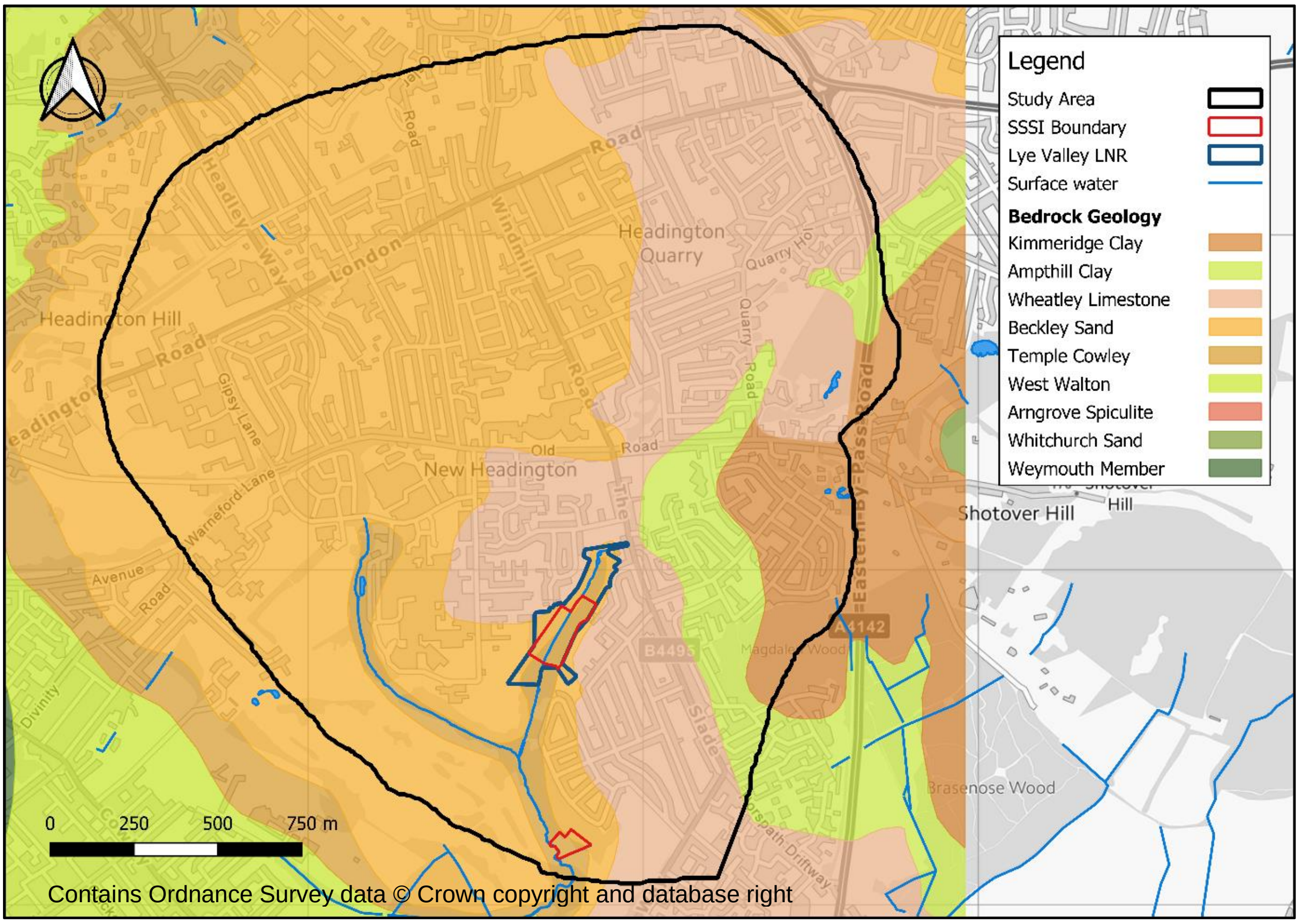


Figure 3-22: Bedrock geology.

3.7.7.1 Bedrock Structures in the SSSI Valley

This section summarises JBA's understanding of the bedrock structures in the Lye Valley North and South SSSI. Intrusive analysis and geological conceptualisations along cross sections have been completed based on the ground investigation borehole logs from BGS GeoIndex (WSP and Geotechnical Engineering Ltd).

Review of boreholes shows the bedrock underlying the SSSI Valley has the following characteristics:

- Beckley Sand Member (6.0m to >9.0m thick): interbedded yellowish brown calcareous sands and limestone
- Limestone lenses (0.1-1.0m thick): weathered grey limestone bands and lenses within the Beckley Sand.
- Temple Cowley Member (> 5m thick): firm grey silty sandy clay.

A series of example boreholes logs below are annotated to show these features:

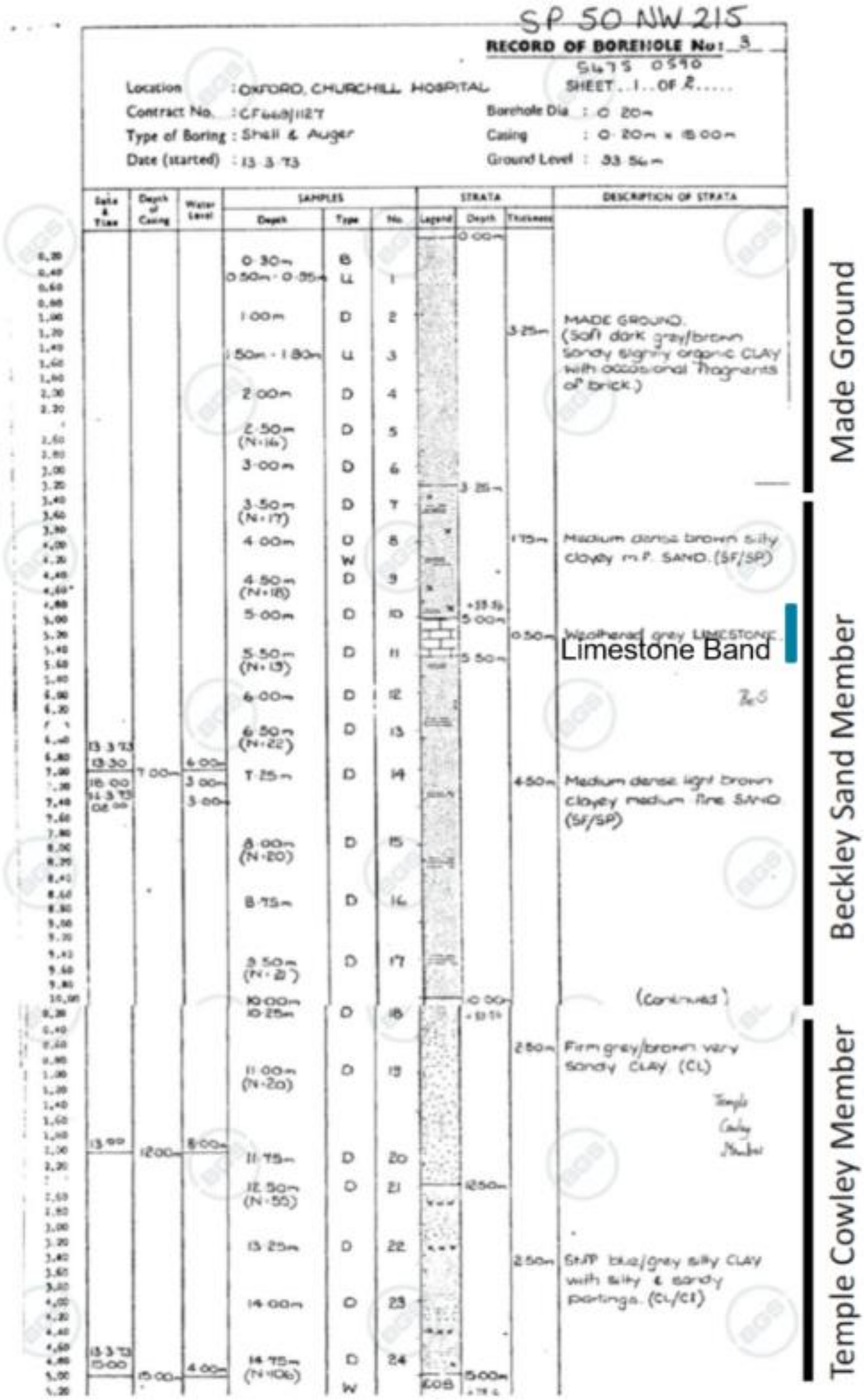


Figure 3-23: BGS GeoIndex borehole SP50NW215 log (1973).

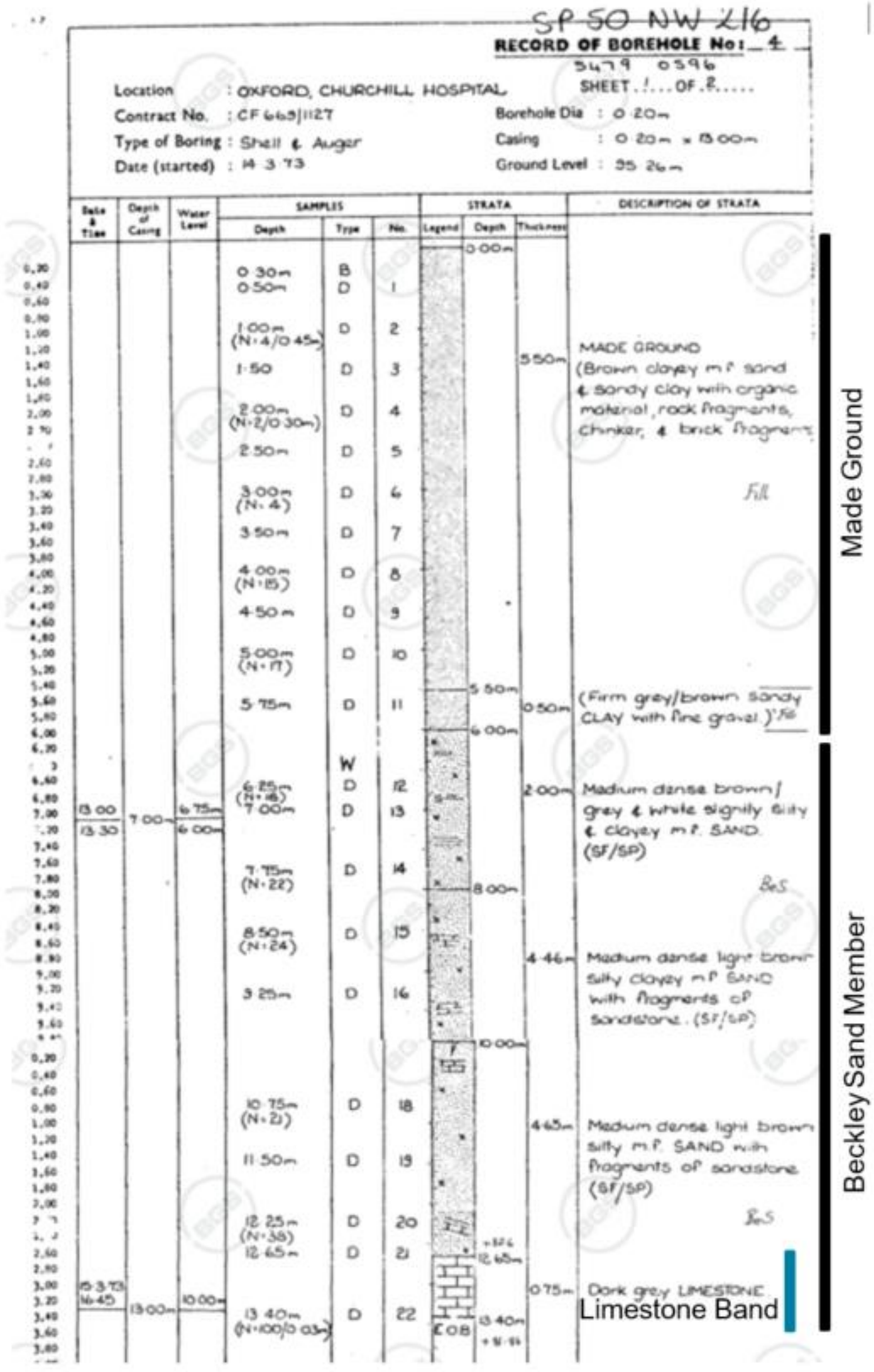


Figure 3-24: BGS GeoIndex borehole SP50NW216 log (1973).

The following paragraphs describes the bedrock structures in the two SSSI Units. Figure 3-25 shows three cross sections through the Lye Valley North SSSI.

Figure 3-26 shows a geological model along AA' parallel to the Lye Brook approximately 25m to the west of the site. This shows a large curvy band of limestone which outcrops on the hill side to the west of Lye Valley. This band of limestone had been historically quarried on the other side of the Valley. Figure 3-27 shows a geological model along BB'. At this point the limestone band appears high up the hillside. The limestone outcrop on the south-east side of the valley has been quarried out. Figure 3-28 shows a geological model along CC'. At this point the limestone band dips and lies beneath the valley floor.

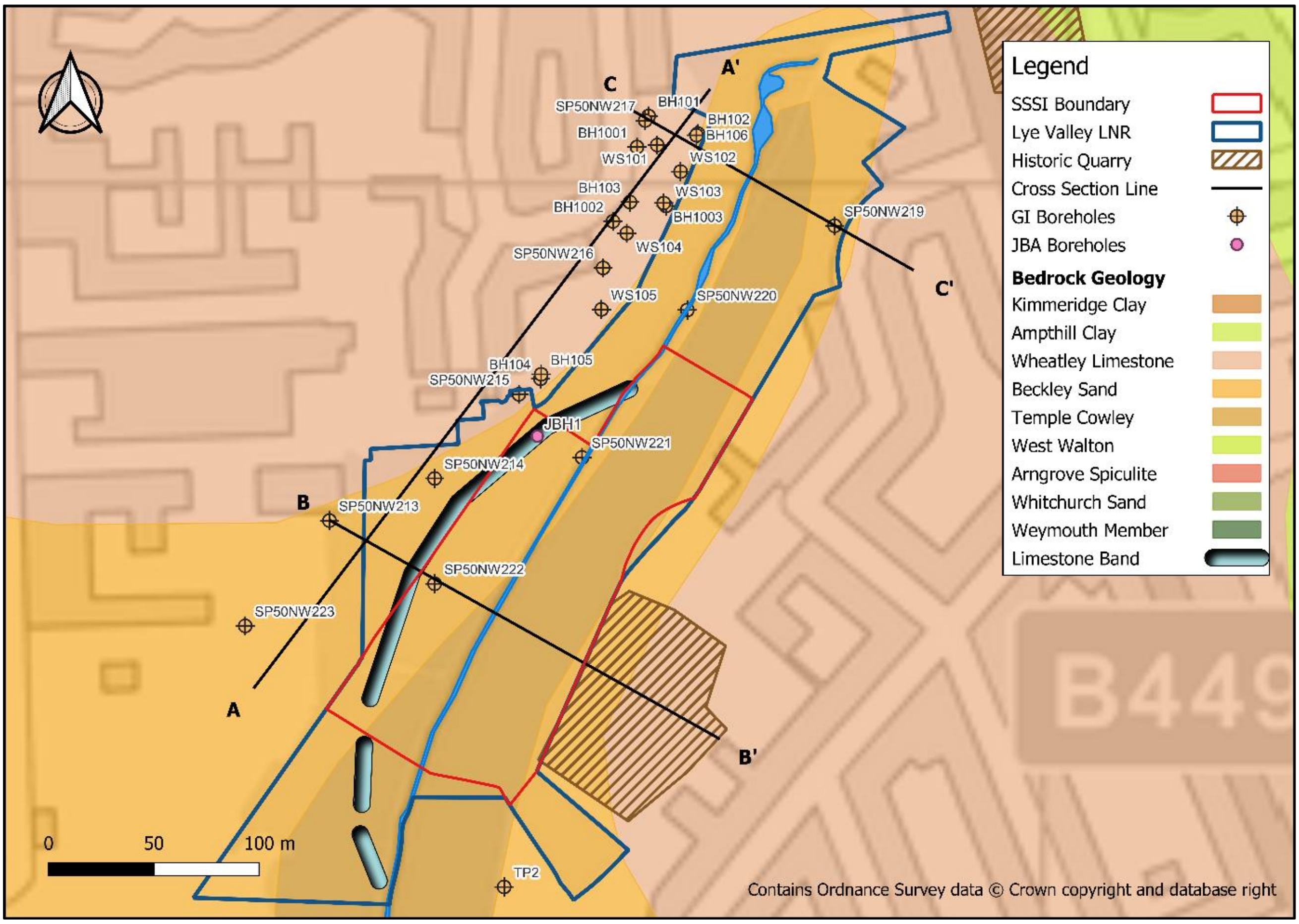


Figure 3-25: Lines of conceptual model cross sections (Lye Valley North SSSI).

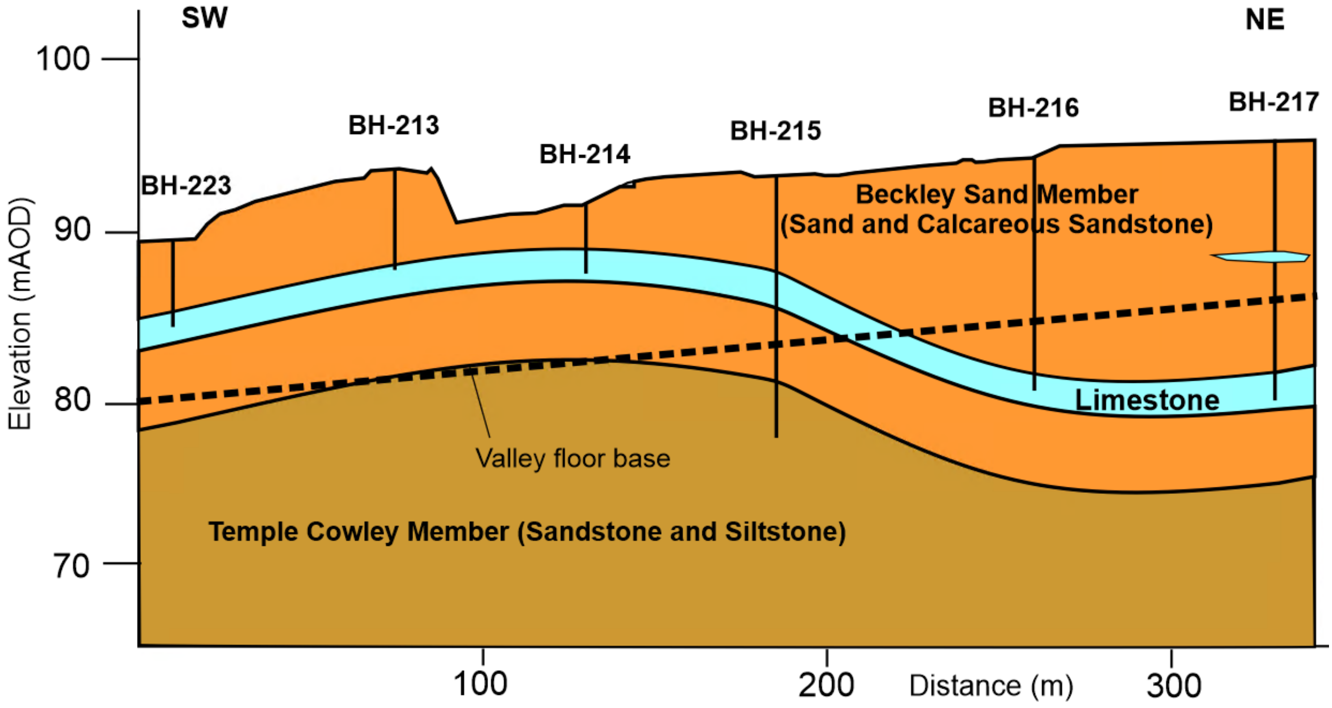


Figure 3-26: Geological conceptual model (not to exact scale) (cross section AA').

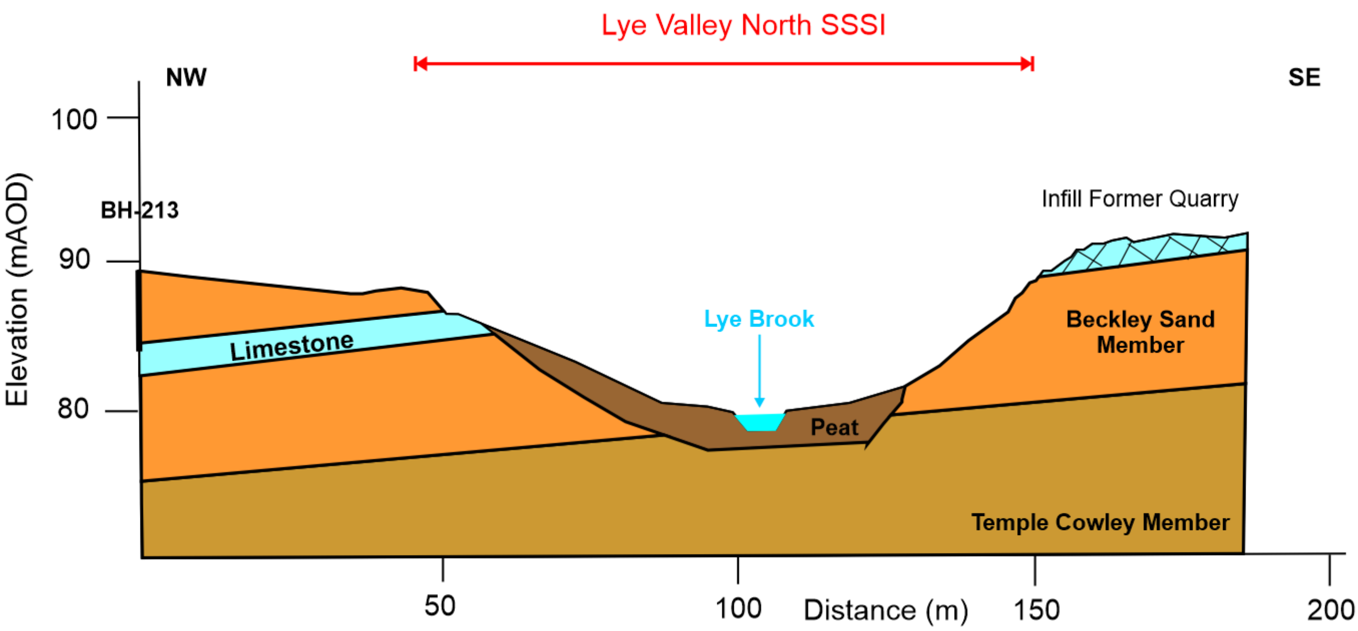


Figure 3-27: Geological conceptual model (not to exact scale) (cross section BB').

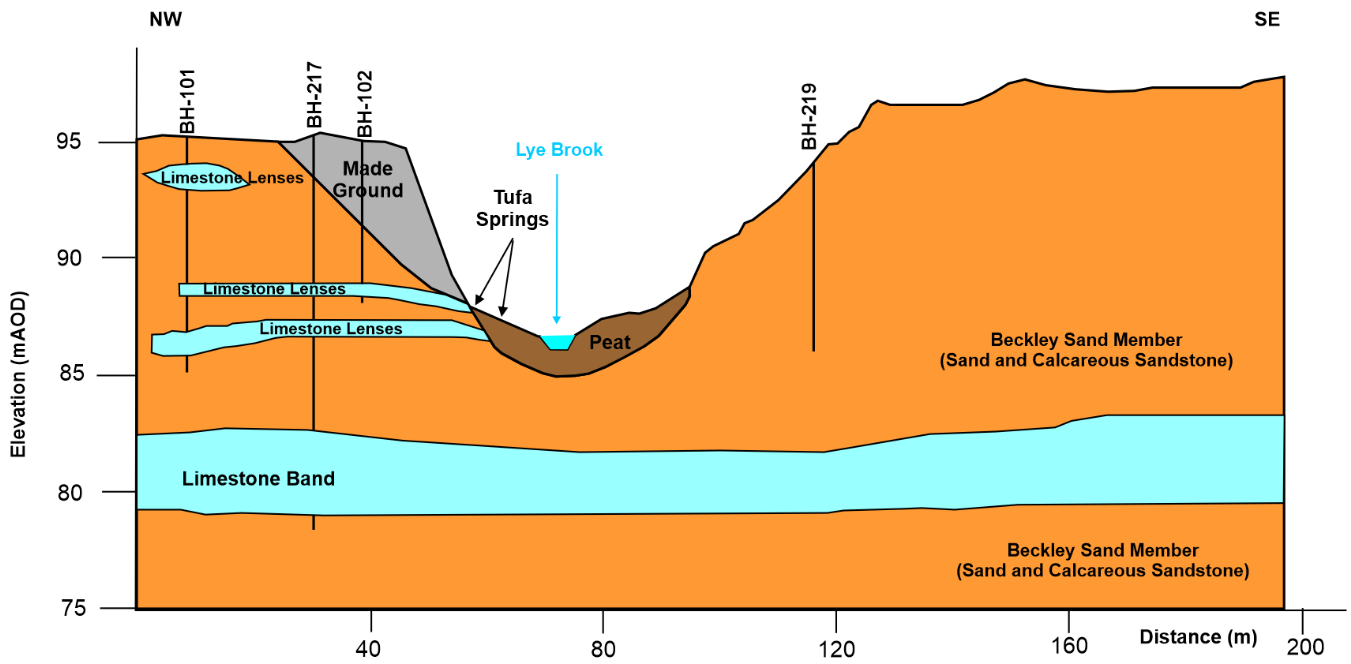


Figure 3-28: Geological conceptual model (not to exact scale) (cross section CC').

Figure 3-29 shows a line of cross section through the Lye Valley South SSSI and Figure 3-30 shows a geological model along DD'. The base of the valley at this point is mapped as being formed of the Temple Cowley Formation. BGS or planning application borehole records are available here to confirm this structure.

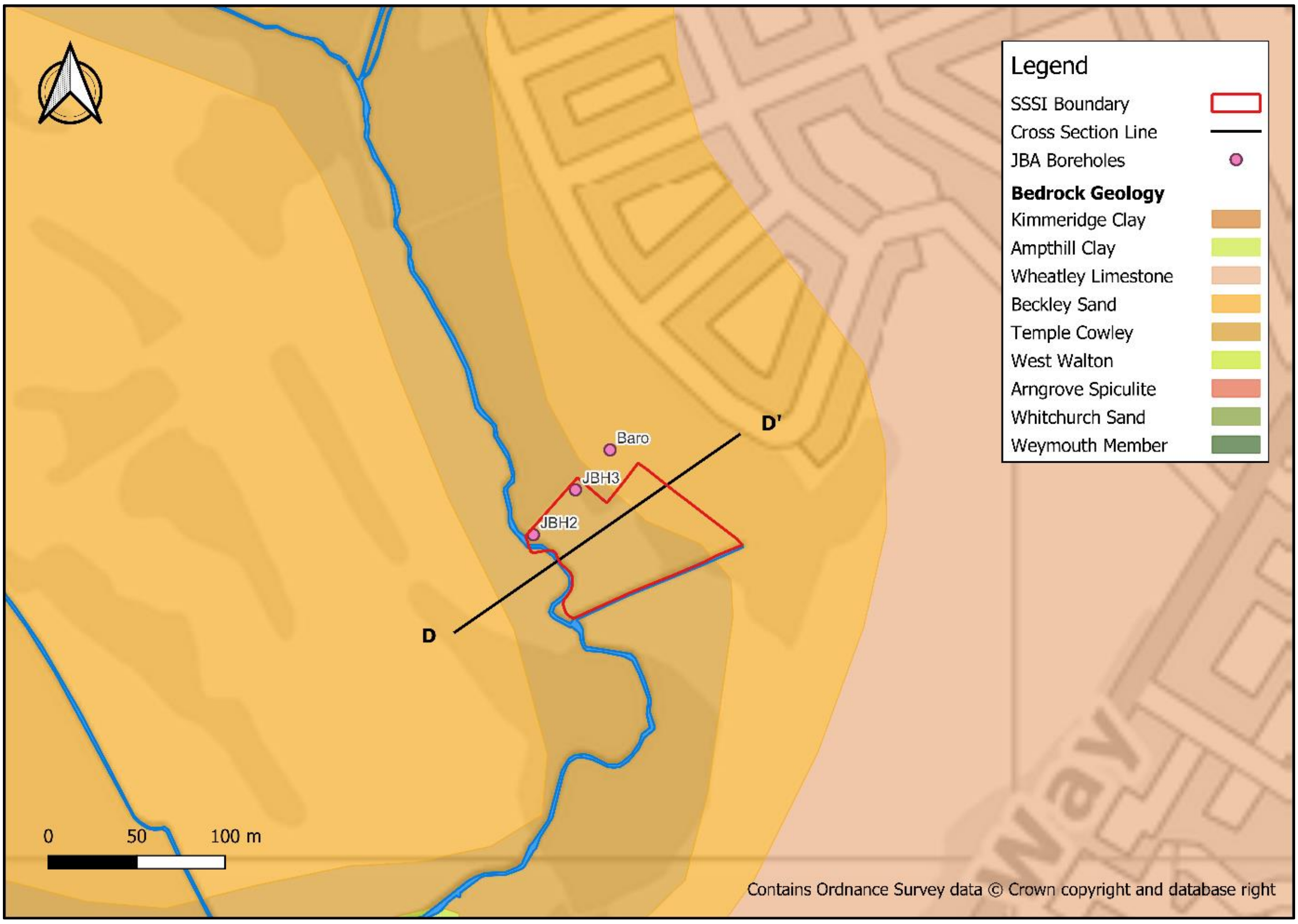


Figure 3-29: Line of conceptual model cross section (Lye Valley South SSSI).

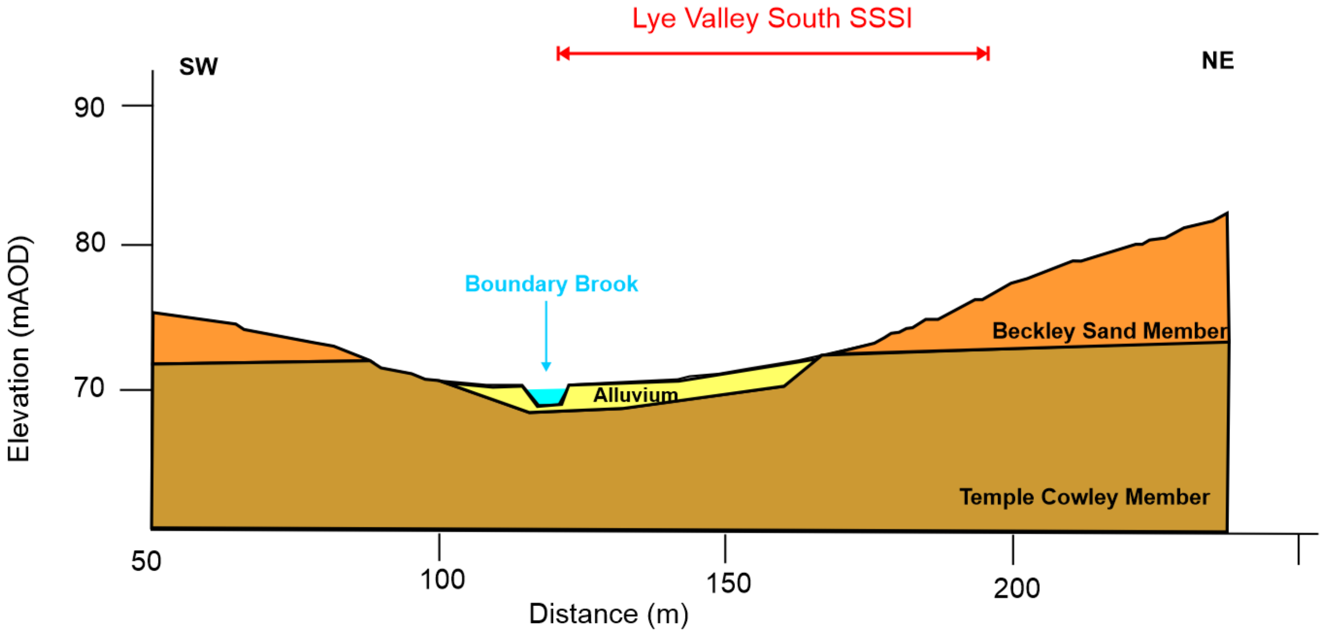


Figure 3-30: Geological conceptual model (not to exact scale) (cross section DD').

