Groundwater assessment of Level 2 sites

1 Introduction

1.1 Background

There is generally a potential risk of groundwater flooding across the study area, but there is no existing mapping or data that describes the magnitude of the risk. As such, a high-level overview of the risk of groundwater flooding has been carried out for six potential allocation sites. It should be noted that detailed site summary tables assessing all other sources of flooding have been prepared for five of the sites. The main flood risk to Highgrove Farm (site AL7) is considered to be from groundwater. Therefore, only a groundwater assessment has been undertaken for this site.

The report provides groundwater constraints analysis for the six potential allocation sites, which aims to identify areas susceptible to groundwater emergence, groundwater flooding, and high groundwater tables; and the degree to which these impacts maybe potentially mitigated.

The potential for mitigation is controlled by the rate and volume of groundwater emergence. It is only where groundwater overwhelms systems that it causes issues. As a result, groundwater flooding issues can range from being akin to waterlogging and possible to manage through low tech solutions such as drains and underdrainage, to creating long duration flooding on a scale that is unable to practically solve.

This report should be read alongside the mapping presented in the Level 2 SFRA Appendix B.

1.2 Data sources

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

- Topography and general mapping:
    - EA Open Data, LiDAR 2m DTM.
    - National Library of Scotland, side by side viewer.
    - Aerial Imaging (Google Earth and Bing Maps).
- Geology and soils
    - BGS 1:50,000 Geology Map, Sheet 317/332: Chichester and Bognor).
    - BGS online Lexicon (BGS website).
    - Cranfield Soil and Agrifood Institute Soilscapes online viewer.
- Hydrogeology
    - Aquifer classification (DEFRAs Magic Map).
    - The physical properties of minor aquifers in England and Wales. Hydrogeology Group Technical Report WD/00/04.
    - GeoSmart Groundwater Flood Risk Map, 5m resolution (GW5).
    - JBA Consulting Groundwater Flood Risk Map

1.3 Flood risk maps

For the purposes of this report, two groundwater risk maps been utilised to provide a detailed assessment of the groundwater flood hazard across the site: the Groundwater Flood Map 5m Resolution GW5 V2.2(GeoSmart licenced product) provided by West Sussex County Council and JBA Consulting Groundwater Risk Map. The modelling used to generate the groundwater flood maps involves simulating groundwater levels for a range of return periods.

The GeoSmart Groundwater Flood Risk Map highlights areas where there is sufficient evidence to suggest that flooding could occur. The map should be interpreted as an initial indicative screening tool.

The V2.2 model categorises four different feature classes (1-4). A detailed description of each individual class is given below in Table 1-1.

Table 1-1: GeoSmart groundwater flood risk classification

Risk Class	Description
Class 1: High	There is a high risk of groundwater flooding in this area with a chance of greater than 1% annual probability of occurrence or more frequent. It is likely that incidence of groundwater flooding will occur, which could lead to damage to property or harm to other sensitive receptors at, or near, this location. Flooding may result in damage to property, road or rail closures and, in exceptional cases, may pose a risk to life. Surface water flooding and failure of drainage systems will be exacerbated when groundwater levels are high. Further consideration of the local level of risk and mitigation, by a suitably qualified professional, is recommended.
Class 2: Moderate	There is a moderate risk of groundwater flooding in this area with a chance of greater than 1% annual probability of occurrence. There will be a significant possibility that incidence of groundwater flooding could lead to damage to property or harm to other sensitive receptors at, or near, this location. Where flooding occurs it is likely to be in the form of shallow pools or streams. There may be basement flooding, but road or rail closures should not be needed and flooding should pose no significant risk to life. Surface water flooding and failure of drainage systems may be exacerbated when groundwater levels are high. Further consideration of the local level of risk and mitigation, by a suitably qualified professional, is recommended.
Class 3: Low	There is a low risk of groundwater flooding in this area with a chance of greater than 1% annual probability of occurrence. There will be a remote possibility that incidence of groundwater flooding could lead to damage to property or harm to other sensitive receptors at, or near, this location. For sensitive land uses further consideration of site topography, drainage, and historical information on flooding in the local area should be undertaken by a suitably qualified professional. Should there be any flooding it is likely to be limited to seepages and waterlogged ground, damage to basements and subsurface infrastructure, and should pose no significant risk to life. Surface water flooding, however, may be exacerbated when groundwater levels are high.
Class 4: Negligible	here is a negligible risk of groundwater flooding in this area and any groundwater flooding incidence has a chance of less than 1% annual probability of occurrence. Comments: No further investigation of risk is deemed necessary unless proposed site use is unusually sensitive. However, data may be lacking in some areas, so assessment as 'negligible risk' on the basis of the map does not rule out local flooding due to features not currently represented in the national datasets used to generate this version of the map.

The JBA Groundwater Risk map classifies groundwater flood risk differently than the Geosmart dataset. It categories how closes to the ground surface the water table is for a 1% Annual Exceedance Probability (AEP) (1 in 100 year) flood event (see Table 1-2).

Table 1-2: Groundwater Flood Hazard Classification for the JBA flood map

Groundwater head difference (m)*	Class
0 to 0.025	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.
0.025 to 0.5	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.
0.5-5	Groundwater levels are between 0.5m and 5m below the ground surface in the 100-year return period flood event There is a risk of flooding to subsurface assets but surface manifestation of groundwater is unlikely.
>5	Groundwater levels are at least 5m below the ground surface in the 100-year return period flood event. Flooding from groundwater is not likely.
N/A	No risk. This zone is deemed as having a negligible risk from groundwater flooding due to the nature of the local geological deposits.
Difference is defined as ground surface in mAOD minus modelled groundwater table in mAOD.	

1.3.1 Limitations of the groundwater flood mapping

The GW5 V2.2 Groundwater Flood Map and the JBA groundwater flood risk map are 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.

Further analysis is required beyond the map to assess whether there are potentially technical solutions to mitigate these issues.

2 Groundwater constraints

This assessment forms a desk-based review into possible groundwater related development constraints across the sites. Groundwater constraints may include:

- Areas of perennially or semi-perennially high-water tables.
  - E.g., peat lined hollows
- Areas where groundwater can periodically emerge.
  - i.e., areas susceptible to groundwater flooding.

The two elements above differ in their regularity. Groundwater flooding is defined by the BGS as the 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 supress their water table. On the other hand, a similar drain cut into high permeability gravels, may quickly be overwhelmed and inundated with groundwater. This later impact is dependent to a degree on the extend of the groundwater catchment draining to the ditch. A small, isolated area of aquifer in a valley floor surrounded by drains and rivers will have a smaller groundwater inputs, than a ditch receiving water from a large uphill catchment.

A number of events, most notably the flood event in Chichester 1993/4 (http://nrfa.ceh.ac.uk/sites/default/files/The_Chichester_Flood_Jan_1994.pdf), 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 Chichester District and 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.

The assessment is split into two parts:

- Hydrogeological and geological indications of high groundwater table - i.e., areas of areas of perennially or semi-perennially high water table.
- 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.

2.1 Review of groundwater flooding mechanisms

The following sections review the various mechanisms of groundwater flooding.

2.1.1 Clearwater groundwater flooding

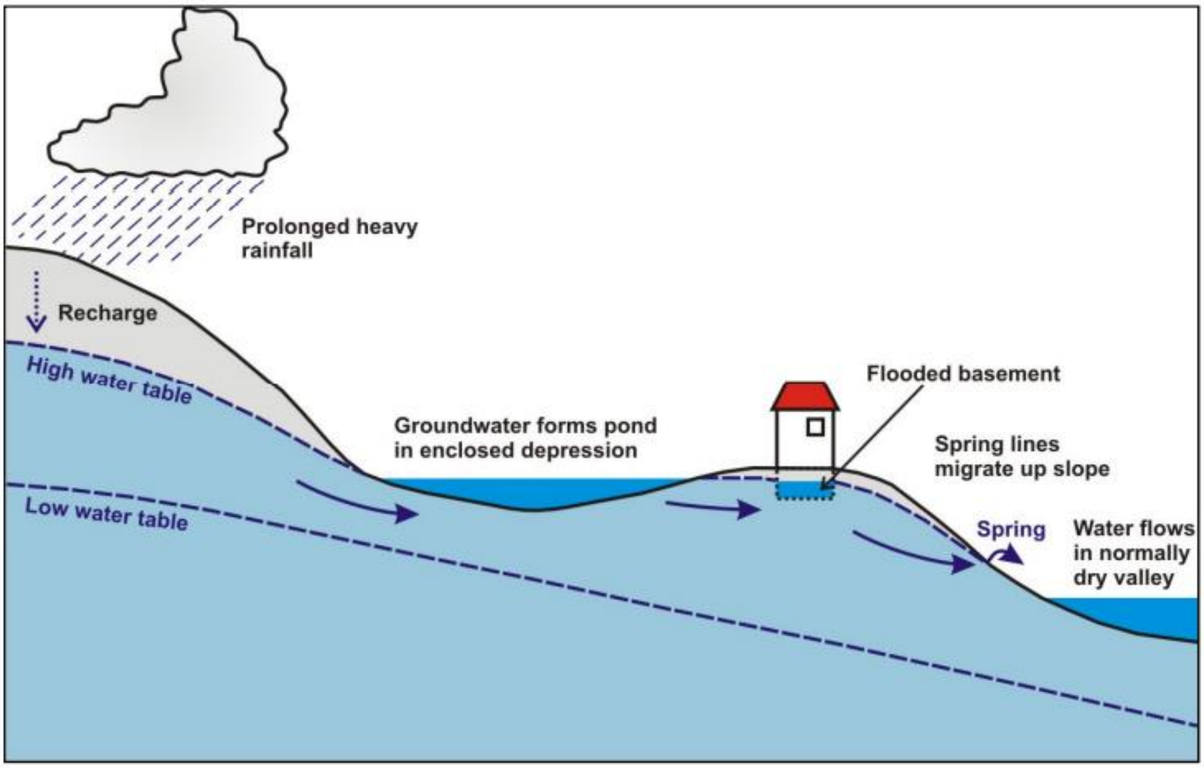
Prolonged heavy rainfall may cause the water table to rise above the ground surface in unconfined aquifer systems or above the floor level of underground structures such as basements. This mechanism is referred to as clearwater flooding (McKenzie et al., 2007) (Figure 2-1).

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 2-1: Conceptual model of clearwater groundwater flooding



2.1.2 Alluvial groundwater flooding

Where an aquifer (such as a deposit of river gravel) is in hydraulic continuity with a river or the sea, high river or sea 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.

