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# Bailrigg Garden Village - Geo-Environmental Assessment

Final Version

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## Contract

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# 1 Introduction

## 1.1 Background

JBA Consulting have been commissioned by Lancaster City Council to conduct a Strategic Phase I Contaminated Land Study and a Strategic Groundwater Constraints Analysis in relation to the proposed Garden Village development at Bailrigg.

## 1.2 Aim and Scope of Study

The report provides the following analysis:

- A strategic phase I contaminated land desk study and site visit:
  - This will provide a broad categorisation of the site, and identify which parts of the site would likely require further contaminated land investigation if they were to be developed.
- Groundwater Constraints Analysis:
  - Identify areas susceptible to groundwater emergence, groundwater flooding, and high groundwater tables.

The report does not include any geotechnical assessment of the site (e.g. assessment of soil and bedrock properties).

### 1.2.1 Report Structure

The table below outlines the structure of the report

Table 1-1: Report Structure

Sections	Purpose
Section 2- Environmental Setting	Compilation of baseline data (e.g. Topography, land use, climate hydrology, geology, hydrogeology)
Section 3- Strategic Phase I Assessment	Identification any potential contamination sources on site, along with any areas of the site that would likely require further site investigation if they were to be developed.
Section 4- Groundwater Constraints Assessment	Assessment of groundwater constraints across the site.

### 1.3 Data Sources

The data used in the assessment were obtained from the following sources;

- Topography and general mapping:
  - EA Open Data, Terrain 50 DTM, LiDAR 2m DTM;
  - Aerial photography (Google Earth and Bing Maps);
- Climate:
  - Flood Estimation Handbook (FEH) and CD-ROM (CEH, 2009).
- Geology and Soils:
  - BGS 1:50,000 Geology Map, Sheet 59, Lancaster.
  - BGS digital geology mapping;
  - BGS online borehole database (BGS website);
  - BGS online Lexicon (BGS website);
  - 1:250,000 soils mapping (Soil Survey of England and Wales, 1983).
- Hydrogeology:
  - Aquifer classification (EA)
  - Groundwater vulnerability (EA);
  - Source Protection Zones (EA);
  - Licensed abstractions (EA);
  - Groundwater quality (EA);
  - Baseline Report Series:18. The Millstone Grit of Northern England. British Geological Survey (BGS) (Abesser et al., 2005)).
- Environmental data and historical mapping (Envirocheck Report, 2017).
- JBA site visit (26/02/18). All areas of the site were accessed via public rights of way only and did not involve any members of staff entering private land.



## 2 Environmental Setting

### 2.1 Introduction

The following sections of the report present an understanding of the environmental setting of the site and the local area, including aspects such as the hydrology, geology and ecology. This analysis will enable the identification of any vulnerable receptors. This may include site workers, future site occupants, productive aquifers and sites of ecological importance. Potential pathways for contamination are also be considered (such as migration through surface and sub-surface water flow). This information also provides an important baseline for the groundwater constraints assessment in Section 4).

### 2.2 Location and Topography

The site is located immediately to the south of the Scotforth, is centred at approximately NGR 348300, 457600 and extends southwards to the village of Galgate. The A589 forms a boundary to west, while the M6 and A6 cut through the centre of the site. The University of Lancaster main campus sits between the M6 and A6. Generally, the site consists of a gently undulating drumlin landscape as highlighted in Figure 2-2. Drumlins are glacial features usually composed of glacial till, which are typically aligned in the direction of the flow of the ice sheet. Maximum elevation on the site are approximately 100 mAOD in the area around Hazelrigg Wood. The minimum elevation on site is approximately 18 mAOD in the region to the east of the Lancaster Canal. In general, the elevation decreases moving from east to west across the site (Figure 2-1). The total area of the site is approximately 752 ha.

Figure 2-1 Topography

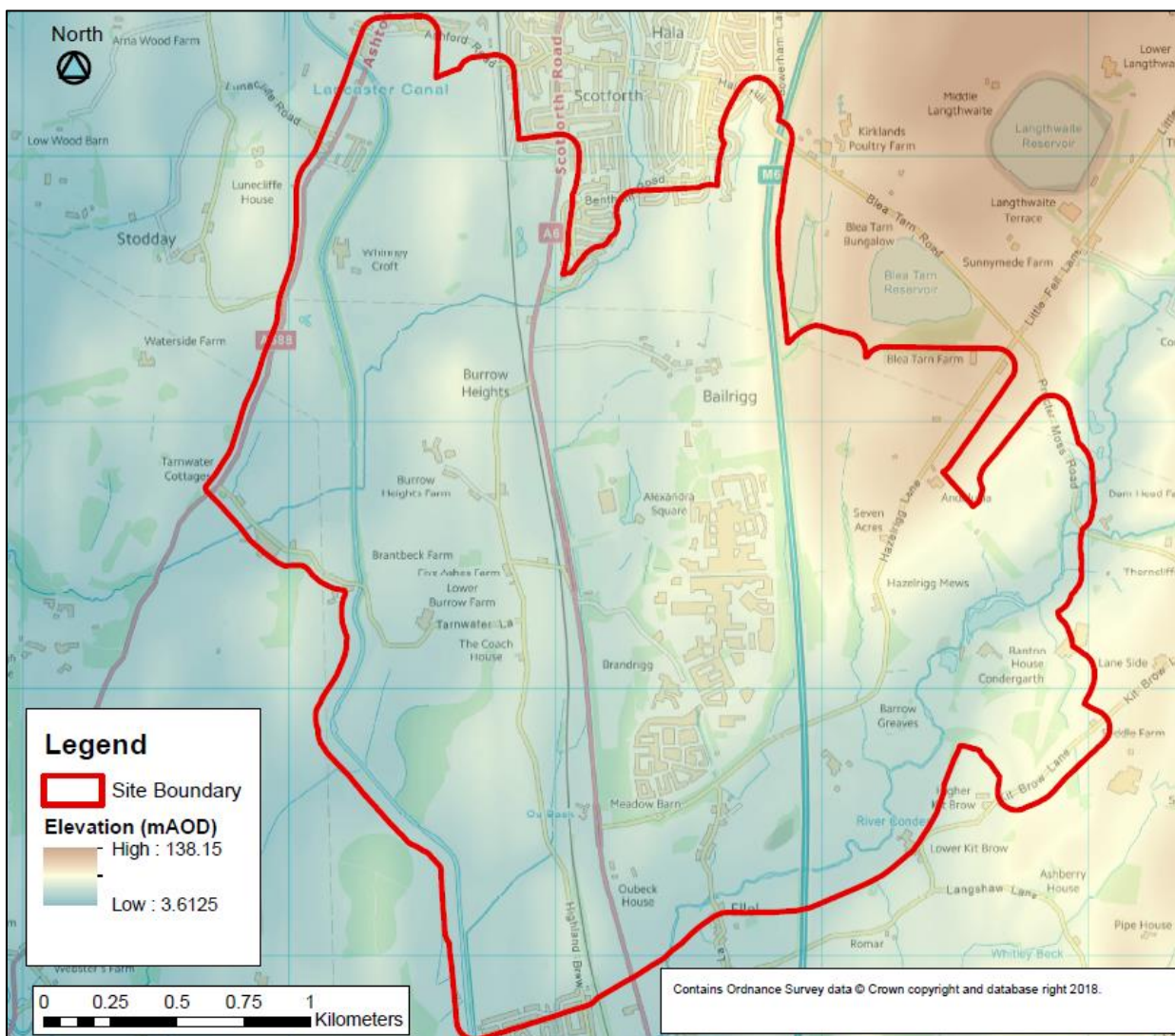


Figure 2-2 Looking north east from the trig point at Burrow Heights (drumlin summit). Approximate NGR 347653 458110.



## 2.3 Current Land Use

Based upon the desk-based assessment and site visit, the areas adjacent to the site extent comprise of the following current broad land uses;

- North
  - A predominantly urban area comprising the suburb of Scotforth. To the east of Scotforth are three reservoirs (Langthwaite, Blea Tarn and an un-named reservoir)
- South
  - The village of Galgate sits immediately to the south of the site boundary, along with a substantial area of farmland and woodland.
- Centre
  - The University of Lancaster main campus sits in the centre of the site. The A6, M6 motorway and the west coast mainline run in a north-south direction through the centre of the site. The remainder of the site consists primarily of farmland, with small wooded areas.
- East
  - Land to the east of the site consists primarily of farmland, that rises towards the Bowland Fells (SSSI and AONB).
- West
  - The site is largely bound to the west by the A589. The Lancaster Canal runs in a north-south direction to the east of the A589, with low lying farmland sits the west of the road. The River Lune and the Lune Estuary (SSSI) sit beyond (Approximately 1.0 to 1.5 km past the western boundary).



## 2.4 Climate

The Flood Estimation Handbook (FEH) CD-ROM includes long-term average rainfall data for catchments in the UK. For the catchment comprising the site the Standard Annual Average Rainfall (SAAR) is 1066 mm/yr for the years 1961-1990. The Met Office long term rainfall data indicates average annual rainfall at the Morecambe monitoring station is 1048 mm/yr for the years 1981-2010.

## 2.5 Catchment Descriptors

The FEH gives the Standard Percentage Runoff (SPR) for the catchment containing the site as being 35.6%. The SPR is the percentage of rainfall responsible for the short-term increase in river flow during and/or following a rainfall event (Boorman et al., 1995).

The Baseflow Index (BFI) for the site is 0.498 (CEH, 2009). This is the proportion of total streamflow made up of baseflow (mostly groundwater input). This suggests that roughly half of the flow to the local watercourses is made up of baseflow in this area.

## 2.6 Surface Water Hydrology

Several surface water bodies flow through the site including the River Conder, Burrow Beck, Ou Beck and the Lancaster Canal. A number of man-made drains and small ponds are also present across the site.

The River Conder flows through the southern reaches of the site (see Figure 2-3). The source of the Conder is located in the Bowland fells to the east of the site and it eventually drains into the Irish Sea at Conder Green, which is located approximately 1.5 km to the east of the site boundary.

Figure 2-3 Meander on the River Conder (looking south). Approximate NGR 349082 456434.



Burrow Beck enters the site at the northern extent source is located approximately 2.5 km to the north of the site in the region close to daisy bank. The stream enters the site at Scotforth and flows westwards towards the Lancaster Canal where it then flows south alongside the canal for approximately 450 m before turning westwards and out towards the Irish Sea.

The source of Ou Beck is situated approximately 250 m to the north of Bailrigg village. The out flow from a Reservoir located to the north of the site boundary also joins Ou Beck immediately east of the village of Bailrigg. The Beck flows westwards towards the Westcoast mainline, then flows south for approximately 1 km before flowing in a south westerly direction towards the western edge of Galgate. Ou Beck flows into the River Conder approximately 400 m to the south of Galgate.

The Lancaster Canal runs in a north-south direction along the western periphery of the site.

### 2.6.1 Surface Water Ecological and Chemical Quality

An assessment of surface water bodies for ecological and chemical quality is maintained by the Environment Agency under the Water Framework Directives and is viewable online.

The River Conder has a 'moderate' ecological quality and 'good' chemical quality.

No data is currently available with regards to the ecological and chemical quality of Ou Beck and Burrow Beck.

### 2.6.2 Surface Water Abstractions

Table 2-1 summarises all known licenced surface water abstractions within 2 km of the site.

Table 2-1 Surface Water Abstractions Within 2 km of the site

Licence Holder	Details	Daily Abstraction Limits
Castle Trout	Fish Farm/cress Pond throughflow	1636 m <sup>3</sup> /d
Wyresdale Anglers Ltd	Fish Farm/cress Pond throughflow	2291 m <sup>3</sup> /d
Hinde	Fish Far/Cress Pond throughflow	392.7 m <sup>3</sup> /d
Robin John Norman	Lake & Pond throughflow	30 m <sup>3</sup> /d
Wyresdale Anglers Ltd	Fish Farm & Cress Pond throughflow	295.49 m <sup>3</sup> /d
Whewell	General Farming and Domestic	27.27 m <sup>3</sup> /d
United Utilities Water Ltd	Potable Water Supply	54552 m <sup>3</sup> /d
Wyreside Hall Ltd	General Faming and Domestic	22.73 m <sup>3</sup> /d
Mark Preston	Hydroelectric Power Generation	172800 m <sup>3</sup> /d
United Utilities Water Ltd	Potable Water Supply	48000 m <sup>3</sup> /d
United Utilities Water Ltd	Potable Water Supply	142744 m <sup>3</sup> /d

## 2.7 Geology and Soils

Information on the soils and geology of the site and surrounding area has been derived from the Soil Survey of England and Wales (1983), 1:50,000 BGS geology mapping (Sheet 59: Lancaster), and the BGS online borehole archive. The geology beneath the site is summarised in Table 2-2 and maps of the surface geology are shown in Figure 2-7 and Figure 2-8.