3.7.8 Mining and Mineral Extraction

3.7.8.1 Introduction

The Headington area of Oxford had been historically heavily quarried for both freestone and limestone and has played a prominent role in most accounts of Corallian stratigraphy[7].

The first evidence of quarrying in Headington comes from Etheldred's charter to St Frideswide's Priory of 1004, which mentions a "fulen pitte" as a landmark[8].

Headington stone was the main construction material for many Oxford buildings from the end of the fourteenth to the middle of the eighteenth century. Many of the stones used to build the walls along the alleyways of the quarry are made of local Coral Rag and contain fossils. Figure 3-31 and Figure 3-32 shows the historical quarries within the study area.

Figure 3-31: Historical quarrying in Headington area of Oxford[9].

[7] British Upper Jurassic Stratigraphy (Oxfordian to Kimmeridgian); J.K. Wright & B.M. Cox
[8] Headington history: The quarries; Introduction
[9] Magdalen (Workhouse) Quarry, Headington

The Magdalen Quarry (formerly known as Workhouse or the Corporation Pit) and Rock Edge Quarry (formerly known as Crossroads Pit) are now designated as Sites of Scientific Special Interest.

3.7.8.2 Magdalen Quarry

Magdalen Quarry has its earliest known reference in 1610 (Arkel, 1947, p.49). The quarry was worked for building stone until just before World War I. Since then it has deteriorated, but has recently been cleaned up and fenced off, and is now managed as a nature reserve by Oxford City Council. The quarry displays fine E-W- and N-S-trending faces some 50m in length where lateral facies changes in carbonate rocks of Corallian Formation Group can be followed closely. The rocks exposed in the cliff face are of Upper Jurassic age, deposited during the Oxfordian Stage. Rocks of a similar age are seen at Rock Edge Quarry, 1km to the south-east. A 60m long, 2.5m (maximum) high rock face is exposed along the south side of the site.

3.7.8.3 Rock Edge Quarry

Rock Edge Quarry (also known as Crossroads Quarry) presents a fine NNE-SSW-trending exposure some 100m in length where lateral facies changes in carbonate rocks can be closely followed. The rocks exposed in the cliff face are of Upper Jurassic age and belong to the Corallian Formation which comprises the Coral Rag and Headington Stone Members which laterally pass into the Wheatley Limestone Member. They are underlain by the Beckley Sand member and overlain by the Ampthill Clay and Kimmeridge Clay Formations.

3.7.8.4 Other quarry works

Other pits and quarries within the local area of Headington are: Jack Phillips's Pit, Vicarage Quarry, Blondin or Munt's Pit, Clayhills Pit (also known as St Ebba's Pit), Harry Bear's Pit, Coppock's Quarry, Mason's Pit, Pound House Quarry and Hundred Acres Pit.

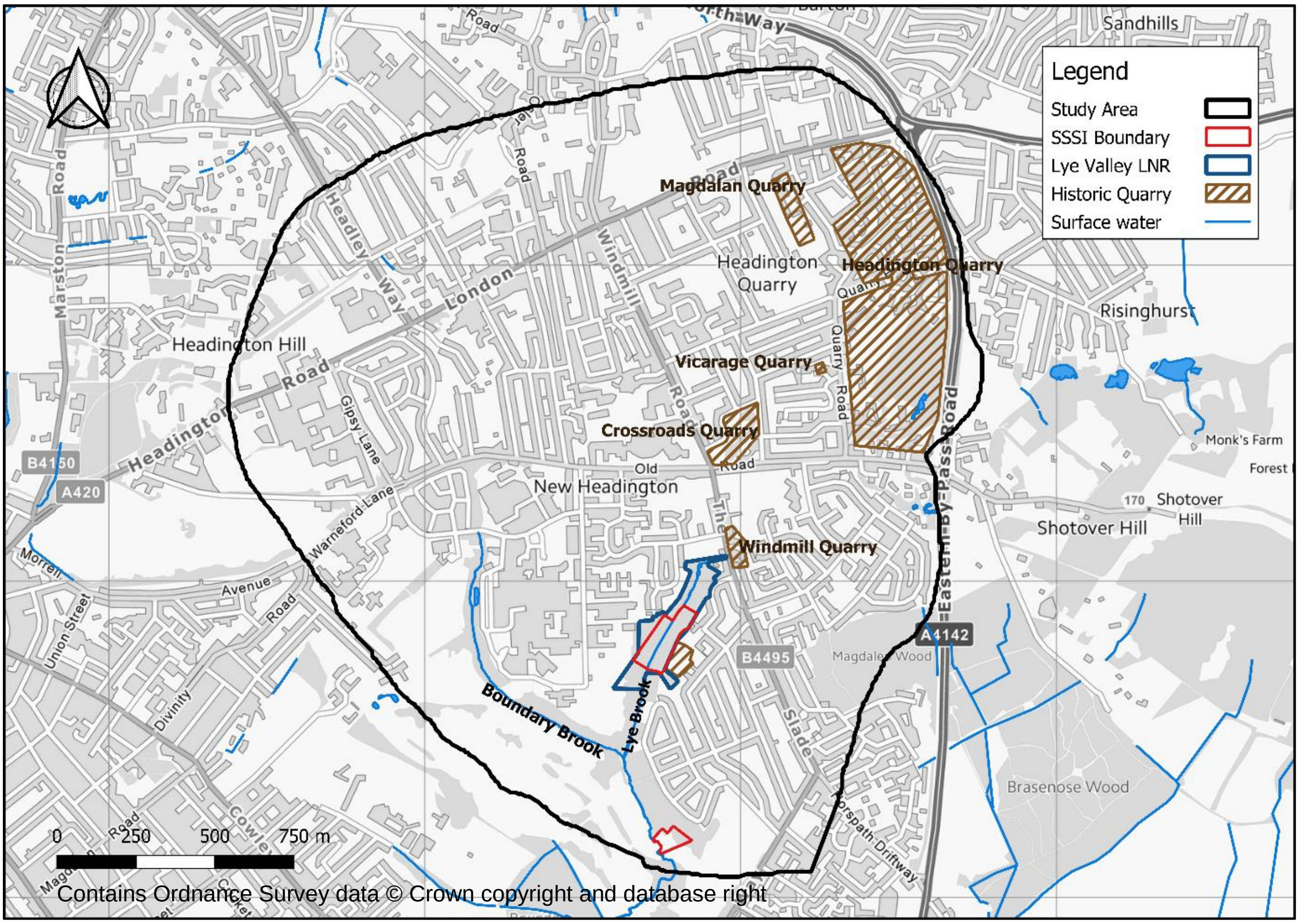


Figure 3-32: Historical quarries.

Figure 3-33 is the locality map for Cross Road Quarry and Magdalen Quarry which shows the outcrop of the Corallian limestone from BGS sheet 273 (Thames).

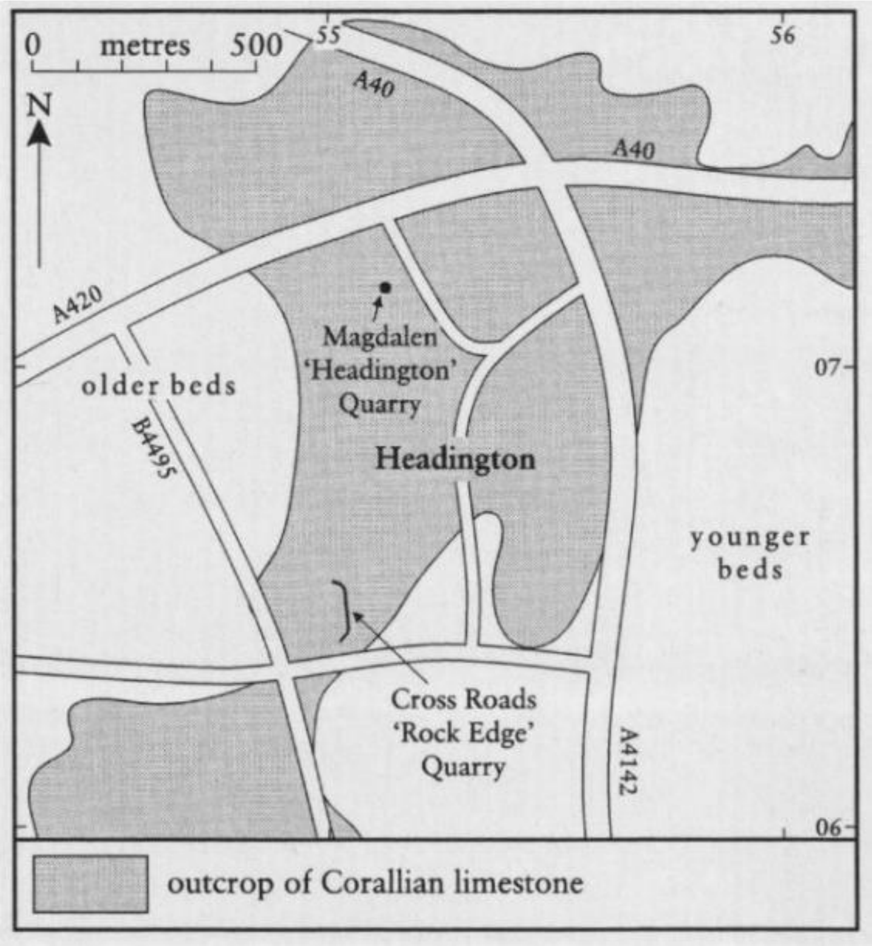


Figure 3-33: Outcrop of the Corallian limestone (British Upper Jurassic Stratigraphy).

Figure 3-34 shows the correlation of sections in Magdalen Quarry, Rock Edge Quarry and Windmill Quarry, showing the transition from Coral Rag reef facies on the right into Wheatley Limestone facies on the left. Figure 3-35 also shows the lateral carbonate transitional relationships of the Corallian rock types around Oxford.

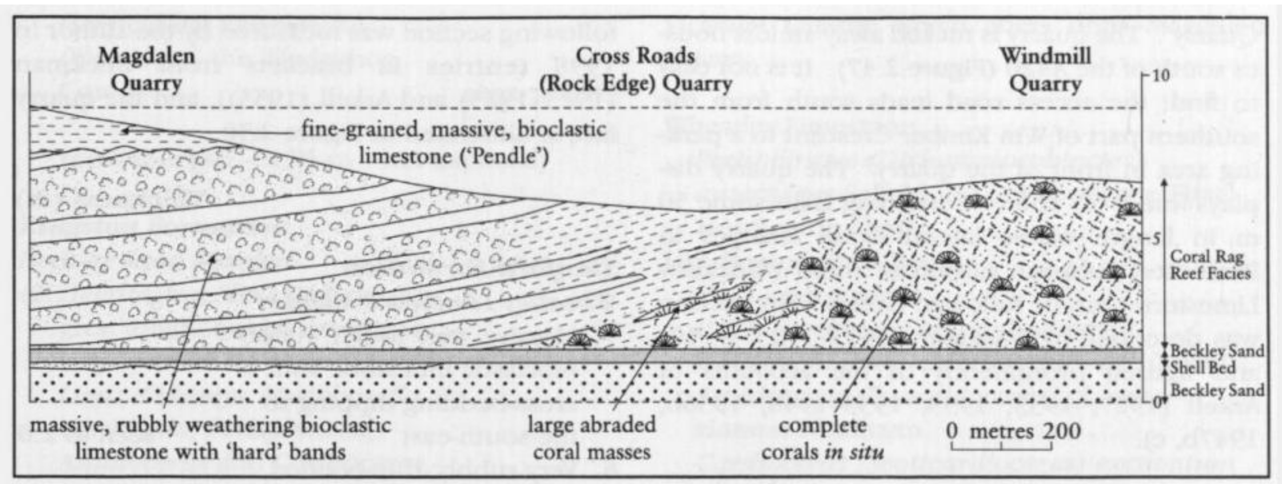


Figure 3-34: Transition of Corallian rock types from Windmill Quarry to Magdalen Quarry (British Upper Jurassic Stratigraphy).

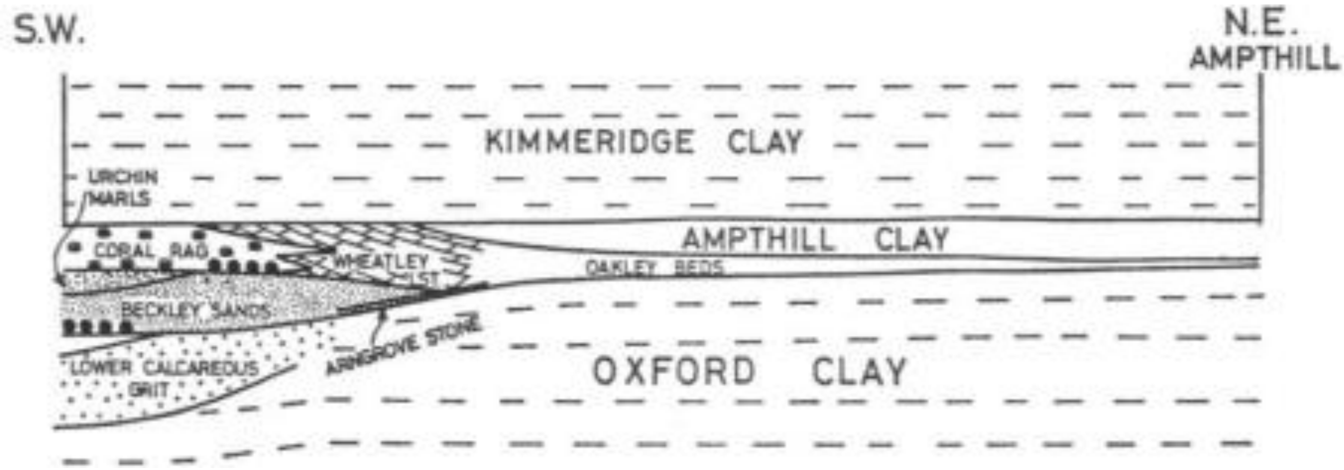


Figure 3-35: Transition of Corallian rock types around Oxford[10].

Figure 3-36 shows the geology and rock types within the Crossroads Quarry.

Figure 3-36: Outcrops at Crossroad Quarry.

[10] http://www.friendsoflyevalley.org.uk/rockedge/pdf/OGT_RockEdge_2017.pdf

3.7.8.5 Quarry adjacent to the Lye Valley North SSSI

Based on historic maps of National Library of Scotland and Headington history: The quarries, it is concluded that the Hundred Acres Pit (also known as Stone Pit or Wood Farm Pit) is the quarry adjacent to the Lye Valley North SSSI boundary on the eastern hill side. This quarry was privately owned by Thomas White, the farmer at Wood Farm, in the late nineteenth century. A historical aerial photograph taken from the north-west in 1928 is available at this link (Historic England archive).

GroundSure's Historical Land Use Database derived from 1:10,560 and 1:10,000 scale historical mapping (Affordable Housing: Phase 1 Ground Condition Assessment for Warren Crescent report; December 2012) shows the following Historical Surface Ground Working Features surrounding the Lye Valley North SSSI:

Direction	NGR	Use	Date
East	454774 , 205766	Refuse Heap	1956
East	454824 , 205817	Stone Pit	1898
East	454825 , 205800	Unspecified Quarry	1938
East	454825 , 205800	Unspecified Quarry	1910

The following Current Ground Workings information is also provided by the British Geological Society:

Direction	NGR	Commodity Produced	Pit Name	Type of Working	Status
East	454829 , 205803	Limestone	Wood Farm	A surface mineral working.	Ceased

3.8 Hydrogeology

3.8.1 Aquifer Properties

The geological strata have been assessed for their hydrogeological properties using the BGS's geological maps and the Environment Agency Aquifer Designation mapping (Table 3-2).

The Corallian Group is classified as a Secondary A aquifer. It is considered a moderately productive aquifer with yields in region of 5-10 L/s in Oxfordshire. The Secondary A category describes permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases form an important source of baseflow to rivers.

The alluvium is also classified as a Secondary A aquifer while Head is classified as Secondary (undifferentiated) Aquifer and Peat as an Unproductive Strata. Secondary undifferentiated are aquifers where it is not possible to apply either a Secondary A or B definition because of the variable characteristics of the rock type. These have only a minor value. Unproductive strata are largely unable to provide usable water supplies and are unlikely to have surface water. Figure 3-37 and Figure 3-38 show the superficial deposits and bedrock units aquifer designations.

Table 3-2 - Hydrogeology of bedrock geology at Lye Valley.

Drift/Bedrock	Unit	Environment Agency Aquifer Classification
Superficial deposits	Peat	Unproductive
Superficial deposits	Alluvium	Secondary A Aquifer
Superficial deposits	Head	Secondary (Undifferentiated)
Bedrock	Corallian Group (Wheatley Limestone, Beckley Sand, and Temple Cowley Member)	Secondary A Aquifer

Explanation of aquifer classes (from Environment Agency website) Principal aquifers - "may support water supply and/or baseflow to rivers on a strategic scale." Secondary A aquifers - "permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of baseflow to rivers." Secondary B aquifers - "predominantly lower permeability layers which may store and yield limited amounts of groundwater."

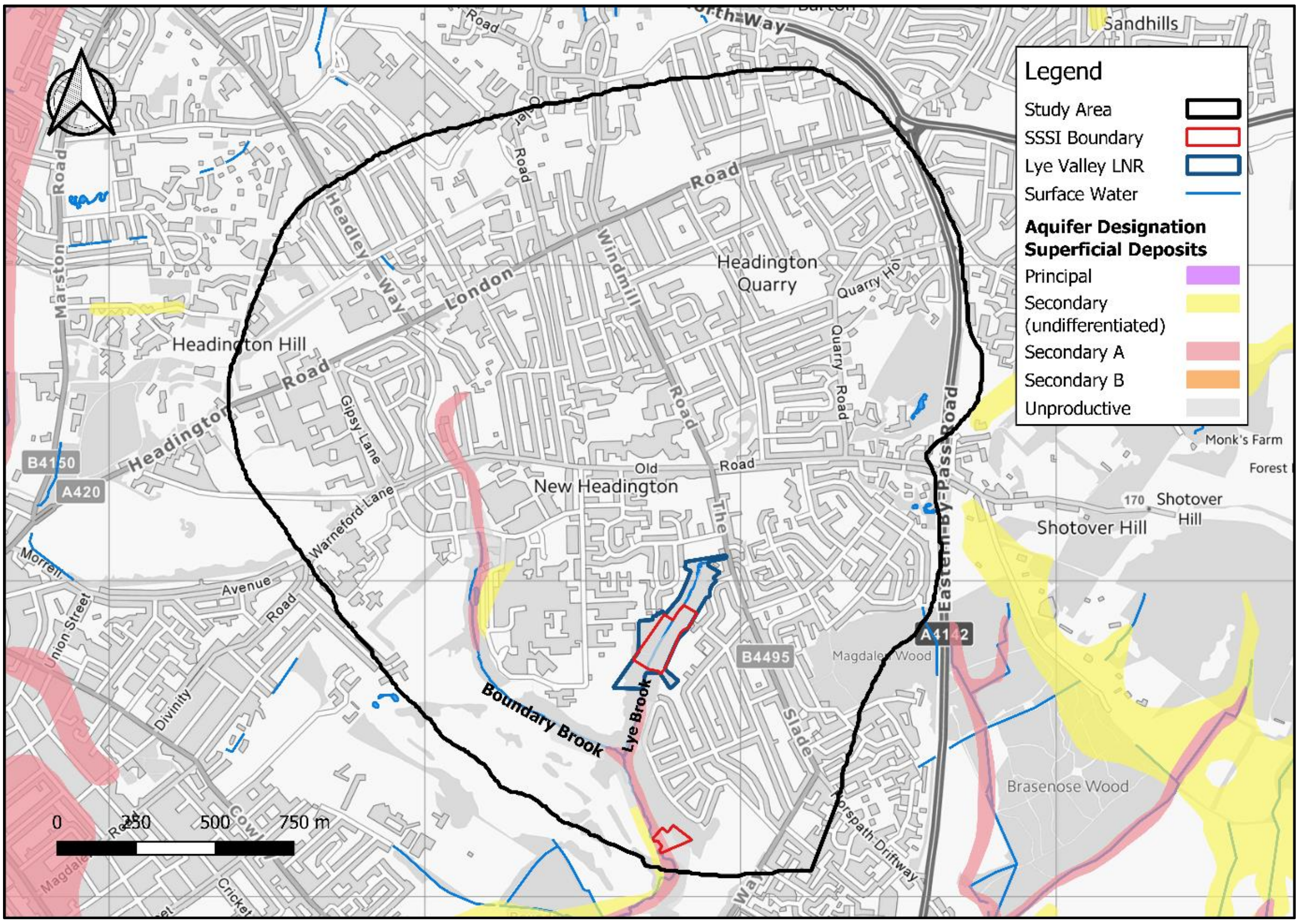


Figure 3-37: Aquifer designations - superficial deposits.

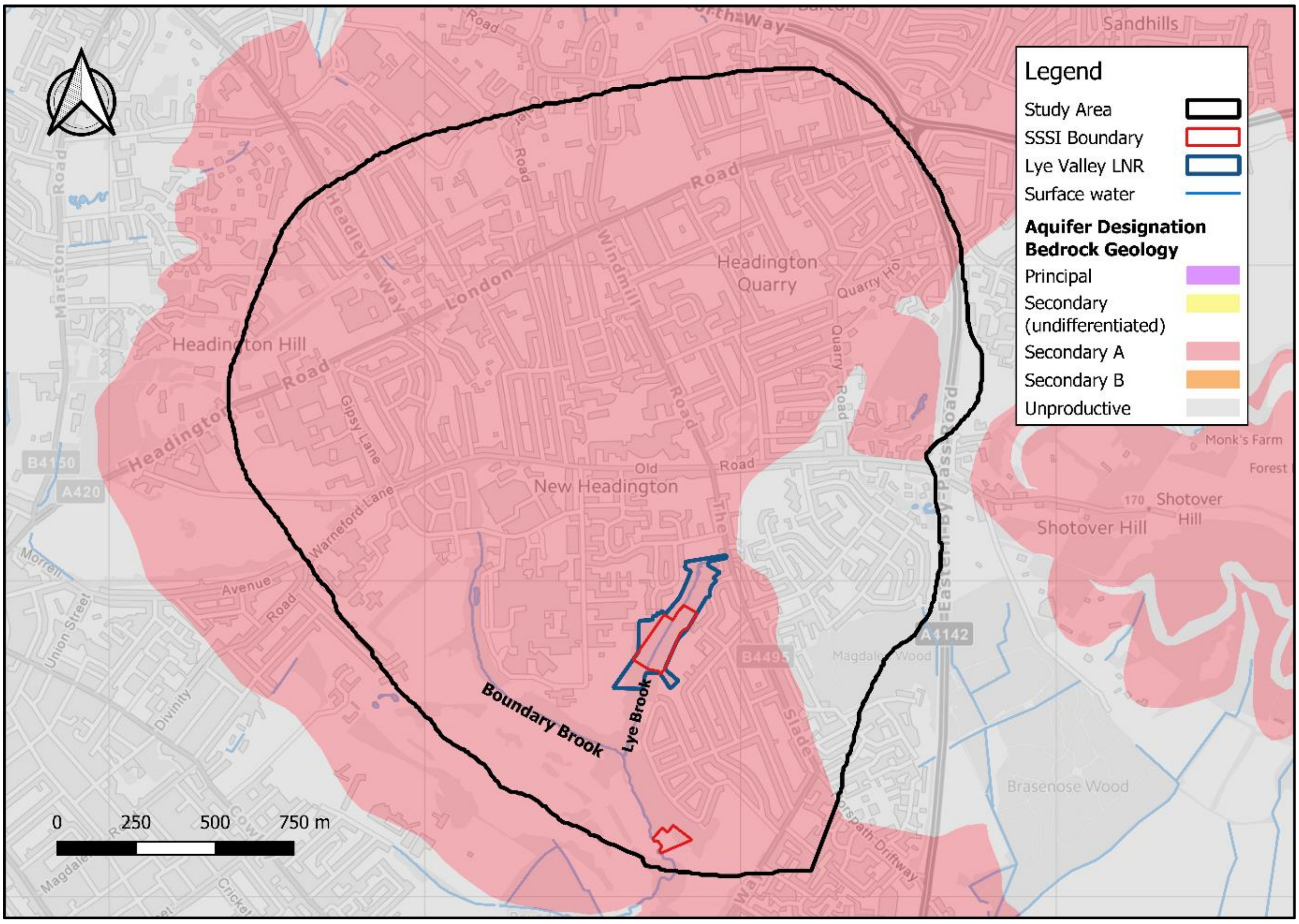


Figure 3-38: Aquifer designations - bedrock.

3.8.2 Aquifer Vulnerability

The EA's groundwater vulnerability mapping indicates the Wheatley Limestone and Beckley Sands are classified as high vulnerability. It means that the groundwater resources of this area have limited natural protection, reflecting that there are very limited superficial deposits in the area to protect them. This results in a high overall pollution risk to groundwater from surface activities. Activities in this area are likely to require additional measures over and above good practice pollution prevention requirements to ensure that groundwater is not impacted.

3.8.3 Local Hydrogeology

The following hydrogeological features are of note:

- Both SSSI Units
    - The Beckley Sandstone Member has variable permeability, with interbedded sandstones (moderate permeability) and limestones (highly permeable):
    - The Temple Cowley Member which lies under Beckley Sandstone contains clays and therefore is likely to be less permeable than the overlying unit.
- Lye Valley North (see Figure 3-39) is characterised by springs across the SSSI, some of which are tufa forming, while others are ochre stained. This may reflect

the local geological bands that they discharge from (e.g. the tufa being more likely to issue from limestone beds). Two seepage faces are also evident (see Figure 3-39), the upper is associated with the outcropping of the limestone band in Lye Valley and the second is likely to represent the regional groundwater table discharging at the junction between the valley floor deposits and the Beckley Sand Member.

- South Fen (see Figure 3-40) is characterised by a seepage face at the base of the slope, possibly at the junction between the Beckley Sand Member and the Temple Cowley Member. Webb (2013) identified a spring further up the hill in the gardens. Potentially this relates to an outcropping of a limestone band but there is no site investigation to confirm this.

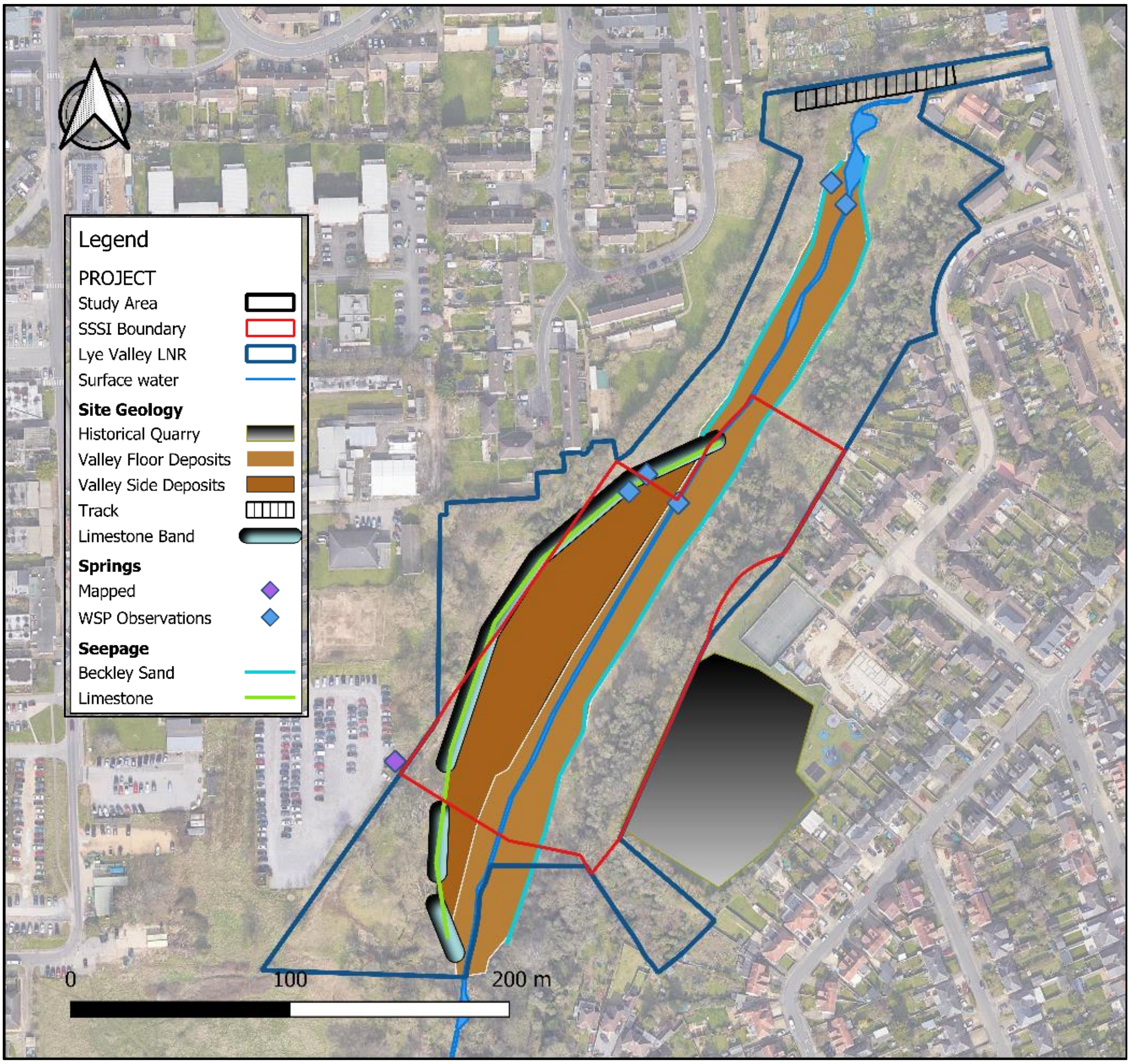


Figure 3-39: Hydrogeological features of Lye Valley North.