Another mechanism is that high groundwater levels can result in surcharging of foul and surface water sewers as a consequence of high infiltration flow magnitudes. The effect of this is to reduce the hydraulic capacity of the sewers and the consequences can be flooding from sewers that is caused by high groundwater levels (this can also be generated by clearwater groundwater flooding).

This can happen even when the river remains bank or the sea level does not exceed the crest of coastal defences. There are two mechanisms involved: (i) flow of water from the river/sea into the aquifer and (ii) a reduction in the ability of water to drain from the aquifer into the river/sea (due to the higher river or sea levels). 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 or the ground levels inland are below mean sea levels .

Alluvial groundwater flooding is most likely to occur in superficial sand and gravel aquifers in river valleys (Figure 2-2) or can be experienced in coastal flood plains (Figure 2-3). 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 or coastal flood plains 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).
- Coastal areas where the ground levels are lower than mean sea levels, such that the long term influence of spring tides augmented by storm surges results in a relatively high hydrystatic head that induces substantive inland groundwater flows.

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

Figure 2-2: Conceptual model of alluvial groundwater flooding - river

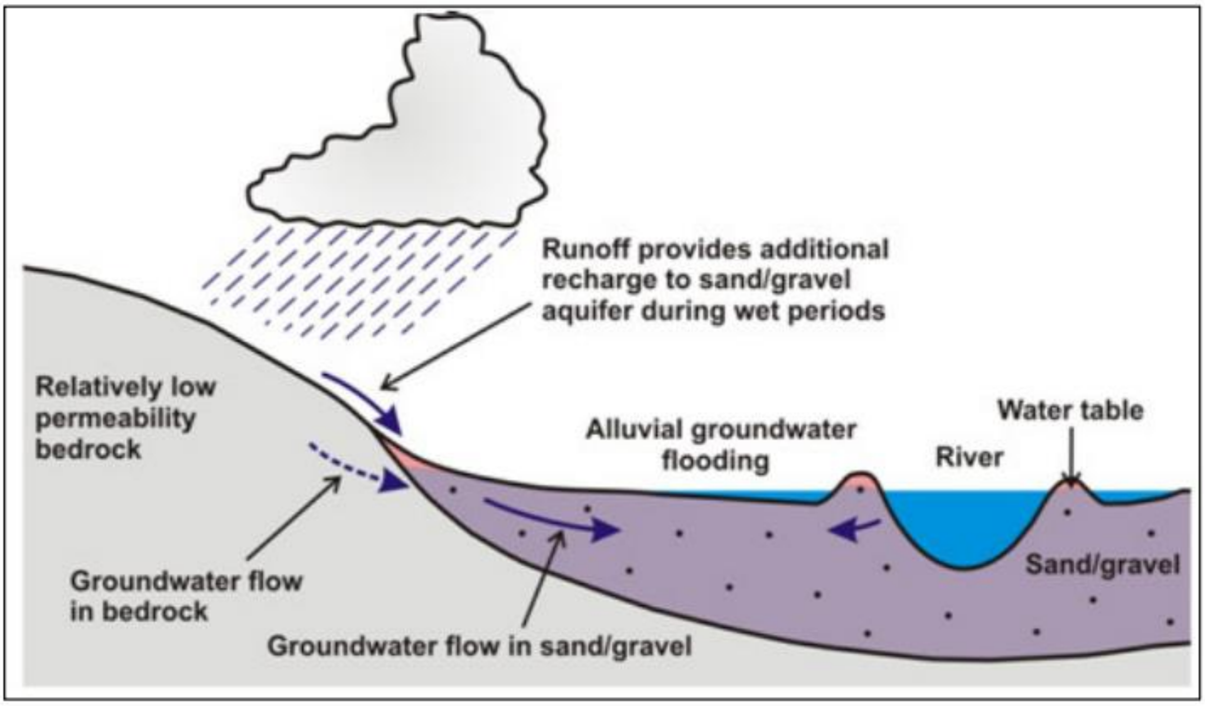
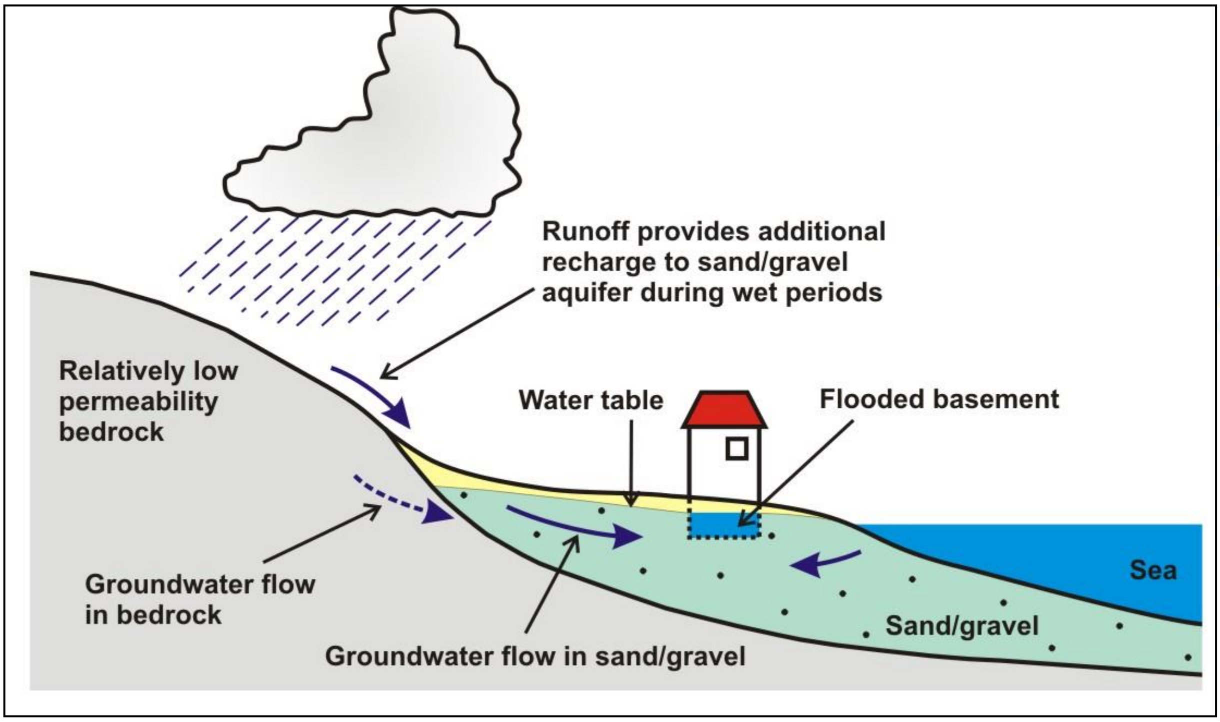


Figure 2-3: Conceptual model of alluvial groundwater flooding - sea



2.2 Climate change

There is substantial uncertainty over the potential effects of climate change on the magnitude of groundwater flows generated by rainfall making it difficult to identify competent evidence that can be used to inform a strategic assessment. As a general rule the order of magnitude of such change is likely to be much less than for other sources of flood risk and thus it is likely that that predicted changes in fluvial and surface water flood risk will be the most influential consideration when evaluating the safety of development over the intended life.

3 Site AL3- Land East of Chichester

3.1 Environmental setting

3.1.1 Introduction

The following section presents an understanding of the environmental setting of the site and the local area, including aspects such as the topography, hydrology, geology and hydrogeology. This information provides an important baseline for the groundwater constraints.

3.1.2 Location and topography

The 55ha site is located adjacent to the east of Chichester (site centre NGR SU883046). The western boundary of the site is marked by the A27 (Chichester bypass), with the Southern railway line marking the southern boundary. Drayton Lane (B2114) borders the site to the east and Shopwhyke Road (B2144) marks the northern boundary.

It should be noted that the vast majority of the southern and western extent of the site comprise the former Drayton Manor landfill site, which received waste (industrial, commercial, household) between September 1982 and October 1990.

The site slopes from west to east, with maximum elevations in the north-western corner of the site of~18mAOD and the lowest elevations in the far south-eastern corner of ~12mAOD.

The site boundary and local topography is presented in Appendix B1.1

3.1.3 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
    - Residential.
- East
    - Farmland.
- South
    - Railway.
- Farmland.
    - Lakes.
- West
    - Chichester bypass with residential beyond.

3.1.4 Surface water hydrology

There are several surface water bodies mapped within the site boundary:

- A drainage ditch that runs along the western and southern boundary of the site.
- A lake in the former Shopwyke Gravel pit measuring approximately 6.8 ha. The centre of the lake is located at NGR SU886045. There appears to be an outflow from the lake which flows in a south westerly direction into the drainage ditch on the southern boundary.
- A small pond in the northwestern corner of the site measuring approximately 0.14 ha. The pond is located at NGR SU880047. An outflow from the pond flows south into the southern boundary ditch.

3.1.5 Geology and soils

Information on the soils and geology of the site and surrounding area has been derived from the Cranfield Soil and Agrifood Institute Soilscapes online viewer, 1:50,000 BGS geology mapping (Sheet 317/332: Chichester and Bognor), and the BGS online borehole archive.

Soils

The soils across the majority of the site are classified as type 6, which are described as freely draining slightly acid loamy soils with a loamy texture. Typically, these soils drain to local groundwater and rivers.

Superficial deposits

The superficial geology mapped across the majority of the site is comprised of Alluvial Fan Deposits (referred to locally as the Chichester Gravels), which consist of low, outspread, relatively flat to gently sloping masses of loose rock material, shaped like a fan or segment of a cone. They are deposited by streams at the mouths of tributary valleys onto a plain or broad valley.

A strip of undifferentiated River Terrace Deposits are also mapped running in a north-south direction across the centre of the site.

Bedrock geology

The superficial deposits across the site are underlain by the London Clay Formation, which comprises CLAY, SILT and SAND.

Summary of site geology

A summary of the local geological stratigraphy is presented below in Table 3-1.