### 2.7.1 Soils

The Soil Survey of England and Wales (1983) classifies the soils on site as Oglethorpe, Wharfe and Brickfield 2. Oglethorpe relates to deep, well drained reddish coarse and fine loamy soils. Some similar, but shallower soils over gravel. Oglethorpe is distributed over the western extent of the site (To the west of the A6) and likely relates to deposits of till and glaciofluvial sands and gravels. Wharfe type soil relates to River Alluvium and consists of deep, stoneless permeable fine loamy soils. Some soils variably affected by groundwater. Generally flat land with risk of flooding. The distribution of Wharfe 2 on site follows the distribution of alluvium along the lower reaches of the River Conder. Brickfield 2 relates to drift from Palaeozoic and Mesozoic sandstone and shale. Slowly permeable seasonally waterlogged fine loamy soils with only slight waterlogging and some deep well drained fine loamy soils. Brickfield 2 is predominantly distributed over the eastern extent of the site (to the east of the A6) and relates to till and Lacustrine deposits.

### 2.7.2 Artificial Ground

Two individual areas of artificial ground have been identified via BGS Mapping on the site at Bailrigg (Figure 2-4). The first area of artificial ground is located at approximately NGR 349451, 457170 and measures approximately 2,360 m<sup>2</sup>. BGS data indicates that the ground in this area consists of 'made ground'. The second area of artificial ground is located at NGR 348838, 456443 and measures 6,892 m<sup>2</sup> respectively. BGS data indicates that the ground in this area consists of 'worked ground'. Made ground is defined as an area where the ground is known to have been deposited by man on a former natural surface. Worked ground is defined as areas where the ground is known to have been excavated by man. Artificial ground is often variable both vertically and horizontally and, can vary substantially in quality. Currently there are no BGS borehole records at either location to confirm the exact nature of the artificial ground on site. Historical mapping acquired through an Envirocheck report (see appendix A) and visual inspection made during the site visit indicate that the area of 'made ground' is likely to be linked to the construction and landscaping works at the Forrest Hills Convention Centre/Golf Park (see Figure 2-5). Whilst the area of 'worked ground' is located in an area of woodland to the north east of Ellel, although there is no indication from historical maps as to the nature of the artificial ground in this area. This area was only visible from a distance during the site visit as the area is located on private land. The area appeared to consist of an excavated pit, which is now covered in an area of trees (see Figure 2-6). The depth of the excavation was unclear as was the nature of the ground within the excavated area.



Figure 2-4 Artificial Ground

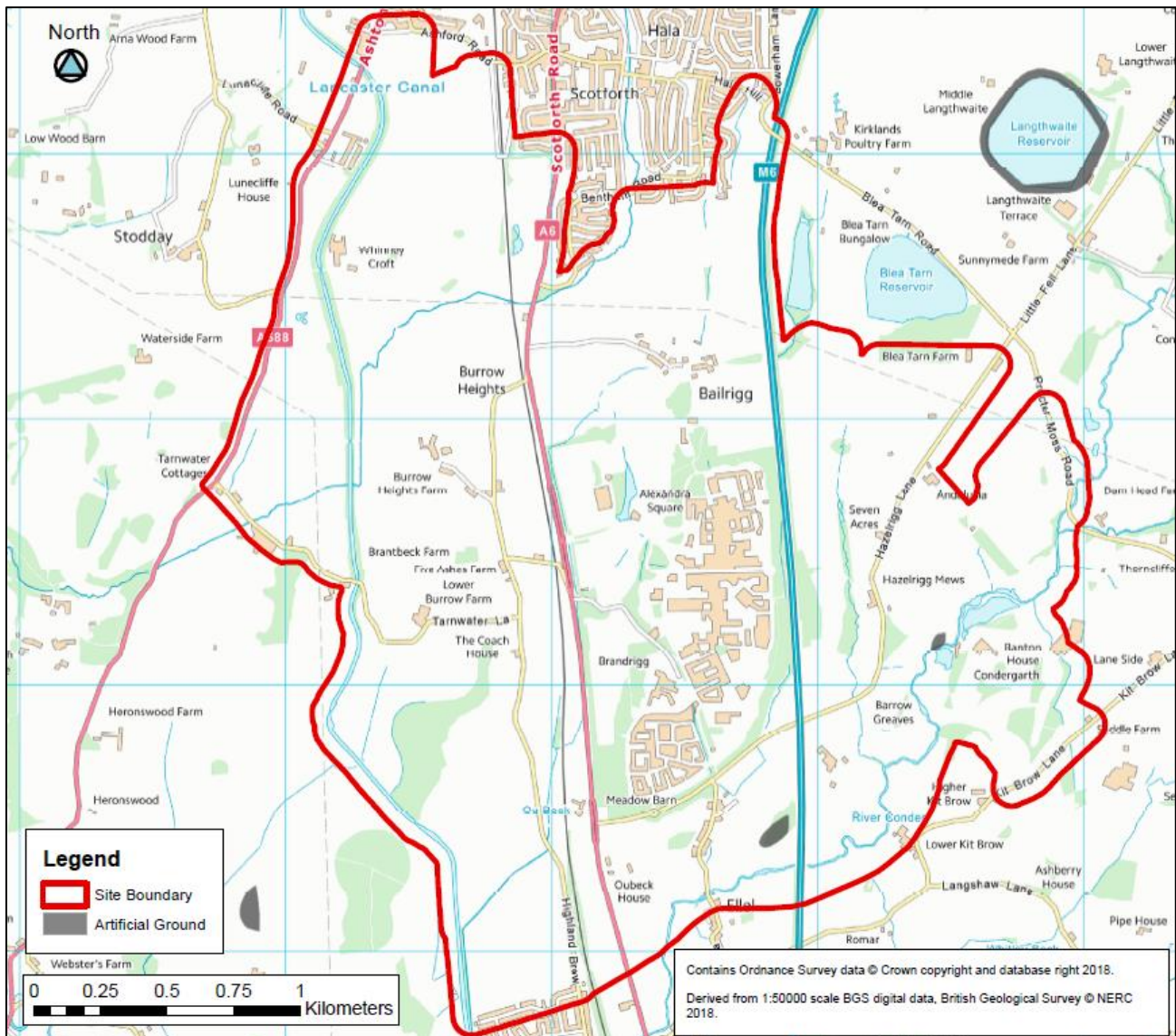


Figure 2-5 Area of artificial ground adjacent to Forrest Hills looking north (NGR 349451, 457170).



Figure 2-6 Area of artificial ground north east of Ellel looking north (NGR 348838, 456443).

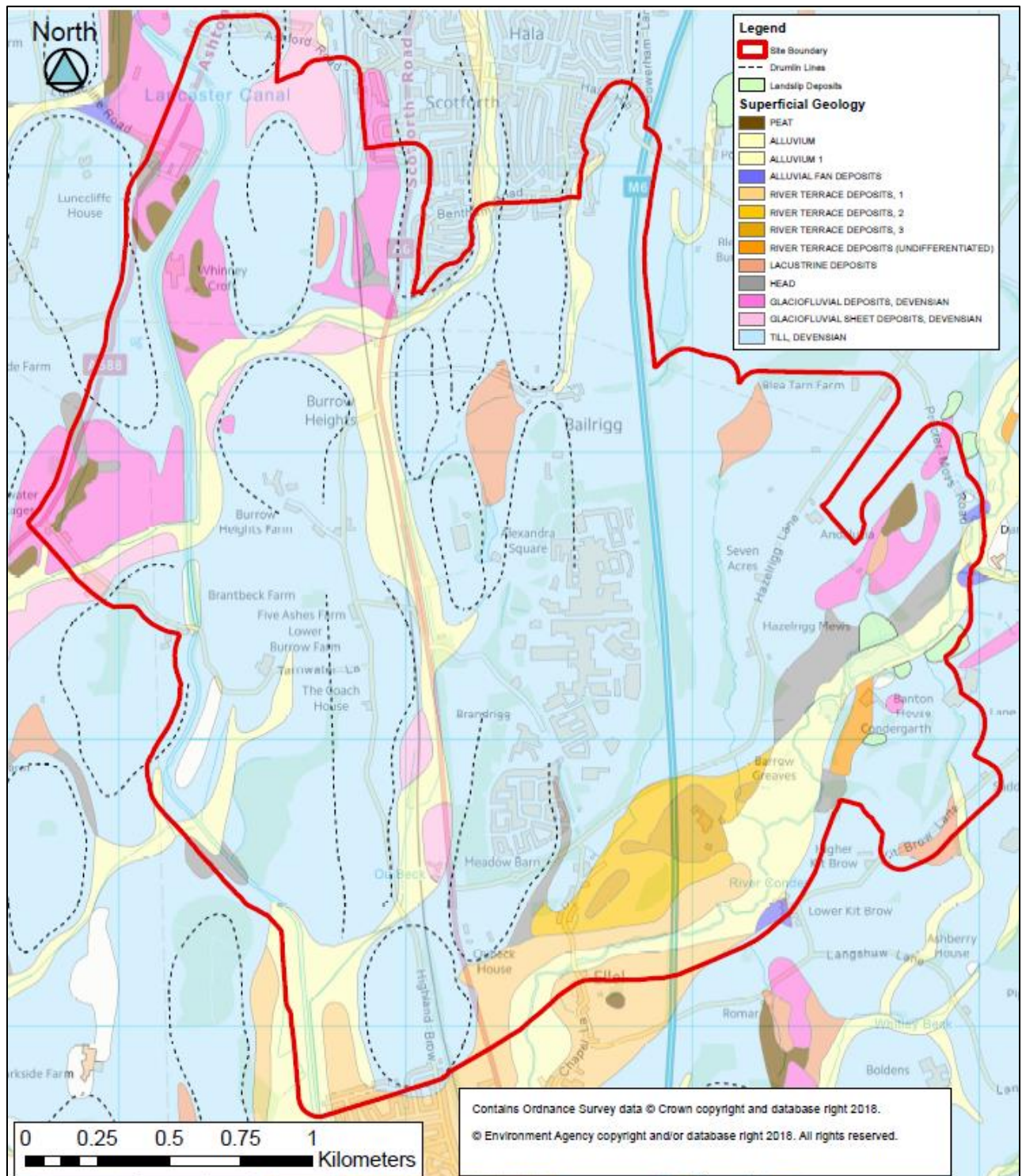




### 2.7.3 Superficial Geology

The site is extensively covered by a variety of Quaternary superficial deposits including, Lacustrine, deposits, Glaciofluvial sands and gravels, river terrace deposits and till (Figure 2-7)