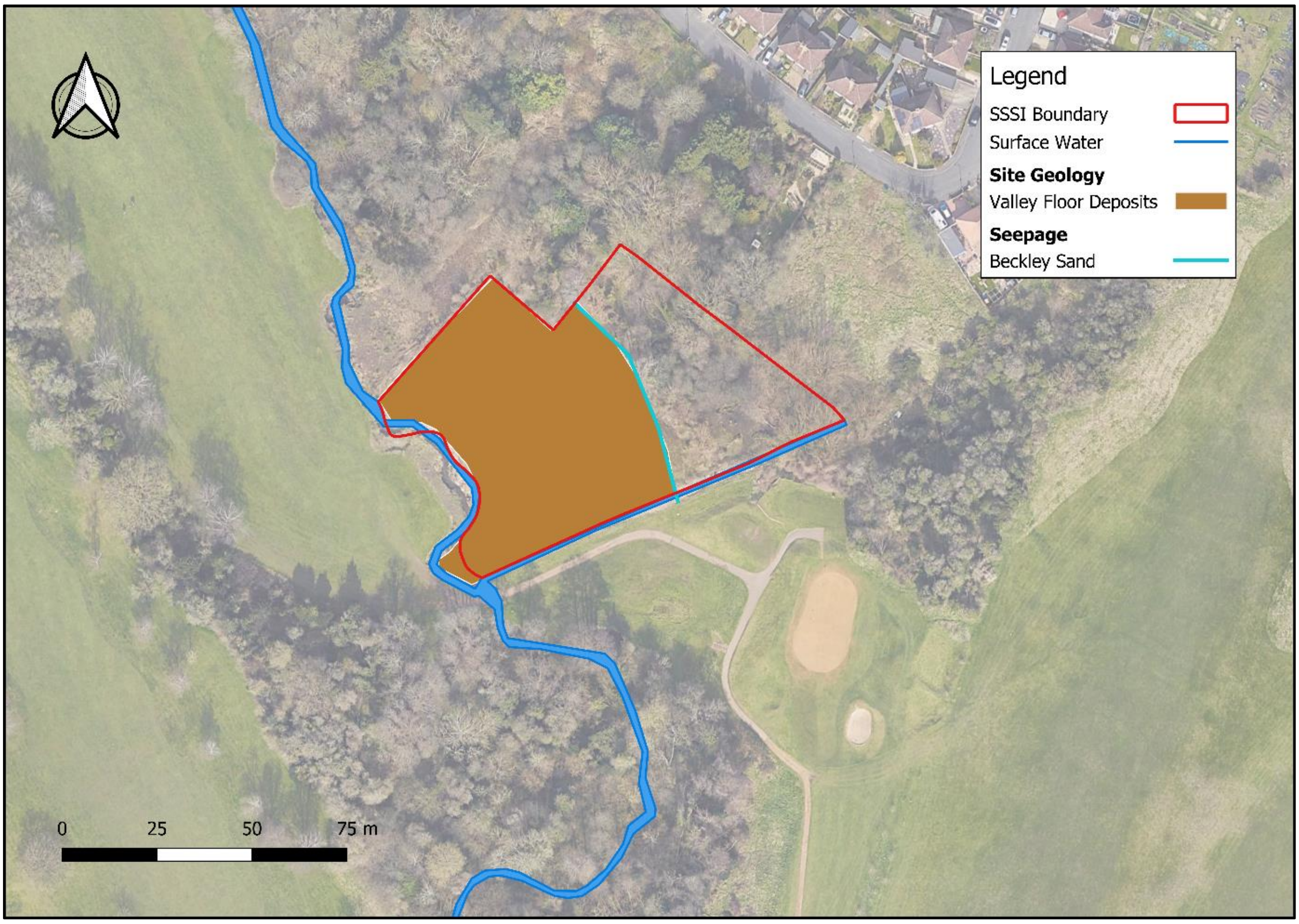


Figure 3-40: Hydrogeological features of South Fen.

3.8.4 Groundwater Levels

A shallow groundwater monitoring network was installed on the SSSI by JBA in February 2023 (see Appendix A). Their locations are shown in Figure 3-41, with the results shown in Figure 3-42. A simple description of the results is given in Table 3-3. Figure 3-43 shows that when groundwater monitoring started groundwater levels were at a 5 year low regionally before reaching a five year high at the end of the period, with groundwater levels peaking in the following winter after the monitoring period finished. This suggests that the monitoring period covered a good range of groundwater conditions, with the summer of 2023 representing a relatively dry period and the winter of 2023-24 a wet one.

The overall rationale for additional monitoring was to improve the understanding of the shallow groundwater conditions on site. Extensive monitoring had been conducted on Lye Valley by Adam Bows (2021). The main gap in that array was to assess the extent to which the main limestone band maintained saturated conditions up the valley side. At South Fen, no groundwater monitoring had occurred before so a transect across the wetland was installed to assess how conditions varied across the valley floor and the impact on the incised Boundary Brook on groundwater levels.

Figure 3-41: Monitoring network.

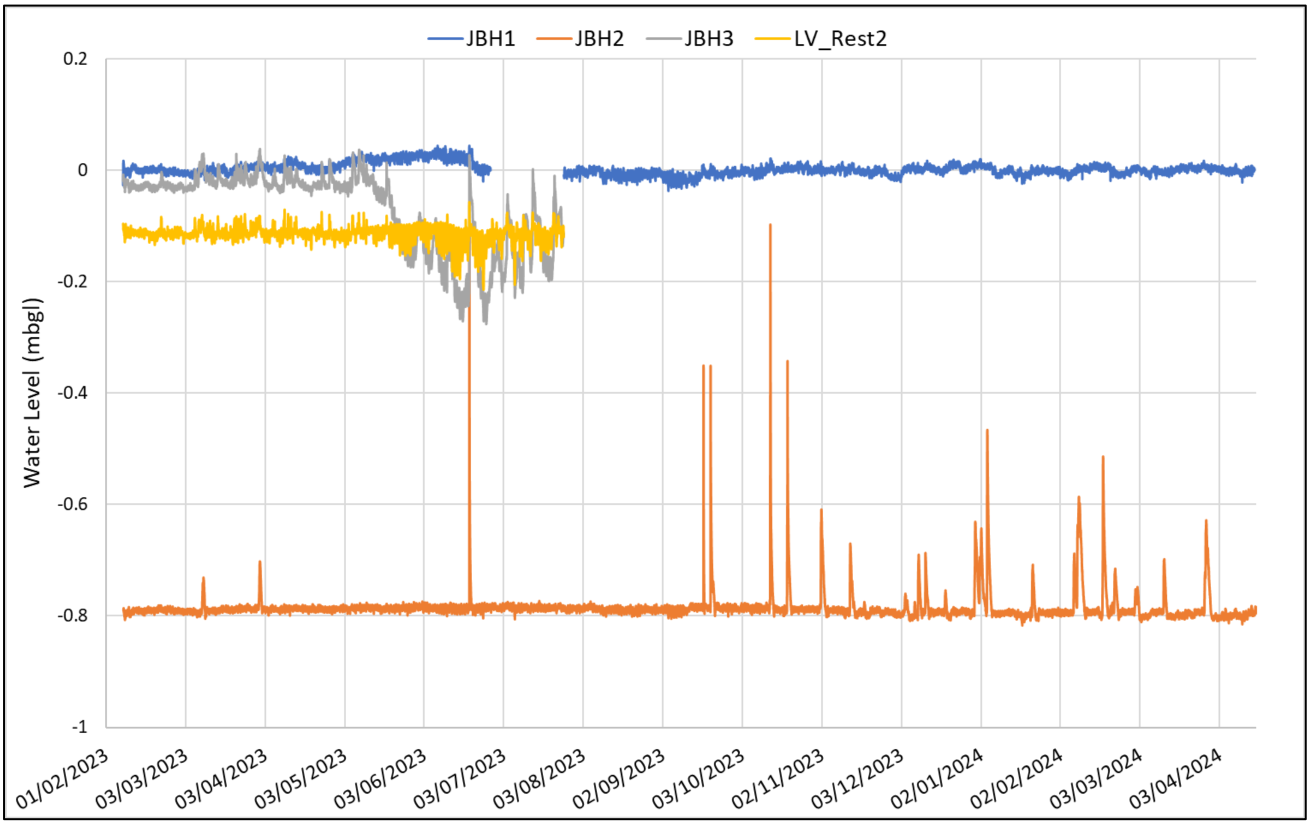


Figure 3-42: Water level monitoring results in metres below ground level.

Table 3-3: Monitoring network descriptions.

Location	Location Description	Water Level Description
JBH1	On the Limestone Seepage Face	Permanently saturated with no seasonal variation.
JBH2	6m from the incised Boundary Brook channel in South Fen	Water levels beneath 0.8mbgl for the majority of the monitoring period. Note the logger lies higher than the water table.
JBH3	Edge of the South Fen, at the base of the valley slope	Saturated through the winter months, and water levels drop on 0.2mbgl in the summer. Note - lost on second download round but data was available for the summer months.
LV-Rest 2	Borehole located in the centre of this plot as part of Adam Bows' MSc (2021), on the slope beneath the limestone seepage face	Very similar to JBH1. Very stable with water table sitting 10cm below surface. It is likely not at the surface due to lying slightly higher than the rest of the surrounding area.

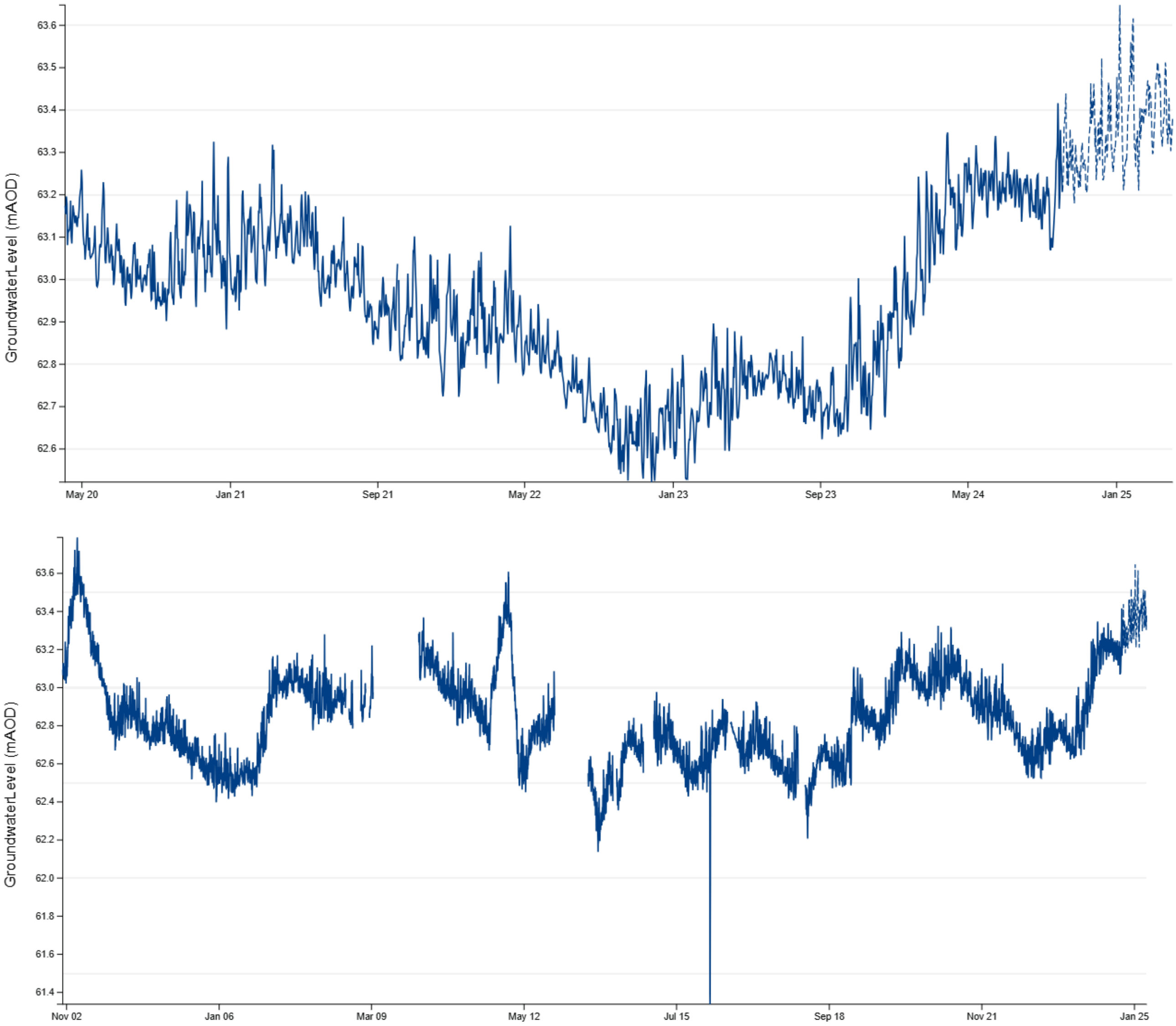


Figure 3-43: Groundwater levels in the Corallian Aquifer at the EA Horspath Monitoring Borehole, Cowley.

Adam Bows' MSc Monitoring network (see Figure 3-45) was monitored through 2020-21 (see Figure 3-44). They showed minimal seasonal variation indicating the groundwater discharges maintained a high water table through the period. LV Bench lies in the valley floor but outside of the zone of drainage impact created by the Lye Brook channel.

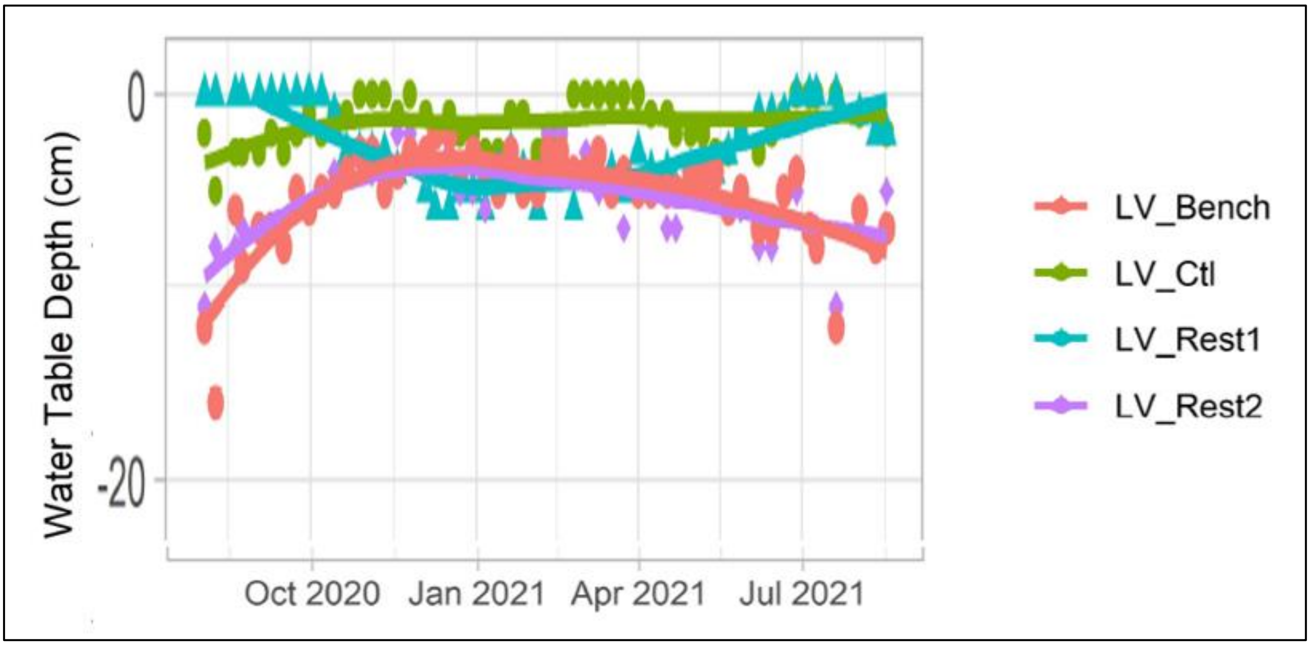


Figure 3-44: Adam Bows' MSc monitoring results.

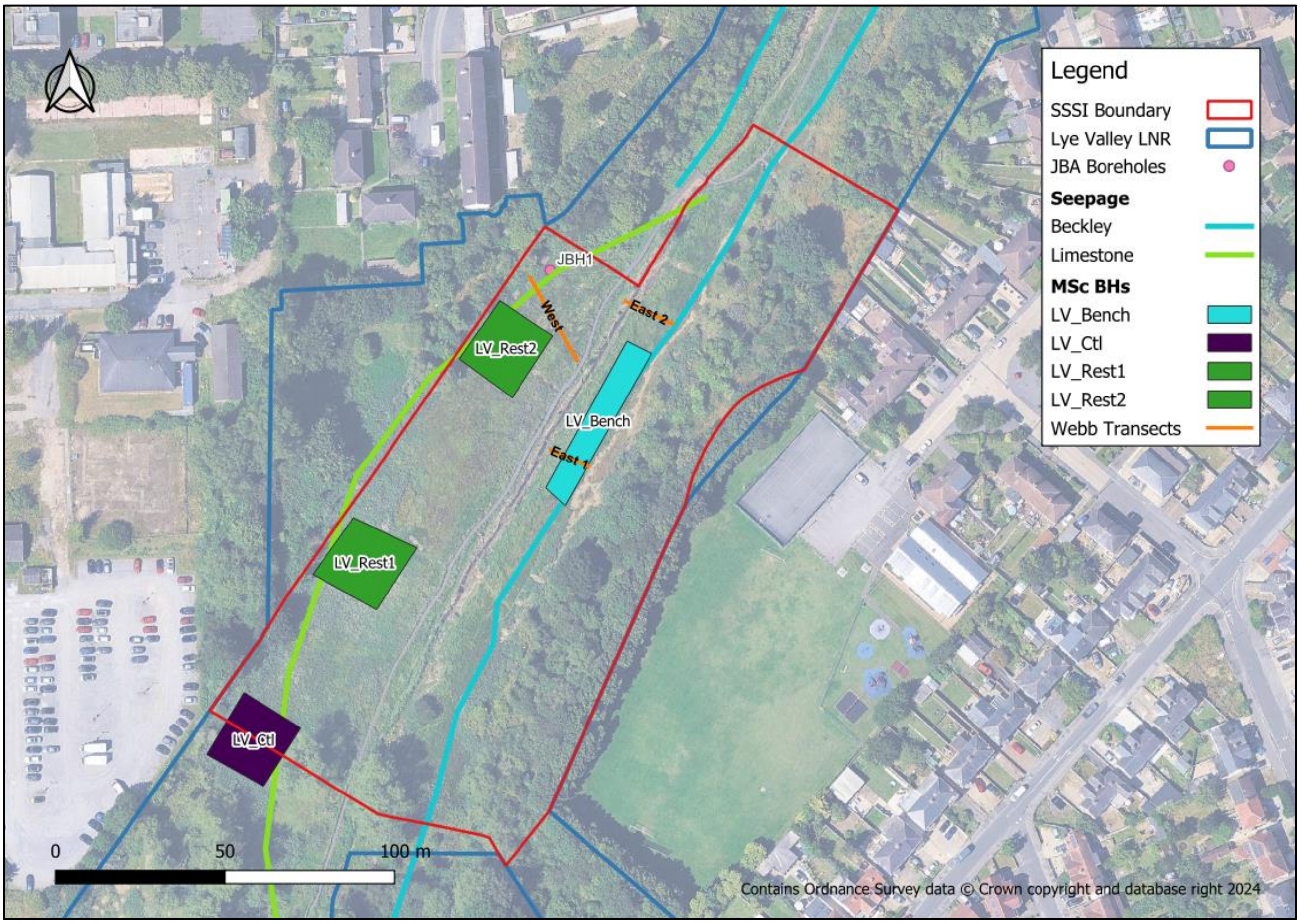


Figure 3-45: Adam Bows' monitoring plots and Webb (2013) North Fen transects.

3.8.5 Ecological Indicators on Groundwater Conditions

Direct water level monitoring is only one data source for water level conditions. Section 2.3.1 notes that when areas of M13 Schoenus nigricans-Juncus subnodulosus mire are drained and "water no longer oozes underfoot in a non-drought summer, can be expected to result in some loss of botanical interest". This means that the distribution of species across the site acts as a long-term record of water level conditions.

Figure 3-46: Drier vegetation around JBH2 close to the brook edge (left) compared to the calcareous fen vegetation at JBH1.

Webb in 2013 conducted two transect studies, one on North Fen (Lye Valley LNR) (2013a) and one on South Fen (2013b) (see Figure 3-45 and Figure 3-47). These support the observations of the site walk-over, showing the drainage impacts on the vegetation of the incised channels.

Webb conducted three transects on North Fen. At East 1 Webb (2013a) states "the rare flowering plants and bryophytes of rich fen (M13b) are restricted to the first 8m of the transect. From 8m to the brook edge a drier community exists, possibly fen meadow, or transitional to meadow". At East 2, Webb states "… first 9m the surface of the fen peat was wet and from 7-10m there was a substantial pool occupied by Chara stonewort. Between 10m and the brook edge at 16m the surface of the peat became merely moist or dry". The LV Bench monitoring location likely reflects the conditions in the first 8m of East 1 and 9m of East 2.

Along the West transect, Webb states "On the North Fen West side there is no evidence of drying along the recorded part of the transect. The variation in plant abundances is due to a past history of cutting and raking or no cutting and raking (combined with arson)". This description aligns with the water level record in JBH1 and LV-Rest2, which are very high and stable. This shows that the limestone band supplied a steady flow of groundwater to the slope during the monitoring period.

Webb conducted one transect at South Fen (see Figure 3-47) concluding:

- "For the first 35m the surface of the fen peat was wet and from 31-32m there was a small open water pool".

- JBH3 lies at the edge of the valley side on this transect and shows a similar pattern of saturation.

- "Between 35 and 40m the surface of the fen peat became merely moist or actually dry and continued in this state to the brook margin at 60m".
- " After 35m there is a clear, sharp, change to a different type of vegetation. Reed and blunt-flowered rush are still present and increased in percentage cover but most of the other good-quality rare fen higher plant species and bryophytes are no longer present"
  - JBH2 lies 6m from the river edge and the water table was constantly below 0.8mbgl. This shows how the incised river channel is drying the surface of the wetland.

Overall, the groundwater monitoring supports the results of the vegetation survey showing that South Fen is an area of groundwater discharge. However, channel incision has lowered water levels in the channel and increased drainage of the SSSI, suppressing the water table close to the channel.

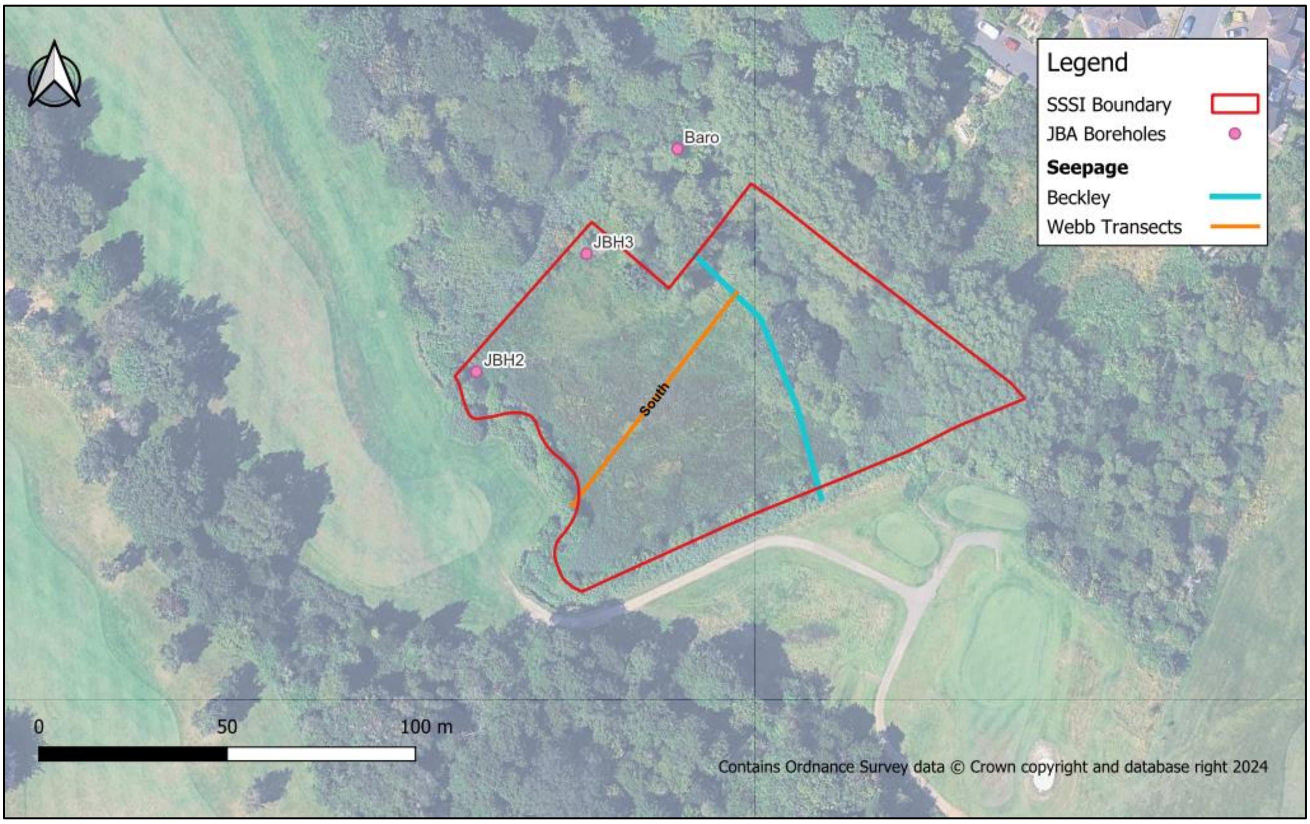


Figure 3-47: Webb (2013b) South Fen transects with JBA monitoring locations.

From this information the following is evident. At North Fen, the western side is supported by the limestone outcrop seepage, and the east by the lower Beckley Sandstone seepage. At south fen, there is a similar seepage that keeps the ground perennially wet. There is evidence of drainage damage from the incised channel units.

3.8.6 Estimated Groundwater Catchments

This section estimates the likely groundwater catchments supplying the SSSI. Figure 3-48 includes groundwater discharge boundaries which are the surface watercourses receiving groundwater inputs. In addition, likely groundwater divide positions (i.e. the groundwater catchment boundaries) are also shown. From this it is also possible to identify bedrock aquifers which are most likely to supply the seepage faces seen in the SSSI and the LNR.

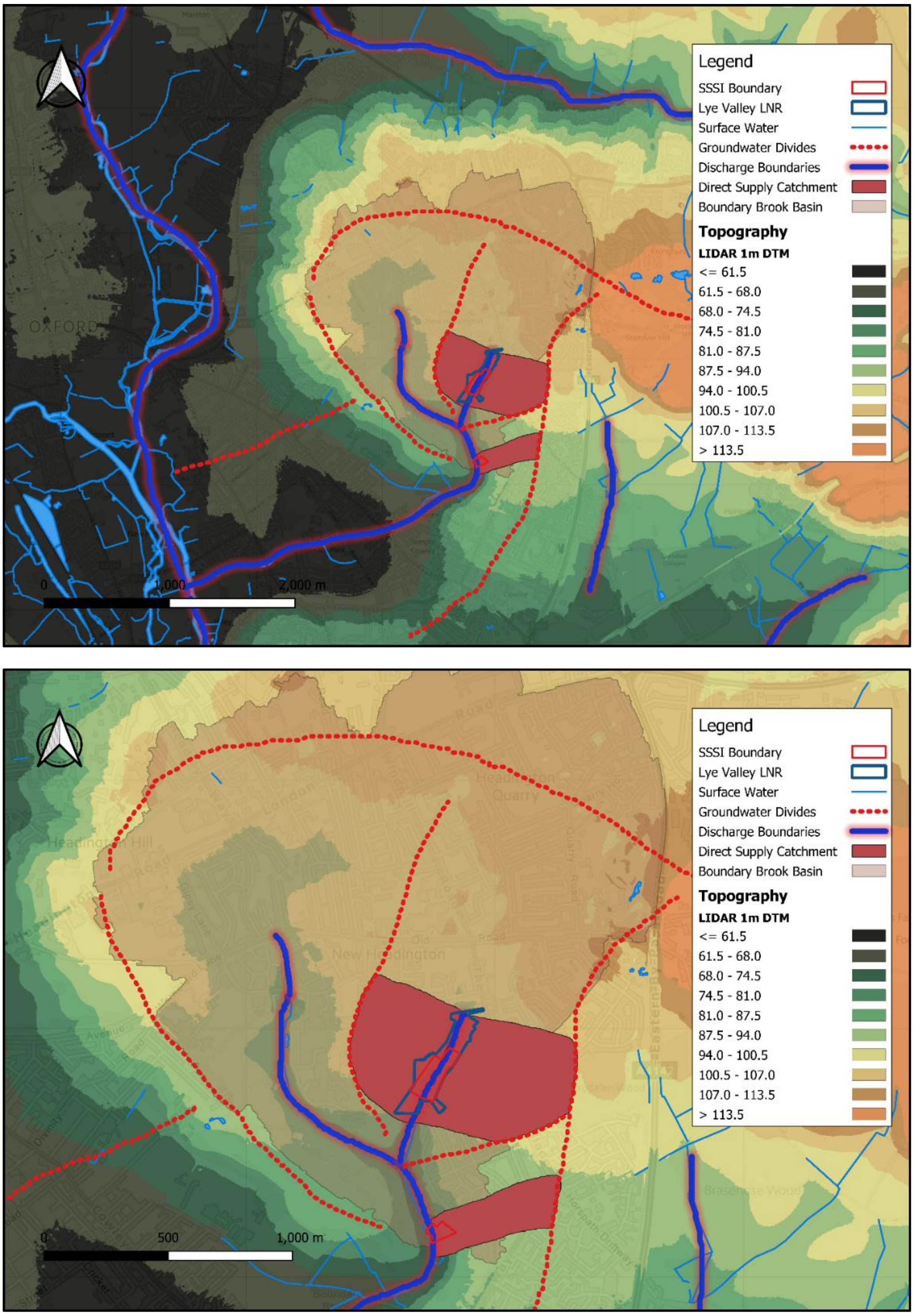


Figure 3-48: Groundwater boundaries and catchments.

The groundwater divides presented in the Figure 3-48 (as dotted red lines) are based on changes in topography and lie between the main groundwater discharge boundaries.

Figure 3-49 shows the potential effect of the limestone bands. Baywater Brook to the north is much lower than Lye Valley or Boundary Brook and the effect of this (if the aquifer were homogenous and isotopic) would be to draw the divide further south than the corresponding surface water catchment boundary.

The Limestone bands that are a feature of the aquifer however potentially could act as "drains" pulling in water from a wider area than the topography may indicate. In order to define the boundaries more accurately, long term monitoring of groundwater levels would be required from a catchment wide monitoring array. However, for the purposes of this assessment, the main uncertainties are at the edge of the areas, where impacts to the SSSI would be more limited (see Section 5.1 for further discussion).