Table 3-1: Summary of local geology

Age	Group	Formation	Description	Thickness
Quaternary	Superficial deposits	Alluvial Fan Deposits ('Fan Gravels)	Clayey gravels	At least 8m*
		River Terrace Deposits (undifferentiated)	Undifferentiated sands and gravels	At least 8m*
Eocene	Bedrock (Thames Group)	London Clay Formation	Bioturbated or poorly laminated, blue-grey or grey-brown, slightly calcareous, silty to very silty clay, clayey silt and sometimes silt, with some layers of sandy clay. It commonly contains thin courses of carbonate concretions ('cementstone nodules') and disseminated pyrite. It also includes a few thin beds of shells and fine sand partings or pockets of sand, which commonly increase towards the base and towards the top of the formation	Unknown
Source: *BGS Borehole Logs				

3.1.6 Hydrogeology

Aquifer designations

The geological strata summarised in the Geology and Soils section have been assessed for their hydrogeological properties. Aquifer designations have been collated via DEFRAs online Magic Map. The superficial deposits on site are classified as secondary A aquifer. Secondary A aquifers are 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. These are generally aquifers formerly classified as minor aquifers.

The London Clay bedrock is not designated as an aquifer.

Groundwater source protection zones

The site is located approximately 3.4 km from a zone I inner Source Protection zone.

Aquifer vulnerability

Groundwater vulnerability mapping shows that groundwater beneath the site is designated as having 'low' vulnerability with no 'soluble rock risk' (DEFRAs Magic Map).

Groundwater flow, springs and issues

The general regional groundwater gradient can be expected to reflect the local topography, with baseflow towards the south. It is possible that groundwater levels within the superficial deposits may be influenced by variations in surface water levels in the local drains. The water levels in the former Shopwyke gravel pit on site likely reflects the level of the local water table. LiDAR data indicates that this maybe in the region of ~10 mAOD, however groundwater level monitoring would be recommended to determine the precise rest level of the groundwater beneath the site and to determine any seasonal fluctuations.

There are no springs or issues mapped on the site.

Aquifer properties

Table 3-2 below presents a summary of aquifer properties.

Table 3-2: Summary of aquifer properties

Formation	Description	Thickness	Properties
Alluvial Fan Deposits	Clayey gravels	At least 8m*	Likely moderate permeability. Intergranular flow.
River Terrace Gravels	Undifferentiated sands and gravels	At least 8m*	High permeability. Intergranular flow.
London Clay Formation	Silty clays, with some layers of sandy clay.	Unknown	Low permeability.

3.2 Groundwater constraints assessment

The following section builds on the geology, hydrology and topography data collated in the previous sections to form a desk-based review into possible groundwater related development constraints across the site. Possible groundwater constraints have been described in Section 2.

3.2.1 Hydrogeological indicators of a high groundwater table

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

Superficial deposits

Alluvium (including Alluvial Fan type deposits) is likely to be an indicator of a perennially or semi perennially high water table.

Alluvial Fan deposits (GRAVEL, SAND, SILT and CLAY) are mapped across the majority of the site.

Low lying areas

The surface water flood map presented in Appendix B1.7 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 typically more liable to pool in low lying valleys covered by extensive low permeability deposits. There are only very small areas of high surface water flood risk indicating that local drainage in most situations can cope with surface water flows and the duration of flooding is likely to be limited.

The flood extents presented in Appendix B1.4 show that the site not considered to be at risk of fluvial flooding in a 1% AEP flood event.

Bedrock level

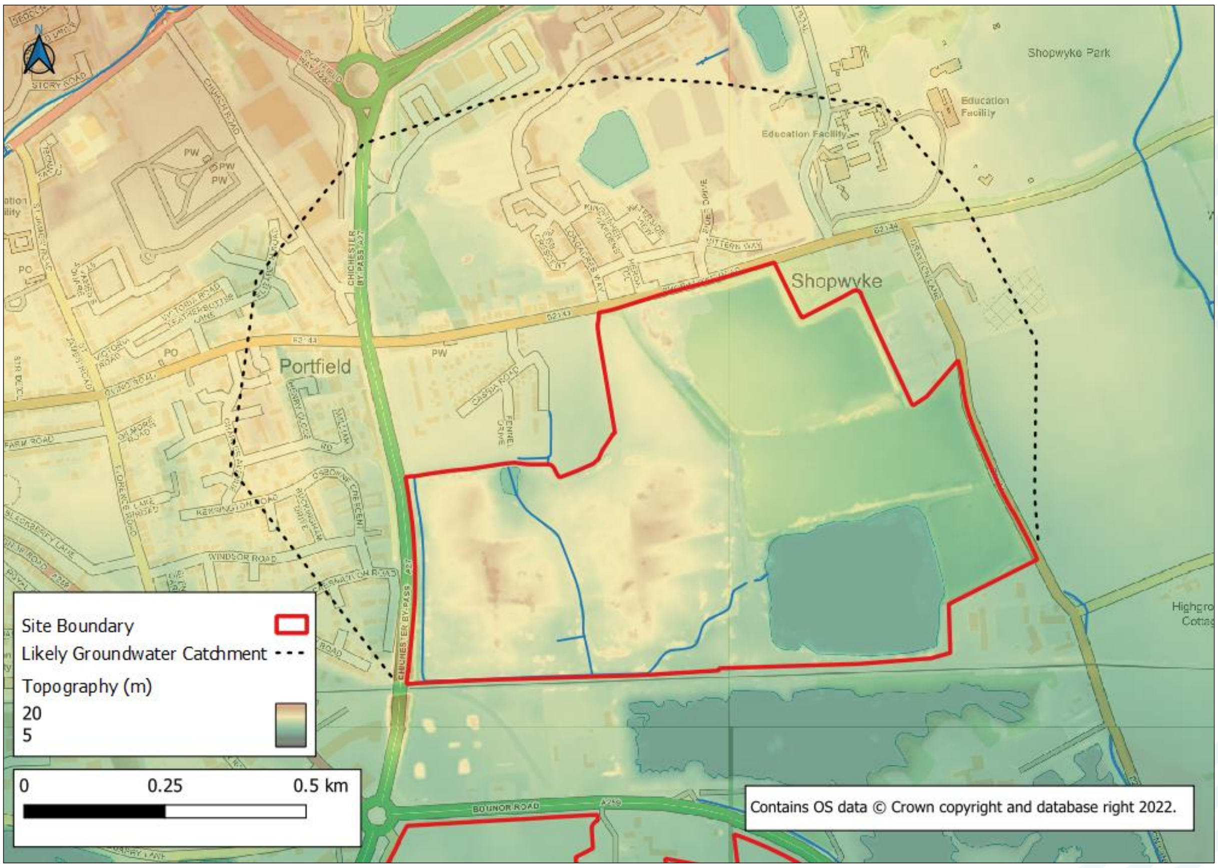
The majority of the site is likely covered by relatively thick superficial deposits.

No springs have been identified on the site from a desk-based assessment that originate from discharges from the bedrock aquifer.

3.2.2 Groundwater movement

Figure 3-1 highlights the likely groundwater catchment for the site based on topographic data. It is evident that the site has a relatively small groundwater catchment measuring approximately 1.2 Km^2 and is therefore unlikely to receive significant volumes of groundwater.

Figure 3-1: Likely groundwater catchment



3.3 Groundwater flooding analysis

The following section summarises the main groundwater constraints associated with the development of the site. This assessment is based on analysis of the local geology, hydrology, topography and the implementation of high-resolution groundwater flood mapping. The difference between clearwater flooding and alluvial groundwater flooding is described in Section 2.1.

3.3.1 Clearwater flooding

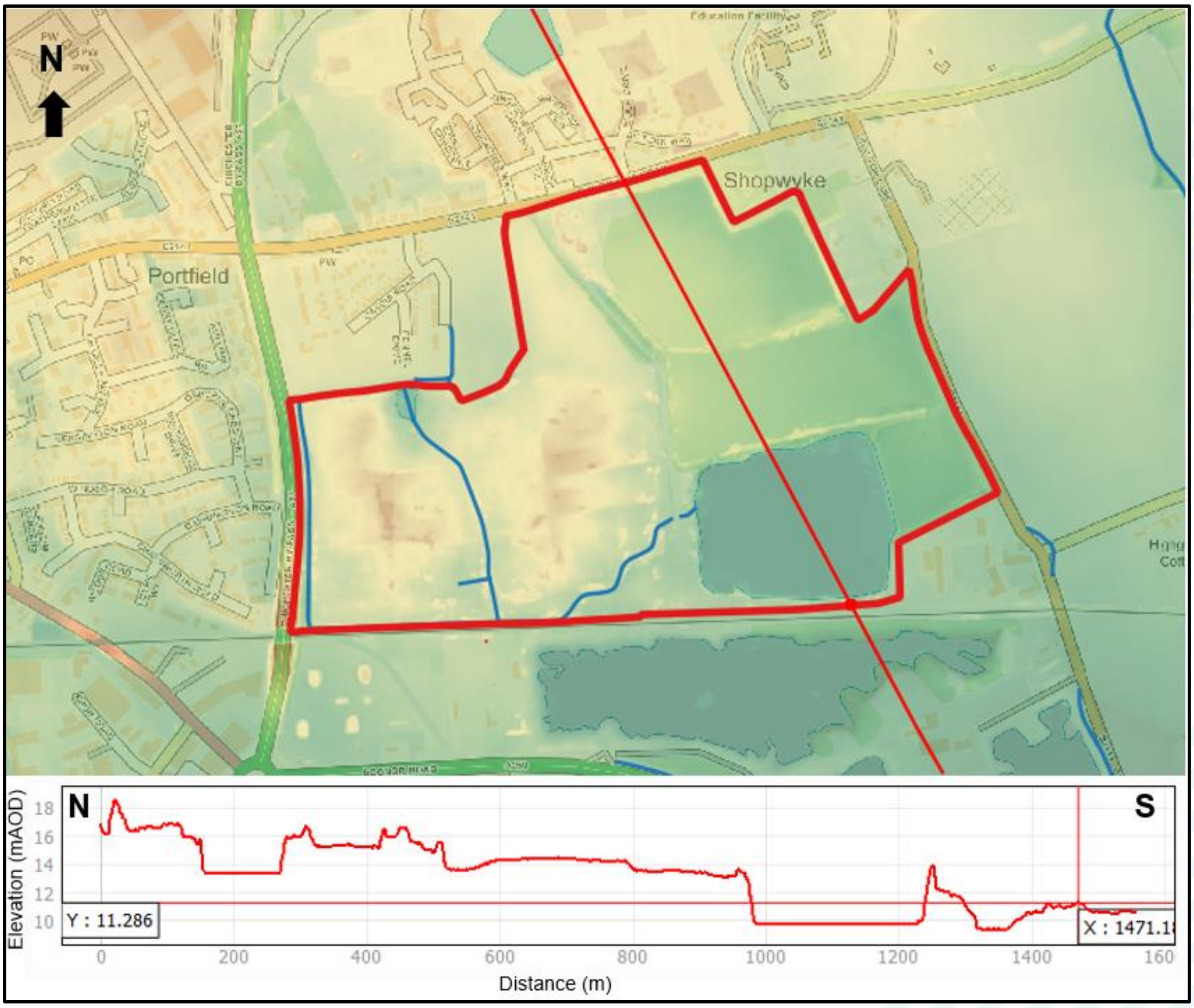
It is evident from the Geosmart groundwater flood map presented above in Appendix B1.12 that vast majority of the site is designated to be at moderate risk of groundwater flooding.