Figure 2-7 Superficial Geology

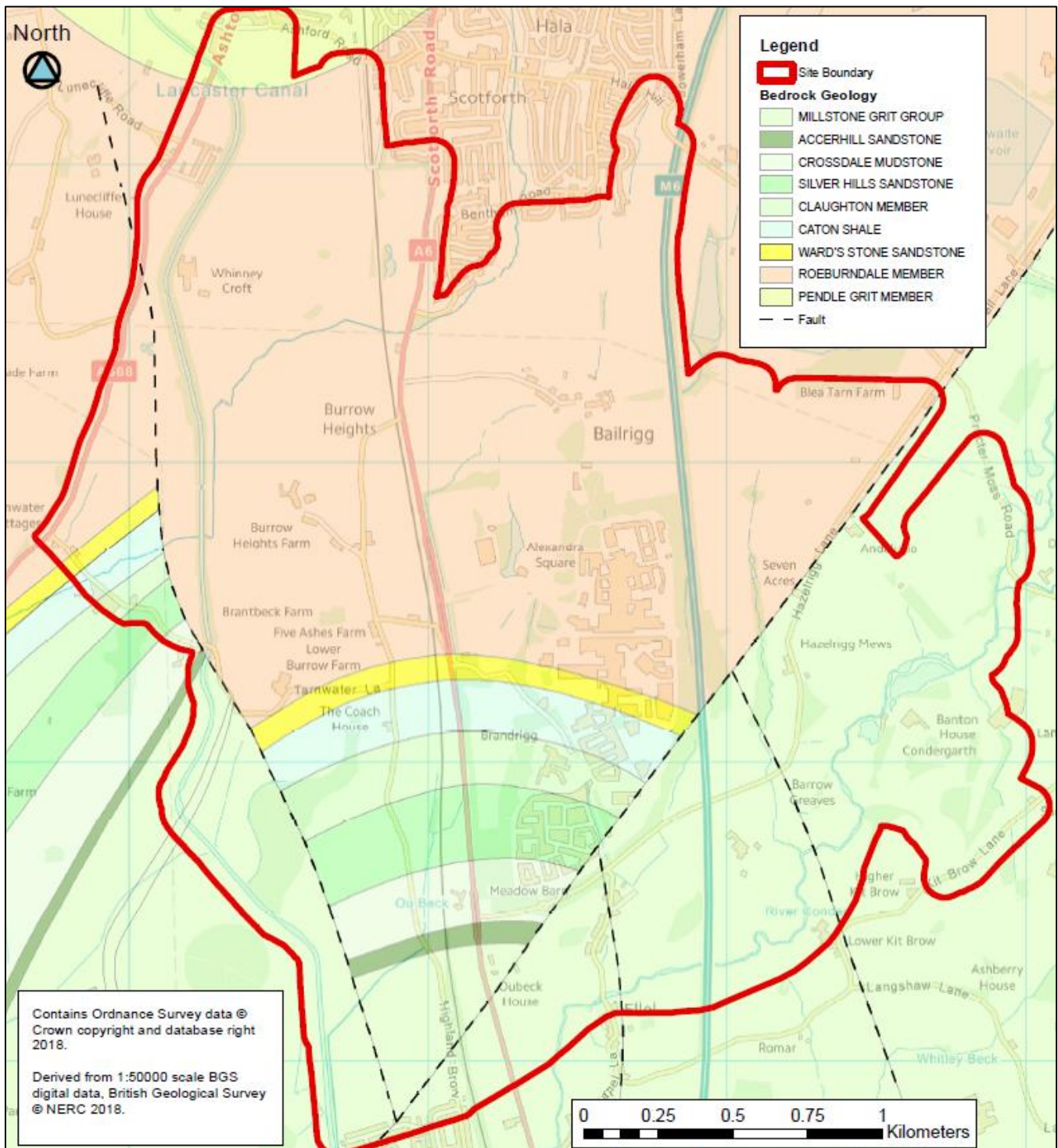


#### 2.7.4 Bedrock Geology

The site is largely underlain by strata belonging to the Carboniferous Millstone Grit Group. The Millstone Grit Group typically contains Fine to very coarse-grained feldspathic sandstones, which may be interbedded with grey siltstones and mudstones, with subordinate marine shaley mudstone, claystone, coals and seatearths (Figure 2-8).

The majority of the site is covered by relatively thick superficial deposits, limiting the area of outcropping to an area adjacent to the canal on the western part of the site (Figure 2-7). The site sits on a block of bedrock bound by a series of faults.

Figure 2-8 Bedrock Geology





### 2.7.5 Summary of Site Geology

A summary of the local geological stratigraphy is given in Table 2-2.

Table 2-2 Summary of geology underlying the site

Age	Group	Formation	Description	Thickness
Quaternary	Superficial Deposits	Peat	Organic-rich clay; humic deposits - accumulation of wet, dark brown, partially decomposed vegetation	Unknown
		Alluvium	Usually 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.	~7m*
		Alluvial Fan Deposits	Alluvium with a low-angle cone form, developed at the mouths of tributary valleys; very localised source.	Unknown
		River Terrace Deposits 1-3	Sand and gravel, locally with lenses of silt, clay or peat	Unknown
		River Terrace Deposits Undifferentiated	Sand and gravel, locally with lenses of silt, clay or peat	Unknown
		Lacustrine Deposits	Silt and clay (can include organic and/or calcareous muds); of lacustrine origin	~8m*
		Head Deposits	Polymictic deposit: comprises gravel, sand and clay depending on upslope source and distance from source. Poorly sorted and poorly stratified deposits formed mostly by solifluction and/or hillwash and soil creep. Essentially comprises sand and gravel, locally with lenses of silt, clay or peat and organic material.	Unknown
		Glaciofluvial Deposits	N/A	5m+ *
		Devensian till	Firm gravelly boulder clay*	9-11m+*
Carboniferous	Millstone Grit Group	Accerhill Sandstone	Fine- to coarse-grained sandstone, with sandstone seatearths and thin coals	10-28m**
		Crossdale Mudstone	Blocky grey to dark grey laminated and fossiliferous mudstone, which becomes fissile on weathering. Mudstone contains siderite mudstone lenses and nodules at some levels. There are several thin marine bands composed of dark grey, platy mudstone with scattered oblate carbonate septarian nodules. Thin beds of sandstone are present in the uppermost few metres.	~5-20m***
		Silverhills Sandstones	Fine- to very coarse-grained sandstone with thin coals and seatearths. Trough cross-bedding in sets up to 0.5m thick. Planar cross-bedding, small-scale cut-and-fill structures, syndepositional faults and slump structures have been recorded	~20m***
		Claughton Formation	Typical delta slope facies. Predominantly sandy grey micaceous shaly siltstones with irregular interbeds of fine- to medium-grained	~100m***

			micaceous plant-rich sandstone, very variable thickness and bedding commonly syndepositionally slumped.	
		Caton Shale	Mudstone (claystone) grey to blue-grey, shaly, fossiliferous, with common calcite mudstone nodules and siderite-mudstone lenses	60-70m**
		Wards Stone Sandstone	Feldspathic to quartzose, coarse -grained to fine-grained sandstones. Fines upwards; several thin coal seams in upper part.	~25-50m***
		Roeburndale Formation	Predominantly grey, sand, micaceous, shaley siltstones with bunches of interbedded, generally fine grained, sharp-soled sandstone lenses locally developed; includes three marine bands	~300-400m***
		Pendle Grit Formation	Medium- to Coarse-grained feldspathic sandstone with subordinate interbedded siltstone and mudstone. Commonly in sharp based beds from 0.2 to 4.5m thick,	200-400m**
<p>Sources:  BGS Borehole Logs*  BGS Lexicon of Named Rock Units**  BGS Geological Mapping***</p>				

## 2.8 Hydrogeology

### 2.8.1 Aquifer Designation

The geological strata summarised in the Geology and Soils section have been assessed for their hydrogeological properties. Aquifer designations have been collated through the Envirocheck Report.

The superficial deposits found on site are classified as 'Secondary - Undifferentiated' and a 'Secondary A' aquifers. A Secondary - Undifferentiated aquifer is described as an aquifer of low importance, with some areas being classified as non-aquifer.

The Millstone Grit Group bedrock strata underlying the site is classified as a 'Secondary A' aquifer, which is described as permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers.

It should be noted that although the Millstone Grit Formation is considered an aquifer, the formation is multi-layered and consists of several distinguishable units. Some of these units have good aquifer properties (e.g. and high permeability and high hydraulic conductivity) and others which display properties consistent with an aquitard (i.e. low permeability and low hydraulic conductivity). The properties of these units are outlined below in Table 2-3.

Table 2-3 Aquifer Properties

Formation	Description	Thickness	Aquifer Properties
Alluvium	Usually 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.	~7m	Aquifer Low permeability Intergranular flow
River Terrace Deposits	Sand and Gravel, locally with lenses of silt, clay or peat	Unknown	May form local aquifer High Permeability Intergranular Flow
Lacustrine Deposits	Silt and clay (can include organic and/or calcareous muds); of lacustrine origin	Unknown	Aquitard Low permeability Intergranular flow
Glaciofluvial Deposits	N/A	5m+ *	Aquifer High Permeability Intergranular flow
Devensian till	N/A	9-11m+*	Aquitard Low permeability Primary permeability
Accerhill Sandstone	Fine- to coarse-grained sandstone, with sandstone seatearths and thin coals	10-28m**	Moderate Permeability Aquifer Intergranular flow
Crossdale Mudstone	Blocky grey to dark grey laminated and fossiliferous mudstone, which becomes fissile on weathering. Mudstone contains siderite mudstone lenses and nodules at some levels. There are several thin marine bands composed of dark grey, platy mudstone with scattered oblate carbonate septarian nodules. Thin beds of sandstone are present in the uppermost few metres.	~5-20m***	Aquitard Low permeability Fracture Flow
Silverhills Sandstones	Fine- to very coarse-grained sandstone with thin coals and seatearths. Trough cross-bedding in sets up to 0.5m thick. Planar cross-bedding, small-scale cut-and-fill structures, syndepositional faults and slump structures have been recorded	~20m***	Moderate permeability Aquifer Intergranular flow
Cloughton Formation	Typical delta slope facies. Predominantly sandy grey micaceous shaley siltstones with irregular interbeds of fine- to medium-grained micaceous plant-rich sandstone, very variable thickness and bedding commonly syndepositionally slumped.	~100m***	Mixture of aquifer and aquitard properties, may differ locally Moderate-Low Permeability Intergranular flow

Caton Shale	Mudstone (claystone) grey to blue-grey, shaley, fossiliferous, with common calcite mudstone nodules and siderite-mudstone lenses	~60-70m**	Aquitard Low Permeability Fracture flow
Wards Stone Sandstone	Feldspathic to quartzose, coarse - grained to fine-grained sandstones. Fines upwards; several thin coal seams in upper part.	~25-50m	Aquifer Moderate-high permeability Intergranular flow
Roeburndale Formation	Predominantly grey, sand, micaceous, shaly siltstones with bunches of interbedded, generally fine grained, sharp-soled sandstone lenses locally developed; includes three marine bands	~300-400m	Mixture of aquifer and aquitard properties, will vary locally Low-moderate permeability Intergranular flow
Pendle Grit Formation	Medium- to Coarse-grained feldspathic sandstone with subordinate interbedded siltstone and mudstone. Commonly in sharp based beds from 0.2 to 4.5m thick,	200-400m**	Aquifer Moderate-high permeability Intergranular flow

### 2.8.2 Groundwater Abstraction

There are currently four groundwater abstraction licences recorded within 2km of the site. All known licenced ground water abstractions are detailed below in Table 2-4.

Table 2-4 Ground Water Abstractions Within 2 km of the Site

Licence Holder	Details	Licence Limits
Al Badar Islamic Trust	Industrial, Commercial and Public Services	150 m <sup>3</sup> /d
Drinkwaters Mushrooms Ltd	Agriculture	40 m <sup>3</sup> /d
Gorst	General Farming and Domestic	28 m <sup>3</sup> /d
Lancaster Farmers Auction Market	General Agriculture	46 m <sup>3</sup> /d

### 2.8.3 Groundwater Source Protection Zones

There are no Source Protection Zones (SPZs) within 500m of the site.

### 2.8.4 Aquifer Vulnerability and Water Quality

Groundwater from the Millstone Grit aquifer is generally soft and of 'good' chemical quality. In general, the water is potable (Abesser et al., 2005).

### 2.8.5 Aquifer Properties

The Millstone Grit Group aquifer beneath the site consists of thick (up to 900m) Sands, Grits, Shales and Mudstones. Individual sandstone members vary in thickness, but rarely exceed 30 m (Abesser et al., 2005). The Millstone Grit forms a multi-layered aquifer system in which the persistent, thick sandstone horizons effectively act as separate aquifers with the intervening mudstones and shales acting as aquicludes or aquitards (Abesser et al., 2005). The sandstone units within the Millstone Grit Formation are usually well cemented, as such, groundwater storage and transport is largely restricted to fracture flow, with minor contributions from intergranular flow (Abesser et al., 2005).

### 2.8.6 Groundwater Flow, Springs and Issues

The general regional groundwater gradient can be expected to reflect the local topography, with baseflow towards the River Conder, Burrow Beck, Ou Beck and any man-made drains on the site. It is possible that groundwater levels within the superficial deposits may be influenced by variations in surface water levels in the rivers and drains. Faulting in the area may also impart some effect on the flow of groundwater beneath the site.

There are currently no springs mapped within the site boundary. However, several issues and sinks are mapped at various locations across the site. Review of desk study information, and the site walk-over suggest that the majority of the issues marked on the map are associated with drainage systems rather than being springs. The majority of the site is covered by relatively thick superficial

deposits, limiting the potential for spring from bedrock to occur on site. Four historical springs/wells were identified from a review of historical mapping. These areas may require further investigation to accurately assess the risk of spring activated groundwater flooding across the site (see Section 4.3.1).