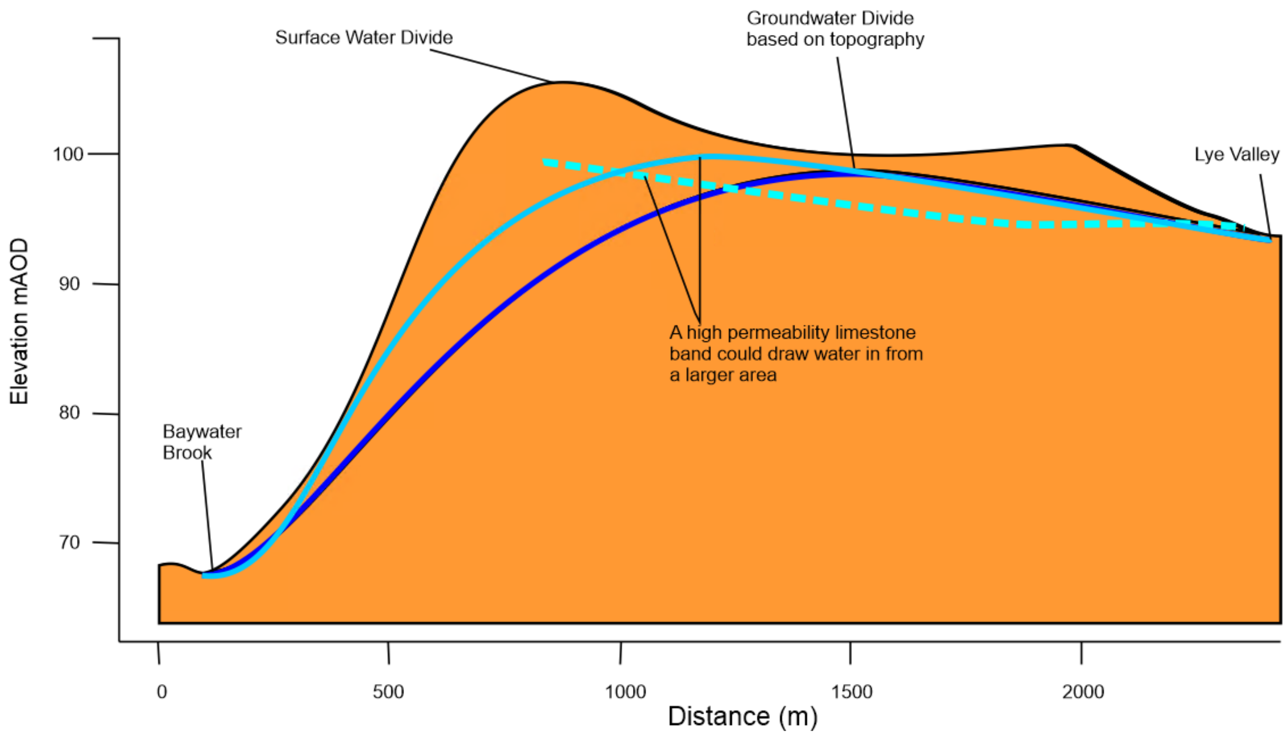


Figure 3-49: Schematic of groundwater divides.

3.9 Water Quality

The following section considers groundwater quality in and around the SSSI. The monitoring shows that there are two groundwater systems:

- A quick system through the Limestone bands affected by elevated nitrate levels
- A slower system through the sandstone which allows denitrification to occur and is not affected by elevated nitrate levels.

It also considers the influence of urban drainage and other contamination sources on water quality.

3.9.1 Nitrate Standards

One of the key indicators of groundwater quality for lowland fens is nitrate. UKTAG (2012) suggests a threshold for Nitrate[11] of 20mg/l for lowland fens (oligotrophic and wetlands at tufa forming springs) (see Table 3-4).

Table 3-4: UKTAG proposed groundwater nitrate threshold values (mg/l NO3).

GWDTE category[1]	Altitude		
	(<175mAOD)	(>175mAOD)	Any altitude
Quaking bog	18	4	
Wet dune			13
Fen (mesotrophic) and Fen Meadow	22	9	
Fen (oligotrophic and wetlands at tufa forming springs	20	4	
Wet grassland	26	9	
Wet heath	13	9	
Peatbog and woodland on peatbog			9
Wetland directly irrigated by spring or seepage			9
Swamp (mesotrophic) and reedbed			22
Swamp (oligotrophic)			18
Wet woodland	22	9	

11 https://www.wfduk.org/sites/default/files/Media/Environmental%20standards/GWDTE%20chemical%20values_Final_230312.pdf

Webb (2016) provides additional thresholds based on the needs of stoneworts[12] of 2.21mg/l. This is ten times less than the threshold for lowland fens in general.

3.9.2 Lambeth 2007 Data

Lambeth 2007 undertook sampling across the catchment (the exact locations are not recorded) (see Table 3-6) and Table 3-5 provides a summary of his observations. Within the SSSI, no sample was above the UKTAG 20mg/l threshold, but some of the springs were above the Webb stonewort threshold.

Table 3-5: Summary of Lambeth (2007) observations.

Location	Summary
Spring water quality	Hard water (300 to 400 mg/l $CaCO_3$) Relatively high conductivity (600 to 850 uS). pH tends to be neutral or alkaline (equal to or greater than pH 7) with higher pH values observed where there is some biological activity. Nitrate concentrations - moderate - around 4 to 6 mg/l nitrate-N depending on the type of land use within each catchment. Phosphate concentrations are mostly low with soluble reactive phosphate ranging from 0.1 to 0.6 mg/l, again depending on the land use. In general, the water quality of the Lye Valley and Boundary Brook springs was good. Ammonium concentrations were all low showing that there was no detectable wastewater infiltration to the groundwater. Tufa deposition was observed at a number of springs
Fen Water Quality	The water quality of the fen was good. Base richness was high and there was evidence of a decrease in pH due to peat formation
Boundary Brook Water Quality	Overall Poor. Elevated electrical conductivity levels. Ammonium concentrations were slightly elevated above the hospital site (0.25 mg/l) but were markedly increased below the hospital site (2 mg/l).
Lye Valley water quality	Overall good. Nitrate and ammonium concentrations were below detection levels except for a trickle of water entering the brook just below the allotments at NGR 454892-206059, this surface water drain showing high concentrations of ammonium (8 mg/l) and nitrate (10 mg/l).

Table 3-6: Lambeth (2007) water quality data.

[12] "Published water quality limits for the health of these stoneworts are available. Stoneworts are disadvantaged if nitrate in the water is above 2.21mg/l (2.2ppm). Stoneworts are disadvantaged if phosphate in water is above 20 micrograms/litre (0.02ppm)."

Table 4 Chemical data from the study. Note that these data were obtained using non NAMAS accredited methods. For Reference Only. pH and conductivity probes were calibrated. Other measurements made using simple aquarium test kits of limited colourimetric resolution.

ID	Feature	Comments	Tufa	EC, uS cm^{-1}	pH	NO_3 mg/l	NH_4 mg/l	Ca/Mg mg/l	CO_3/HCO_3 mg/l
1	Spring	Tufa depositing spring	y	879	8.0	7.5	0	358	465
2	Ditch	Runs alongside golf course		785	8.2	5	0	340	465
3	Fen	Best part of remaining fen.		913	7.8	0	0	394	465
4	Spring	Dry. Sandra Diesel's sink, tufa depositing.	y						
5	Lye Brook	Sample from Brook		990	8.2	5	0	269	394
6	Spring	Golf course spring.		719	8.3	7.5	0	251	412
7	Spring	Golf course drain and springs, lower than 2/ tufa depositing.	y	730	8.2	7.5	0	251	430
8	Spring	Golf course woodland riparian zone. Tufa depositing.	y	684	8.2	10	0	251	376
9	Spring	Golf course interception drain.		788	8.5	20	0	251	376
10	Ditch	Point when dritch from 9 enters Lye Brook.		772	8.2	5	0	304	483
11	Spring	Wet flush on the N side of brook.		715	7.9				
15	Lye Brook	Lye Brook, Confluence of Lye Brook and Boundary Brook		820	8.7	0	0	269	412
15	Boundary Brook	Boundary Brook, Confluence of Lye Brook and Boundary Brook		999	7.8	2.5	2	269	412
16	Boundary Brook	Boundary Brook		1024					
18	Spring	Tufa deposition at spring issue point.	y	1018	7.9	0	0	269	322
19	Boundary Brook	Boundary Brook		1020	7.8	5	0.25	269	394
20	Land Drain	Under Bridge		905	8.0				
21	Spring	Peat deposition		1154	8.0				
22	Spring	Major spring area.		852	7.6	0	0	215	394
32	Spring	Headington Hill Park	y	782	7.0	5			
33	Spring	South Parks		598	7.0	5			
39	Pipe Drain	15" pipe surface water issue to Lye Brook head.		792	7.7	10	8	286	322
40	Spring	Next to path as enter Lye Valley		887	8.2	0	0	269	376
42	Lye Brook	Bridge over brook.		850	8.4	0	0.1	251	412
43	Fen	Fen 10 m east of stream.		769	7.7	0	0	286	376

3.9.3 A Bows MSc Dissertation

A Bows (2021) identified nitrate levels at around 0.2mg/l for three of his monitoring sites with a fourth at 3.4mg/l (see Table 3-7 and Figure 3-50). Of note here was that the valley floor location was not elevated with respect to nitrates. There was no evidence of surface water flooding causing the valley floor's nitrate concentrations to be elevated.

Table 3-7: Mean conductivity, pH and water chemistry values of A Bows' sample locations.

Research Plot	Measured manually in-situ						Laboratory tests by Chemtech Environmental						
	pH		Conductivity (μS)		Mean (n = 2)		Single sample						
	Mean (n = 14)	Sd	Mean (n = 17)	Sd	Nitrates (mg/l)	Phosphates (mg/l)	pH	Nitrates (mg/l)	Phosphates (mg/l)	Calcium (mg/l)	Potassium (mg/l)	Iron (μg/l)	Sodium (mg/l)
LV_Bench	7.0	0.16	747	54	0.2	0.02	7.2	0.2	0.3	137	1.5	8.1	26
LV_Ctl	7.0	0.17	709	35	3.0	0.02	7.1	3.4	0.3	154	0.1	20	21
LV_Rest1	6.8	0.21	735	38	0.2	0.02	7.1	0.2	0.3	160	0.1	7.9	39
LV_Rest2	6.9	0.23	772	110	0.2	0.02	6.9	0.2	0.3	157	1.3	7.5	16

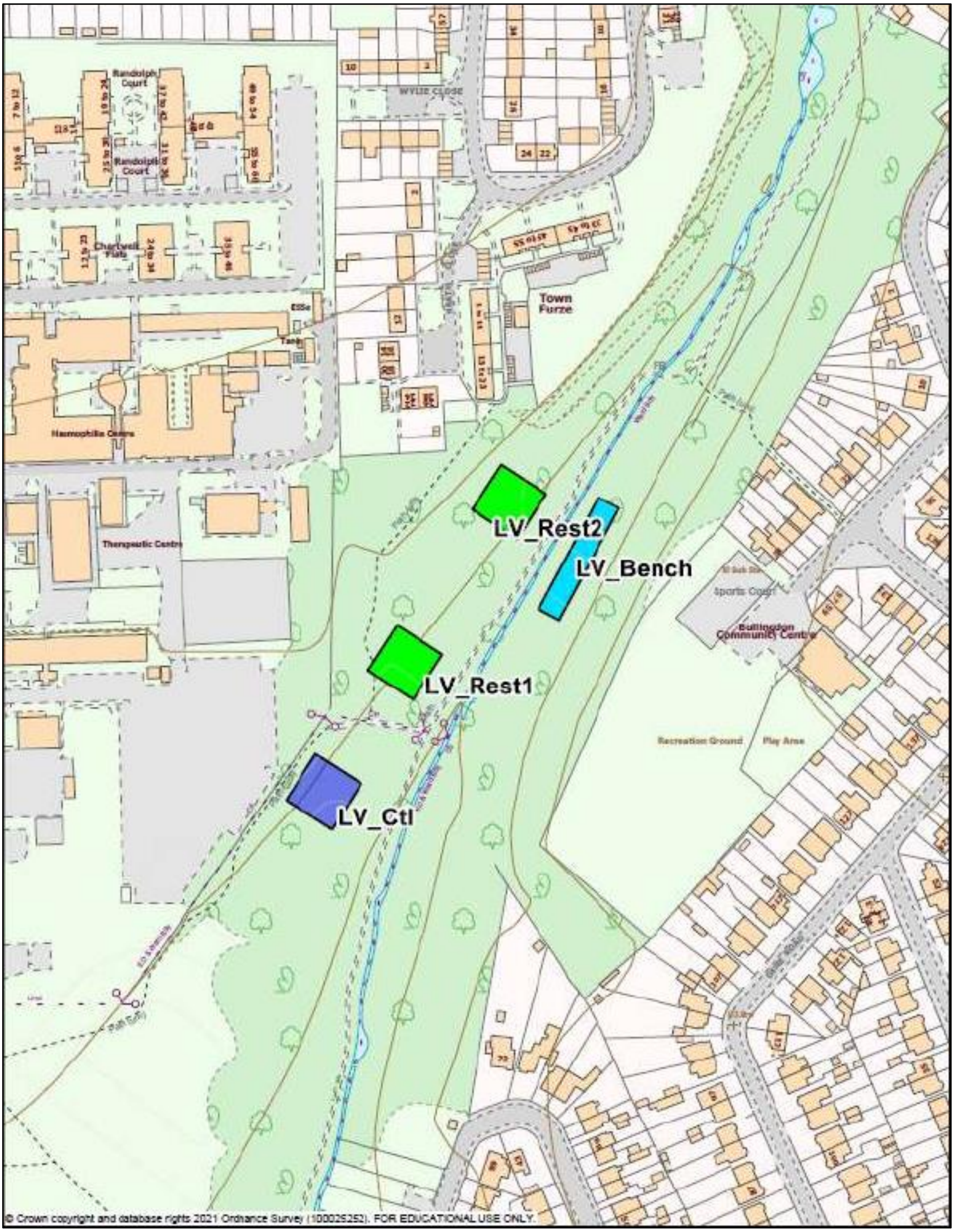


Figure 3-50: Location of A Bows' sample locations.

3.9.4 Webb 2016 Study

Webb 2016 classified the springs based on the 2.21mg/l stonewort threshold and are summarised in the Figure 3-51 below. The springs had variable nitrate levels. Springs A-C had nitrate levels at between 5-10+mg/l and Spring D had undetectable nitrate levels. The pattern aligns with JBA's hydrogeological understanding of the site and reflects the residence time (how quickly water moves through the site) and the potential for denitrification to occur on route. Denitrification is a process by which nitrate is converted to nitrogen gas in conditions with low oxygen (anaerobic) conditions (see Box 1 for further details). The following is observed from Webb's results:

- Surface water discharges were classified as poor. Water rapidly moves through the urbanised sewer system and there is little potential for denitrification. It should be noted that outside of flood events, this water is contained within the channel.
- Springs A-C - these are on the large limestone band which lies close to the surface. Groundwater can rapidly flow through, leaving little potential for denitrification. E-G are supplied by the same limestone bands and are classified as moderate.
- 2 Westside Tufa Springs - these discharge from a smaller limestone band, which is supplied through infiltration through a thicker band on Beckley Sand Member sandstone units than Spring A-C. There is greater potential for denitrification on this slower pathway.
- Spring D and the ponds are supplied by the Beckley Sands Member so a relatively slow pathway.
- The ochre deposits from the Beckley Sands Member springs may reflect anaerobic conditions.

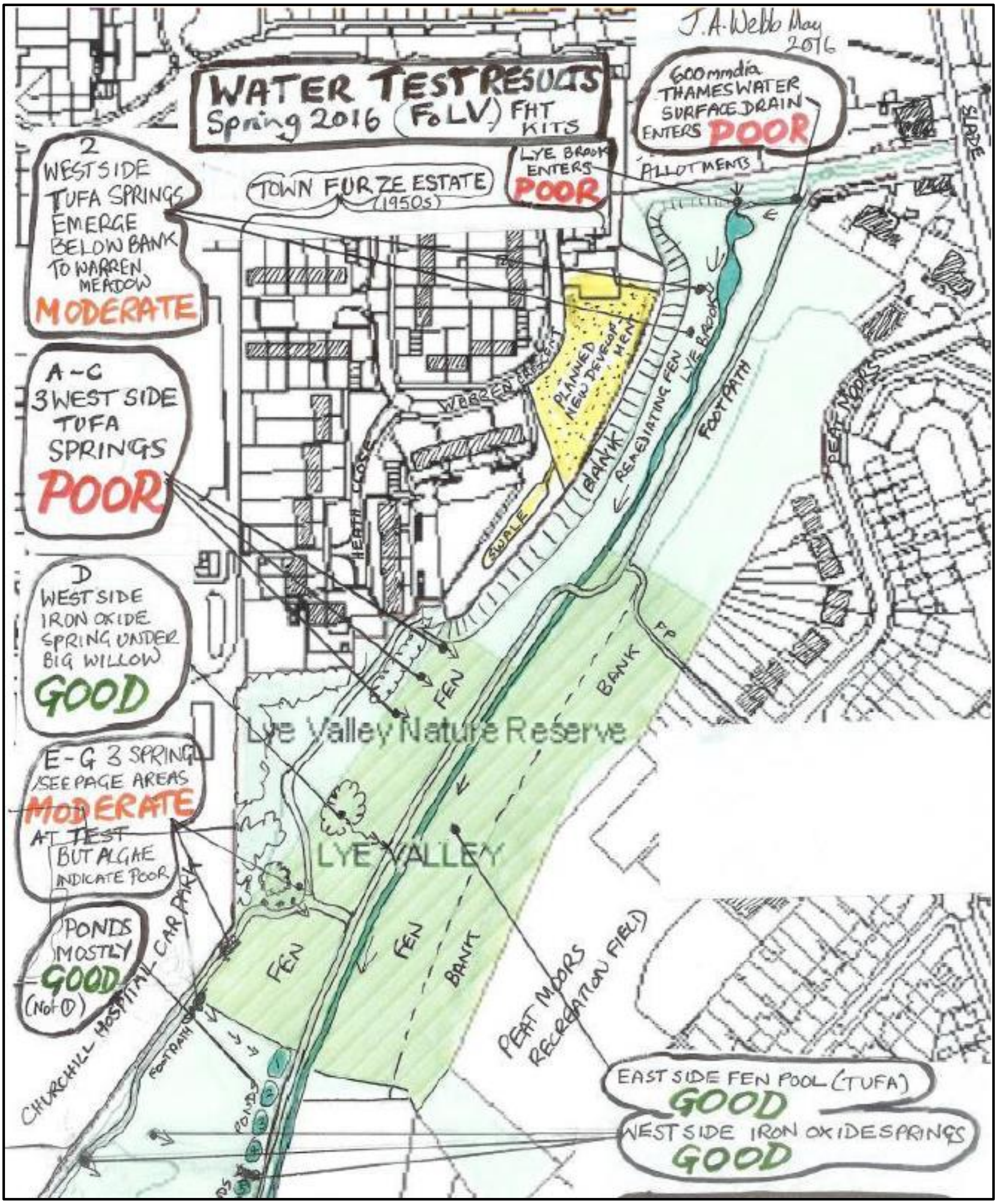


Figure 3-51: Webb (2017) water quality results.

Box 1 - Denitrification from BGS (2018)
This reaction sequence is commonly seen along groundwater flow lines (Edmunds et al., 1982; Edmunds et al., 1984) typically as aquifers become confined. Water at recharge is

Box 1 - Denitrification from BGS (2018)

generally saturated with Dissolved Oxygen (DO) at the partial pressure of the atmosphere (10-12 mg/L depending upon barometric conditions). Passing through the soil and the unsaturated zone some of this O_2 will react as a result of microbiological processes and oxidation-reduction reactions. However, almost all water reaching the water table still contains several mg/L O_2. Geochemical and microbial reactions progressively remove the O_2 along flow lines. Once all the O_2 has reacted an abrupt change of water chemistry takes place (redox boundary). Down-gradient of the redox boundary, denitrification occurs, and it is likely that Fe^{2+} concentrations will increase. Sulphate reduction and the production of sulphide (H_2S as S^{2-} in solution) may also occur at greater depths.

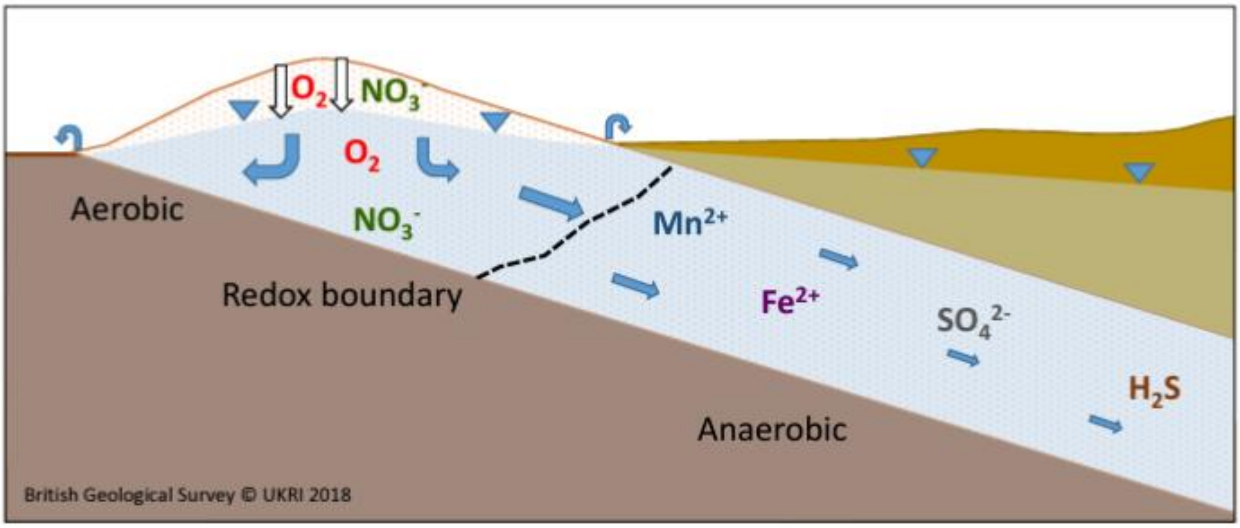


Figure 2.2 **Schematic redox boundary in the Lincolnshire Limestone aquifer** (after Griffiths et al., 2006)

https://nora.nerc.ac.uk/id/eprint/522242/1/OR18011.pdf

3.9.5 Tufa Formation

Several tufa springs occur on site (see Figure 3-52). Tufa is a sedimentary deposit composed of calcium carbonate ($CaCO_3$), formed by evaporation as a superficial, spongy, porous, semi friable incrustation around the mouth of a hot or cold spring or seep, or along a stream carrying calcium carbonate in solution, and exceptionally as a thick, bulbous, concretionary or compact deposit in a lake or along its shore.

Box 2 - Tufa Formation

Tufa formation is derived from the dissolution of rocks rich in calcium carbonate and can also be a significant hydrogeological characteristic of karst environments (Banks & Jones, 2012[13]). These rocks will principally be limestone or other carbonate rich strata……. A basic understanding of the hydrochemical process of tufa formation and the carbonate

[13] Hydrogeological Significance of Secondary Terrestrial Carbonate Deposition in Karst Environments, Hydrogeology - A Global Perspective

Box 2 - Tufa Formation

system is provided below as a background to understanding how geology and hydrogeology influences where the tufa occurs.

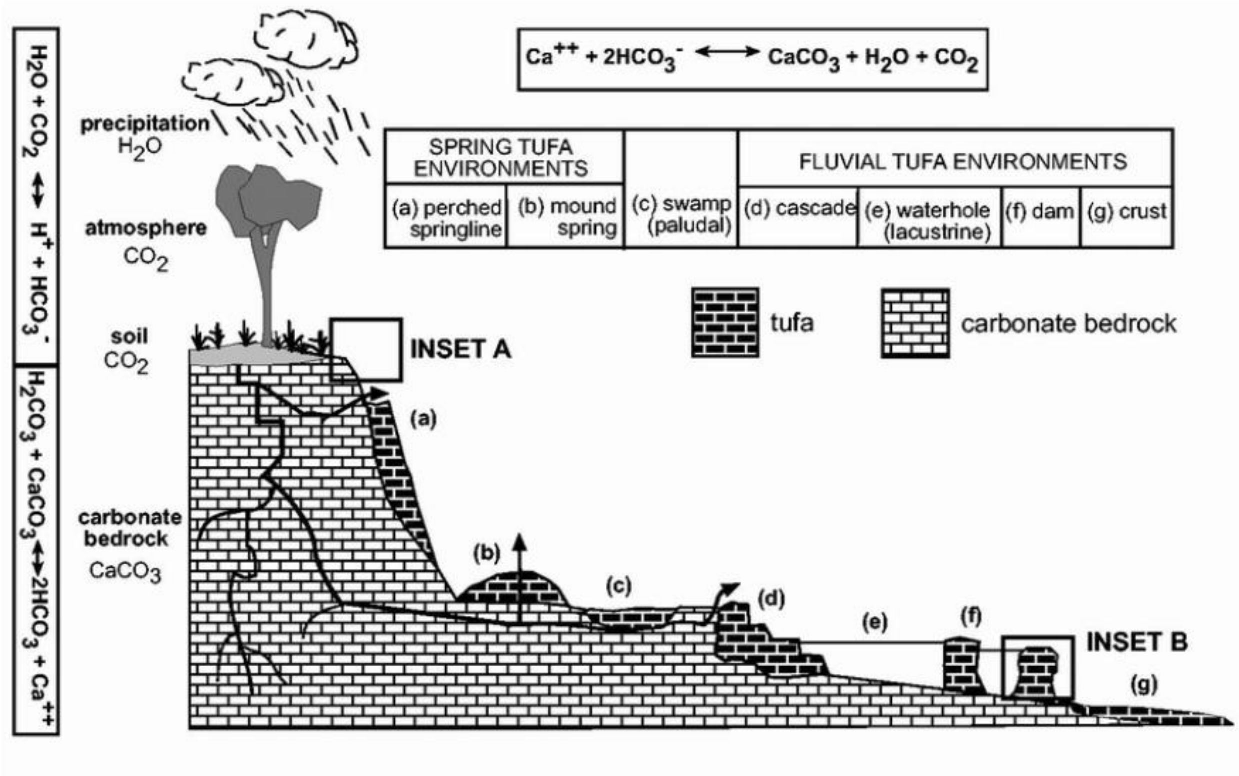
Precipitation provides effective recharge to aquifers in the form of rainfall or snow and ice melt. Precipitation is also acidic and undersaturated with respect to calcium carbonate. During the recharge process via the soil layer (infiltration through soil), superficial deposits and bedrock, dissolved carbon dioxide in the water can dissolve ions (cations and anions) including Ca, HCO_3, Mg, Na, K, and SO_4. It is during this process that the more acidic recharge can dissolve calcium carbonate and other ions in the soils and bedrock. The groundwater ultimately becomes supersaturated with respect to calcium bicarbonate creating the perfect conditions for tufa deposition. Groundwater will need to leave the aquifer, or interact with the atmosphere, in order to deposit tufa and this occurs where the water table intersects the topographical land surface, in simple terms this is where springs and seepages often occur.

Once the groundwater emerges at the surface, via a spring or seepage or as river baseflow, interactions with the atmosphere cause the loss or evasion of CO_2 and the resultant precipitation of calcium carbonate, as tufa:

$$Ca^{2+} + 2\ HCO_3^{-} \leftrightarrow CaCO_3 + CO_2 + H_2O$$

https://earthwise.bgs.ac.uk/index.php/OR/14/043_Processes_of_tufa_formation_and_tufa_classification

Box 2 - Tufa Formation
Figure below shows how the Tufa owes its origin to solution weathering, where solutes produced by carbonation are reworked through the karst system and deposited in streams and lakes. In the Lye Valley, the tufa is deposited in spring tufa environment in perched springline (a) and in mound springs (b).



Carthew, Karen & Drysdale, Russell & Taylor, Mark. (2003). Tufa Deposits and Biological Activity, Riversleigh, Northwestern Queensland.

Figure 3-52: Evidence of Tufa in Lye Brook (JBA walkover).

3.9.6 Pollution Incidents

Webb (2016) identified that there are likely misconnections in the surface water sewer network and the discharges from the sewers in the north of the Lye Valley are often cloudy indicating poor water quality. A minor pollution incident affecting water was recorded on 27/2/2003 in the head of the valley and a second in the centre of the Lye Valley North SSSI unit on 28/3/2003.

3.9.7 JBA Water Quality Monitoring

JBA Consulting undertook a water quality monitoring survey on 16th April 2024, where eleven water samples (and one duplicate) from either groundwater springs, seepages or surface water were collected. The recovered samples were placed in containers supplied by the laboratory appropriate to the type of analysis being undertaken and stored in cool boxes with ice packs. All samples were dispatched accompanied by chain of custody documentation to an ISO 17025 and MCERTS accredited laboratory (ALS) for analysis.

For Quality Assurance purposes, a duplicate sample was taken from 13 (named DUP 01). The laboratory analysis for these two samples shows good correlation and thus appropriate confidence in the laboratory data.

The aims of the monitoring were as follows:

- Identify sources of water:
    - Use a range of water quality parameters to identify the sources of water entering the system.
- Pollution:
    - Identify signs of nutrient and urban pollution affecting the site.

Table 3-8 below shows the sampling location descriptions and outlines the rationale for the sampling undertaken and Figure 3-53 shows the sampling locations.

Table 3-8: Sampling rationale.

Analytical Suite	Rationale	No. of groundwater samples submitted	No. of surface water samples submitted
Ion Suite (HCO_3^-, Ca^{2+}, Mg^{2+}, F^- etc)	To analyse overall water chemistry	5	6
Nitrate (as NO_3^-) and nitrite (as NO_2^-)	To determine extent of nutrient/urban pollution	5	6
Phosphate (as PO_4^{3-})	To determine extent of nutrient/urban pollution	5	6
Geochemical parameters (i.e., pH, electrical conductivity, hardness (as calcium carbonate) etc)	To understand the overall water geochemistry	5	6
Polycyclic aromatic hydrocarbons (PAHs)	Typically associated with fuels/oil products and anthropogenic substances	5	6
Ammoniacal nitrogen	To determine extent of nutrient/urban pollution	5	6

Based on other water quality studies, Table 3-9 outlines the expected pattern of water quality from a range of sources:

- Rainfall is expected to have low values across the parameters.
- Urban Drainage/Surface Water and Limestone bands are expected to have variable nitrate and PAH levels depending on whether there is a source of pollution on the pathway.
- The difference between groundwater from the Beckley Sandstone and Limestone bands will be reflected in alkalinity levels.
- No evidence of elevated Nitrate or PAHs may be a sign that the source of water is the Beckley Sandstone or that there is no source of those contaminants in the sub catchment.

Table 3-9: Water quality patterns.