The JBA groundwater flood map in Appendix B1.13 shows that there is a risk of groundwater emergence across the majority of the site except the high ground in the south-west.

Further analysis is required beyond the maps to assess whether there are potentially technical solutions to mitigate these issues.

The topographic profile across the site presented below in Figure 3-2 indicates that groundwater levels may be ~2-4m below the surface in the lowest parts of the site (assuming that the water levels in the lake reflect the local groundwater table). It should be noted that this is an estimation based on 1m LiDAR data. Before development, groundwater level monitoring should be undertaken to gauge groundwater levels more accurately.

Figure 3-3-2: North - south topographic profile across the site



The area appears to be highlighted as it is low lying and underlain by permeable sands and gravel deposits. The groundwater emergence may occur:

- In periods of high rainfall,
- If the lake levels in the surrounding area rise.

The lowest lying areas in the east and south-east of the site are likely to be most affected by high groundwater levels where historical mapping identifies a series of ponds existed.

3.3.2 Alluvial groundwater flooding

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".

Although there are moderate permeability Alluvial Fan deposits on site they are not in contact with the alluvial floodplain of the larger watercourses and rivers in the area. Therefore, it is unlikely that the site is at risk from alluvial groundwater flooding.

3.3.3 Effects of historical landfill on groundwater flooding

Given the history of landfilling on the site and the nature of the wastes (i.e., the landfill holds commercial, industrial, and household waste), it is likely that the landfill is lined with some form of engineered liner (e.g., geotextile). There is the potential that this could impede the flow of groundwater and causes local elevations in groundwater levels

3.3.4 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 also 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.

Historical mapping from 1882-1914 indicates that there were historically a series of small ponds present just beyond the southeast of the site that are no longer present. This suggests that the watertable was near the surface for these ponds to persist. The gravel extraction works may have supressed the watertable leading to this pond disappearing.

3.4 Conclusions and mitigation strategy considerations

Section 3.3 identifies whether the site may be subject to groundwater flooding mechanisms. This section assesses the potential, if necessary for mitigation and the likely scale of that mitigation.

The table below outlines the main considerations when assessing groundwater flood risk and the potential for simple mitigation.

Table 3-3: Main groundwater flooding constraints

Questions	Explanation	Answer
What groundwater flood risk zone is the allocation in?	The GeoSmart V2.2 flood map should be used as an initial indicative screening tool categorises groundwater flood risk into four classes. 1- High risk, 2- Moderate risk, 3 - low risk, 4 - negligible risk.	Mainly Class 2 - Moderate risk And Groundwater levels are either at very near (within 0.025m of) the ground surface in the 100-year return period flood event.
Is the site vulnerable to clearwater flooding?	Clearwater flooding 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).	Yes - Groundwater flood mapping indicates the site is at moderate risk from groundwater flooding. Water levels in the former gravel pit on site is likely to be an expression of the local groundwater table and topographic data suggests that that water levels in the eastern and south-eastern extent of the site may only be a couple of meters below the ground surface.
Is the site vulnerable to alluvial groundwater flooding?	Alluvial groundwater flooding is most likely to occur in: • River valleys in which alluvial sand/gravel aquifers are both extensive and laterally well connected. • The lower reaches of rivers	No - Although there are moderate permeability Alluvial Fan deposits on site they are not in contact with the alluvial floodplain of the larger watercourses and rivers in the area. Therefore,

	with large catchments, where flood hydrographs have a long "time to peak".	it is unlikely that the site is at risk from alluvial groundwater flooding
Does the site receive groundwater from a relatively large groundwater catchment?	If there is a large groundwater catchment, groundwater inputs may be harder to manage through drainage	No - groundwater catchment is small (~1.2km^2), the site lies on a slight ridge.
Are the main groundwater discharge boundaries (ditches, rivers, lakes) within surface water or fluvial flood zones?	If yes, there may be periods when these discharge boundaries will be overwhelmed with surface water and will not function to suppress the groundwater watertable	Yes - but these are likely to be short duration, long return period surface water flooding events which would not likely overwhelm the drainage for significant periods.
Are there discharge boundaries potentially outside of the control of the allocation?	Groundwater level may change in future.	Yes - Water levels in the lake to the south of the allocation should be controlled
Are there areas of the site lower than the lowest point of the banktop of the drain/river network?	If yes, then alluvial groundwater flooding may be a potential mechanism as water in the neighbouring surface water body could be higher than the surface of the site	No.

The area is underlain by permeable superficial deposits and has been highlighted as have a potential clearwater flooding risk. Groundwater within these deposits likely discharge to the drains and lakes on site and the lake to the southern boundary. The groundwater catchment outside of allocation is relatively small and the drains will only be subjected to limited surface water flooding and no fluvial flooding so it is expected that a drainage design could be incorporated in the future development of the site that could supress the water table. This would however be reliant on the lakes on site and to the south being maintained at a low level.

The assessment performed does not suggest that the risk from groundwater flooding provides evidence that it is a necessity to consider reasonably available alternative locations. A sequential approach to development will be required so that groundwater risk is managed appropriately for the lifetime of development.

This initial assessment indicates that it is feasible to design a drainage system to suppress groundwater flooding. Such a design should be based on:

- Groundwater monitoring,
- Groundwater modelling to determine the spacing and sizing of drainage requirements,
- Potential zoning of the site limit development in the lowest lying parts of the site.
- A long term commitment to control water levels in the lake to the south of the allocation so groundwater flood risk is appropriately addressed.
- This assessment does not consider underground structures such as basements.

3.5 Climate change

In view of the topographic elevation of the site it is unlikely that local groundwater flow or flood risk will be affected by long term changes in mean sea level. However, it is possible that long term changes in mean sea level could affect the performance of local watercourse systems and so consideration will need to be given to the arrangements for water level management as affects local watercourses and water features.

4 Site AL5-Southern Gateway

4.1 Environmental setting

4.1.1 Introduction

The following section presents an understanding of the environmental setting of the site and the local area, including aspects such as the topography, hydrology, geology and hydrogeology. This information provides an important baseline for the groundwater constraints.

4.1.2 Location and topography

The site is located to the south of the Chichester inner ring road (A286). The site centre is located at approximately NGR485956, 104295. It covers the area around the train and police stations.

There is little variation in topography on the site with elevations typically between 10 - 12m AOD.

The site boundary and local topography are presented in Appendix B2.1.

4.1.3 Current land use

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

- North
  - Residential.
- East
  - Residential
- South
  - Chichester Ship Canal (Wharf).
- West
  - Commerical buildings including a supermarket.

4.1.4 Surface water hydrology

There are no surface water bodies mapped within the site boundary.

Notable surface water features outside of the site boundary include the Chichester Canal to the south and the River Lavant to the west and north (some reaches are culverted) .

4.1.5 Geology and soils

Information on the soils and geology of the site and surrounding area has been derived from the Cranfield Soil and Agrifood Institute Soilscapes online viewer, 1:50,000 BGS geology mapping (Sheet 317/332: Chichester and Bognor), and the BGS online borehole archive.

Soils

The soils across the majority of the site are classified as type 6, which are described as freely draining slightly acid loamy soils with a loamy texture. Typically, these soils drain to local groundwater and rivers.

Made ground

Made ground is an area where the pre-existing (natural or artificial) land surface is raised by artificial deposits. Given the urban nature of the area made ground may be widespread.

Superficial geology

The superficial geology mapped across the site is comprised of Alluvial Fan Deposits (known locally as the Chichester Gravels), which consist of low, outspread, relatively flat to gently sloping masses of loose rock material, shaped like a fan or segment of a cone. They are deposited by streams at the mouths of tributary valleys onto a plain or broad valley.

Bedrock geology

The site is covered by three geology types

- The north is underlain by the London Clay Formation
- The middle by the Lambeth Group (historically called the Reading Beds), which comprises CLAY, SILT & SANDS.
- And the south by the Chalk

Summary of site geology

Table 4-1 presents a summary of local superficial and bedrock geology.

Table 4-1: Summary of local geology

Age	Group	Formation	Description	Thickness
Quaternary	Superficial Deposits	Alluvial Fan	Clayey gravels. Low, outspread, relatively flat to gently sloping masses of loose rock material, shaped like a fan or segment of a cone. They are deposited by streams at the mouths of tributary valleys onto a plain or broad valley	circa 5m of sands an gravels
Palaeogene	Thames Group	London Clay	The London Clay mainly comprises bioturbated or poorly laminated, blue-grey or grey-brown, slightly calcareous, silty to very silty clay, clayey silt and sometimes silt, with some layers of sandy clay.	Variable
	Lambeth Group	Reading Formation	Vertically and laterally variable sequences mainly of clay, some silty or sandy, with some sands and gravels, minor limestones and lignites and occasional sandstone and conglomerate.	
Upper Cretaceous	Chalk	White Chalk Subgroup	Chalk with flints. With discrete marl seams, nodular chalk, sponge-rich and flint seams throughout.	
Data source: BGS Borehole logs*				

4.1.6 Hydrogeology

Aquifer designation

The aquifer designations for the area have been collated using DEFRA's Magic Map application are classified as:

- Superficial deposits and Lambeth Group: Secondary A, meaning 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. These are generally aquifers formerly classified as minor aquifers.
- White Chalk: Principal aquifer, meaning layers of rock or drift deposits that have high intergranular and/or fracture permeability - meaning they usually provide a

high level of water storage. They may support water supply and/or river base flow on a strategic scale. In most cases, principal aquifers are aquifers previously designated as major aquifers.

Groundwater source protection zones

The site is located within 2.2 km of a Zone 1 inner protection zone.

Aquifer vulnerability

Groundwater vulnerability mapping shows that groundwater beneath the site is designated as having 'low' to 'medium' vulnerability with a 'soluble rock risk' (DEFRAs Magic Map).

Groundwater flow, springs and issues

Groundwater flow patterns within an urban area are complex. This is made more complex by the culverting of the river to the north, which will change how groundwater interacts with it. The general regional groundwater gradient can be expected to reflect the local topography, with baseflow towards the south and southwest. There are no springs or issues mapped on the site.