## 2.9 Ecological Designations

There is one major Site of Special Scientific Interest (SSSI), one Special Area of Conservation (SAC), one Special Protection Area (SPA) and one Ramsar designation within 1km of the site extent. These are summarised in Table 2-5. In addition, several areas of ancient and semi-natural woodland are also present either on, or within close proximity to the site.

Table 2-5 Ecological sites

Site Name	Type	Reasoning for SSSI designation	Distance (m)
Lune Estuary	SSSI	The Lune Estuary forms part of the Morecambe Bay intertidal system and includes extensive sand/silt flats, together with salt marsh. The saltmarshes are important breeding sites for birds and a variety of uncommon plant species. The estuary also provides important feeding grounds for waders and wildfowl.	885
Morecambe Bay	SSSI	Morecambe Bay is one of the largest areas of intertidal estuarine flats in the UK. The area is of international significance for wading birds and of national significance for wintering wildfowl.	885
The saltmarshes are particularly important for their vegetation.			

## 2.10 Summary of Potential Environmental Receptors

A summary of environmental receptors that may be present in or near to the site is given in Table 2-6. This shows receptor types and their associated sensitivity.

Table 2-6 Summary of potential environmental receptors

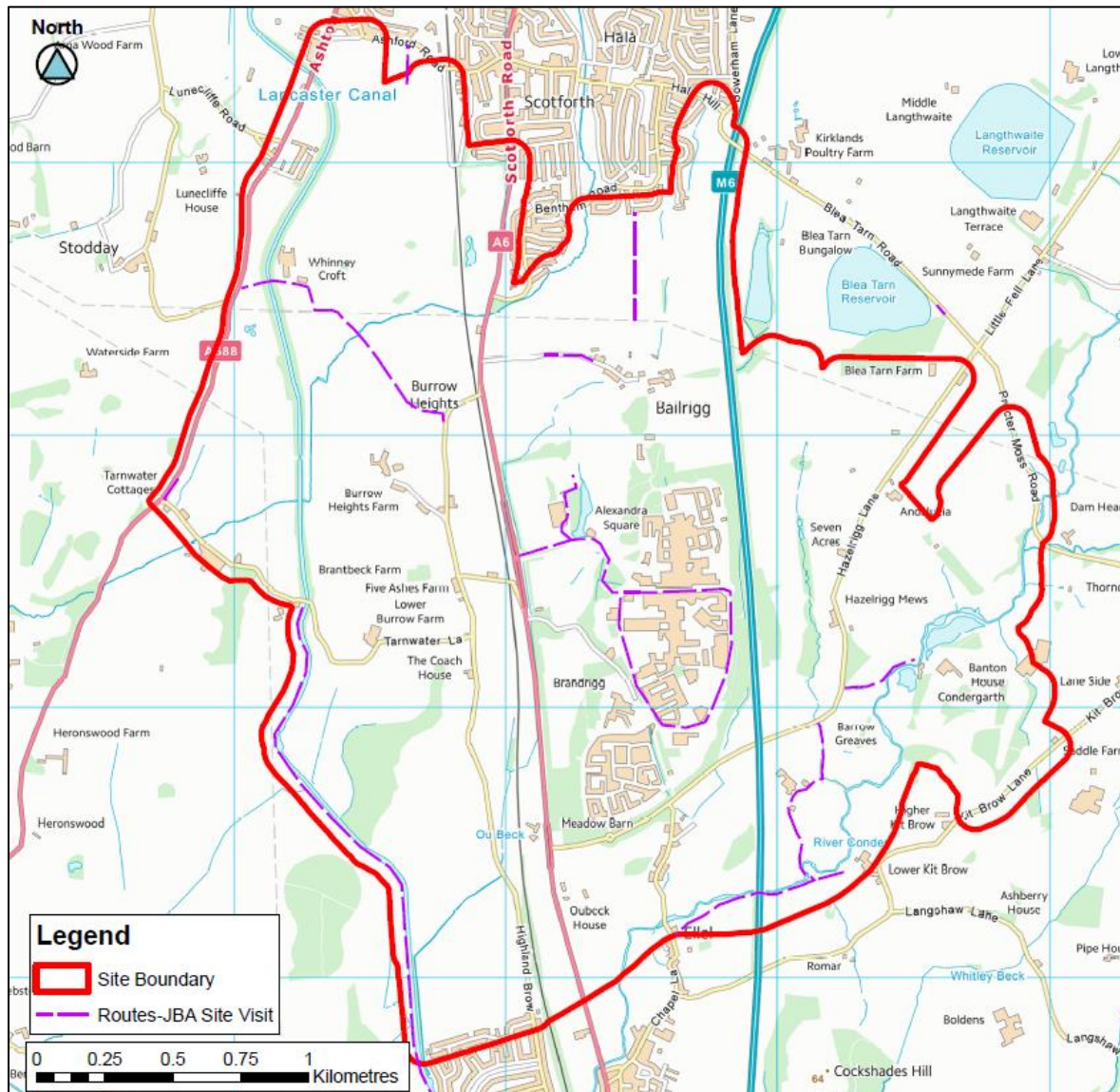
Receptor	Type	Sensitivity	Reasoning
Millstone Grit Group (Secondary A aquifer)	Groundwater	Moderate	Mixture of variable permeability units, consisting of higher permeability sands and grits along with lower permeability muds and shales. An aquifer of 'good' chemical quality.
Superficial Deposits (Secondary A)	Groundwater	Moderate	Higher permeability alluvial sand and gravel type deposits. Potential to transmit significant yields of groundwater. Can form important source of base flow to Rivers.
Superficial Deposits (Secondary Undifferentiated)	Groundwater	Low	Lower Permeability Glacial Till Deposits. Unlikely to yield significant amounts of groundwater.
Lune Estuary /Morecambe Bay	Surface water / SSSI / SAC / SPA	High	A sensitive tidal estuary environment supporting internationally important wildlife.
River Conder	Surface water	Moderate	A River of 'moderate' ecological quality and 'good' chemical quality. Likely to be in hydraulic connectivity with higher permeability sands and gravels.
Ou Beck	Surface Water	Moderate	Likely to be in good hydraulic connectivity with higher permeability superficial deposits.
Burrow Beck	Surface Water	Moderate	Likely to be in good hydraulic connectivity with higher permeability superficial deposits.



## 2.11 Site Visit

JBA staff visited selected locations across the Bailrigg site on 26/02/18. All areas of the site were accessed via public rights of way only and did not involve any members of staff entering private land (Figure 2-9). The visit consisted of a targeted site walkover to assess the general topography across the site. In addition, some areas believed to be at risk of ground water flooding were targeted during the site visit. The majority of the areas identified as potential pollution hotspots in section 2.3 were not accessible during the site visit due to the fact that they are predominantly located on private land.

Figure 2-9 Routes taken during JBA site visit



## 3 Strategic Phase 1 Assessment

### 3.1 Introduction

The following section of the report consists of a strategic phase 1 contaminated land study. This will provide a broad categorisation of the site, and identify which parts of the site would likely require further site investigation if they were to be developed.

### 3.2 Potential Contamination Sources

#### 3.2.1 Introduction

An analysis of potential contamination sources has been completed through a review of various data sources. This includes regulatory data (such as waste management licences, trade directories and pollution incident records), historical mapping and a review of mining and mineral extraction reports. Regulatory data and historical mapping was sourced through a Envirocheck Report and can be found in Appendix A.

#### 3.2.2 Regulatory and Environmental Data

All of the relevant regulatory data sourced through the Envirocheck Report is summarised below in Table 3-1.

Table 3-1 Regulatory data

Data Source	Details	Potential for impact on site?
Dangerous substances inventory sites	Yes- There are 5 registered radioactive substances registered at Lancaster University	Unlikely- These sites are authorised to handle these substances as such, they should be stored and handled in accordance with licence permit conditions.
Contaminated land sites	No sites recorded as contaminated land within 500m.	No.
Mineral Sites	Yes- There are 16 BGS registered mineral sites within 500m of the site, with 9 of the mineral sites located within the site boundary. All sites relate to historic Clay, Sand and Gravel pits.	Yes- These areas may contain regions of unmapped 'made ground'/fill material.
Landfill sites	There are no current or historical landfill site recorded on site.  There are two historical landfill sites located within 35m of the site boundary, to the south of Blea Tarn Reservoir. The site has been used for the disposal of inert rock soil and glass.	Yes
Other Waste Management Sites	Yes-There is currently one waste management site located within 500m of the site and 12 radioactive substances registered on the site.  The waste management site relates to a united utilities waste management facility at Ashton with Stodday, while the radioactive substances relate to the storage, disposal and use of radioactive substances at the Lancaster University main campus site.	Unlikely-These sites are authorised to handle dangerous substances as such, they should be stored and handled in accordance with licence permit conditions.
IPC authorisations and IPPC permits	No- There are no IPC or IPPC authorisations or permits within 500m of the site.	No.
LAPPC authorisations	Yes- There are 3 LAPPC within 500 m of the site.	Unlikely-These sites are authorised to handle dangerous substances as such, they should be stored and handled in accordance with licence permit conditions.
Fuel Stations Entries	Yes- There is one fuel station on site and two fuel stations within 500m of the site.	Unlikely-The fuel station is situated on the site at Lancaster University and will not likely effect any of the developments across the site.
Discharge consents	Yes- There are 17 recorded discharge consents within 500m	Yes.

	of the site. There are 8 still active on site, which relate to the release of treated sewage effluent into the Tributaries of the River Conder, including condergarth and Ou Beck. In addition, discharge consents relating to the discharge of treated sewage to ground via a soakaway. All of the sewage discharges on site are non-water company discharges.	
Recorded pollution incidents	Yes- There have been two pollution incidents within 500m of the site, one of these was recorded on site and appears to relate to an incident on the M6 motorway. The pollution incident on site was recorded as a Category 2 incident (Significant incident) in terms of water impact and Category 3 land impact (minor incident). The incident involved inorganic chemicals/products.  A second incident off site was recorded as a Category 2 incident (Significant incident) in terms of water impact and Category 4 (no impact) land impact. The incident involved agricultural silage products.	Unlikely- Although one of the pollution incidents was significant, the incident is historic (2005).
Radon	There are several regions of the site, which are located in Radon Affected Area, as between 5 and 10% of properties are above the Action Level. Basic Radon protection measures are necessary when building new dwellings.	Yes- buildings are to be constructed on the site.
Gas Pipelines	There is one gas pipeline which crosses the eastern extent of the site and runs in a north-south direction. There is a building proximity of 95 m.	Yes- A building proximity of 95 m is assigned to the pipeline.
Notes: IPC = Integrated Pollution Control; IPPC = Integrated Pollution Prevention & Control; LAPPC = Local Authority Pollution Prevention Control		

### 3.2.3 Historical Land Use

The historical land uses on and adjacent to the site has been determined from a review of historical OS mapping supplied as part of the Envirocheck Report (Appendix A) and a summary is outlined in the sections below. In general, the majority of the site has remained farmland throughout the sites history. Major developments on the site include Lancaster University, the west coast mainline, Lancaster Canal and the M6 motorway. In addition, extensive quarrying has taken place across the site. The mapping includes scales of 1:1125, 1:2500, 1:10000 and 1: 10560, and were produced between 1848 to 2017. A chronological summary of historical land uses within 500m of the site is given in the summary below;

- 1848
  - The Lancaster and Preston Railway is evident crossing the site. The railway follows the same track as the now west coast mainline,
  - Several clay pits and sandstone quarries are evident to the south east of the site boundary. These are primarily located to the west of Old Park Wood and Forerigg Wood.
  - Well adjacent to the west of Burrow.
  - Ellet Hall is present approximately 300 m beyond the Southern site boundary.
  - A lime kiln is present on the map in the area between Tarnwater Lane and the Lancaster Canal.
  - Land to the south of the site consists primarily of farmland.
- 1895
  - A clay pit is present on the site at approximately NGR 347951, 455958
  - Two individual clay pits are evident close to the southern boundary of the site at NGR 349127, 456352 and 349102, 456341.
  - Blea Tarn evident to the north east of the site.
  - Well to to west of Burrow Heights now marked as a spring
  - Spring present next to the Lancaster Canal in the south western corner of the site.
- 1912-1913
  - A small covered reservoir appears on the map at approximately NGR 348614, 456734.
- 1914-1916
  - Numerous pits (Gravel and Clay) are present in the area to the east of Hazlerigg
  - Modification of Blea Tarn to form Blea Tarn Reservoir.
  - An un-named reservoir is present to the north east of the site boundary.
  - Scotforth Cemetery evident on the site.
  - Wind pump and two tanks to the north of Burrow Heights.
- 1919-1933
  - Wooded area with small pond to the north east of Ellet (approximate area of the now artificial ground).
- 1933
  - Allotments present adjacent to Scotforth Cemetery.
- 1955
  - The town of Galgate expands to the north, up to the southern edge of the site boundary.
- 1962-1965
  - The M6 motorway cuts through the centre of the site
- 1970
  - The University of Lancaster is present in the centre of the site along with a field station at NGR 348607, 456869.
- 1973
  - The Village of Galgate now extends in to the south-western corner of the site boundary.
- 2001

- A hotel is present on the map associated with the Lancaster university campus.