	Conductivity	Alkalinity	Nitrate	PAH
Rainfall	Very Low	Very Low	Very Low	Absent
Urban Drainage/ surface water	Low	Low	Variable	Variable
Beckley Sandstone	Moderate	Moderate	Absent / Very Low	Absent / Very Low
Limestone Bands	High	High	Variable	Variable

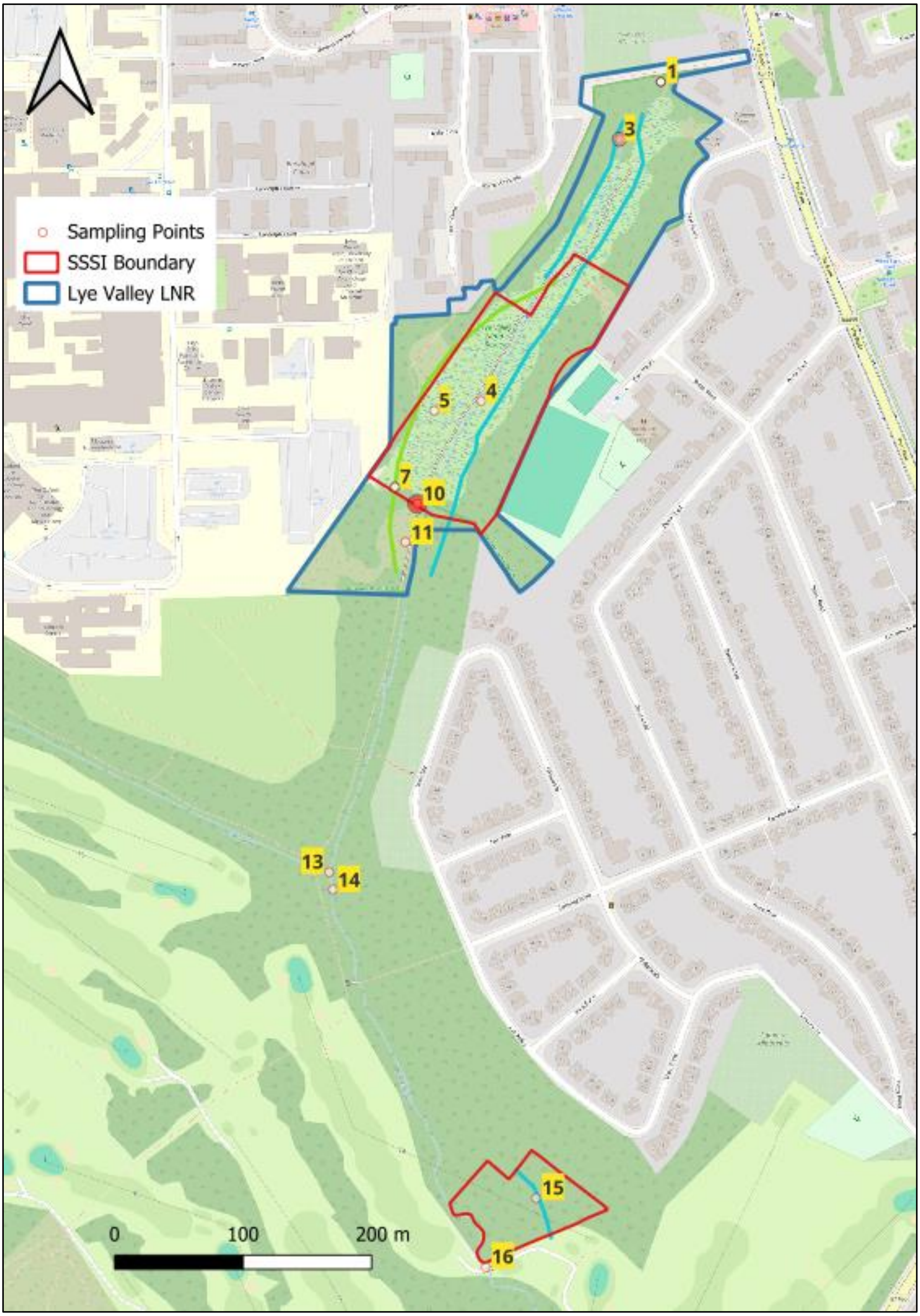


Figure 3-53: Sampling locations.

Table 3-10: Sample location descriptions.

Sample Location	Description
1	Sample from Lye Brook upon entrance into Lye Valley LNR
3	Sample from spring in northern Lye Valley
4	Taken from mid-way down Lye Brook within the SSSI
5	Seepage from west side of SSSI
7	Seepage from west side of SSSI, close to hospital car park
10	Seepage from west side of SSSI
11	Sample taken from pond
13	Sample from downstream of Lye Brook, before confluence with Boundary Brook
14	Sample from Boundary Brook immediately after confluence with Lye Brook
15	Sample from spring in lower Lye Valley area
16	Sample from Boundary Brook, adjacent to the golf course bridge

Figure 3-54 to Figure 3-58 shows the main results. The main patterns observed are described in Table 3-11. The full results of the screening including individual PAH exceedances is provided in Appendix B.

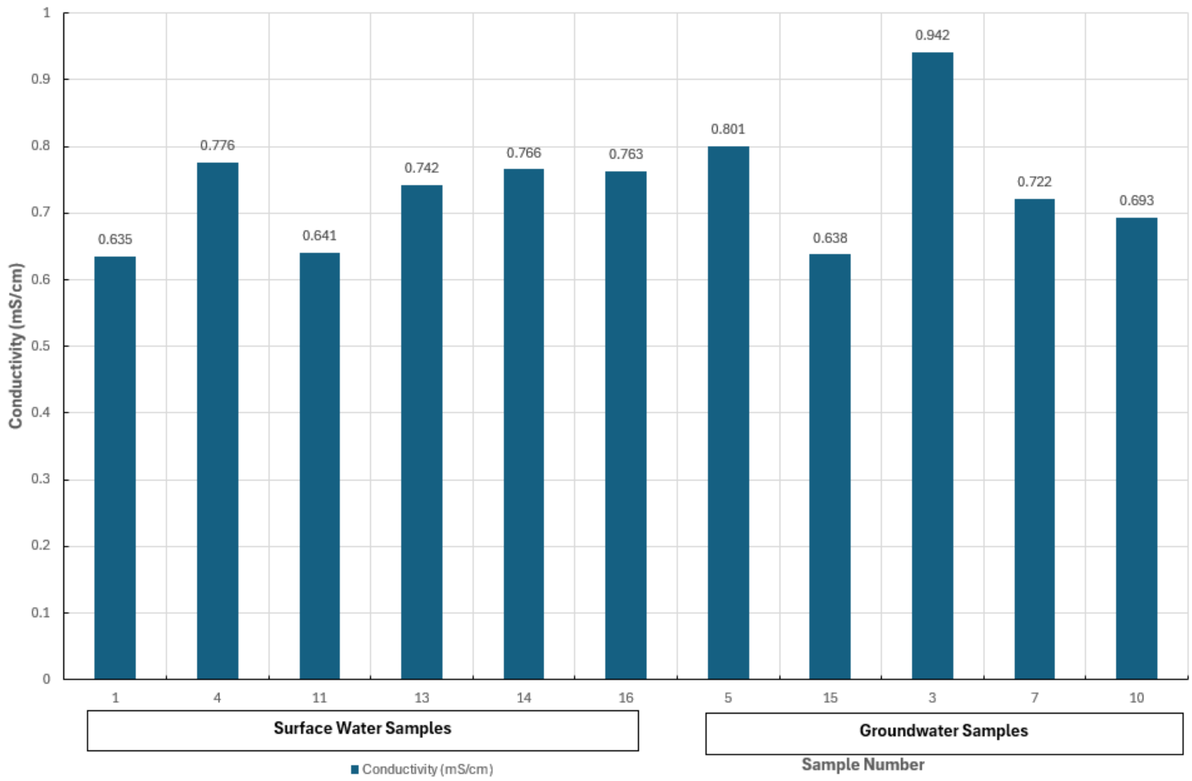


Figure 3-54: Conductivity.

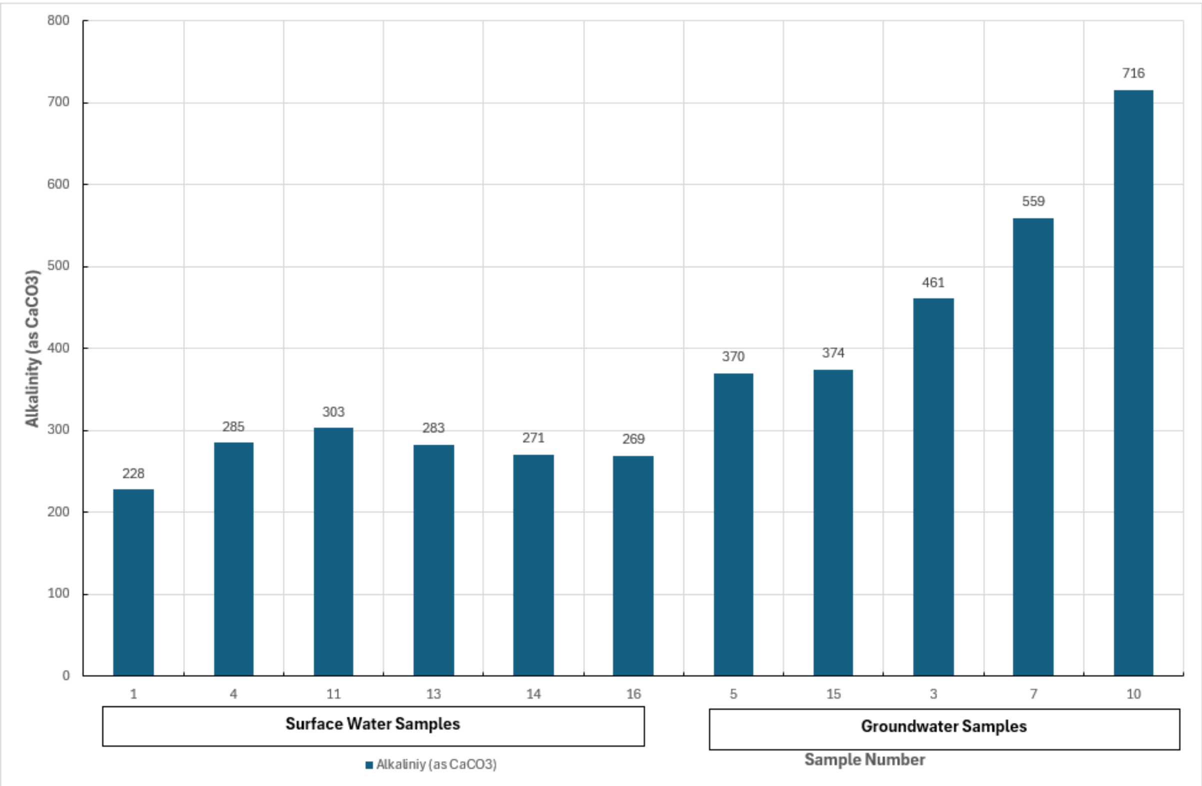


Figure 3-55: Alkalinity concentrations.

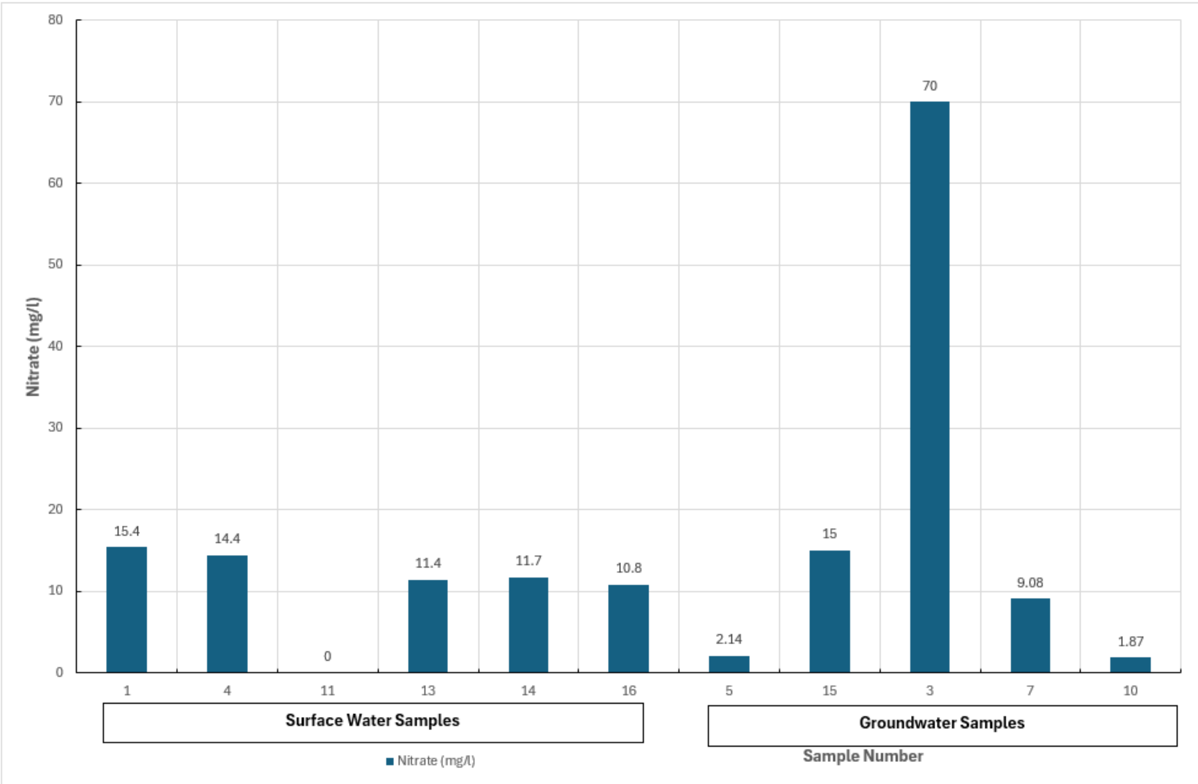


Figure 3-56: Nitrate concentrations.

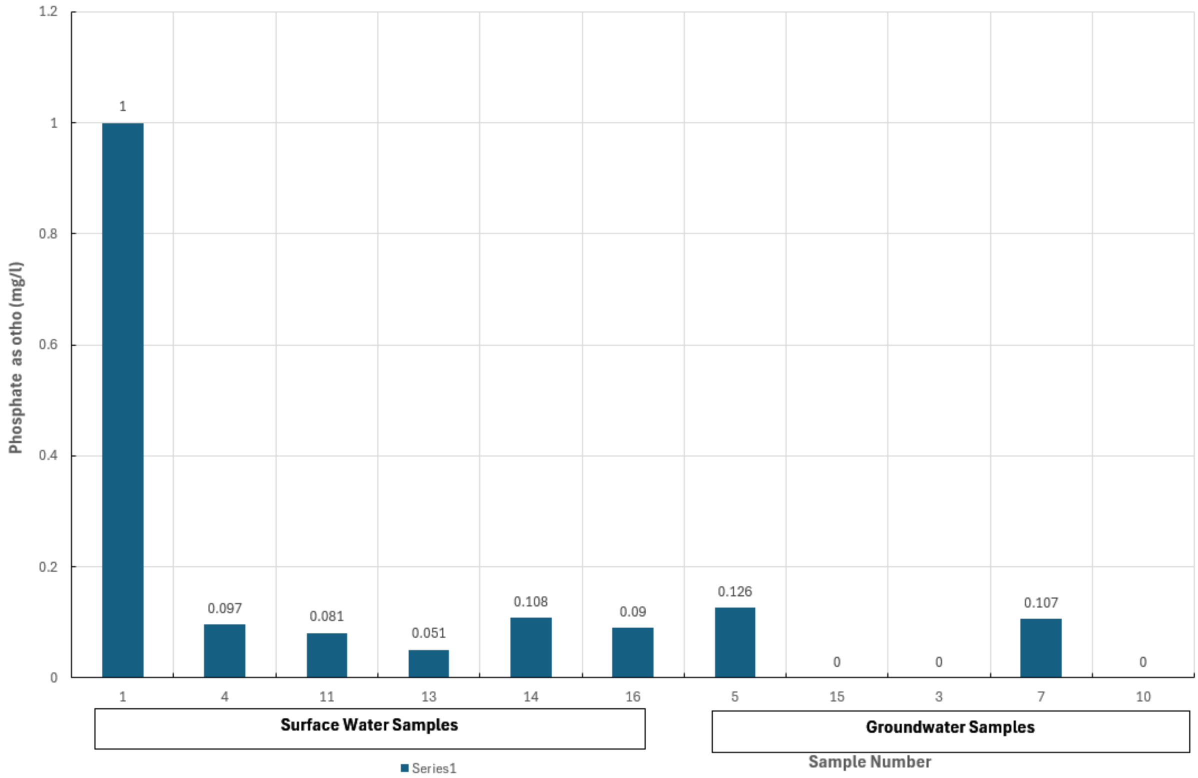


Figure 3-57: Phosphate.

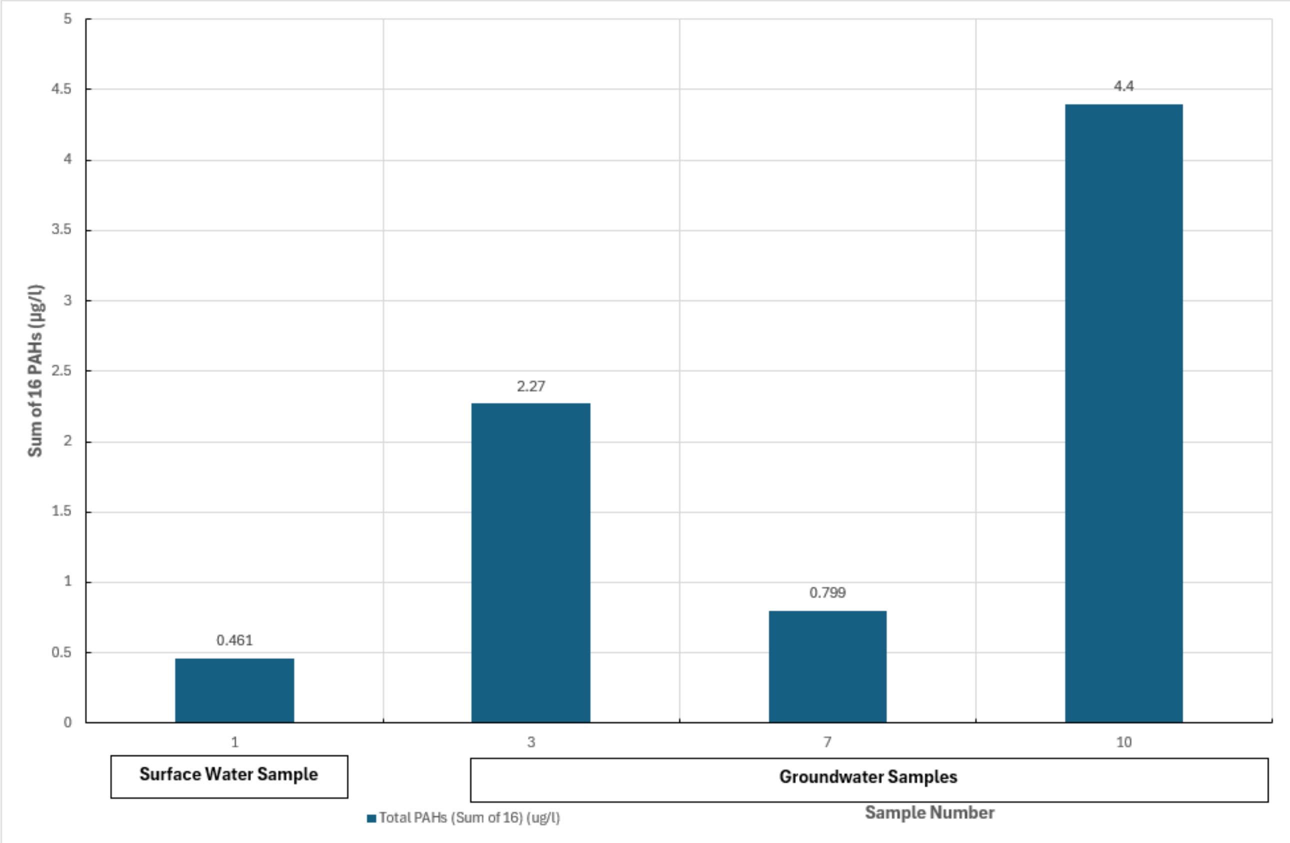


Figure 3-58: Sum of 16 PAHs.

Table 3-11: Discussion of parameters.

Parameter	Discussion
Conductivity	Figure 3-54 shows the conductivity of the samples had some variability and there was no distinct trend between surface water and groundwater samples. Whilst Sample 3 and Sample 5 had the highest conductivity values, surface water concentrations were not distinctly low suggesting that a high proportion of the surface flow may be supplied by groundwater.
Alkalinity	Based off the alkalinity results shown in Figure 3-55 and Table 3-9, a clear difference is noted between surface water samples and groundwater samples. The groundwater samples typically have more alkalinity, with Samples 3, 7 and 10 having noticeably higher alkalinity, likely where groundwater is discharging from limestone bands.
Nitrate	Figure 3-56 shows variability in nitrate concentrations. The highest concentration of nitrate was 70mg/l at Sample 3 at a spring. The same location had high alkalinity; this may indicate a quick limestone system with limited denitrification. Out of the five groundwater samples, one exceeded the GWDTE lowland fen nitrate standard of 20mg/l (Sample 3). Three of the groundwater

Parameter	Discussion
	samples exceeded the stonewort water quality limits of 2.21mg/l (Sample 3, Sample 7 and Sample 15). Sample 3 is associated with the quick limestone system. The highest nitrate concentration was detected in the surface water samples at Sample 1 with 15.4mg/l of nitrate. These concentrations appeared to diminish down Lye Valley, until a slight increase with the confluence of Boundary Brook (sample 14, 11.7mg/l). Sample 11 (pond, standing water) did not exceed the laboratory reporting limit. All samples except Sample 11 exceeded the stonewort water quality limits, and no samples exceeded the GWDTE lowland fen nitrate standards.
Phosphate	Figure 3-57 shows that higher phosphate is recorded at the upstream end of the Lye Valley. All results are below 20mg/l, which was the threshold identified for stoneworts by Webb (2016).
PAHs	PAH were detected groundwater at Sample 7 and 10 (see Figure 3-58). This suggests a source of PAHs in the catchments of these springs. All of these samples are associated with the limestone, indicating that the PAHs may pass through the system with limited buffering/attenuation. Sample 15 did not detect any PAHs over the laboratory detection limit. The only surface water sample with PAHs above Environmental Quality Standards (EQS) was Sample 1 (northern end of Lye Valley LNR). This may indicate that PAHs are present in surface water off-stream to the north and are transported downstream to Lye Brook. Although there were detections of individual PAHs within surface water samples downstream (most notably benzo(b)fluoranthene and fluoranthene), the concentrations are diluted.

Figure 3-59 and

Table 3-12 show and discuss the main spatial trends in the water quality samples.

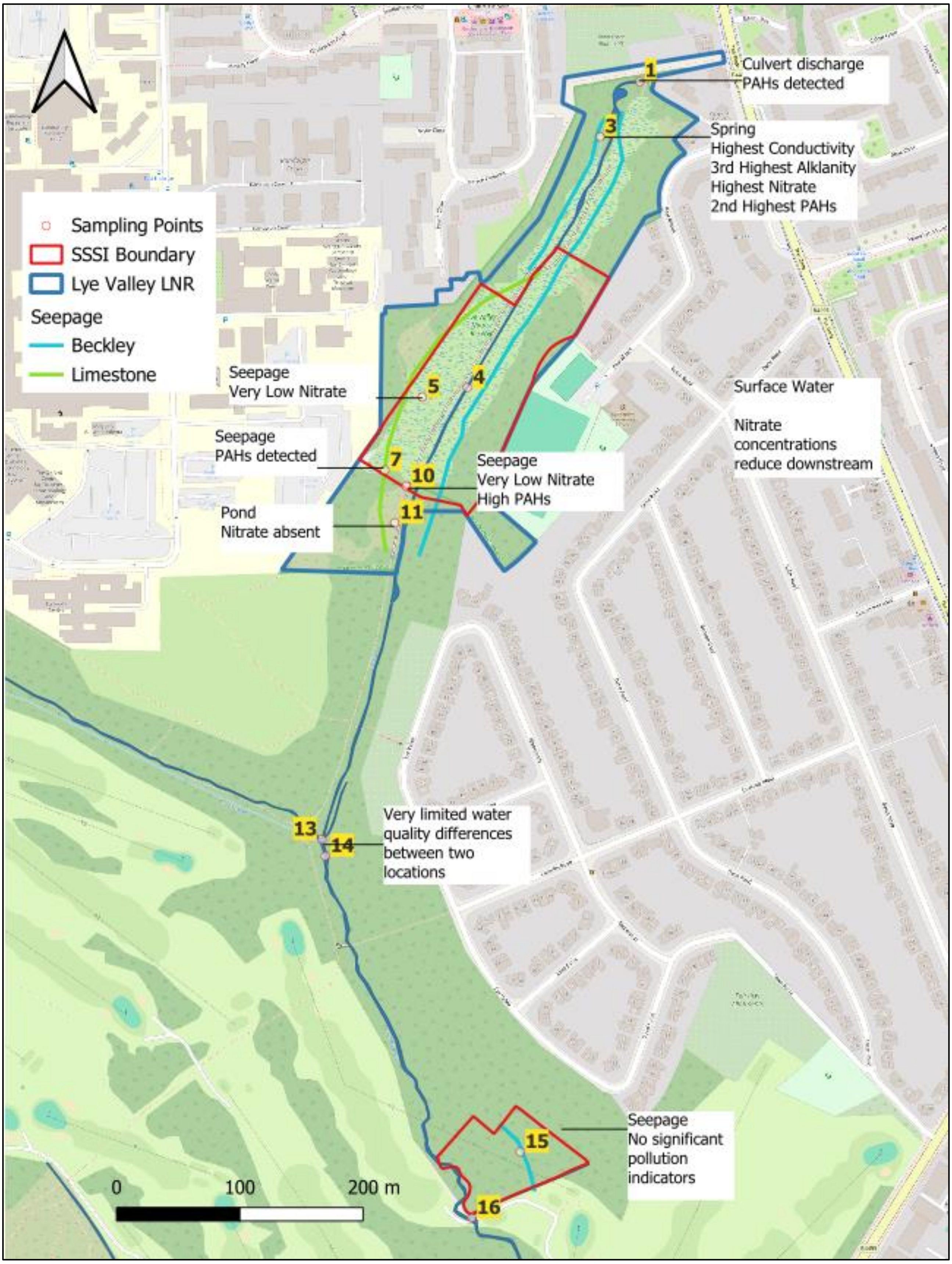


Figure 3-59: Main spatial trends in water quality samples.

Table 3-12: Discussion of individual locations.

Sample Location	Description	Discussion
1	Sample from Lye Brook upon entrance into Lye Valley LNR	Some evidence of urban pollution with elevated PAHs and the highest phosphate record
3	Sample from spring in northern Lye Valley	This spring is supplied by limestone bands with high conductivity and high alkalinity. There is evidence of pollution sources in its catchments with the highest nitrate and second highest PAH levels
5	Seepage from west side of SSSI	Very low nitrate levels
7	Seepage from west side of SSSI, close to hospital car park	These seepages appear to have a source of PAHs pollution it its catchment. Likely that these are supplied by limestone bands, limiting the potential for PAHs to be attenuated.
10	Seepage from west side of SSSI	These seepages appear to have a source of PAHs pollution it its catchment. Likely that these are supplied by limestone bands, limiting the potential for PAHs to be attenuated.
11	Sample taken from pond	Nitrates absent
15	Sample from spring in lower Lye Valley area	No significant pollution indicators
All locations	Surface Water	Nitrate concentration reduced downstream. The proportion of green open space increases downstream may be a cause.

Based on Table 3-10 and all of the above water quality patterns, it is interpreted that samples 5 and 15 are seepages/springs from the Beckley Sandstone and samples 3, 7 and 10 are from limestone bands (see Figure 3-60). The main indicators are the high alkalinity and PAH concentrations within the latter samples.

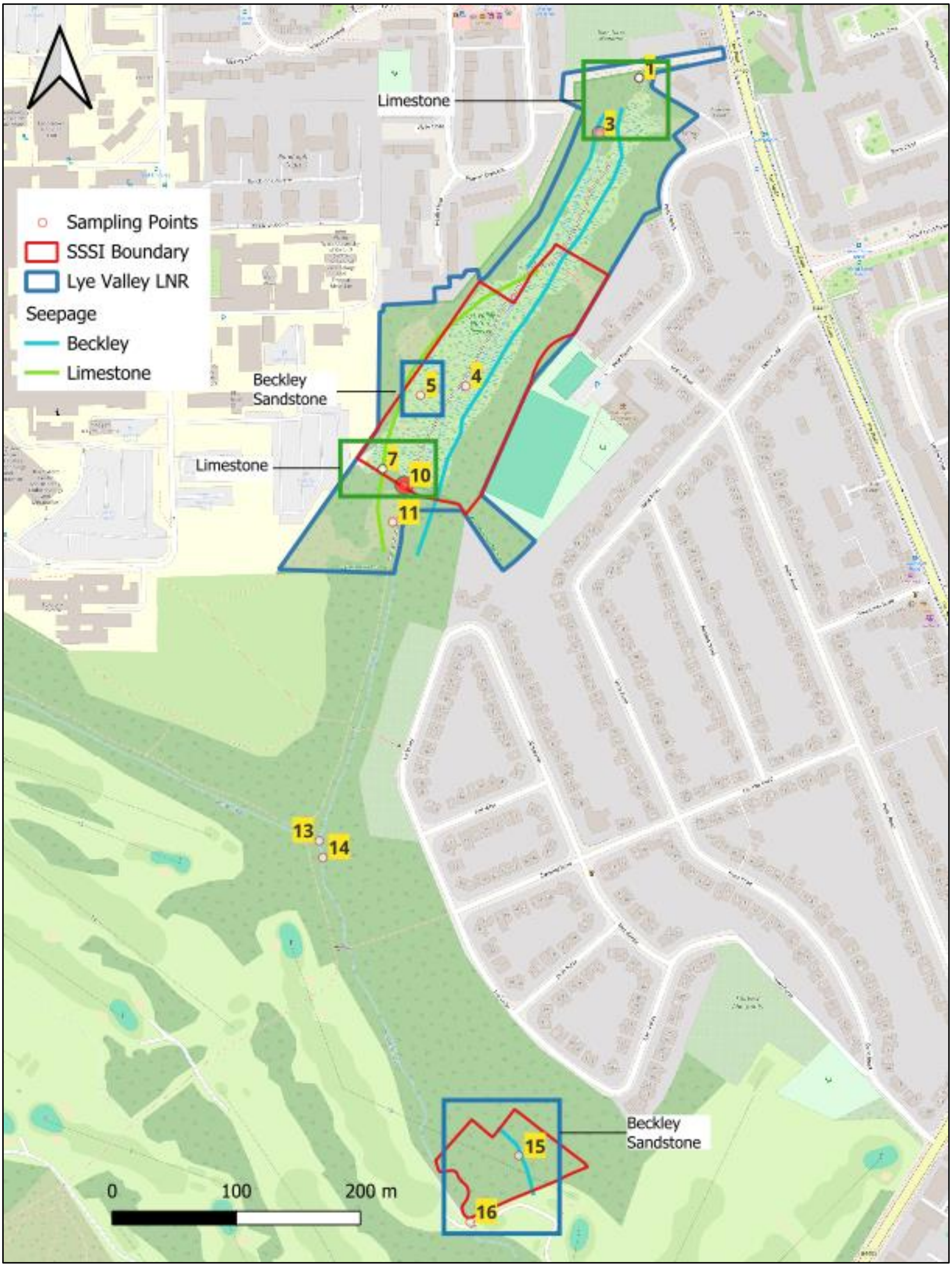


Figure 3-60: Map of inferred spring sources based off Table 3-12.