Aquifer properties

The properties of the aquifers underlying the site are:

- Alluvial Fan:
    - Likley low -moderately permeable deposits.
- The Lambeth Group:
    - Highly variable lithology; mottled clay and silt. Fine to medium grained sand in layers and channels.
    - The variation of the hydraulic conductivity at any one locality is likely to be between 2 and 60 m/d, with a tendency to increase towards the top of the deposit. A representative average value is about 20 m/d but the aquifer typically provides low yields.
    - The Reading Formation is sometimes in hydraulic continuity with the underlying Chalk aquifer.
- White Chalk Subgroup:
    - Principal aquifer in UK which is up to 450 m thick and yields 50 to 100 L/s from large diameter boreholes and up to 300 L/s from adited systems. The aquifer is considered to produce hard to very hard, good quality water.

4.2 Groundwater constraints assessment

The following section builds on the geology, hydrology and topography data collated in the previous sections to form a desk-based review into possible groundwater related development constraints across the site. Possible groundwater constraints have been described in Section 2.

4.2.1 Hydrogeological indicators of a high groundwater table

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

Superficial deposits

Alluvium (including Alluvial Fan type deposits) is likely to be an indicator of a perennially or semi perennially high water table.

Alluvial Fan deposits (GRAVEL, SAND, SILT and CLAY) are mapped across the entire site area.

Historical BGS borehole logs show that a water strike was recorded in the Alluvial Fan gravels at the old gas works located approximately 130m to the west of the site at ~4.2 mbgl with a resting water level of ~ 2.4 mbgl.

Low lying areas

The surface water flood map presented in Appendix B2.18 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 on the site is liable to pool in the lowest lying areas of the site.

The flood extents presented in Appendix B2.4 highlights areas at risk of flooding from rivers in a defended scenario. The east of the site is considered to be at risk of flooding from fluvial sources in a 0.1% AEP event. This does take into account the effect of any flood defences in the area. These defences reduce but do not completely stop the chance of flooding as they can be overtopped, or fail.

Bedrock level

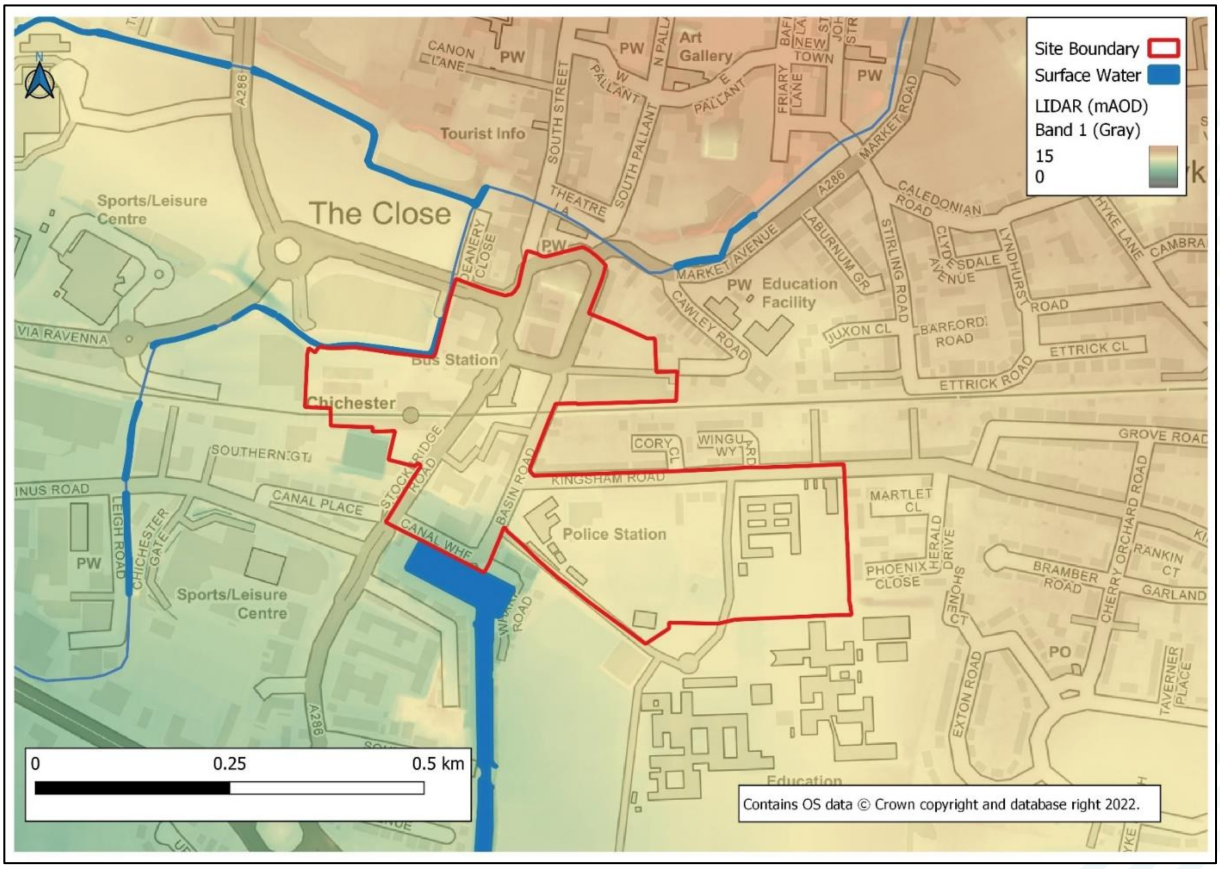
The majority of the site is likely covered by relatively thick superficial deposits.

No springs have been identified on the site that originate from discharges from the bedrock aquifer.

4.2.2 Groundwater movement

Figure 4-1 shows the topography and main surface water features in the area. The culverting of parts of the river means establishing a groundwater catchment is difficult. The direction of groundwater flow in the area may change depending on the height of water in the river. The presence of the fluvial flood risk is potentially indicative of the extent of groundwater flooding that could be generated by high water tables in the chalk to the north of Chichester, as was experienced in 1993/94.

Figure 4-1: Topography and surface water features



4.3 Groundwater flooding analysis

The following section summarises the main groundwater constraints associated with the development of the site. This assessment is based on analysis of the local geology, hydrology, topography and the implementation of high-resolution groundwater flood mapping. The difference between clearwater flooding and alluvial groundwater flooding is described in Section 2.1.

4.3.1 Clearwater flooding

Groundwater flood maps

It is evident from the Geosmart groundwater flood map presented in Appendix B2.23 that the north of the site is considered to be at negligible risk while the area underlain by Chalk as a moderate to high risk from groundwater flooding.

However, the JBA groundwater flood map in Appendix B2.24 shows that there is a risk of groundwater emergence across the whole site.

Further analysis is required beyond the map to assess whether there are potentially technical solutions to mitigate these issues.

4.3.2 Alluvial groundwater flooding

As highlighted previously, 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 predicted fluvial flood risk is indicative of the potential risk from alluvial groundwater flooding, such as experienced at Chichester in 1993/94.

4.3.3 Historical evidence of groundwater flooding

Outside of the events of Chichester in 1993/94, a review of historical maps did not highlight any obvious areas across the site which may be prone to local 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.

4.4 Conclusions and mitigation strategy considerations

4.4.1 Summary

Section 4.3 identifies whether the site may be subject to groundwater flooding mechanisms. This section assesses the potential, if necessary for mitigation and the likely scale of that mitigation.

The table below outlines the main considerations when assessing groundwater flood risk and the potential for simple mitigation.

Table 4-2: Main groundwater flooding constraints

Questions	Explanation	Answer
What groundwater flood risk zone is the allocation in?	The GeoSmart V2.2 flood map should be used as an initial indicative screening tool categorises groundwater flood risk into four classes. 1- High risk, 2- Moderate risk, 3 - low risk, 4 - negligible risk.	The south of the site is in moderate to high risk under the Geosmart mapping The site is classed as have a risk of water at or very near the surface in the JBA mapping.
Is the site vulnerable to local clearwater flooding?	Clearwater flooding 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).	No (but the presence of the fluvial flood risk is indicative that it could be at risk from groundwater flood events, such as experienced in 1993/94).
Is the site vulnerable to alluvial groundwater flooding?	Alluvial groundwater flooding is most likely to occur in: • 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".	Potentially - as the experience in 1993/94 shows
Does the site receive groundwater from a relatively large groundwater catchment?	If there is a large groundwater catchment, groundwater inputs may be harder to manage through drainage	No

Are the main groundwater discharge boundaries (ditches, rivers, lakes) within surface water or fluvial flood zones?	If yes, there may be periods when these discharge boundaries will be overwhelmed with surface water and will not function to suppress the groundwater watertable	There is a flood zone in the area and the pattern of groundwater flows in the area are potentially complex
Are there discharge boundaries potentially outside of the control of the allocation?	Groundwater level may change in future.	No
Are there areas of the site lower than the lowest point of the bank top of the drain/river network?	If yes, then alluvial groundwater flooding may be a potential mechanism as water in the neighbouring surface water body could be higher than the surface of the site	No

This initial assessment indicates that overall, the risk of groundwater flooding on site is moderate. It should be noted that this assessment does not consider underground structures such as basements, which may disrupt groundwater flow on a localised scale.

The assessment performed does not suggest that the risk from groundwater flooding provides evidence that it is a necessity to consider reasonably available alternative locations. The proposals will require adherence to a sequential approach so that groundwater risk is managed appropriately for the lifetime of development.

This initial assessment indicates that it is feasible to implement development at the site that addresses the groundwater flood risk. The predicted fluvial flood risk is indicative of the potential risk from groundwater flooding, such as experienced at Chichester in 1993/94. In this instance measures to address the potential fluvial flood risk would also address the risk of flooding from groundwater.

4.4.2 Climate change

There is substantial uncertainty over the potential effects of climate change on the magnitude of groundwater flows generated by rainfall making it difficult to identify competent evidence that can be used to inform a strategic assessment. As a general rule the order of magnitude of such change is likely to be much less than for other sources of flood risk and thus it is likely that that predicted changes in fluvial and surface water flood risk will be the most influential consideration when evaluating the safety of development over the intended life.

In view of the topographic elevation and location of the site it is unlikely that local groundwater flow or flood risk will be affected by long term changes in mean sea level. However, it is possible that long term changes in mean sea level could affect the performance of local watercourse systems and so consideration will need to be given to the arrangements for water level management as affects local watercourses.