### 3.2.4 Mining and Mineral Extraction

The site does not lie within a Coal Authority Coal Mining Reporting area. However, there are a number of former opencast quarries, clay, sand and gravel pits are located in a number of locations across the site and beyond the proposed site boundary. All of the mining operations associated with the aforementioned clay, sand and gravel pits has now ceased.

### 3.2.5 Summary of Potential Contamination Sources

A summary of the potential contaminative sources found through the investigation of regulatory data and historical mapping are summarised below;

- Current land use-Scotforth Cemetery.
- Historical landfill site at Blea Tarn Reservoir.
- Former clay, sand and gravel pits.
- Waste water treatment sites.
- Areas of unknown fill material (Artificial ground).
- Historical and commercial industrial sites. This includes fuel stations and railway networks.

## 3.3 Preliminary Environmental Assessment

### 3.3.1 Introduction

This section reviews any sources of pollution identified from the Envirocheck report and historical mapping of the site.

### 3.3.2 Identified Sources

The following potential sources of contamination have been identified from regulatory data and historic and current land uses on the site and surrounding area:

- Scotforth Cemetery.
- Historical landfill site at Blea Tarn Reservoir.
- Former clay, sand and gravel pits.
- Waste water treatment sites and domestic sewage discharge consents.
- Areas of unknown fill material (Artificial ground/landfills).
- Historical and commercial industrial sites. This primarily relates to fuel stations and railway networks.

### 3.3.3 Pathways and Receptors

Potential high-level receptors and possible pathways for contaminants to reach these receptors are summarised below:

- Current and future site users such as construction workers and/or workers taking part in investigative ground works and future site users/occupants.
- Groundwater, Secondary A bedrock and superficial aquifers identified beneath the site.
- Surface waters (e.g. River Conder, Ou Beck, Burrow Beck and man-made drains present on the site).
- Ecologically sensitive sites (e.g. Lune Estuary/Morecambe Bay SSSI).

### 3.3.4 Conceptual Site 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).

A preliminary conceptual model for the site and surrounding environment has been developed based on the information available as outlined in Appendix B.

The main features of the conceptual understanding are as follows:

- Development of the site includes proposals to develop areas of the site for mixed purposes.



- Major developments on site and key above ground infrastructure include university of Lancaster main campus, the M6 motorway, the A6 and the West Coast Mainline Railway.
- The superficial geology on the site consists primarily of low permeability Devensian till and lacustrine deposits. Smaller regions of high permeability quaternary alluvium and glaciofluvial sand and gravel deposits are present in the regions adjacent to the main river/stream channels.
- The bedrock geology across the site consists of the Carboniferous Millstone Grit Group, which comprises of Sandstones, Grits, Shales and Mudstones that display variable permeability. The Roeburndale Formation dominates the bedrock geology across the majority of the site. There is also some faulting across the site.
- There two areas of artificial ground at the southern extent of the site. The composition of the artificial ground is currently unknown. However, the one area of artificial ground (NGR 348838, 456443) is believed to consist of 'worked ground', while the second area of artificial ground (NGR 349451, 457170) consists of 'made ground'.
- Groundwater flow on-site will likely reflect local topography, with baseflow towards the River Conder, Burrow Beck, Ou Beck and any man-made drains on the site.
- Potential environmental receptors include site workers that may be involved in any future investigative or construction work, or future visitors to the site. The underlying aquifer and nearby surface water bodies such as, The Lune Estuary/Morecambe Bay (SSSI), The River Conder, Ou Beck and Burrow Beck.
- A conceptual understanding of the site is presented in Appendix B.

### 3.3.5 Qualitative Risk Assessment

A tabulated summary of the potential pollution sources identified from the review of the Envirocheck report and historical mapping is presented in Table 3-2. Each pollution source has been classified depending on the likelihood of contamination being a) encountered on the site and b) likelihood of the pollutant reaching any potential receptors.

The classifications assigned to the identified pollution sources are as follows:

- Red = Caution required. A potential contamination source has been identified and action or intervention would likely be required (e.g. additional investigations, monitoring, risk mitigation) should any development be proposed on, or within close proximity to these areas.
- Amber = Unclear based on desk-based evidence if a potential contamination source is present. Further site investigation required if development is to take place in close proximity to this area.

Potential pollution sources are highlighted visually in Figure 3-1 along with areas of currently developed land.

The areas of currently developed land highlighted in Figure 3-1 includes the university of Lancaster, villages and isolated farmsteads. Farms may often store fuel and/or have septic tanks associated with the dwelling, which in some instances may act as a point source of contamination. Although individual farmsteads have not been classified above as Red or Amber pollution sources, their presence should be considered if development is to take place in close proximity to these sites.

It is also important to note that the location of the individual pollution sources identified in Figure 3-1 represent the centre points of the identified sources and do not indicated the lateral extent to which pollution may be encountered. With regards to the remainder of the site (i.e. areas where a red or amber designation has not been assigned), it is assumed that the area is greenfield, and has remained greenfield throughout the history of the site.

Figure 3-1 Contamination Classifications

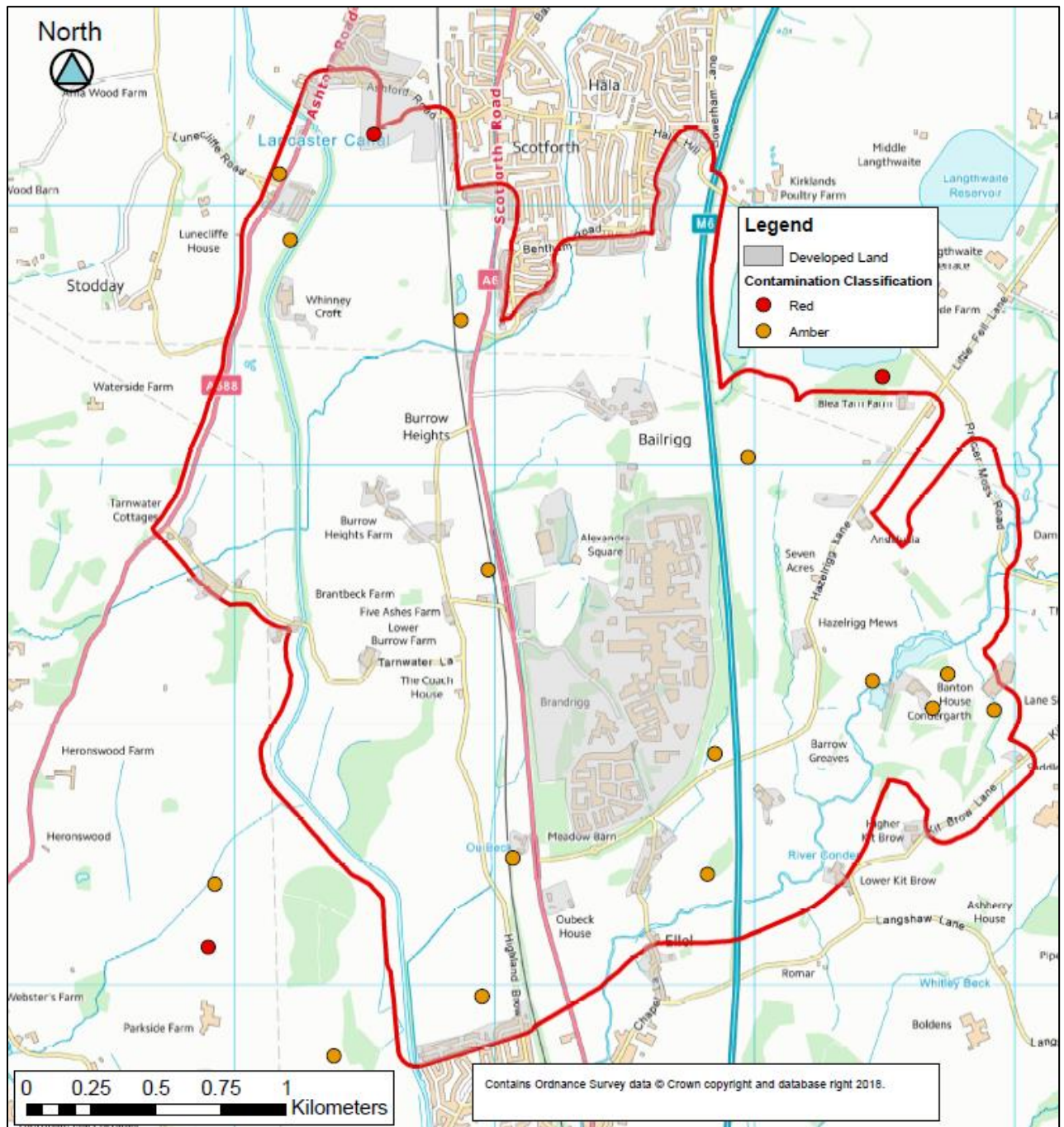




Table 3-2 Identified pollution sources and recommendations

Source	Classification	Potential Pollution issues	Recommendations
Scotforth Cemetery	Red	Pollutants typically associated with burial sites are generally found as dissolved and gaseous organic compounds and dissolved nitrogenous forms (particularly ammoniacal nitrogen). Pathogens may also be present but will reduce in concentration with increased distance from the cemetery site. Any contaminants from the site may migrate into the soil zone surrounding the site, the unsaturated zone of the underlying aquifer or the saturated zone of the aquifer.	Action is likely required if development is to take place in the areas adjacent to the cemetery. An appropriate boundary would be required between the cemetery and any development on the site.
Blea Tarn Landfill Site	Red	Landfills containing various household, commercial and industrial waste. Potential generation of leachates via the infiltration of rainfall leading to the mobilisation of contaminants in the leachate. Potential migration and generation of gasses.	Action is likely to be required should development take place on the site, to the south of Blea tarn reservoir landfill (~35m from the site boundary). The direction of groundwater movement around the landfill site is likely to reflect the local topography (i.e. flow towards the site) increasing the risk of the migration of any potential leachates towards the site. Although the superficial geology surrounding the landfill site consists of 'lower' permeability tills, the exact permeability of the till is unknown. As such, the leaching of contaminants towards the site cannot be ruled out without further investigation.
Former clay, sand and gravel pits	Amber	Pollution concerns surrounding former quarry sites are typically associated with the possible historic deposition of potentially polluting materials of unknown composition. These sites may often be associated with the illegal dumping of waste material.	May require further site investigation to confirm the nature of any potential fill materials at these sites. Although no artificial ground is mapped at these sites, the presence of any fill and/or deposited waste materials should be assessed prior to any development close to these sites.
Areas of unknown fill (Artificial ground)	Amber	Unknown composition of fill materials. Artificial ground typically varies both in terms of thickness and quality.	May require further site investigation to inform the nature of the material should development take place in close proximity to these areas.
Waste water treatment	Amber	Pollution may occasionally occur via the leakage or overflow of sewage material from the drainage network. This could include numerous biodegradable and non-bio-degradable components.	Potentially require some further site investigation development take place in close proximity to these areas. Discharge of treated sewage effluents to ground via soakaways is of primary concern.
Historical industrial sites (Primarily associated with railway network)	Amber	Potential contamination of any artificial ground material including fill material associated with railway embankments. Pollutants could vary widely. In the past wastes from alkali manufacture were used in the construction of railway embankments in the north-west region.	May require further site investigation to inform the nature of the material should development take place in close proximity to any embankments of the west coast mainline railway.

### 3.4 Phase I Assessment- Conclusions

#### 3.4.1 Summary of Site History & Potential Sources of Contamination

Land uses close to the site extent largely includes, the university of Lancaster main campus, along with numerous residential areas, farmsteads and rural/agricultural land. Several major transport routes including the M6, A6, the West Coast Mainline and the Lancaster Canal also cross the site in a north-south direction. Historical mapping indicates that the quarrying of clays/sands and gravels has taken place at various locations across the site throughout its history, although all quarrying operations appear to have now ceased. There are currently no major industrial or commercial facilities on site. BGS mapping indicates two areas of artificial ground on the site which consist of both 'worked ground' and 'made ground'.