Overall, the JBA water quality monitoring replicates findings identified from earlier work. Nutrient and pollution issues are seen in the streams and limestone fed seepages. These supplies are vulnerable to pollution. Not all water supplies from surface water and limestone seepages have elevated nutrient and pollution issues. This is dependent on there being a source. The water supplies from the Beckley Sandstone appear to be naturally low in nitrate. This may be the result of denitrification processes, removing nitrate from the groundwater.

4 Eco-Hydrogeological Conceptual Model

4.1 Introduction

This section presents an eco-hydrogeological conceptual model of the site and surrounding area which can be used as a basis for the assessment of the possible impact of potential future development activities within the Lye Brook and Boundary Brook catchments, with particular focus on the Lye Valley SSSI.

4.2 Hydrogeological Conceptual Model

The Environment Agency defines a conceptual model as "a description of how a hydrogeological system is believed to behave" and its development as "an iterative or cyclical process of development and testing in which new observations are used to evaluate and improve the model." (Environment Agency, 2002, p.4.1-2).

Based upon the information described in the previous chapter the hydrogeological conceptual model is presented through a series of cross sections (see Figure 4-1 to Figure 4-3) shown in Figure 3-25 and an overview conceptualisation in Figure 4-4.

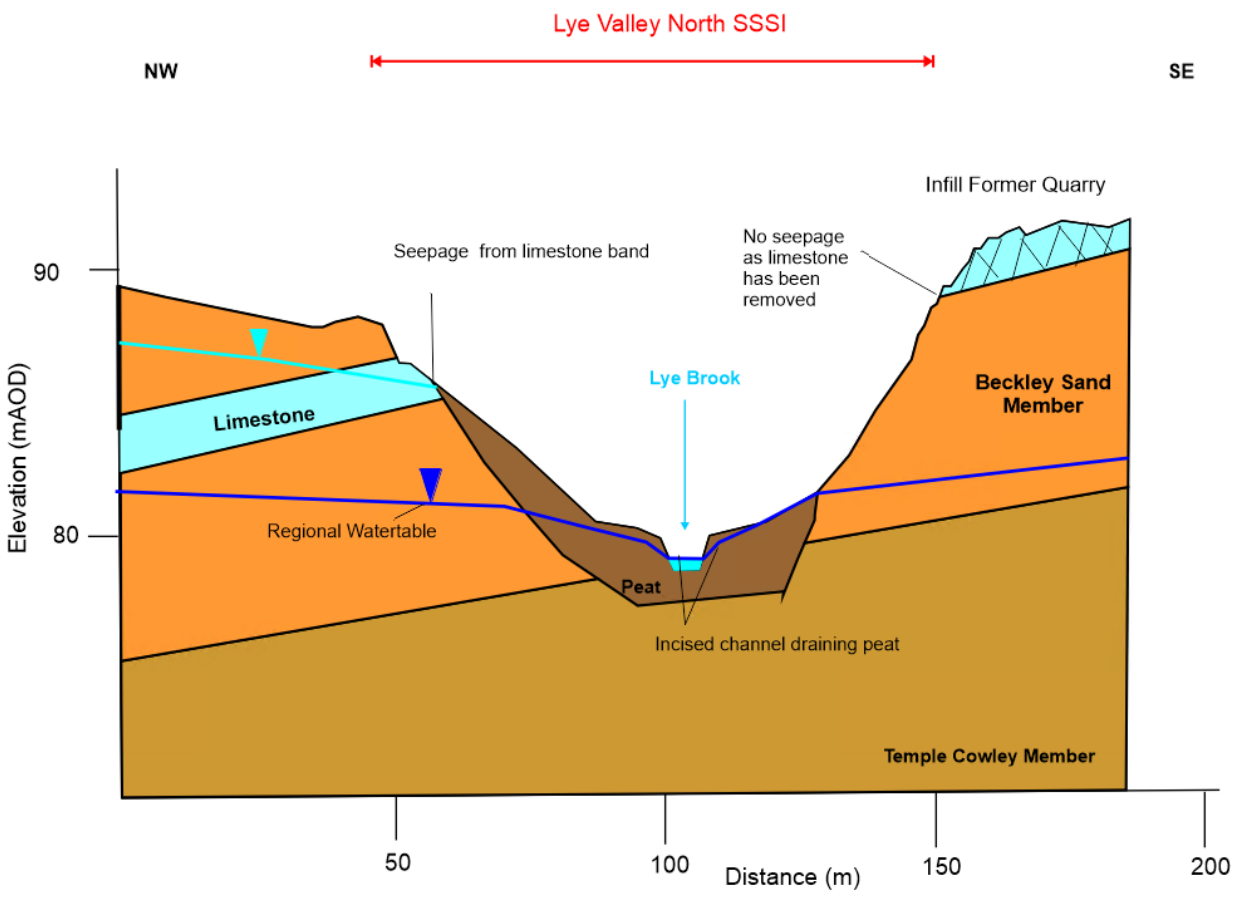


Figure 4-1: Hydrogeological conceptual model; Lye Valley North SSSI through high Seepage Face (NW-SE) (BB' - not to exact scale).

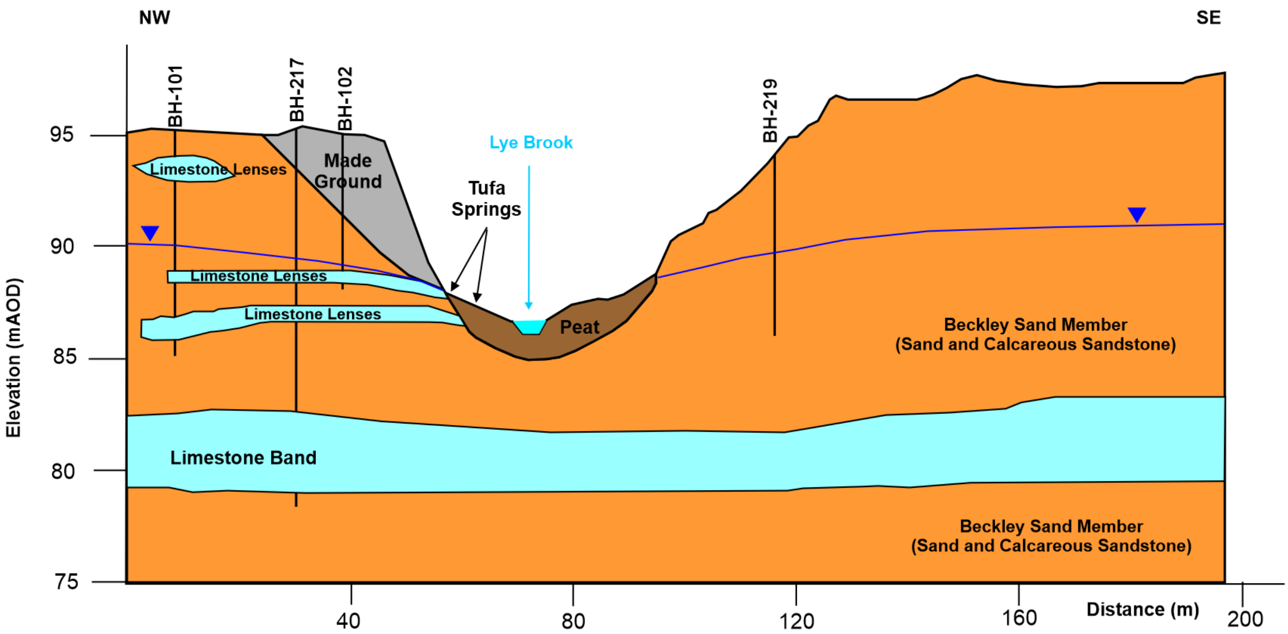


Figure 4-2: Hydrogeological conceptual model; Lye Valley North LNR through Tip (NW-SE) (CC' - not to exact scale).

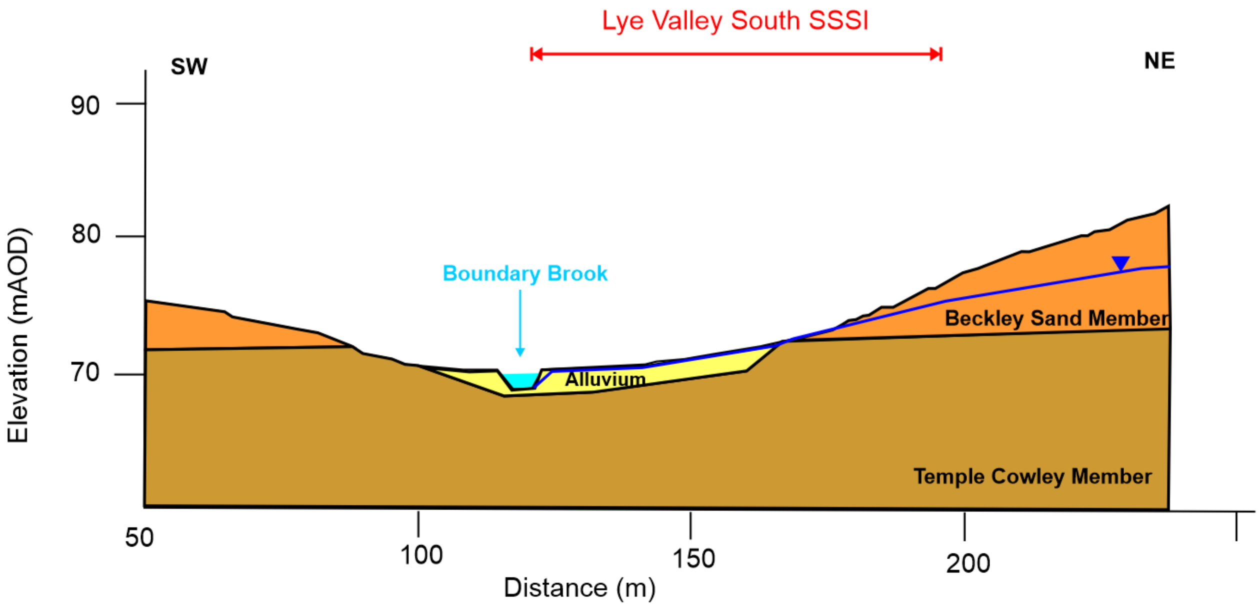


Figure 4-3: Hydrogeological conceptual model; Lye Valley South SSSI (SW-NE) (DD' - not to exact scale).

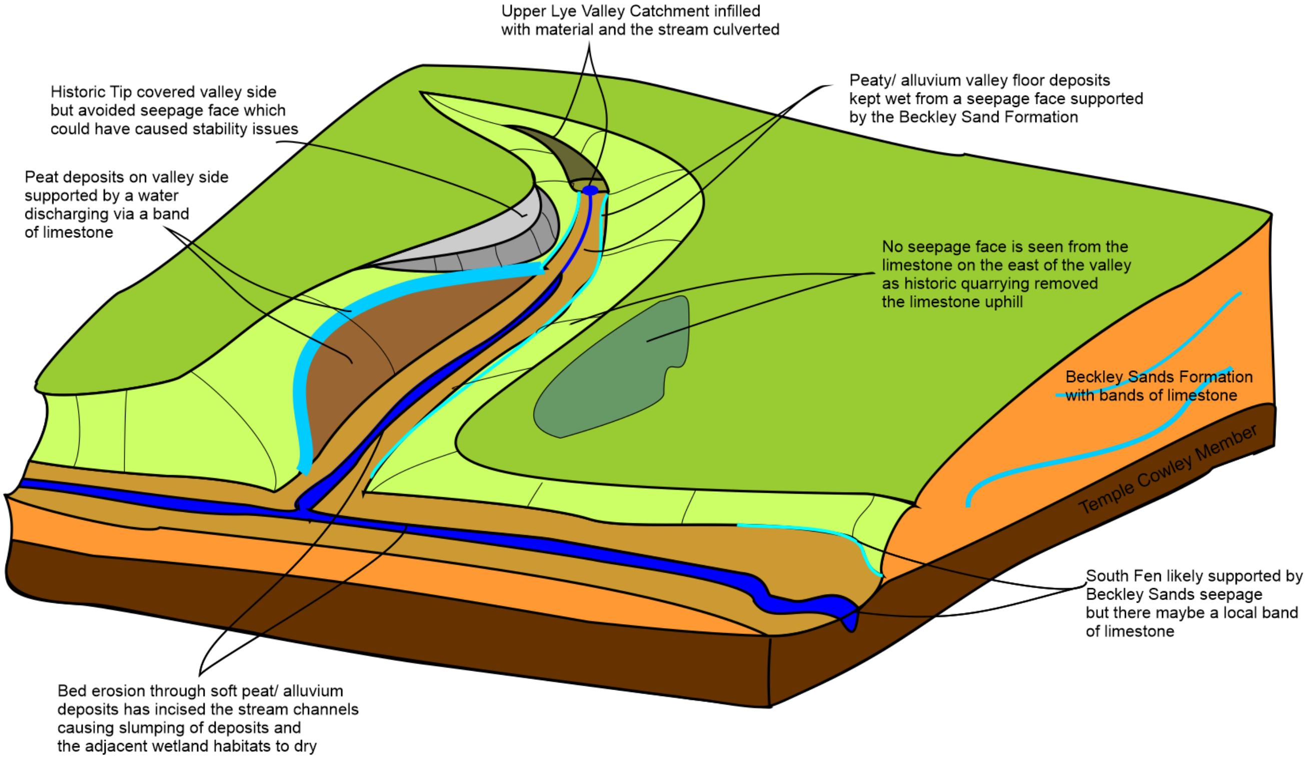


Figure 4-4: Overview conceptual model.

The main features of the conceptual model are

- Bedrock
  - The SSSI is underlain by the Beckley Sand Member followed by the Temple Cowley Member which outcrops in the lower section of Lye Valley North and in the valley base of South Fen.
- Superficial
  - The valley floor is underlain by soft peats and clay deposits
  - Part of the western valley side of Lye Valley is covered by a lobe of peat.
- Made Ground
  - A tip covers the western side of the LNR. This avoids the area of peat (likely because tipping on the peat would have causes stability issues).
- Hydrogeology
  - Beckley Sand Member - moderate permeability
  - Beckley Sand Member - Limestone bands - high permeability and where it outcrops it supports the peat lobe in Lye Valley North.
  - Temple Cowley Member - slightly lower permeability than the Beckley Sand Member
- Water Quality
  - Tufa forming springs are supplied by limestone bands.
  - Ochre precipitating springs are supplied by sandstone bands.

    - Nitrate levels in springs supplied by limestone bands are higher than those supplied by the Beckley Sand Member sandstones as there is less opportunity for denitrification by microorganisms along the flow pathway.
- Surface Water:
    - The streams have incised through the soft valley floor superficial deposits
    - This will cause drainage impacts and slumping
    - The catchment is urbanised, and the top of Lye Brook and Boundary Brook are discharge points for the surface water sewer system.

4.3 Ecohydrological Conceptual Model

The ecohydrological conceptual model builds on the hydrogeological conceptual model, combining it with ecology sources of data to describe the hydrological conditions the ecological features of interest depend upon, and the water supply mechanisms that create those conditions. They are shown in Figure 4-5 and Figure 4-6 below.

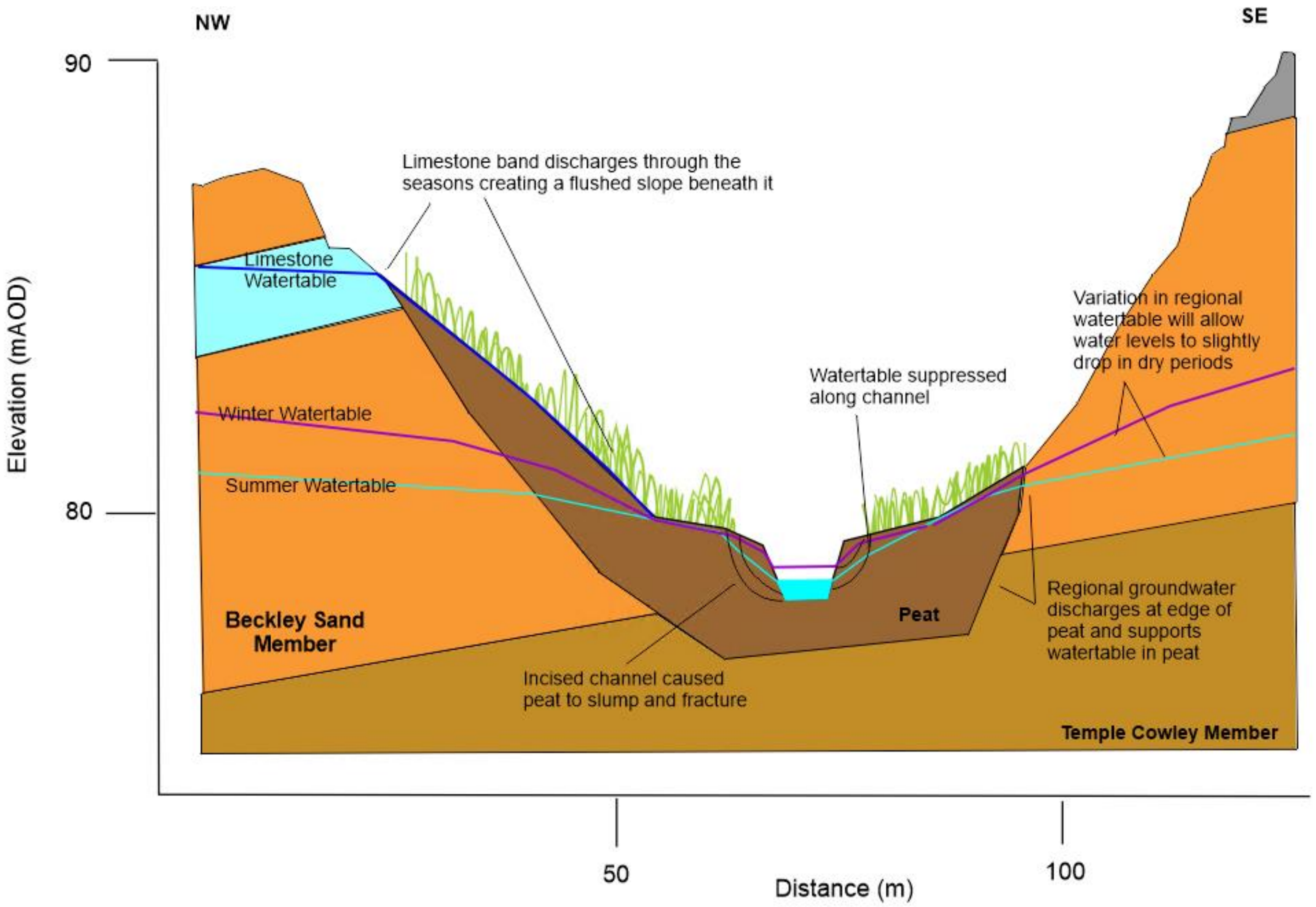


Figure 4-5: Lye Valley ecohydrological conceptual model.

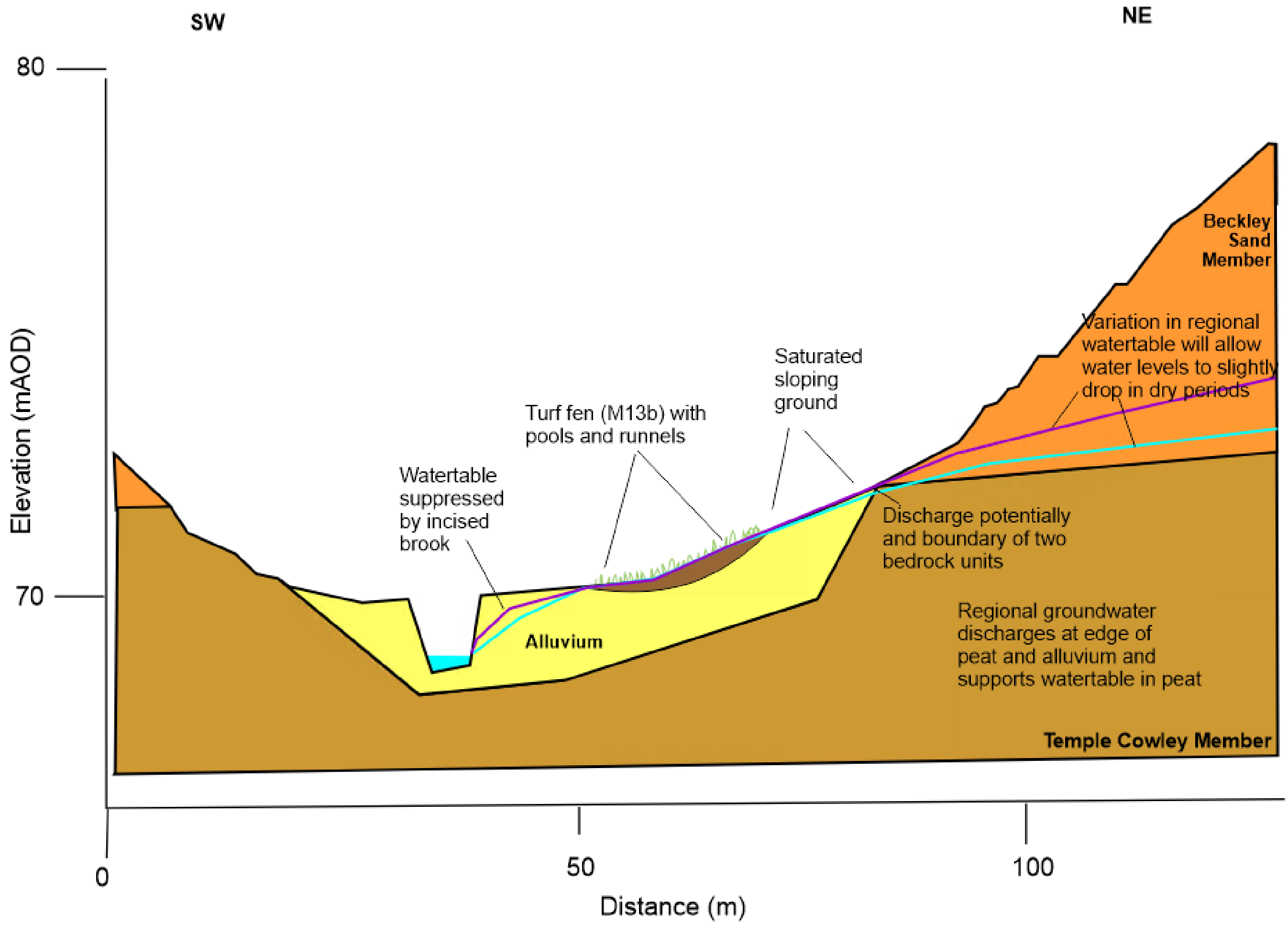


Figure 4-6: South Fen ecohydrological conceptual model.

4.4 Lye Valley Sensitivities to Change

Section 2.3 identified general sensitivity to change of the habitats in Lye Valley. This section discusses how the conditions that support the habitats at Lye Valley create particular sensitivities to change.

The review of Lye Valley has identified two significant historic changes that have affected ecohydrological conditions that support habitats of the site:

- Changes in stream power that has led to the incision of the channels, and the drainage impacts on the immediately surrounding habitats,
- Changes in nutrients, leading to elevated nutrients in some areas of the site.

The fact that Lye Valley continues to support a range of rare species and habitats despite all the changes to the catchment that have occurred suggests that some features of the site are relatively robust and insensitive to change.

4.4.1.1 Groundwater Quantity

Urbanisation has the potential to affect recharge through increased impermeable surfaces in the catchment. However in this instance, catchment development does not appear to have caused a change in recharge significant enough to affect the supply to the wetlands. The water level monitoring shows that groundwater supplies to the SSSI continue to create saturated conditions through the year. Only along incised drains, do the groundwater levels drop.

This means that despite the urbanisation of the catchment, recharge to the aquifer appears to be sufficient to support the wetland. Although urbanised, the catchments still have a high proportion of gardens, allotments, verges and other greenspace which allows recharge to be maintained.

4.4.1.2 Water Quality

The variation in nitrate levels in groundwater discharges across the site indicates that denitrification is an effective process on the slower groundwater flow pathways. Areas of the site that are dependent on rapid groundwater flows through some limestone bands are more vulnerable to nitrate pollution.

Tufa formation is also dependent on complex chemistry systems. Notably processes in the soil zone can increase the acidity of recharge and allow more ions to be dissolved. Increased hardstanding and artificial infiltration that bypasses the soil zone could change the concentration of ions in groundwater. Reviewing available borehole logs, it appears that the soils in the catchment are typically around 0.3m deep which aligns with the soil description in Section 3.7.2. This indicates that only a thin soil zone is locally necessary for the tufa forming process (this may be able to be reproduced within some types of infiltration SUDs schemes).

Other areas that are vulnerable to nitrate pollution are those affected by flooding from the watercourses. These inputs would be ephemeral but may lead to the loss of very sensitive species such as Chara spp. The incised nature of the channels means that the number of out of bank events are reduced.

4.4.1.3 Drainage Impacts

Section 3.6.1.1 describes that urbanisation appears to have led to changes in the response of the catchment to storm events, leading to increases in peak run-off and the power of the watercourses. This in turn has led to the incision of the channel.

The incised channel has led to the slumping of peat, and the lowering of the water table in the vicinity. This appears to have led to a loss of wetland species occupying these areas. The work by the Friends of Lye Valley has aided in arresting this along the main water course.

4.4.1.4 Summary

The features of the SSSI are most sensitive to:

- Changes in nutrients supplied to the limestone aquifer system,
- Changes in quality of the water infiltrating to ground and reaching the main limestone band,
- Nutrient inputs from flooding,
- Drainage impacts from the watercourses created by incised channels,
    - Therefore sensitive to increase peak run-off through urbanisation.

On the other hand the SSSI appears relatively robust to changes from:

- Changes in recharge to the Beckley Sandstone
- Nitrate inputs to the Beckley Sandstone (due to denitrification)

5 Potential Impact Mechanisms

This section considers potential impact mechanisms that could affect the SSSI and attempts to identify zones where these impacts could be sourced.

Based on the conceptualisation work the following impact mechanisms have been identified (Table 5-1 and Figure 5-1):

Table 5-1: Impact mechanisms.

Category	Linkage	Discussion
Run-off	Pollution affected run-off	The SSSI lies in a valley. Direct run-off from the immediate surrounding slopes could bring in pollution.
Sewers and Streams	Pollution discharges from the sewer network to the watercourses	Pollution sources in the catchment could be transported to the SSSI via the surface water sewer network. There is some evidence of cloudy water discharging from certain outfalls (Webb 2016).
Sewers and Streams	Increases in peak flows in sewer network	This would exacerbate the issues with the incision of the channel through the soft valley floor wetland deposits.
Groundwater	Pollution to regional groundwater	Pollution that enters the groundwater within the boundaries of the groundwater catchment may reach the SSSI. Monitoring has shown that nitrate levels are relatively low in the sandstone system, likely due to denitrification processes.
Groundwater	Pollution to limestone bands	Due to the relatively quick pathway through the limestone bands, pollution can rapidly make its way to the sections of the SSSI supported by them. Elevated nitrate levels from these bands have been monitored.

Category	Linkage	Discussion
Groundwater	Changes in groundwater chemistry - tufa formation	The tufa formation process is reliant on carbon dioxide being dissolved through the recharge process as water passes through the soil zone. The carbon dioxide makes the water more acidic (by forming carbonic acid) allowing more calcium carbonate to dissolve. Changes in land use could change the recharge process in the catchment.
Groundwater	Groundwater flow	Excavations, dewatering and piling could change groundwater discharges to the site. They could affect the regional groundwater flow through the Beckley Sand Member, and the flows through the limestone bands that support the high-level seepage face and tufa springs.
Groundwater	Groundwater volumes	Reduction in recharge would reduce the groundwater flows entering the SSSI. The most sensitive areas for change would be the recharge area supporting the Lye Valley limestone band. Elsewhere in the wider groundwater catchment, changes in recharge would affect the regional water table level.

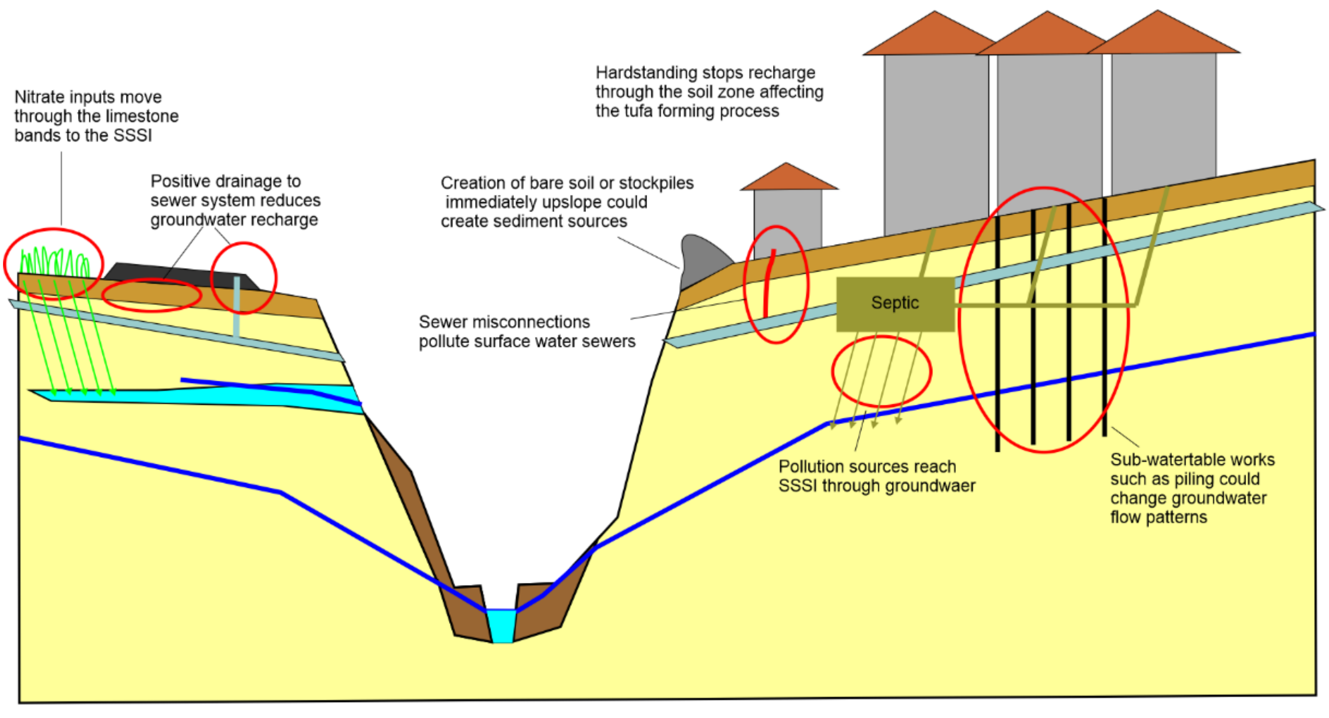


Figure 5-1: Impact conceptual model.

5.1 Impact Mechanism Zone

Each of the impact mechanisms identified in the section above will have a different spatial extent over which they could occur, for example:

- Changes in run-off causing higher peak flows to the streams will affect the surface water and sewer catchments.
- Changes to the tufa forming chemistry will be limited to the parts of the aquifer supplying the springs and seepage faces of the SSSI units.