5 Site HWH0014-Land north of Maudlin Farm

5.1 Environmental setting

5.1.1 Introduction

The following section presents an understanding of the environmental setting of the site and the local area, including aspects such as the topography, hydrology, geology and hydrogeology. This information provides an important baseline for the groundwater constraints.

5.1.2 Location and topography

The 14.1 ha site is located approximately 1.5 km to the northeast of Chichester (site centre NGR SU889063). The southern and eastern boundary of the site is marked by the A27, with dairy land bordering the west of the site and Old Arundel Road marking the northern extent of the site.

The site slopes from north to south with elevations at the northern extent of the site ~24mAOD and elevations in the south ~16mAOD.

The site boundary and local topography are presented in Appendix B3.1.

5.1.3 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
  - Old Arundel Road (Roman Road).
  - Residential.
  - Farmland.
- East
  - Westhampnett bypass (A27) with fields and farmland beyond.
- South
  - Westhampnett bypass (A27) with fields and farmland beyond.
- West
  - Landfill site, now redeveloped as a solar farm.
  - Chichester Watersports.
  - Residential.

5.1.4 Surface water hydrology

There are two surface water bodies mapped within the site boundary;

A pond located in the southwestern corner of the site measuring approximately 160m^2 (NGR SU889061). The pond has been present on the site since at least 1888 as indicated by historical mapping.

- A drainage ditch marks the eastern boundary of the site.

Notable surface water bodies outside of the site boundary include;

- Lake approximately 150m to the south associated with historical quarry (gravel pit) excavations (SU888058).
- Lake associated with Chichester Watersports approximately 500m to the west associated with historical quarry (gravel pit) excavations (NGR SU881058).

5.1.5 Geology and soils

Information on the soils and geology of the site and surrounding area has been derived from the Cranfield Soil and Agrifood Institute Soilscapes online viewer, 1:50,000 BGS geology mapping (Sheet 317/332: Chichester and Bognor), and the BGS online borehole archive.

Soils

The soils across the majority of the site are classified as type 6, which are described as freely draining slightly acid loamy soils with a loamy texture. Typically, these soils drain to local groundwater and rivers.

Soils in the far eastern extent of the site are classified as type 20, which are described as loamy and clayey floodplain soils with naturally high groundwater. These soils may be associated with the alluvial fan deposits, which extend down the eastern edge of the site.

Superficial geology

The superficial geology mapped across the site is variable, comprising of Head- GRAVEL, SAND, SILT, CLAY at the southern extent of the site, with Quaternary age raised storm beach deposits comprised of GRAVEL across the northern section of the site. BGS borehole logs on land adjacent to the site indicate that the gravels may be up to~10m thick (BGS BH SU80NE163) at southern extent of site and possibly up to 15m thick at north end of site (SU80NE14).

Alluvial Fan deposits are also mapped in along the far eastern extent of the site.

Bedrock geology

The superficial deposits across the site are underlain by the Lambeth Group (historically called the Reading Beds), which comprises CLAY, SILT & SANDS (aka Reading Beds).

The Lewes Nodular Chalk underlays the superficial deposits directly adjacent to north of the site.

Summary of site geology

A summary of the local geological stratigraphy is presented below in Table 5-1.

Table 5-1: Summary of geological stratigraphy

Age	Group	Formation	Description	Thickness
Quaternary	Superficial Deposits	Head	Variable deposits of impure Clays, Silts and Sands, which may be locally Gravelly. Chalky and flinty in dry valleys.	At least 5m*
		Alluvial Fan	Clayey gravels.	Unknown
		Storm Beach Deposits 2	Gravels and gravely Sands	At least 1.2m*
Palaeocene	Bedrock	Lambeth Group/Reading Formation	Mottled Clays, locally sandy.	At least 16m* Thicknesses recorded of up to 38m in the wider Chichester area**

Upper Cretaceous		Lewes Nodular Chalk Formation	Hard nodular Chalk with flints	Unknown
Source: *BGS Borehole Logs ** Sheet 6 -Hydrogeological Map of the South Downs and Adjacent Parts of the Weald (1:100,000)				

5.2 Hydrogeology

Aquifer designation

The geological strata summarised in the Geology and Soils section have been assessed for their hydrogeological properties. Aquifer designations have been collated via DEFRAs online Magic Map.

The superficial deposits on site are classified as secondary A aquifer. Secondary A aquifers are 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. These are generally aquifers formerly classified as minor aquifers.

The Lambeth Group bedrock directly underlying the site is also classified as Secondary A Aquifer.

Groundwater source protection zones

The site is located within 480 m of a Zone III total catchment protection zone, 1.3 km from a zone II protection zone and 3 km from a zone I inner protection zone.

Aquifer vulnerability

Groundwater vulnerability mapping shows that groundwater beneath the site is designated as having 'medium' to 'medium-high' vulnerability with a 'soluble rock risk' (DEFRAs Magic Map).

Groundwater flow, springs and issues

The general regional groundwater gradient can be expected to reflect the local topography, with baseflow towards the south. It is possible that groundwater levels within the superficial deposits may be influenced by variations in surface water levels in local streams and drains.

It is currently unclear whether the water level in the pond on the site is reflective of the local groundwater table.

Aquifer properties

Table 5-2 presents a summary of aquifer properties.

Table 5-2: Summary of aquifer properties

Formation	Description	Thickness	Properties
Head	Variable deposits of impure Clays, Silts and Sands, which may be locally Gravelly. Chalky and flinty in dry valleys.	At least 5m*	Varable
Alluvial Fan	Clayey gravels.	Unknown	Likely moderate-Low permeability. Intergranular flow.
Storm Beach Deposits 2	Gravels and gravely Sands	At least 1.2m*	High Permeability. Intergranular Flow.
Lambeth Formation/ Reading Formation	Variable sequence of clays, shell beds, fine sands, silts and pebble beds locally sandy. Sometimes in hydraulic continuity with underlying Chalk aquifer.	Up to 68m in the Chichester area.	Typically provides low yields. The variation of the hydraulic conductivity at any one locality is likely to be between 2 and 60 m/d, with a tendency to increase towards the top of the deposit. A representative average value is about 20 m/d *
Lewes Nodular Chalk	Hard nodular Chalk with flints.	Unknown	Principal aquifer in the UK yielding 50 to 100 L/s from large diameter boreholes and up to 300 L/s from adited systems. Hard to very hard, good quality water.
Source: *Minor aquifers of England and Wales (Jones et al., 2000) Major aquifers of England and Wales (Allen et al., 1997).			

5.3 Groundwater constraints assessment

The following section builds on the geology, hydrology and topography data collated in the previous sections to form a desk-based review into possible groundwater related development constraints across the site. Possible groundwater constraints have been described in Section 2.

5.3.1 Hydrogeological indicators of a high groundwater table

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

5.3.2 Superficial deposits

Alluvium (including Alluvial Fan type deposits) is likely to be an indicator of a perennially or semi perennially high water table.

Alluvial Fan deposits (GRAVEL, SAND, SILT and CLAY) are mapped along the eastern section of the site.

Current artificial drainage (drainage ditch) adjacent to the eastern boundary of the site likely acts to locally suppress the water table in this area.

5.3.3 Low lying areas

The surface water flood map presented in Appendix B3.7 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 deposits. There are only very small areas of high surface water flood risk, mainly in the south western corner of the site, in close proximity to the existing pond and in the north eastern corner of the site. Local drainage in most situations will likely cope with surface water flows and the duration of flooding is likely to be limited.

The flood zone mapping presented in Appendix B3.3 highlights areas at risk of flooding from rivers and seas. It is clear that the site is not considered to be at risk of flooding from alluvial sources.

5.3.4 Bedrock level

The majority of the site is likely covered by relatively thick superficial deposits.

No springs have been identified on the site from a desk-based assessment that originates from discharges from the bedrock aquifer.

5.4 Groundwater flooding analysis

The following section summarises the main groundwater constraints associated with the development of the site. This assessment is based on analysis of the local geology, hydrology, topography and the implementation of high-resolution groundwater flood mapping. The difference between clearwater flooding and alluvial groundwater flooding is described in Section 2.1.

5.4.1 Clearwater flooding

It is evident from the Geosmart groundwater flood map in Appendix B3.12 that the highest risk areas of the site (i.e., risk class 2: moderate) with respect to groundwater flooding are located in the lower lying ground in the southern extent of the site in close proximity to the pond. In addition, the far north-eastern area of the site, which is underlain by Alluvial Fan Gravels is also classed as having a moderate risk from groundwater flooding.

The JBA Groundwater flood map in Appendix B3.13 shows that there is a risk of groundwater emergence across the south lying part of the site with groundwater close to the surface across the rest.