Regulatory data indicates that two historical landfill sites are present approximately 35m from the site (Blea Tarn reservoir). There is also one operational fuel station onsite and several within close proximity to the site boundary. A significant historical pollution incident was reported on the site in 2005, although this is believed to relate to an incident on the M6 motorway. Scotforth cemetery, which is located in the north-western extent of the site also presents a potential contamination source and has been classified as 'red' in the qualitative risk assessment (section 3.3.5).

It should also be noted that several areas across the site are reported as 'Radon Affected Areas' with 5-10% of the properties above the action level. This should be considered given the fact that buildings are to be constructed on the site. In addition, a major gas pipeline cuts across the eastern extent of the site in a north-south direction. A building proximity of 95 m is associated with the pipeline.

#### 3.4.2 Summary and Recommendations

Based upon the findings of our preliminary risk assessment it is evident that there is limited potential of encountering contamination beneath the site, with the majority of the site identified as being 'greenfield'.

A number of potential point contamination sources have been identified on the basis of desk-based study. These include four Amber (Unclear if a pollution source is present. Further site investigation required if development is to take place in close proximity to this area) and two Red (Caution required) designated sites as defined in the previous section of this report. A pollution source has been identified and action would be required should any development be proposed in close proximity to these areas) have been identified within or close to the boundary of the site.

## 4 Groundwater Constraints Assessment

The following sections of the report build on the geology, hydrology and topography data collated as part of the strategic phase 1 contamination assessment to form a desk-based review into possible groundwater related development constraints across the site. Groundwater constraints include:

- Areas of perennially or semi-perennially high watertables
  - e.g. peat deposit lined hollows.
- Areas where groundwater can periodically emerge
  - i.e. areas of susceptible to groundwater flooding

The two elements above differ in their regularity. Groundwater flooding is defined by the BGS as following

*the emergence of groundwater at the ground surface away from perennial river channels or the rising of groundwater into man-made ground, under conditions where the 'normal' ranges of groundwater level and groundwater flow are exceeded.*

*Exceptionally large flows from perennial springs or large flows from intermittent or dormant springs, which also come under the above definition of groundwater flooding, can cause both localised flooding in the vicinity of the springs and down gradient where surface water drainage channels may not be adequate.*

This means that areas which are regularly waterlogged are excluded from the definition of groundwater flooding.

In addition to where groundwater emerges, the rate of flow is also an important consideration in understanding the risk associated with groundwater. In general, low permeability deposits such as clay are more prone to waterlogging than higher permeability deposits, however they yield less water, and therefore small-scale interventions (e.g. small drains) can often effectively suppress their watertable. On the other hand, a similar drain cut into high permeability gravels, may quickly be overwhelmed and inundated with groundwater.

The section below is split into two parts

- Hydrogeological and geological indications of high groundwater table - i.e. areas of areas of perennially or semi-perennially high watertables.
- The identification of areas with a high groundwater flood risk - i.e. areas of that may be susceptible to periodic high groundwater levels which will cause flooding issues.

## 4.1 Hydrogeological and Geological Indications of High Groundwater Table

This section identifies the areas of the site likely to be prone to perennially or semi perennially high watertables.

### 4.1.1 Superficial deposits

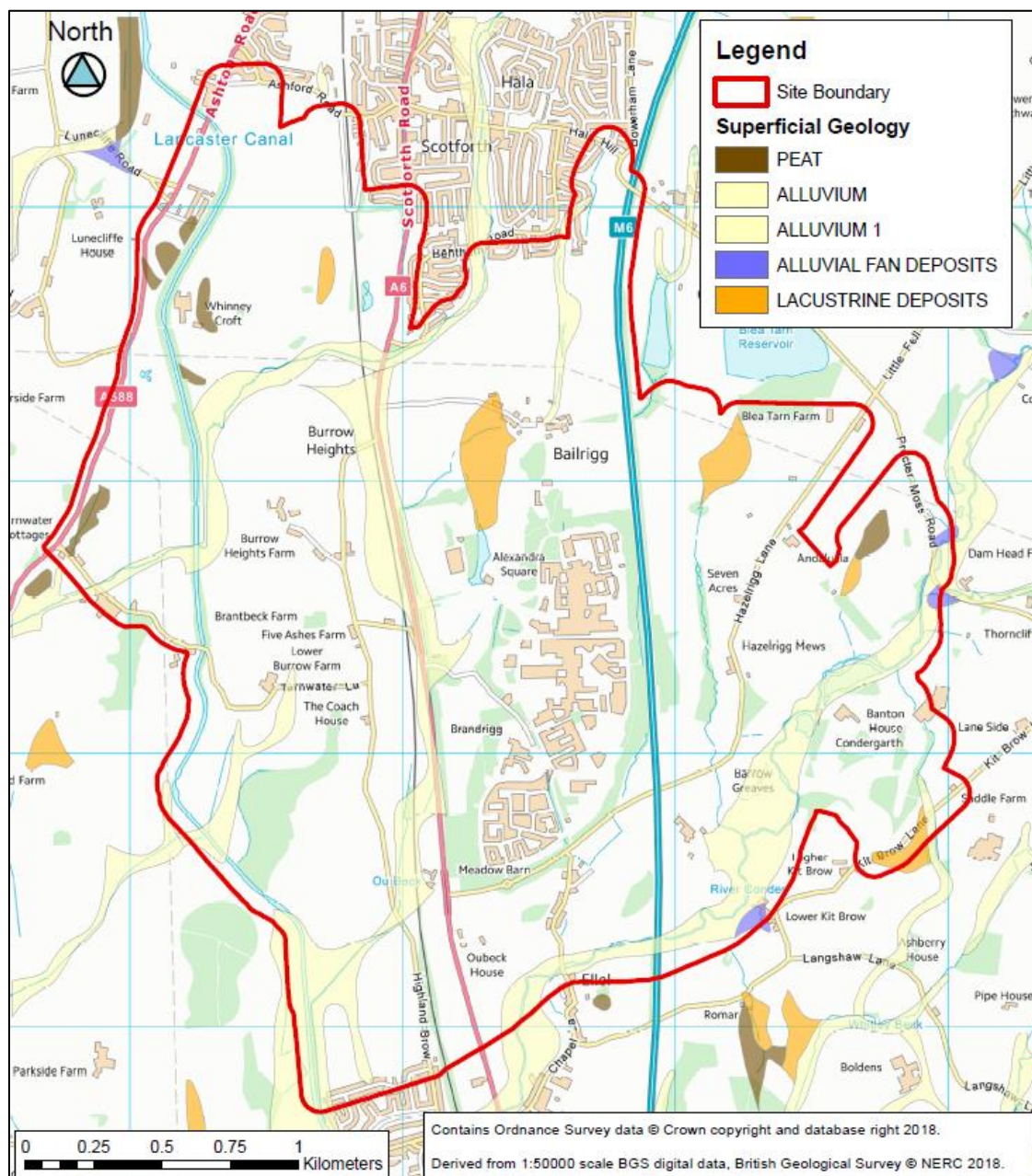
The following deposits are likely to be indicators of perennially or semi perennially high watertables:

- Peat,
- Lacustrine (lake) deposits,
- Alluvium.

Current artificial drainage on-site acts to locally suppress the watertables in these areas. Notably, the areas of peat and lacustrine deposits are likely to be areas of permanent emergent groundwater if it was not for the current drainage in place.

These areas are presented below in Figure 4-1. In addition, it was evident during the site visit that the groundwater levels on the adjacent floodplain of the River Conder in particular were relatively high.

Figure 4-1 High Groundwater Level Indicators

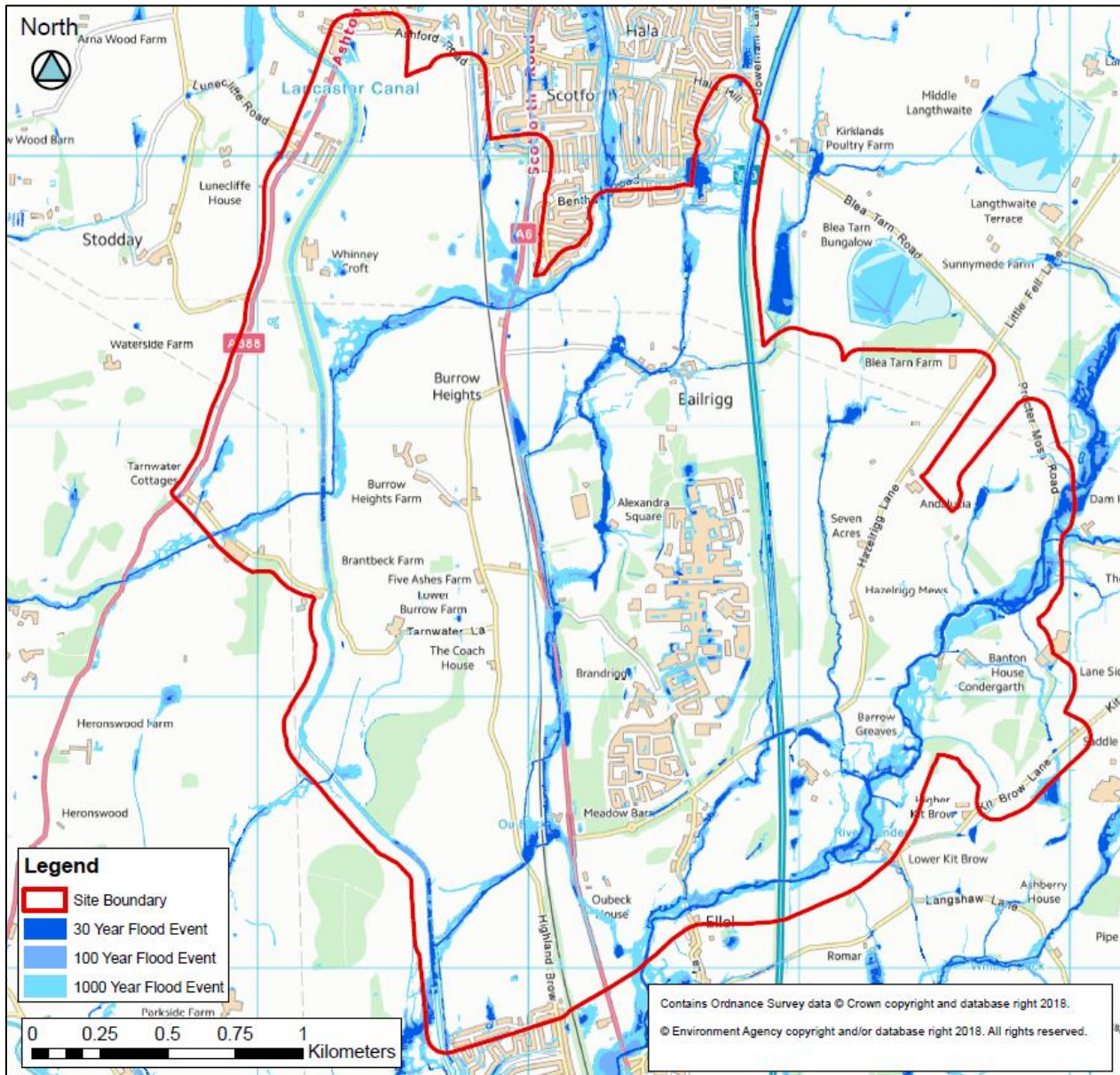




#### 4.1.2 Low lying areas

The surface water flood map presented in Figure 4-2 indicates areas of the site where water is liable to pool on site. It is evident that the surface water flood map closely reflects surface topography, Water is liable to pool in low lying valleys covered by extensive low permeability till deposits.

Figure 4-2 Surface Water Flood Map



## 4.2 Bedrock

Section 2.8.6 identifies that the majority of the site is covered by relatively thick superficial deposits. No springs have been identified on the site that originate from discharges of bedrock aquifer.

## 4.3 Groundwater Flooding

The BGS define groundwater flooding as the emergence of groundwater at the ground surface away from perennial river channels or the rising of groundwater into man-made ground, under conditions where the 'normal' ranges of groundwater level and groundwater flow are exceeded (MacDonald *et al.*, 2008;2010).