Table 5-2 describes a series of impact zones and Figure 5-2 to Figure 5-6 presents these zones.

Table 5-2: Impact zones.

Pathway	Receptor	Impact	Area of impact	Zone
Runoff	Water Quality	Direct runoff over soil (Sediment, pollution release and soil stripping from the hillside)	Slopes immediately surrounding the SSSI where run-off could directly affect the SSSI Extent based on review of LIDAR topography mapping	Figure 5-2
Runoff	Water Quantity	Changes in the direct run-off catchment (e.g. through changes in drainage)	Slopes immediately surrounding the SSSI where run-off could directly affect the SSSI Extent based on review of LIDAR topography mapping	Figure 5-2
Sewers and Streams	Water Quality	Pollution that is released in the modified surface water catchment could reach the SSSI through surface water flood pathways	Modified Surface Water catchment	Figure 5-3
Sewers and Streams	Water Quality	Flood events may lead to pollution entrainment	Surface Water Flooding Area	Figure 5-4
Sewers and Streams	Water Quantity	Increasing flow during flood/storm events	Modified Surface Water catchment	Figure 5-3

Pathway	Receptor	Impact	Area of impact	Zone
Groundwater	Water Quality	Beckley Sand and limestone discharges: Pollution entering aquifer will reach SSSI. Urban pollution and nitrates are likely to be attenuated in the Beckley Sandstone but may rapidly reach the site through the main limestone and smaller bands. Change in soil processes affecting Tufa formation.	Area of direct groundwater supply	Figure 5-5
Groundwater	Water Quantity	Wider Aquifer - Changes in recharge: Reduction in groundwater levels and flows to SSSI.	Area limited to groundwater divides	Figure 5-6
Groundwater	Water Quantity	Limestone Band - Changes in flow at limestone seepage: Changes in flow to Limestone seepage.	Limestone Groundwater Supply area	Figure 5-5
Groundwater	Groundwater flow direction	Direct groundwater supply: Change the direction of flows to the SSSI including changing the distribution of groundwater discharges within the SSSI such as reducing flows to particular springs.	Area of direct groundwater supply	Figure 5-5

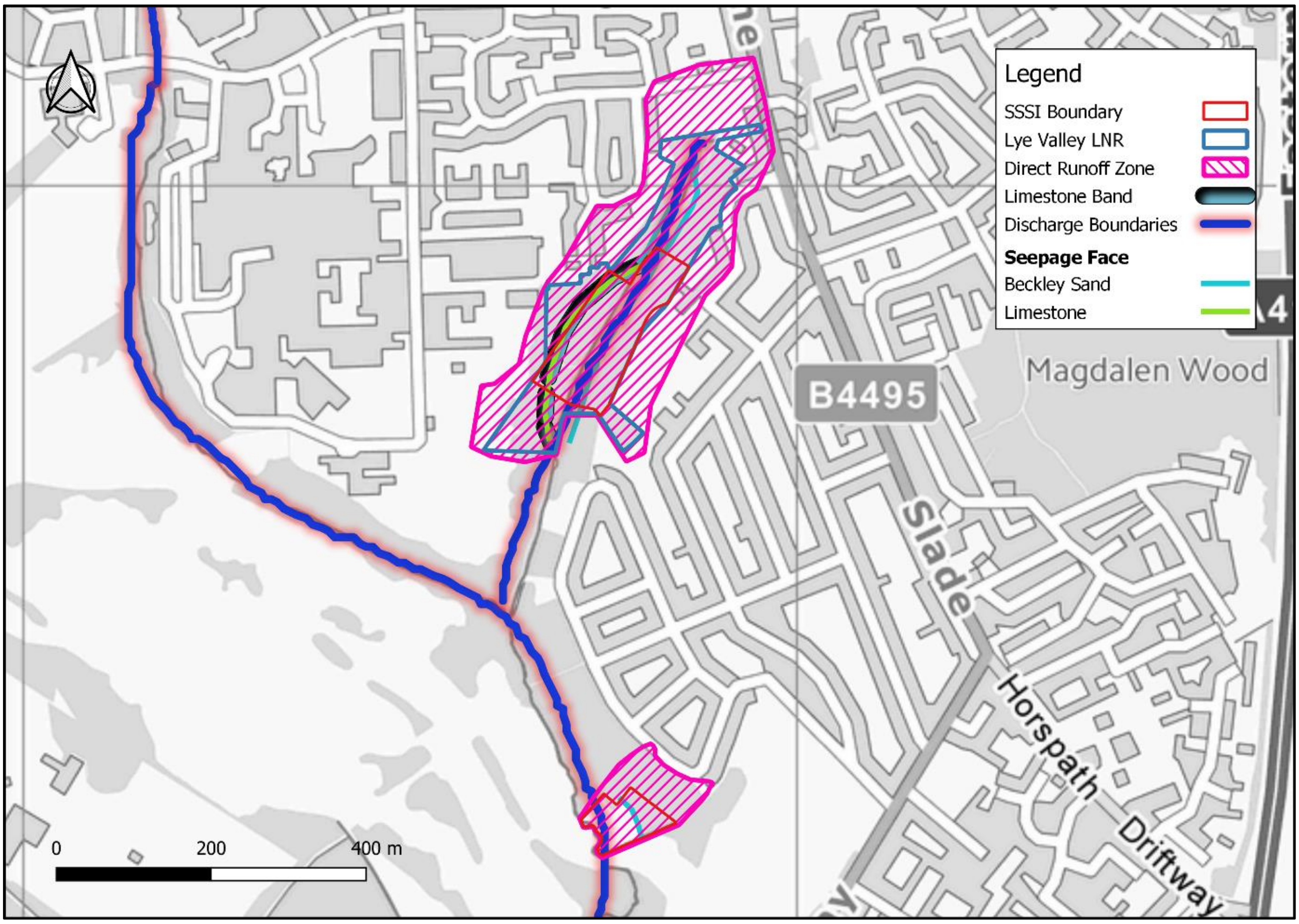


Figure 5-2: Direct runoff zone.

The Direct Runoff Zone in Figure 5-2 has been derived through review of LIDAR DTM topography data.

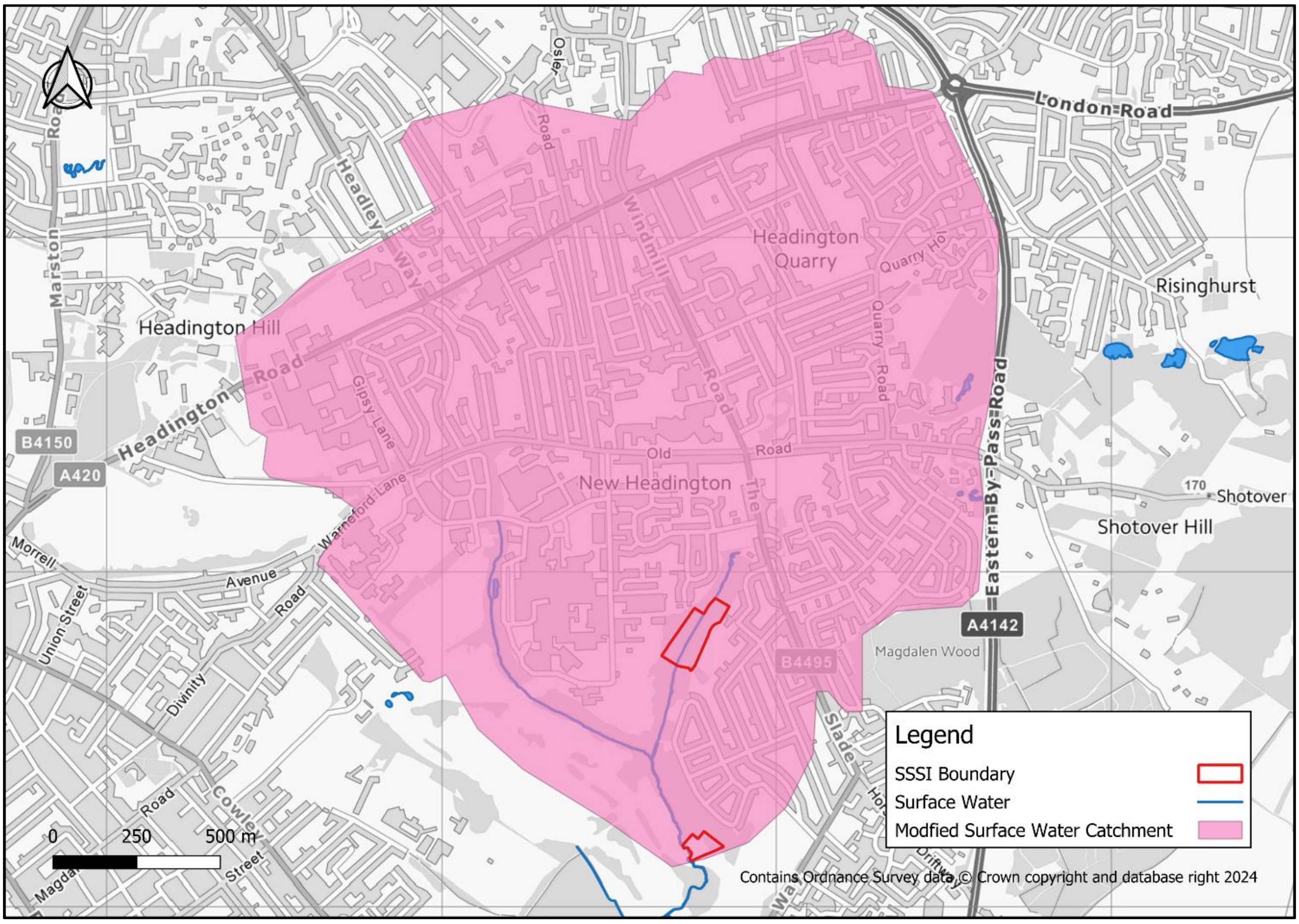


Figure 5-3: Modified surface water catchment.

The rationale behind Modified Surface Water Catchment shown in Figure 5-3 is provided in Section 3.6.3.

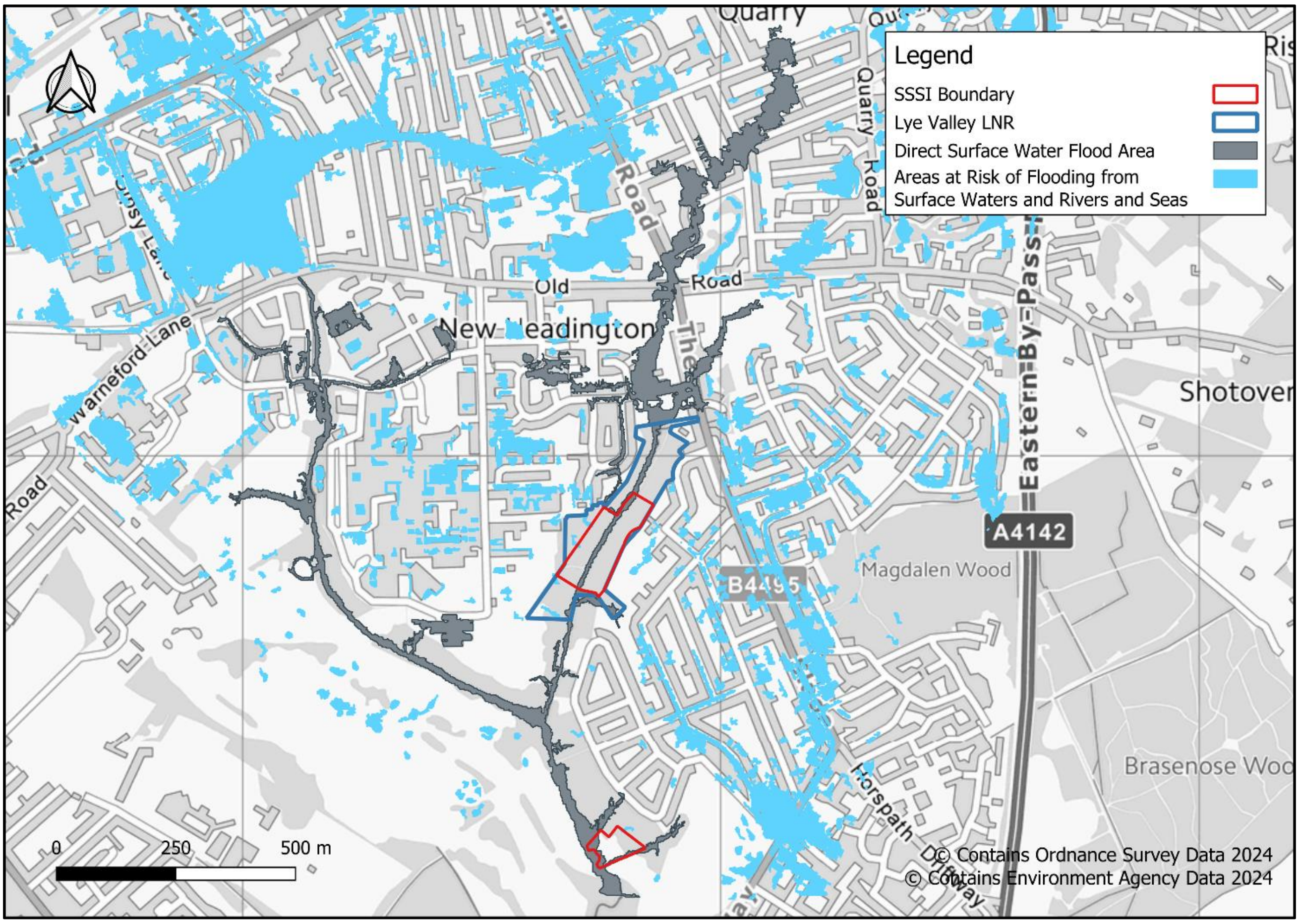


Figure 5-4: Surface water flood areas.

The surface water flood area in Figure 5-4 is based on the Environment Agency surface water flood map. The area of surface water flooding that is directly connected to the SSSI has been delineated.

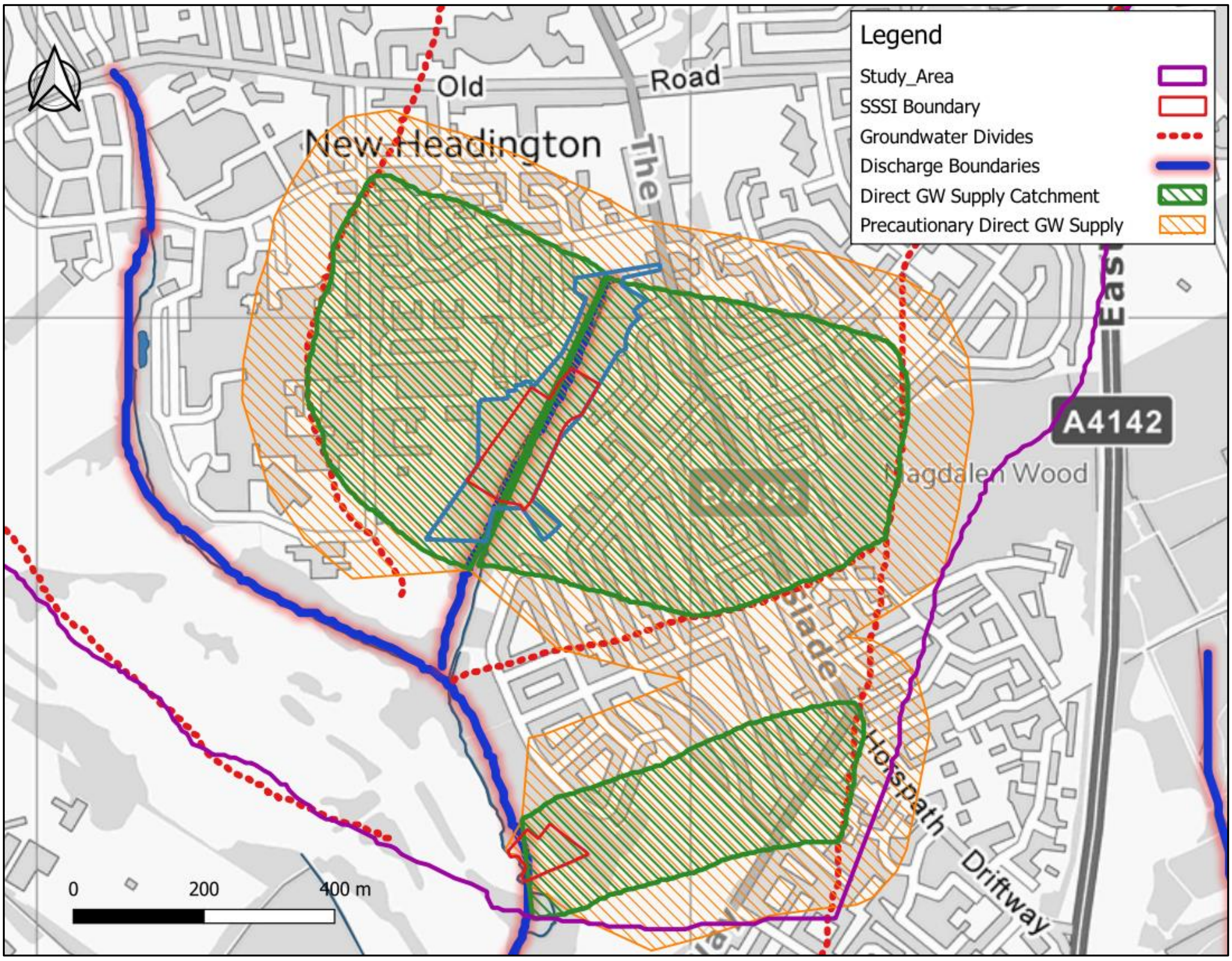


Figure 5-5: Zone of direct groundwater supply.

The rationale for the direct groundwater supply catchments is provided in Section 3.8.6. The section notes that there is some uncertainty around the edges of these areas due to the influence of limestone bands. Figure 5-5 includes a Precautionary Direct Groundwater Supply Catchment. This takes the originally derived groundwater catchment and adds a 100m buffer. It is tied in closer near the SSSIs, where there is more certainty about the groundwater flow paths. 100m has been chosen as it encompasses a significant proportion of the ground between the groundwater divides and the discharge boundaries.

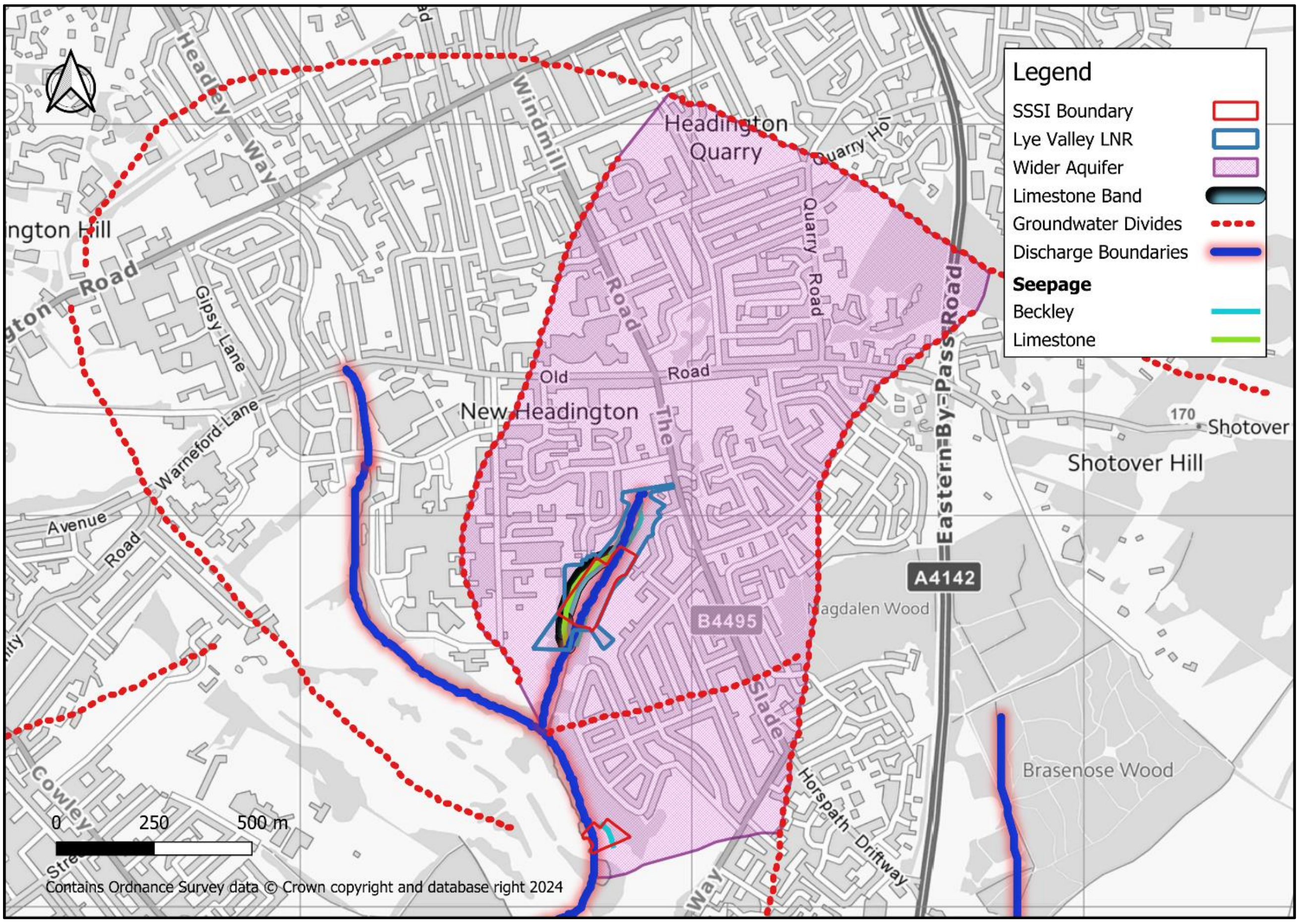


Figure 5-6: Wider aquifer.

The rationale for the Wider Aquifer in Figure 5-6 is provided in Section 3.8.6. Its boundaries are formed of the main groundwater divides.

6 Planning Guidance

The following section outlines guidance for assessing planning applications within the study area. It first outlines the test under the National Planning Policy Framework (NPPF) regarding impacts on Lye Valley. It then provides a screening assessment to be used for small scale developments that would be allowed with reduced supporting information. Section 7 goes on to identify spatially which tests a development would need to pass to be in alignment with the NPPF and the nature of the supporting documentation required to show this.

6.1 Planning Requirements

The box below outlines Paragraph 193 of the National Planning Policy Framework (accessed December 2024). Lye Valley is a SSSI and the lowland fen habitats within in are classified as Irreplaceable habitats[14]. The paragraph indicates that schemes which have an adverse effect on a SSSI should not normally be permitted and/or schemes that lead to a deterioration of irreplaceable habitats should be refused unless there is a wholly exceptional reason, and a suitable compensation strategy exists.

Box 4 - Paragraph 193 of the National Planning Policy Framework
193. When determining planning applications, local planning authorities should apply the following principles: (a) if significant harm to biodiversity resulting from a development cannot be avoided (through locating on an alternative site with less harmful impacts), adequately mitigated, or, as a last resort, compensated for, then planning permission should be refused; (b) development on land within or outside a Site of Special Scientific Interest, and which is likely to have an adverse effect on it (either individually or in combination with other developments), should not normally be permitted. The only exception is where the benefits of the development in the location proposed clearly outweigh both its likely impact on the features of the site that make it of special scientific interest, and any broader impacts on the national network of Sites of Special Scientific Interest; (c) development resulting in the loss or deterioration of irreplaceable habitats (such as ancient woodland and ancient or veteran trees) should be refused, unless there are wholly exceptional reasons and a suitable compensation strategy exists; and

14 Irreplaceable habitats - GOV.UK (www.gov.uk)

Box 4 - Paragraph 193 of the National Planning Policy Framework
(d) development whose primary objective is to conserve or enhance biodiversity should be supported; while opportunities to improve biodiversity in and around developments should be integrated as part of their design, especially where this can secure measurable net gains for biodiversity or enhance public access to nature where this is appropriate.

6.2 Screening of Small Scale Developments

The majority of planning applications in the study area that have occurred in the last 10 years within the catchment have been small in scale. This section identifies where in the catchment small scale developments could be permitted without adverse impacts. It considers the impact zones developed in Section 5, and considers whether small scale developments are of a scale that they could generate particular impacts.

Table 6-1 provides a definition of small scale development which is used in this document. It has been adapted from the definition of Minor Developments set out in the NPPF flood risk guidance, with the following modifications. 1) If a proposed development includes significant beneath water table works that have the potential to change downstream groundwater flow patterns to the SSSI (e.g. extensive basements), it cannot be defined as small scale. Works like micropilings or limited individual piling are unlikely to change groundwater flood patterns outside of the vicinity of the works. 2) The second modification to the definition is that the NPPF definition also included minor non-residential extensions. These have been excluded as the variety in those applications does not lend them to screening and it is considered to be more appropriate to subject these to the full set of tests where applicable.

Table 6-1: Definition of small scale development as adapted from the Minor Developments definition in the NPPF Flood Risk and Coastal Change Guidance.

Definition of small scale development
Small scale development in the context of this study means: • alterations: development that does not increase the size of buildings, e.g. alterations to external appearance. • householder development: for example, sheds, garages, games rooms etc. within the curtilage of the existing dwelling, in addition to physical extensions to the existing dwelling itself. This definition excludes any proposed development that would create a separate dwelling within the curtilage of the existing dwelling (e.g. subdivision of houses into flats) or any other development with a purpose not incidental to the enjoyment of the dwelling.

Figure 6-1 shows the area of the total catchment where small scale residential developments can be permitted without adverse impact on the SSSI and the irreplaceable habitats. The impact zones excluded from the Small Scale Screening Zone are outlined in Figure 6-2. Table 6-2, which follows these figures, should be referred to alongside them as it presents the rationale of the areas included and excluded from the screening zone by reviewing the impact zones outlined in Table 5-2 and presenting an assessment as to whether small scale development could cause an impact linkage to the SSSI.

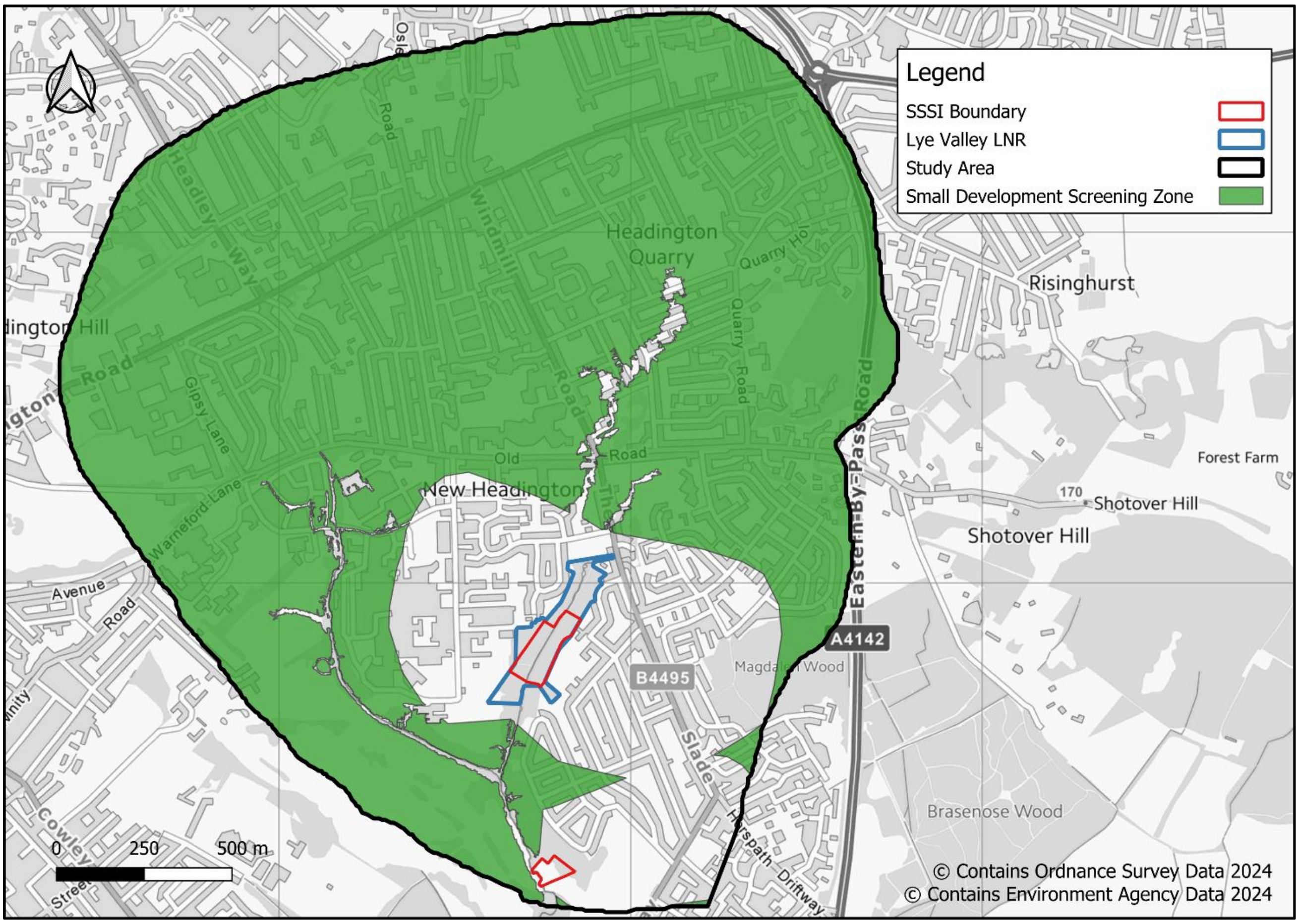


Figure 6-1: Small scale development screening zone.