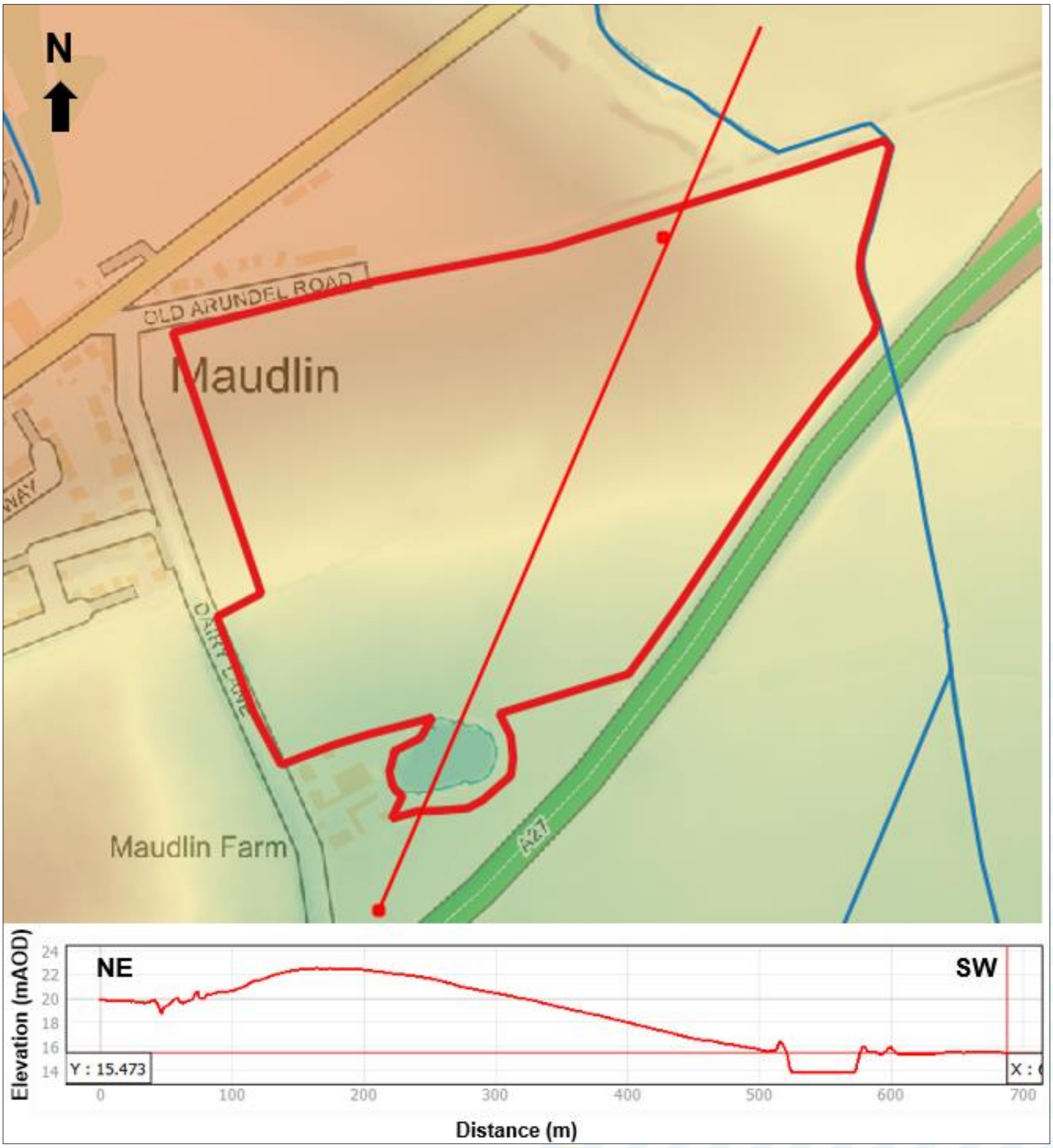
The topographic profile across the site presented below in Figure 5-1. A pond level is shown but if levels in this pond rise to near ground level, the watertable in the surrounding low lying area will be near the surface. It should be noted that this is an estimation based off 1m LiDAR data. Before development, groundwater level monitoring should be undertaken to gauge groundwater levels more accurately.

The area appears to be highlighted as it is low lying and underlain by permeable sands and gravel deposits. The groundwater emergence may occur:

- In periods of high rainfall,
- If the pond level rises.

As outlined above in the topographic cross section, it is likely that the lowest areas of the site around the existing pond are most likely to be affected by high groundwater levels

Figure 5-1: Northeast - Southwest topographic profile across the site



5.4.2 Alluvial groundwater flooding

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 alluvial gravels along the eastern extent of the site may present some risk of some alluvial groundwater flooding. Although it is considered that the catchment of this surface water body is unlikely to be sufficiently large enough to pose a substantial risk from alluvial groundwater flooding.

5.4.3 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.

5.5 Conclusions and mitigation strategy considerations

5.5.1 Summary

Section 5.4 identifies whether the site may be subject to groundwater flooding mechanisms. This section assesses the potential, if necessary for mitigation and the likely scale of that mitigation.

The table below outlines the main considerations when assessing groundwater flood risk and the potential for simple mitigation.

Table 5-3: Main groundwater flooding constraints

Questions	Explanation	Answer
What groundwater flood risk zone is the allocation in?	The GeoSmart V2.2 flood map should be used as an initial indicative screening tool categorises groundwater flood risk into four classes. 1- High risk, 2- Moderate risk, 3 - low risk, 4 - negligible risk.	A mixture of moderate risk, low risk and negligible risk. The area considered to be at moderate risk is located in the lowest elevations in the area around the existing pond. And JBA Map shows broadly the same pattern
Is the site vulnerable to clearwater flooding?	Clearwater flooding 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).	Yes - Groundwater flood mapping indicates part of the site is at moderate risk from local groundwater flooding. Water levels in the pond on site may be an expression of the local groundwater table If there are periods of high pond water levels, the watertable in the surrounding low lying area will be close to the surface.
Is the site vulnerable to alluvial groundwater flooding?	Alluvial groundwater flooding is most likely to occur in: • 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".	No - Although there are moderate permeability Alluvial Fan deposits on site they are not in contact with the alluvial floodplain of the larger watercourses and rivers in the area. Therefore, it is unlikely that the site is at risk from alluvial groundwater flooding.
Does the site receive groundwater from a relatively large groundwater catchment?	If there is a large groundwater catchment, groundwater inputs may be harder to manage through drainage	No - groundwater catchment is small.
Are the main groundwater discharge boundaries (ditches, rivers, lakes) within surface	If yes, there may be periods when these discharge boundaries will be overwhelmed with surface water and will not function to	Yes - but these are likely to be short duration, long return period surface water flooding events which would not likely overwhelm

water or fluvial flood zones?	suppress the groundwater watertable	the drainage for significant periods. Levels in the pond to the south of the allocation should be controlled so it allows the low lying area to drain.
Are there discharge boundaries potentially outside of the control of the allocation?	Groundwater level maybe change in future	Yes.
Are there areas of the site lower than the lowest point of the banktop of the drain/river network?	If yes, then alluvial groundwater flooding may be a potential mechanism as water in the neighbouring surface water body could be higher than the surface of the site	No.

The area is underlain by permeable superficial deposits and has been highlighted as have a potential clearwater flooding risk. Groundwater within these deposits likely discharge to the drains and the pond on site and the lake to the southern boundary. The groundwater catchment outside of proposed allocation is relatively small and the drains will only be subjected to limited surface water flooding and no fluvial flooding. As such, it is expected that a drainage design could be incorporated in the future development of the site that could supress the water table. This would however be reliant on the pond on site being maintained at a low level.

This initial assessment indicates that it is feasible to design a drainage system to suppress groundwater flooding. Such a design should be based on:

- Groundwater monitoring,
- Groundwater modelling to determine the spacing and sizing of drainage requirements,
- Potential zoning of the site limit development in the lowest lying parts of the site (i.e. close to the existing pond).
- A long term commitment to controlling water levels in the pond.
- This assessment does not consider underground structures such as basements.

5.5.2 Climate change

In view of the topographic elevation of the site it is unlikely that local groundwater flow or flood risk will be affected by long term changes in mean sea level.

6 Site AL6- Land south of Bognor Road

6.1 Environmental setting

6.1.1 Introduction

The following section presents an understanding of the environmental setting of the site and the local area, including aspects such as the topography, hydrology, geology and hydrogeology. This information provides an important baseline for the groundwater constraints.

6.1.2 Location and topography

The site covers a total area of 19.5 ha and is located approximately 1.8 km to the Southeast of Chichester (site NGR: SU 88221 04092)

The topographic profile across the site shows the site is reasonably flat, gently sloping from North to South with an average gradient of 1 in 80 (equivalent to 1.3%). Refer to mapping in Appendix B4.1.

6.1.3 Current land use

The site is bound by Bognor Road to the north and east, and Vinnetrow Road to the west. South of the site is used for agricultural purposes. The proposed site is surrounded by several lakes related to local gravel pits.

6.1.4 Geology and soils

Surface water hydrology

There are no major watercourses mapped within or close to the site boundary. There are several lakes associated with gravel pits, as can be seen from the topographic lows in the immediate vicinity of the site (Appendix B4.2). Based on LiDAR data, the water level is approximately 9m AOD in the northeast gravel pits and roughly 8m AOD to the southwest. The water level in the gravel pit lakes is likely an expression of local groundwater level.

Overview

Information on the soil and geology of the site was derived from the Soilscapes Online Viewer by Cranfield University, BGS Geoindex and BGS borehole records. The geology beneath the site is summarised in Table 6-1.

Soils

The soil covering the site is classified as:

- Soil type 6: covers the majority of the site and is described as freely draining slightly acid loamy soils with a loamy texture. Typically, these soils drain to local groundwater and rivers.
- Soil type 20: covers the most westerly extent of the site, immediately adjacent to Vinnetrow Road, and is described as a loamy and clayey floodplain soil with naturally high groundwater. This type of soil generally drains to local groundwater feeding into rivers.

Superficial geology

Based on BGS mapping, the site is mostly covered by Quaternary river terrace deposits, comprising of undifferentiated sand, silt and clay. Alluvial fan deposits underlay the east and west boundaries.

Bedrock geology

The site is entirely underlain by London Clay and mainly comprises of bioturbated or poorly laminated, blue-grey/grey-brown, slightly calcareous, silty clay.

Summary of site geology

A summary of the local superficial and bedrock geology is shown in Table 6-1.

Table 6-1: Summary of local geology

Age	Group	Formation	Description	Thickness
Quaternary	Superficial Deposits	River Terrace deposits	Sand and gravel, locally with lenses of silt, clay or peat.	At least 3 m*
		Alluvial Fan deposits	Alluvial fan deposits are low, outspread, relatively flat to gently sloping masses of loose rock material, shaped like a fan or segment of a cone.	At least 3 m*
Palaeogene	Thames Group	London Clay	The London Clay mainly comprises bioturbated or poorly laminated, blue-grey or grey-brown, slightly calcareous, silty to very silty clay, clayey silt and sometimes silt, with some layers of sandy clay.	At least 20 m*
Sources: BGS Borehole Logs"				

6.1.5 Hydrogeology

Aquifer designation

The aquifer designations for the area have been collated using DEFRA's Magic Map application are classified as:

- Superficial deposits: Secondary A, meaning 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.
- London Clay: Unproductive, meaning these are rock layers with low permeability that have negligible significance for water supply or river base flow.

Groundwater source protection zones

There is a Zone II source protection zone located 3.2km to the northeast of the area. All source protection zones are located upgradient of the site.

Aquifer vulnerability

The groundwater vulnerability mapping shows that groundwater beneath the entire site is designated as having 'Low' to 'Medium-Low' vulnerability.'

Groundwater flow, springs and issues

The general regional groundwater gradient can be expected to reflect the local topography, with baseflow towards the lakes surrounding the site.

There are currently no springs mapped within the site boundary, but it is assumed the surrounding lakes, that represent gravel pits, reflect local groundwater levels.

Aquifer properties

Table 6-2 below presents a summary of aquifer properties.