A number of recent events, most notably the flooding in England and Wales during the winters of 2000/2001 and 2002/2003 and the summer of 2007 (Cobby *et al.*, 2009), have illustrated the potential impact of groundwater flooding in the UK. As such, it is important to consider the potential combined effects of flooding from groundwater and from other sources, as well as considering flooding from groundwater alone.

### 4.3.1 Review of Groundwater Flooding Mechanisms

The following sections review the various mechanisms of groundwater flooding and considers the possible occurrence of each groundwater flooding mechanism at the Bailrigg site.

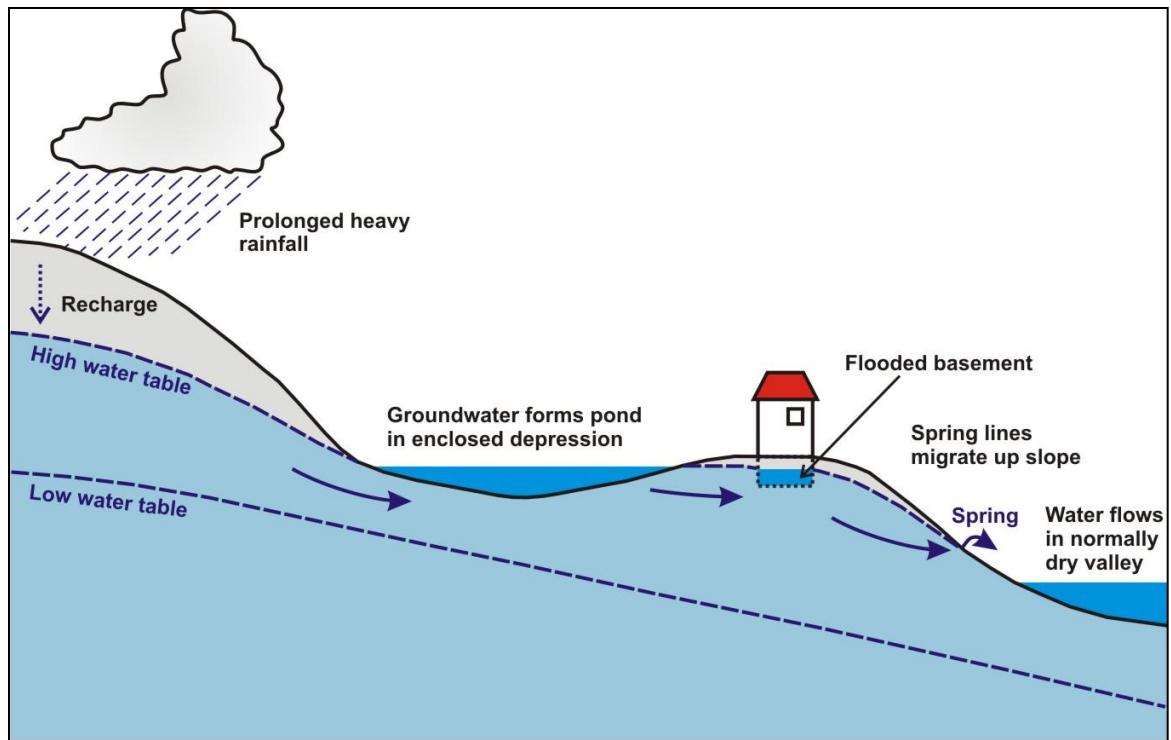
#### 4.3.1.1 Clearwater Groundwater Flooding

Prolonged heavy rainfall may cause the water table to rise above the ground surface in unconfined aquifer systems or above the floor level of underground structures such as basements. This mechanism is referred to as clearwater flooding (McKenzie *et al.*, 2007) ( Figure 4-3). It is most likely to occur in:

- Areas with a shallow water table
- Aquifers that are readily recharged, but that have a low storage capacity (such aquifers will typically display large fluctuations in groundwater level).

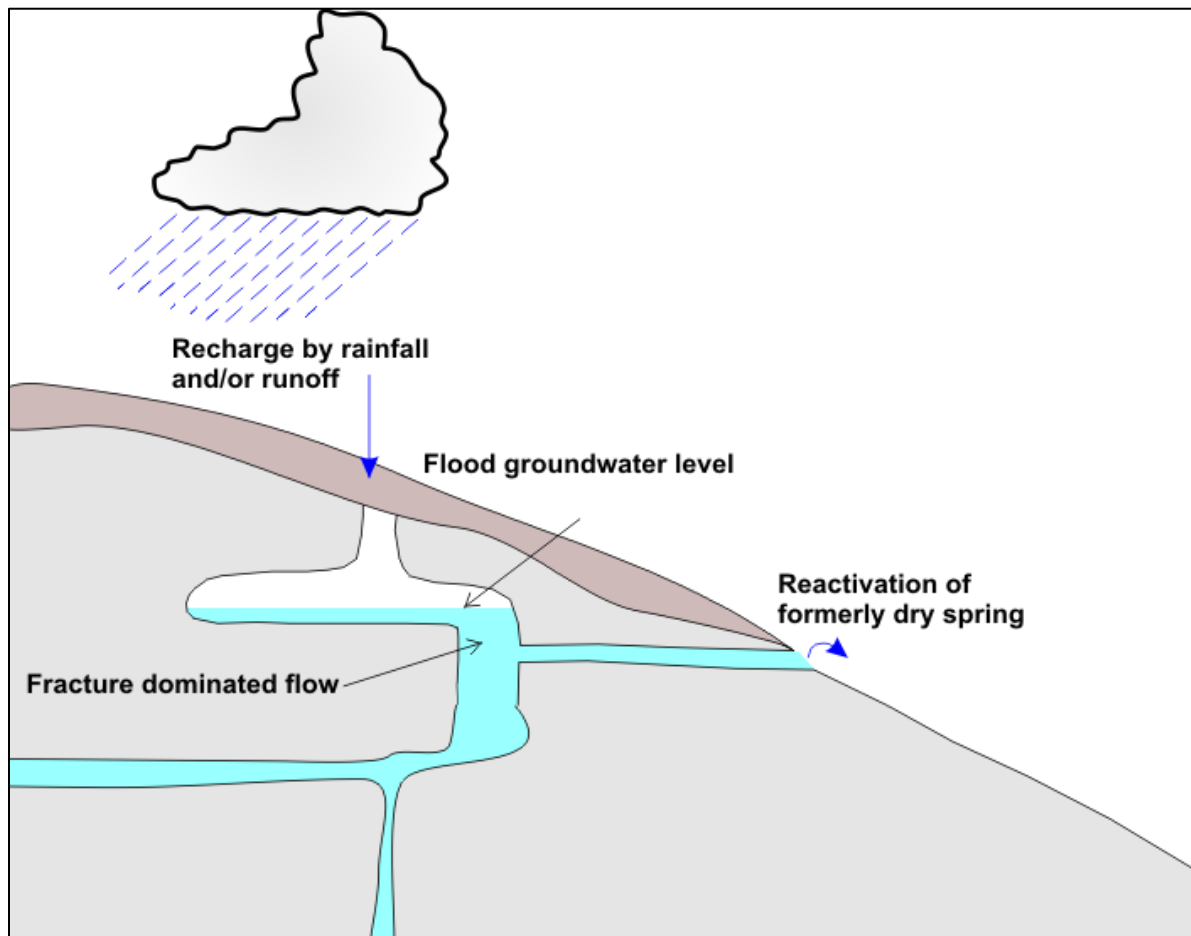
Unlike alluvial flooding, which represents the short-term response of a catchment to rainfall, groundwater flooding is often dependent on the longer-term water balance and the amount of water stored in the aquifer. For example, groundwater flooding is often more likely following a wet winter when groundwater levels are unusually high and little additional rainfall is required to bring the water table to the ground surface. However, if an aquifer has a very low storage capacity, or if additional sources of water are present (such as a river or a leaking water main), then a wet winter may not be necessary in order for groundwater flooding to occur.

Figure 4-3 Conceptual Model for Clearwater Flooding



Spring activated groundwater flooding is a subset of clearwater flooding (see Figure 4-4). Where groundwater flow within a bedrock unit is dominated by fracture flow, periods of prolonged heavy rainfall can lead to: a) the activation of ephemeral springs, or b) significant increases in existing spring activity.



Figure 4-4 Conceptual Model for Spring Activated Flooding<sup>1</sup>

#### 4.3.1.2 Alluvial Groundwater Flooding

Where an aquifer (such as a deposit of river gravel) is in hydraulic continuity with a river, high river levels will, if sustained for a long enough period of time, lead to high groundwater levels within the aquifer (Jacobs, 2007). If groundwater levels exceed the elevation of the floodplain (or the floor level of underground structures such as basements) then groundwater flooding will likely occur. This can happen even when the river remains in-bank. There are two mechanisms involved: (i) flow of water from the river into the aquifer and (ii) a reduction in the ability of water to drain from the aquifer into the river (due to the higher river level). The first of these mechanisms is most likely to be important where the river is raised within levees (or confined by flood defences) above the level of the floodplain.

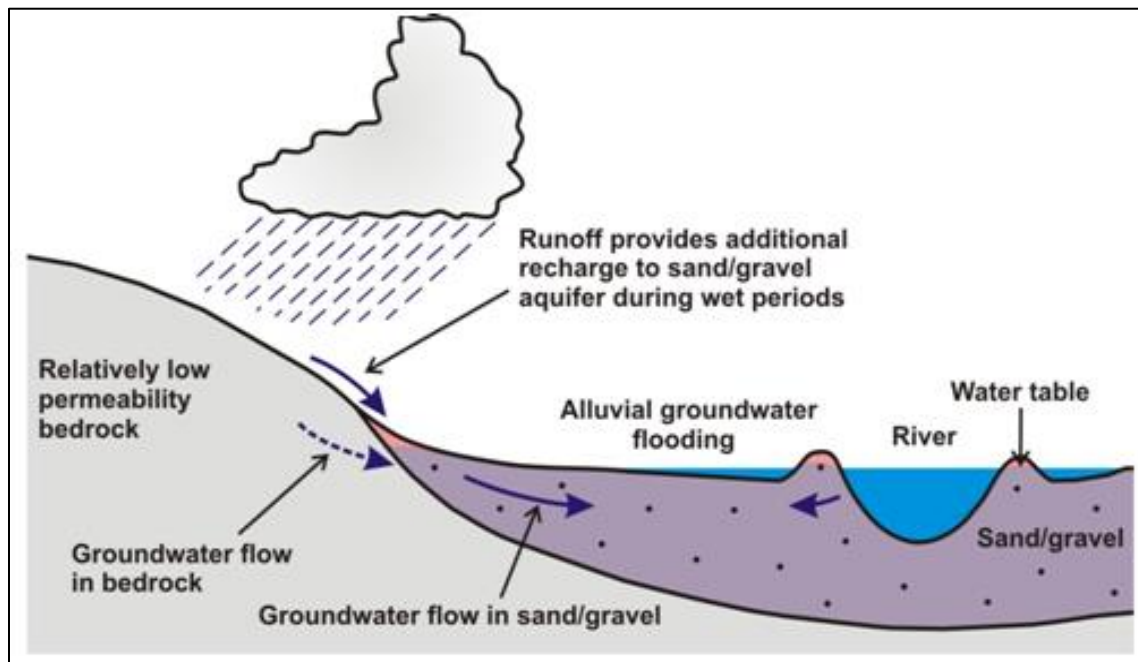
Alluvial groundwater flooding is most likely to occur in superficial sand and gravel aquifers in river valleys (Figure 4-5). As such, this mechanism of flooding is sometimes referred to as Permeable Superficial Deposits (PSD) groundwater flooding (McKenzie *et al.*, 2007). Sand and gravel aquifers are highly permeable and can respond relatively rapidly to changes in river level. Extensive alluvial groundwater flooding is most likely to occur in the following situations:

- River valleys in which alluvial sand/gravel aquifers are both extensive and laterally well connected (both internally, and to the river)
- The lower reaches of rivers with large catchments, where flood hydrographs have a long "time to peak" (so that high river levels are maintained for a relatively long period, allowing time for groundwater levels to rise significantly)

Tidal river reaches with a large tidal range (tidal locking and spring high tides in particular can lead to high river levels).

<sup>1</sup> Size of the fractures are not to scale and have been added only to aid conceptualisation  
2017s6815Bailrigg - Geo-environmental and Groundwater flooding\_Final\_Issue\_080318

Figure 4-5 Conceptual model for Alluvial Groundwater Flooding



## 4.4 Groundwater Flooding Analysis

The following section summarises the main groundwater constraints associated the development of the site at Bailrigg. This assessment is based on analysis of the local geology, hydrology, topography and the implementation of high resolution groundwater flood mapping.