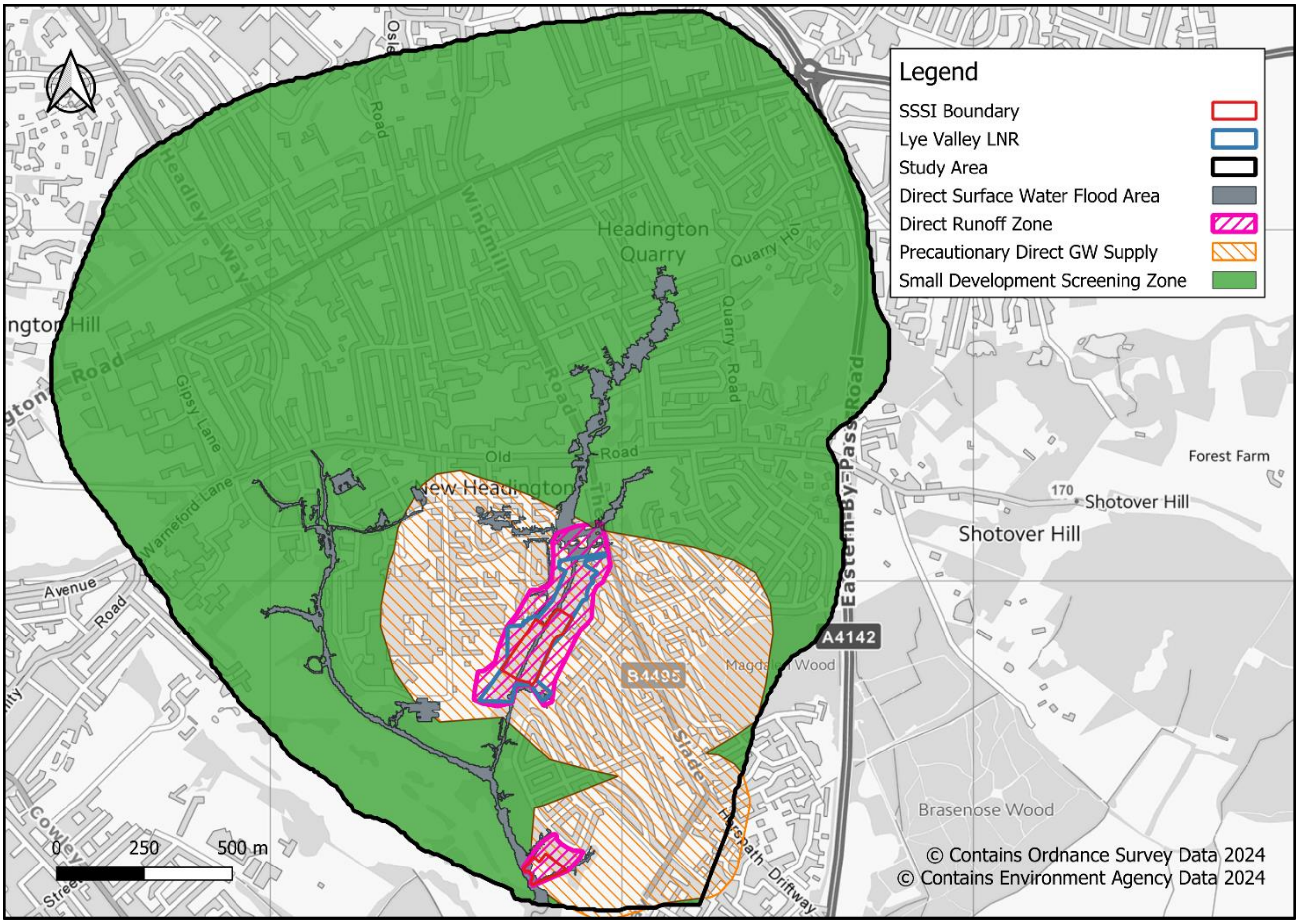


Figure 6-2: Small scale development screening zone rationale – see also the following table which explains the rationale applicable to each zone.

Table 6-2: Screening area rationale.

Pathway	Receptor	Impact	Area of impact	Zone	Impact from Minor Developments	Discussion
Runoff	Water Quality	Direct runoff over soil (Sediment, pollution release and soil stripping from the hillside).	Slopes immediately surrounding the SSSI where run-off could directly affect the SSSI	Figure 5-2	Potentially	This area is excluded from the Small Development Screening Zone as small developments could create impacts.
Runoff	Water Quantity	Changes in the direct run-off catchment (e.g. through changes in drainage).	Slopes immediately surrounding the SSSI where run-off could directly affect the SSSI	Figure 5-2	Potentially	This area is excluded from the Small Development Screening Zone as small developments could create impacts.
Sewers and Streams	Water Quality	Pollution that enters the surface water sewer network will discharge to the SSSI.	Modified Surface Water Catchment	Figure 5-3	No	Small scale developments will lead to negligible changes in water quality and quantity to sewers and streams See Section 6.2.1 for further discussion
Sewers and Streams	Water Quality	Flood events may lead to pollution entrainment.	Surface Water Flooding Area	Figure 5-4	Potentially	This area is excluded from the Small Development Screening Zone as small developments could create impacts.
Sewers and Streams	Water Quantity	Increasing flow during flood/storm events.	Modified Surface Water Catchment	Figure 5-3	No	Small Scale developments will lead to negligible changes in water quality and quantity to sewers and streams See Section 6.2.1 for further discussion
Groundwater	Water Quality	Beckley Sand And Limestone: Pollution entering aquifer will reach SSSI. Urban pollutions and nitrates are likely to be attenuated in the Beckley Sandstone but may rapidly reach the site through limestone bands. Change in soil processes affecting Tufa formation.	Precautionary area of direct groundwater supply	Figure 5-5	Potentially	This area is excluded from the Small-Scale Development Screening Zone as small developments could create impacts.
Groundwater	Water Quantity	Wider Aquifer - Changes in recharge: Reduction in groundwater levels and flows to SSSI.	Area limited to groundwater divides	Figure 5-6	No	Small Scale development will lead to negligible change groundwater recharge See Section 6.2.2

Pathway	Receptor	Impact	Area of impact	Zone	Impact from Minor Developments	Discussion
Groundwater	Groundwater flow direction	Direct Groundwater Supply Zone: Change the direction of flows to the SSSI including changing the distribution of groundwater discharges within the SSSI such as reducing flows to particular springs.	Precautionary area of direct groundwater supply	Figure 5-5	No	By definition, small scale developments will not have significant foundations or beneath water table works. Any scheme with significant foundations or beneath water table works cannot be defined as small scale.

6.2.1 Impact of Small Scale Developments on the Surface Water System

Table 6-2 identifies that there are two potential impacts of small scale developments on Lye Valley through sewers and surface water flow pathways that require further consideration:

- Increase in peak run-off rates and therefore the stream power of Lye Brook and Boundary Brook.
- Reduction in water quality through increased pressure on the foul sewer system.

Table 6-3 outlines criteria used in the NPPF to assess the effects of minor developments on flood risk which would also incorporate consideration of surface water impacts that are the key concern in this area. It then discusses if a small scale development in the Lye Valley Study Area could have an effect on peak surface water runoff rates. The table concludes that small scale developments would not have a significant impact on peak surface water runoff rates in this area.

Table 6-3: Small scale development potential impact criteria.

NPPF Criteria	Discussion
They would have an adverse effect on a watercourse, floodplain or its flood defences;	The direct surface water flooding areas are excluded from the screening zone so this is not applicable;
Where the cumulative impact of such developments would have a significant effect on local flood storage capacity or flood flows.	The modified surface water catchment is circa 3,900,000m^2 and a minor householder development is typically <50m^2 in size. This equates to 0.000013% of the catchment and would be a negligible change. Developments must be drained in accordance with building regulations, which require use of infiltration where viable. The sewer catchment upstream of Lye Valley has been estimated to be 920,000 m^2 by Thames Water. Here a small development would equate to 0.000054% of the catchment.

Table 6-3 notes that a maximum size small scale development equates to between 0.000054% to 0.000013% of the surface water catchment, depending on how far down the system a small scale development would lie. This illustrates that a very low threshold has been chosen for Small Scale Developments in line with the Precautionary Principle.

On cumulative impacts, a review of planning applications since 2018 has shown that there were around three small scale development applications per year in the study area in that time (see Appendix D). Based on that rate, if all were a maximum typical size of 50m^2, then in fifty years' time, small scale developments would occupy an additional 0.2% of the catchment. In reality, most of the small developments are much smaller in scale and often do not result in a change in hardstanding areas as they consist of a reuse of an existing site. It is suggested that a periodic review of the rate of small-scale developments be undertaken to confirm there is not a marked change in this pattern. If there is a significant change then the guidance should be revisited.

Regarding connection of foul sewerage for Small Scale Developments, it is assumed that connections to Thames Waters network will be done in alignment with their guidance and Section 106 of the Water Industry Act. Where a foul sewerage connection is required, Planning Conditions could be set requiring that this is evidenced by the applicant/agent.

6.2.2 Impact of Small Scale Developments on Recharge

Section 4.4.1.1 outlines that monitoring has shown that groundwater inputs into the SSSI continue to create saturated conditions through the year and that despite the urbanisation of the catchment, recharge to the aquifer appears to be sufficient to support the wetland and the scale of urbanisation in the catchment to date does not appear to have caused a significant change to general recharge (see Section 4.4.1.1). The wider aquifer area in Figure 5-6 is circa 1,500,000m^2 and a minor development may be circa 50m^2 in size. This equates to 0.00032% of the catchment and would be a negligible change given the scale of urbanisation in the catchment.

7 Assessment Areas

7.1 Assessment Areas and the Relevant Tests

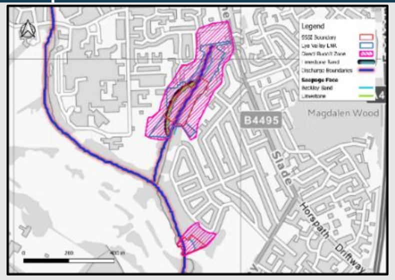
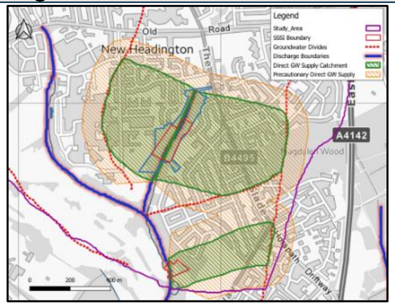
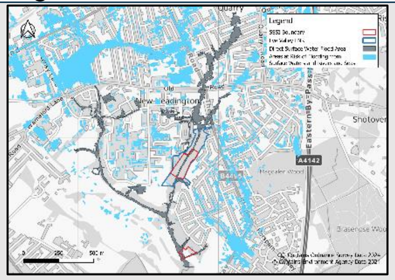
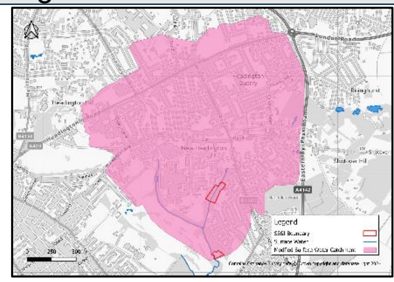
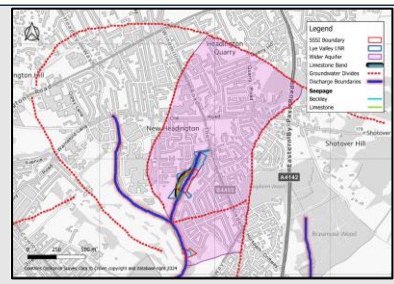
All developments which had not been excluded through the small scale development screening outlined in Section 6.2 may have the potential to adversely affect the Lye Valley SSSI or lead to a loss or deterioration of irreplaceable habitats.

This section outlines four Assessment Areas and the tests that should be passed to ensure a development in those areas meets the planning requirements outlined in Section 6.1. The Assessment Areas in Table 7-1 are based on the Impact Zones outlined in Section 5.1.

In Table 7-1, for each Assessment Area, simple tests have been developed based on potential impact mechanisms. For example, in the Precautionary Direct Groundwater Supply Area, the SSSI may be affected by changes in groundwater flow patterns and groundwater quality. Applicants must therefore show that there is no change in groundwater flow patterns or groundwater quality resulting from the development.

There may be a range of ways an applicant can show that the tests are passed, however the table also includes typical documents that may be used to address the test. For example a Drainage Strategy could be used to assess changes in peak run-off to Lye Valley.

Table 7-1: Assessment areas and tests.

Assessment Areas	Test	Typical Supporting Document	Small-Scale Development Requirements	Map Insert
1. Direct Run-off Area	1.a. No deterioration in surface water run-off quality	Construction Environmental Management Plan with a specific mitigation of impacts on Lye Valley SSSI	Construction Environmental Management Plan with a specific mitigation of impacts on Lye Valley SSSI	 Figure 5-2
2. Precautionary Direct Groundwater Supply Areas	2.a. No change in groundwater flow patterns (e.g. caused by basements and sheet piling operations) 2.b. No change in groundwater quality – which can be addressed using the SUDs method	Hydrogeological Impact Assessment with a specific assessment of impacts on Lye Valley SSSI	See Section 7.2	 Figure 5-5
3. Direct Surface Water Flooding Catchment	3.a. No deterioration in surface water run-off quality 3.b. No change in surface water flooding patterns on the SSSI	Drainage Strategy and Construction Environmental Management Plan	Construction Environmental Management Plan	 Figure 5-4
4. Modified Surface Water Catchment	4.a. No increase in run-off rates peak discharges to the surface water drainage network or run-off to streams. Preferably a reduction should be secured. 4.b. No change in water quality entering the drainage network	If proposing to connect to surface water sewer or watercourse: Drainage Strategy with a specific assessment of impacts on Lye Valley SSSI	Excluded through the screening of small scale developments (see Section 6.2)	 Figure 5-3
5. Aquifer Recharge	5.a. No change in recharge rates to the aquifer e.g. Drainage schemes should allow all typical rainfall to be infiltrated to ground outside of storm events.	Drainage Strategy with a specific assessment of impacts on Lye Valley SSSI	Excluded through the screening of minor development (see Section 6.2)	 Figure 5-6

7.2 Small-Scale Development Requirements of the Direct Groundwater Supply Areas

Tests in the Precautionary Direct Groundwater Supply Zone are limited to:

- No change in groundwater flow patterns,
- No change in groundwater quality.

Small-Scale Developments are defined in Section 6.2, which notes that the definition excludes developments that include significant beneath water table works. Therefore, they by definition will not result in changes in groundwater flow patterns. The assessment requirements are therefore limited to reviewing changes in groundwater quality. A screening assessment can be undertaken by Oxford City Council through reviewing the questions in Table 7-2. If the answer to any question is yes, then it is recommended that additional evidence, such as might be included in a fuller hydrogeological risk assessment, would be required. If answers to all questions are no, then the development is unlikely to be a source of impacts, and no additional assessment would be required.

Table 7-2: Small scale development in the direct groundwater supply area screening questions.

Screening Question	Discussion
Excluding roof run-off, does the proposal include infiltration SUDs?	Infiltration SUDs could be a potential source of/pathway for contaminants e.g. from vehicles/trafficked areas. The exception to this is clear rain roof drainage which Environment Agency guidance suggests is suitable in sensitive groundwater settings such as Source Protection Zone 1[15].
Does the proposal include conversion of land to landscaping?	This could be a potential source of nitrate.
Does the proposal include foul sewerage being dealt with other than through connection to the foul sewer network?	Septic tanks and potentially cesspits could be a source of nutrients and other contaminants and may not be appropriate.
Does the proposal include other potential sources of significant contamination?	The potential main sources of contamination from small developments are considered in the other questions, however there may always be other sources of contamination particular to a development. By only including residential developments in the definition of small scale developments, the potential for contamination sources is limited.

[15] The Environment Agency's approach to groundwater protection February 2018 Version 1.2 https://assets.publishing.service.gov.uk/media/5ab38864e5274a3dc898e29b/Envirnment-Agency-approach-to-groundwater-protection.pdf

8 Conclusion

Changes in the catchment of Lye Valley have led to impacts on the quality of the habitats in the SSSI and LNR. Through a baseline study and the development of a conceptual model, the sensitivity to changes of those habitats and the sources of those changes has been spatially identified. The impact zones produced from this process have formed the basis of planning guidance and identify the tests required to be passed for developments to ensure that there is no deterioration of the irreplaceable habitats of Lye Valley.

A JBA Borehole Logs

A.1 Installation Information

JBA installed 3 Boreholes on the 7th of February. A Barometer was also installed near JBH3.

Table A1 shows the names and locations of each Borehole installed on the day. Sediment descriptions were also carried out in the subsequent locations and presented in Section A.2 below.

Table A1: Borehole names and locations.

Borehole	Grid Reference (E, N)	Depth to Base (m)	Casing Above ground (cm)
JBH1	454758 , 205880	1	10
JBH2	454726 , 205185	1	10
JBH3	454749 , 205210	1	5
Barometer	54769 , 205233	-	-

A.2 Sediment Description

A.2.1 JBH1 Log

0-10cm: Surface water (highly saturated seepage face)

10-90cm: Very Wet silty clayey soil

A.2.2 JBH2 Log

0-20cm: Topsoil. Dark with route fibres.

20-30cm: 20-30cm: Wet sandy clay with some root fibres.

30-90cm: Very wet and light grey clayey sand getting wetter with depth.

A.2.3 JBH3 Log

0-20cm: Topsoil. Soil is wet from the top with root fibres throughout.

20-30cm: Wet sandy clay with some root fibres.

40-60cm: Increase in sand content in the clay with depth.

60-95cm: Grey silty sand

B Water Quality Testing

2022s0852 Lye Valley Oxford

					SW	SW	Pond	SW	SW	SW	SST	SST	Seepage (LST)	LST	LST	SW
Laboratory Sample Number					29661973	29661975	29661979	29661980	29661981	29661984	29661976	29661983	29661974	29661977	29661978	29661985
Sample Number					1	4	11	13	14	16	5	15	3	7	10	DUP 01
Date Sampled					16/04/2024	16/04/2024	16/04/2024	16/04/2024	16/04/2024	16/04/2024	16/04/2024	16/04/2024	16/04/2024	16/04/2024	16/04/2024	16/04/2024
General Inorganics	**Units**	EQS - Annual Average	EQS - Maximum Allowable Concentration	Maximum Concentration												
pH	pH Units		**<6,>9**	8.27	8.27	7.91	7.7	8.21	8.21	8.2	8.04	8.07	7.83	7.81	7.88	8.19
Alkalinity, Bicarbonate as CaCO3	mg/l			716	228	285	303	283	271	269	370	374	461	559	716	284
Alkalinity, Total as CaCO3	mg/l			716	228	285	303	283	271	269	370	374	461	559	716	284
Ammoniacal Nitrogen as N	mg/l	**0.3**			<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Chloride	mg/l	**250**		65.2	47	54.4	44.9	52	65.2	62.6	54.9	28.6	51.1	46.2	45.4	51.7
Conductivity @ 20 deg.C	mS/cm			0.942	0.635	0.776	0.641	0.742	0.766	0.763	0.801	0.638	0.942	0.722	0.693	0.743
Fluoride	mg/l	**5**	**15**		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Nitrate as NO3	mg/l			70	15.4	14.4	<0.3	11.4	11.7	10.8	2.14	15	70	9.08	1.87	11.3
Nitrite as NO2	mg/l			0.096	0.06	0.096	<0.05	<0.05	0.06	0.059	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Phosphate (Ortho as PO4)	mg/l			1	1	0.097	0.081	0.051	0.108	0.09	0.126	<0.05	<0.05	0.107	<0.05	0.053
Sulphate	mg/l	**400**		111	55.8	77.9	3.8	68.1	70.3	68.8	56.5	41.9	111	57.2	36.1	68
Filtered Metals (Dissolved)																
Calcium (Dis.Filt)	mg/l			186	97.5	142	120	136	130	129	122	128	186	129	123	134
Iron (Dis.Filt)	mg/l	**1**		0.145	<0.019	0.145	0.0503	0.0623	0.0564	0.0516	0.0415	0.0391	<0.019	<0.019	0.0457	0.0602
Magnesium (Dis.Filt)	mg/l			6.29	6.29	4.75	2.51	4.36	4.73	4.53	3.09	2.4	5.04	3.17	3.26	4.35
Potassium (Dis.Filt)	mg/l			3.36	2.91	2.65	<0.2	2.36	3.36	3.16	1.07	0.762	1.99	3.05	3.16	2.38
Sodium (Dis.Filt)	mg/l			57.5	29.7	25.9	20.5	25.1	35.5	32.8	57.5	19.2	24.6	26.3	26.7	25
Unfiltered Metals (Total)																
Hardness, Total as CaCO3 unfiltered	mg/l			592	267	382	313	356	340	331	480	429	592	368	544	359
PAHs																
Acenaphthene (aq)	µg/l			0.0419	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.0315	<0.05	0.0419	<0.025	0.0369	<0.005
Acenaphthylene (aq)	µg/l				<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.025	<0.05	<0.025	<0.025	<0.025	<0.005
Anthracene (aq)	µg/l	**0.1**		0.0599	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.025	<0.05	0.0557	<0.025	0.0599	<0.005
Benzo(a)anthracene (aq)	µg/l			0.215	0.00751	<0.005	<0.005	<0.005	<0.005	<0.005	<0.025	<0.05	0.0728	<0.025	0.215	<0.005
Benzo(a)pyrene (aq)	µg/l	**1.74E-04**		**0.456**	0.0532	<0.002	<0.002	<0.002	<0.002	<0.002	<0.01	<0.02	0.19	0.103	0.456	<0.002
Benzo(b)fluoranthene (aq)	µg/l	**1.74E-04**		**0.59**	0.0829	0.0142	<0.005	<0.005	0.00783	<0.005	0.0345	<0.05	0.256	0.138	0.59	<0.005
Benzo(g,h,i)perylene (aq)	µg/l	**1.74E-04**		**0.241**	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.025	<0.05	<0.025	<0.025	0.241	<0.005
Benzo(k)fluoranthene (aq)	µg/l	**1.74E-04**		**0.294**	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.025	<0.05	0.115	<0.025	0.294	<0.005
Chrysene (aq)	µg/l			0.509	0.0599	<0.005	<0.005	<0.005	<0.005	<0.005	<0.025	<0.05	0.235	0.117	0.509	<0.005
Dibenzo(a,h)anthracene (aq)	µg/l				<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.025	<0.05	<0.025	<0.025	<0.025	<0.005
Fluoranthene (aq)	µg/l	**0.0063**		**0.721**	0.0914	0.0219	<0.005	0.0104	0.0164	0.0119	0.0618	<0.05	0.483	0.196	0.721	<0.005
Fluorene (aq)	µg/l			0.0544	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.025	<0.05	0.0544	<0.025	<0.025	<0.005
Indeno(1,2,3-cd)pyrene (aq)	µg/l	**1.74E-04**		**0.272**	0.0351	<0.005	<0.005	<0.005	<0.005	<0.005	<0.025	<0.05	0.123	0.0602	0.272	<0.005
Naphthalene (aq)	µg/l	**2**		0.0767	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.0767	<0.1	<0.05	<0.05	0.0745	<0.01
PAH, Total Detected USEPA 16 (aq)	µg/l			4.4	0.461	<0.082	<0.082	<0.082	<0.082	<0.082	<0.41	<0.82	2.27	0.799	4.4	<0.082
Phenanthrene (aq)	µg/l			0.202	0.0353	<0.005	<0.005	<0.005	<0.005	<0.005	<0.025	<0.05	0.185	<0.025	0.202	<0.005
Pyrene (aq)	µg/l			0.729	0.0956	0.0226	<0.005	0.0098	0.0149	0.0104	0.0523	<0.05	0.461	0.185	0.729	0.00863

Indicates an Exceedance of EQS

Annual Average - The AA EQS provides protection against long term chemical exposure. Monitoring data should therefore be carried out over a number of seasons.

Environment Agency EQSs utilised in surface water risk assessments as part of environmental permit applications and WFD assessments in ENGLAND. https://www.gov.uk/guidance/surface-water-pollution-risk-assessment-for-your-environmental-permit

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					SW	SW	Pond	SW	SW	SW	Spring (SST)	SST	Seepage (LST)	LST	LST	SW
Laboratory Sample Number					29661973	29661975	29661979	29661980	29661981	29661984	29661976	29661983	29661974	29661977	29661978	29661985
Sample Number					1	4	11	13	14	16	5	15	3	7	10	DUP 01
Date Sampled					16/04/2024	16/04/2024	16/04/2024	16/04/2024	16/04/2024	16/04/2024	16/04/2024	16/04/2024	16/04/2024	16/04/2024	16/04/2024	16/04/2024
General Inorganics	**Units**	GWDTE - Lowland fen nitrate standard	Stonewort Water Quality Limits	Maximum Concentration												
pH	pH Units			8.27	8.27	7.91	7.7	8.21	8.21	8.2	8.04	8.07	7.83	7.81	7.88	8.19
Alkalinity, Bicarbonate as CaCO3	mg/l			716	228	285	303	283	271	269	370	374	461	559	716	284
Alkalinity, Total as CaCO3	mg/l			716	228	285	303	283	271	269	370	374	461	559	716	284
Ammoniacal Nitrogen as N	mg/l				<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Chloride	mg/l			65.2	47	54.4	44.9	52	65.2	62.6	54.9	28.6	51.1	46.2	45.4	51.7
Conductivity @ 20 deg.C	mS/cm			0.942	0.635	0.776	0.641	0.742	0.766	0.763	0.801	0.638	0.942	0.722	0.693	0.743
Fluoride	mg/l				<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Nitrate as NO3	mg/l	**20**	**2.21**	70	15.4	14.4	<0.3	11.4	11.7	10.8	2.14	15	70	9.08	1.87	11.3
Nitrite as NO2	mg/l			0.096	0.06	0.096	<0.05	<0.05	0.06	0.059	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Phosphate (Ortho as PO4)	mg/l		**0.02**	1	1	0.097	0.081	0.051	0.108	0.09	0.126	<0.05	<0.05	0.107	<0.05	0.053
Sulphate	mg/l			111	55.8	77.9	3.8	68.1	70.3	68.8	56.5	41.9	111	57.2	36.1	68
Filtered Metals (Dissolved)																
Calcium (Dis.Filt)	mg/l			186	97.5	142	120	136	130	129	122	128	186	129	123	134
Iron (Dis.Filt)	mg/l			0.145	<0.019	0.145	0.0503	0.0623	0.0564	0.0516	0.0415	0.0391	<0.019	<0.019	0.0457	0.0602
Magnesium (Dis.Filt)	mg/l			6.29	6.29	4.75	2.51	4.36	4.73	4.53	3.09	2.4	5.04	3.17	3.26	4.35
Potassium (Dis.Filt)	mg/l			3.36	2.91	2.65	<0.2	2.36	3.36	3.16	1.07	0.762	1.99	3.05	3.16	2.38
Sodium (Dis.Filt)	mg/l			57.5	29.7	25.9	20.5	25.1	35.5	32.8	57.5	19.2	24.6	26.3	26.7	25
Unfiltered Metals (Total)																
Hardness, Total as CaCO3 unfiltered	mg/l			592	267	382	313	356	340	331	480	429	592	368	544	359
PAHs																
Acenaphthene (aq)	µg/l			0.0419	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.0315	<0.05	0.0419	<0.025	0.0369	<0.005
Acenaphthylene (aq)	µg/l				<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.025	<0.05	<0.025	<0.025	<0.025	<0.005
Anthracene (aq)	µg/l			0.0599	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.025	<0.05	0.0557	<0.025	0.0599	<0.005
Benzo(a)anthracene (aq)	µg/l			0.215	0.00751	<0.005	<0.005	<0.005	<0.005	<0.005	<0.025	<0.05	0.0728	<0.025	0.215	<0.005
Benzo(a)pyrene (aq)	µg/l			**0.456**	0.0532	<0.002	<0.002	<0.002	<0.002	<0.002	<0.01	<0.02	0.19	0.103	0.456	<0.002
Benzo(b)fluoranthene (aq)	µg/l			0.59	0.0829	0.0142	<0.005	<0.005	0.00783	<0.005	0.0345	<0.05	0.256	0.138	0.59	<0.005
Benzo(g,h,i)perylene (aq)	µg/l			0.241	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.025	<0.05	<0.025	<0.025	0.241	<0.005
Benzo(k)fluoranthene (aq)	µg/l			0.294	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.025	<0.05	0.115	<0.025	0.294	<0.005
Chrysene (aq)	µg/l			0.509	0.0599	<0.005	<0.005	<0.005	<0.005	<0.005	<0.025	<0.05	0.235	0.117	0.509	<0.005
Dibenzo(a,h)anthracene (aq)	µg/l				<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.025	<0.05	<0.025	<0.025	<0.025	<0.005
Fluoranthene (aq)	µg/l			0.721	0.0914	0.0219	<0.005	0.0104	0.0164	0.0119	0.0618	<0.05	0.483	0.196	0.721	<0.005
Fluorene (aq)	µg/l			0.0544	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.025	<0.05	0.0544	<0.025	<0.025	<0.005
Indeno(1,2,3-cd)pyrene (aq)	µg/l			0.272	0.0351	<0.005	<0.005	<0.005	<0.005	<0.005	<0.025	<0.05	0.123	0.0602	0.272	<0.005
Naphthalene (aq)	µg/l			0.0767	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.0767	<0.1	<0.05	<0.05	0.0745	<0.01
PAH, Total Detected USEPA 16 (aq)	µg/l			4.4	0.461	<0.082	<0.082	<0.082	<0.082	<0.082	<0.41	<0.82	2.27	0.799	4.4	<0.082
Phenanthrene (aq)	µg/l			0.202	0.0353	<0.005	<0.005	<0.005	<0.005	<0.005	<0.025	<0.05	0.185	<0.025	0.202	<0.005
Pyrene (aq)	µg/l			0.729	0.0956	0.0226	<0.005	0.0098	0.0149	0.0104	0.0523	<0.05	0.461	0.185	0.729	0.00863

Indicates an exceedance of lowland fen water quality limit

Indicates an exceedance of stonewort water quality limit

UKTAG (2012) suggests a threshold for nitrate of 20mg/l for lowland fens (oligotrophic and wetlands at tufa forming springs) https://www.wfduk.org/sites/default/files/Media/Environmental%20standards/GWDTE%20chemica

Published water quality limits for the health of these stoneworts are available. Stoneworts are disadvantaged if nitrate in the water is above 2.21mg/l (2.2ppm).

Stoneworts are disadvantaged if phosphate in water is above 20 micrograms/litre (0.02ppm).

C Land East of Warren Cresent, Land Quality Assessment, WSP, 2018

D List of the types of Planning Applications in the area: September 2018 – September 2023

D.1 Direct runoff zone

- Erection of 10 dwellings together with associated car parking, cycle and bin storage (Affordable Housing Statement)
- Renewal and relocation of bin stores and associated landscaping
- Erection of rear extension
- Formation of ramped access to the Peat Moors Maisonettes. Alterations to landscaping and provision of bin stores.

D.2 Stream flow zone

- Erection of 10 dwellings together with associated car parking, cycle and bin storage (Affordable Housing Statement)
- Erection of dwellinghouses
- Demolition of existing conservatory/porch/garage/extension and erection of rear and/or side extension
- Loft conversion and alteration to the roof
- Bin and cycle storage, drainage and SUDs maintenance of existing planning permission

D.3 Zone of direct groundwater supply

- Erection of dwellinghouses
- Demolition of existing conservatory/porch/garage/extension and erection of rear and/or side extension
- Loft conversion and alteration to the roof
- Bin and cycle storage, drainage and SUDs maintenance of existing planning permission

D.4 Zone of limestone groundwater supply

- Demolition of buildings, store and garage
- Erection of 10 dwellings together with associated car parking, cycle and bin storage (Affordable Housing Statement)
- Erection of dwellinghouses
- Change of use of the John Warin Ward from Use Class C2 to Use Class D1 for use as a clinical research facility and respiratory medicine centre. Refurbishment of the building to include ancillary offices, an incidental overnight monitoring facility and installation of associated external plant, flues, landscaping and a

bicycle shed.) to allow additional 3no. flue stacks sited within a new plant compound.

D.5 Wider aquifer

- Erection of 10 dwellings together with associated car parking, cycle and bin storage (Affordable Housing Statement)
- Erection of dwellinghouses
- Demolition of existing conservatory/porch/garage/extension and erection of rear and/or side extension
- Loft conversion and alteration to the roof
- Bin and cycle storage, drainage and SUDs maintenance of existing planning permission

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Note additional online sources are listed in Section 3.1 and in footnotes throughout the report.

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