### 4.4.1 Clearwater Flooding

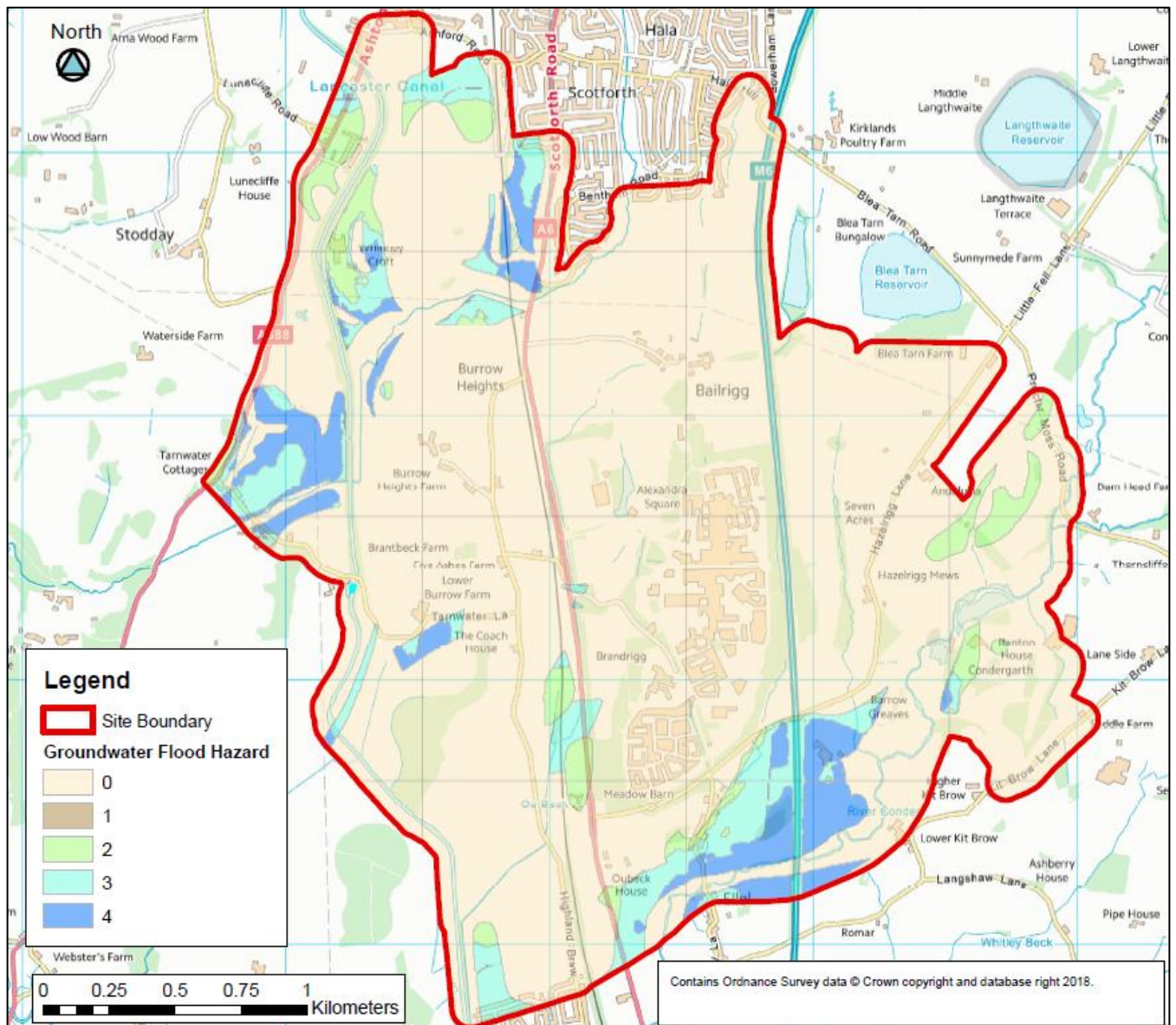
For the purposes of this report, the Groundwater Flood Map 5m Resolution V2.3 (JBA licenced product) has been utilised to provide a detailed assessment of the groundwater flood hazard across the site. The modelling used to generate the groundwater flood map involves simulating groundwater level for a range of return periods (including 75, 100 and 200-years). Groundwater levels are then compared to ground surface levels to determine the head difference (in m), where a zero head suggests artesian discharge at the ground surface. The head difference is defined on a 5m grid.

The V2.3 model categorises the head difference (in m) into five different feature classes (0-4). A detailed description of each individual class is given in Table 4-1. The groundwater flood map generated by the V2.3 model for the site is presented in Figure 4-6.

Table 4-1 Groundwater Flood Risk Classification

Groundwater Head Difference (m)	Feature Class	Description
N/A	0	No Risk. This zone is deemed as having a negligible risk from groundwater flooding due to the nature of the local geological deposits.
>5	1	Groundwater levels are at least 5m below the ground surface in the 100-year return period for a flood event.
0.5-5	2	Groundwater levels are between 0.5m and 5m below the ground surface in the 100-year return period for a flood event.  There is a risk of flooding to subsurface assets, but the surface manifestation of groundwater is unlikely.
0.025- 0.5	3	Groundwater levels are between 0.025m and 0.5m below the ground surface in the 100-year return period flood event.  Within this zone there is a risk of groundwater flooding to surface and subsurface assets. There is the possibility of groundwater emerging at the surface locally.
0-0.025	4	Groundwater levels are either at very near (within 0.025m of) the ground surface in the 100-year return period flood event.  Within this zone there is a risk of groundwater flooding to both surface and subsurface assets. Groundwater may emerge at significant rates and has the capacity to flow overland and/or pond within any topographic low spots.

Figure 4-6 Groundwater Flood Map



It is evident from the groundwater flood map in Figure 4-6, that the highest risk areas (i.e. ground water flood hazard classifications 2-4) correlate well with the presence of high permeability glaciofluvial sands and gravels and river terrace deposits. The remainder of the site, which is covered by thick, low permeability glacial till and lacustrine deposits is classified as be at low risk of groundwater flooding. Excluded from the mapping are areas of peat, alluvium and lacustrine deposits. While these regions are likely to be regularly waterlogged, the low permeability of these deposits, means that the volume of water yielded from these deposits is limited.

Risk of clearwater flooding from bedrock deposits (e.g. through the activation of springs) is limited due to the thickness of superficial deposits across the site.

#### 4.4.1.1 Limitations of the Groundwater Flood Mapping

The V2.3 Groundwater Flood Map presented in Figure 4-6 is suitable for general broad-scale assessment of the groundwater flood hazard in an area, but it is not explicitly designed for the assessment of the flood hazard at the scale of individual properties. In areas of the site deemed as high risk, a site-specific risk assessment for groundwater flooding is recommended to fully inform the likelihood of flooding.



#### 4.4.2 Alluvial Groundwater Flooding

As identified in Section 4.3.1.2 extensive alluvial groundwater flooding is most likely to occur in the following situations:

- River valleys in which alluvial sand/gravel aquifers are both extensive and laterally well connected.
- The lower reaches of rivers with large catchments, where flood hydrographs have a long "time to peak".

The corridor of high permeability sands and gravels underlying the alluvium, and forming river terrace deposits, and glacial fluvial deposits along the River Condor, is most likely to be prone to alluvial groundwater flooding. This area is highlighted by the blue polygon in Figure 4-7 below. Saturated ground was evident in this area during the JBA site visit (see Figure 4-8 and Figure 4-9).

Figure 4-7 Alluvial Groundwater Flooding Risk Areas

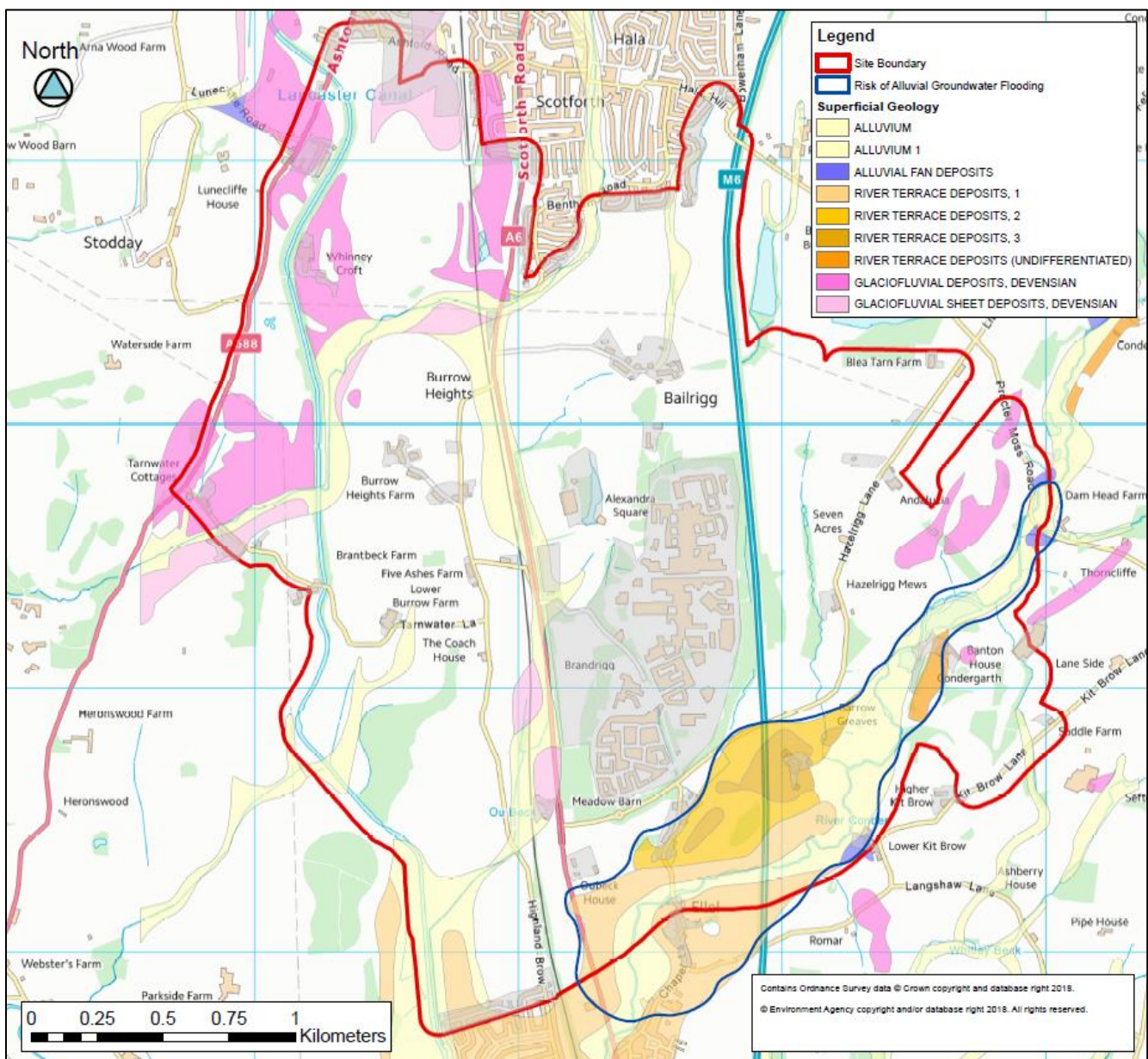




Figure 4-8 Evidence of high groundwater levels in alluvium along the River Conder (looking east).  
Approximate NGR 348680 456224.



Figure 4-9 Evidence of high groundwater levels in alluvium along the River Conder (looking south). Approximate NGR 349196 456387.



#### 4.5 Historical Evidence of Groundwater Flooding

A review of historical maps did not highlight any obvious areas across the site which may be prone to groundwater flooding. Evidence would typically include areas of marshy ground, flashes, spring lines, ephemeral watercourses etc., The review of historical maps was conducted to identify regions across the site such as waterlogged areas and regions where lakes and/or ponds were previously present but were drained at some point during sites history.

## Appendices

### A Envirocheck Report

## B Conceptual Understanding of the Site

## References

- BGS website (2016); Borehole database: <http://www.bgs.ac.uk/data/boreholescans/> Lexicon of Named Rock Units: <http://www.bgs.ac.uk/lexicon/home.html>
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