Table 6-2: Summary of aquifer properties

Formation	Description	Thickness	Properties
Alluvial Fan Deposits	Clayey gravels	At least 3m*	Likely moderate permeability. Intergranular flow.
River Terrace Gravels	Undifferentiated sands and gravels	At least 3m*	High permeability. Intergranular flow.
London Clay Formation	Silty clays, with some layers of sandy clay.	Unknown	Low permeability.

6.1.6 Environmental designations

There are two major Sites of Special Scientific Interest (SSSI) within 5km of the site.

- Fishbourne Channel: part of Chichester and Langstone Harbour which is 4.2km to the west and is also a Special Area of Conservation (SAC), Special Protection Area (SPA) and Ramsar designation. All designations relate to Chichester Harbour and the associated channels.
- Pagham Harbour: the waterbody is located 4.2km to the south of the site and is designated as a SSSI, SPA and Ramsar.

6.2 Groundwater constraints assessment

The following section builds on the geology, hydrology and topography data collated in the previous sections to form a desk-based review into possible groundwater related development constraints across the site. Possible groundwater constraints have been described in Section 2.

6.2.1 Hydrogeological indicators of a high groundwater table

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

6.2.2 Superficial deposits

Alluvium (including alluvial fan and river terrace deposits) across the site is likely to be an indicator of a perennially or semi perennially high water table.

6.2.3 Low lying areas

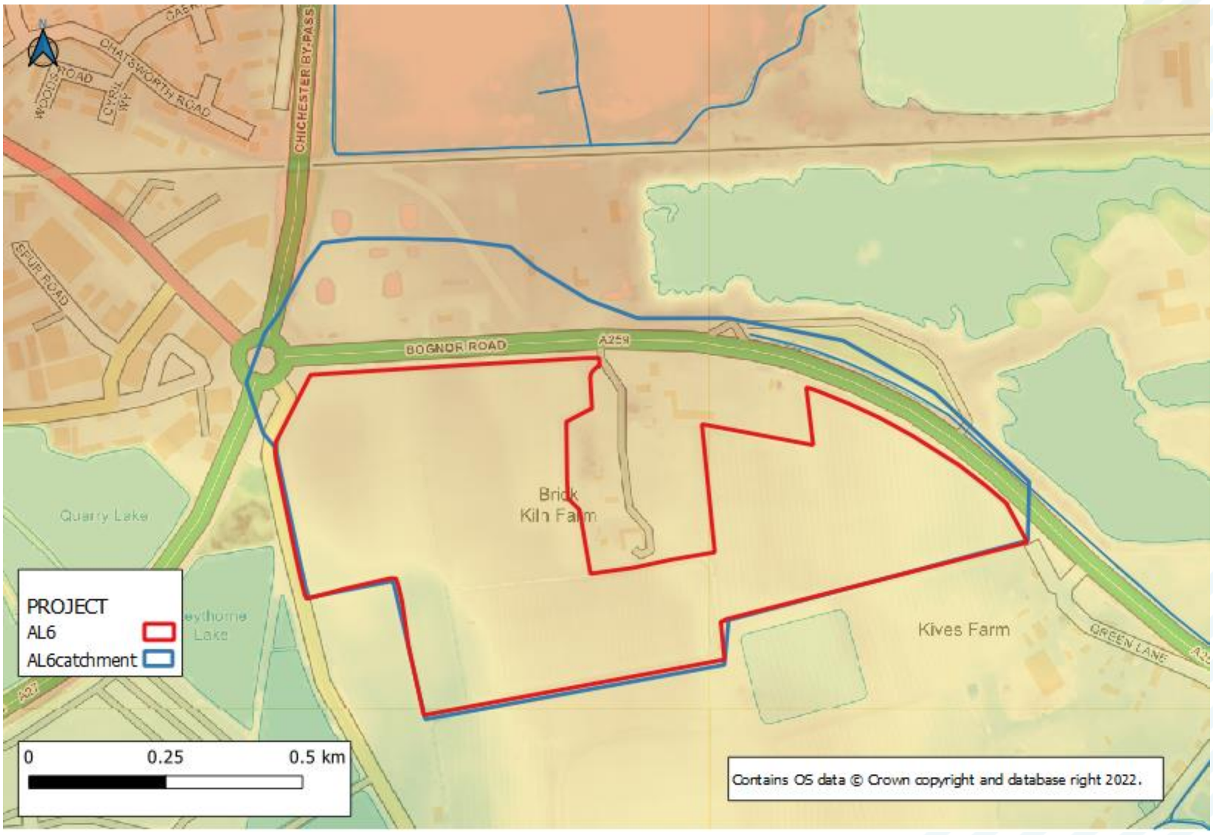
The surface water flood map presented in Appendix B4.7 indicates areas of the site where water is liable to pool on site. It is evident that the surface water flood map closely reflects surface topography, flowing towards the southwest, with low lying areas more likely to intercept the local water table or collected perched water when over low permeability deposits.

The flood zone map presented Appendix B4.3 highlights areas at risk of flooding from rivers and sea. It is clear that the site is not considered to be at risk of flooding from alluvial sources.

6.2.4 Groundwater catchment

Figure 6-1 highlights the likely local groundwater catchment for the site based on topographic data. It is clear that the site has a very small local groundwater catchment due to the presence of the lakes on most sides which potentially draw water away from the site.

Figure 6-1: Likely groundwater catchment



6.3 Groundwater flooding analysis

The following section summarises the main groundwater constraints associated with the development of the site. This assessment is based on analysis of the local geology, hydrology, topography and the implementation of high-resolution groundwater flood mapping. The difference between clearwater flooding and alluvial groundwater flooding is described in Section 2.1.

6.3.1 Clearwater flooding

The Geosmart groundwater flood risk ranking across the site, demonstrated in Appendix B4.12 shows that much of the site comes under class 2, which signals that there is a moderate risk of flooding in the area. The southeast corner is classified 3, suggesting there is a low risk of groundwater flooding in this area

The JBA Groundwater Flood Map shows in Appendix B.13 shows that there is a risk of groundwater emergence across the majority of the site.

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.

On the basis of the assessment performed it is considered likely that there is a strong hydraulic connection between the levels of water in the surrounding lakes and the groundwater levels on site.

6.3.2 Alluvial groundwater flooding

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".

Although there are permeable River Terrace and Alluvial Fan deposits on site they are not in contact with the alluvial floodplain of a larger watercourses and/or river in the area. Therefore, it is unlikely that the site is at risk from alluvial groundwater flooding.

6.3.3 Historical evidence of groundwater flooding

A review of historical maps highlights any obvious areas which may be prone to local 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 the site's history

A review of historic maps does not indicate any previously boggy conditions on site, with the fields largely the same as they are at present.

6.4 Conclusions and mitigation strategy considerations

Table 6-3 outlines the main considerations when assessing groundwater flood risk and the potential, if necessary for mitigation and the likely scale of that mitigation

The table below outlines the main considerations when assessing groundwater flood risk and the potential for simple mitigation.

Table 6-3: Main groundwater flooding constraints

Questions	Explanation	Answer
What groundwater flood risk zone is the allocation in?	The GeoSmart V2.2 flood map should be used as an initial indicative screening tool categorises groundwater flood risk into four classes. 1- High risk, 2- Moderate risk, 3 - low risk, 4 - negligible risk.	Mainly Class 2 - Moderate risk And Groundwater levels are either at very near (within 0.025m of) the ground surface in the 100-year return period flood event.
Is the site vulnerable to local clearwater flooding?	Clearwater flooding 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).	Yes - Groundwater flood mapping indicates the site is at moderate risk from groundwater flooding. Water levels in the former gravel pit on in the surrounding area is likely to be an expression of the local groundwater table and are likely to influence groundwater levels at the site.
Is the site vulnerable to alluvial groundwater flooding?	Alluvial groundwater flooding is most likely to occur in: • 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".	No. - Although there are moderate permeability Alluvial Fan deposits on site they are not in contact with the alluvial floodplain of the larger watercourses and rivers in the area. Therefore, it is unlikely that the site is at risk from alluvial groundwater

		flooding
Does the site receive groundwater from a relatively large groundwater catchment?	If there is a large groundwater catchment, groundwater inputs may be harder to manage through drainage	No - local groundwater catchment is small as water drains to the surrounding lakes.
Are the main groundwater discharge boundaries (ditches, rivers, lakes) within surface water or fluvial flood zones?	If yes, there may be periods when these discharge boundaries will be overwhelmed with surface water and will not function to suppress the groundwater watertable	Yes but these are likely to be short duration, long return period surface water flooding events which would not likely overwhelm the drainage for significant periods.
Are there discharge boundaries potentially outside of the control of the allocation?	Groundwater level maybe change in future	Yes - The surrounding lake of the allocation should be controlled
Are there areas of the site lower than the lowest point of the banktop of the drain/river network?	If yes, then alluvial groundwater flooding may be a potential mechanism as water in the neighbouring surface water body could be higher than the surface of the site	No.

The area is underlain by permeable superficial deposits and has been highlighted as having a potential clearwater flooding risk. Groundwater within these deposits likely discharges to the lakes surrounding the site. The groundwater catchment outside of allocation is relatively small so it is expected that a drainage design could be incorporated that could suppress the water table. This would however be reliant on the lakes being maintained at a low level.

This initial assessment indicates that it is feasible to design a drainage system to suppress groundwater flooding. Such a design should be based on:

- Groundwater monitoring
- Groundwater modelling to determine the spacing and sizing of drainage requirements
- Potential zoning of the site limit development in the lowest-lying parts of the site.
- A long term commitment to control water levels in the adjacent lakes so groundwater flood risk is appropriately addressed.
- This assessment does not consider underground structures sure as basements.

6.5 Climate change

For low lying locations on the coastal flood plain the potential effects of rise in mean sea level could be influential with respect to the performance of local drainage systems, water level management and groundwater flood levels. Accordingly at such locations it is appropriate to perform a more detailed assessment within the Flood Risk Assessment to understand the potential magnitude of such effects so that any modifications required to water level management or site drainage arrangements can be identified.

7 Site HSY0010B- Land West of Park Farm, Selsey

7.1 Environmental setting

7.1.1 Introduction

The following section presents an understanding of the environmental setting of the site and the local area, including aspects such as the topography, hydrology, geology and hydrogeology. This information provides an important baseline for the groundwater constraints.

7.1.2 Location and topography

The 11.8ha site is located approximately 8.5 km to the south of Chichester on the northern edge of the town of Selsey. Site centre (NGR SZ860945). The site is bordered by the B1245 Chichester Road to the north and east, by Golf Links Road to the south and a drainage ditch to the west.

The site is on a slight ridge but generally low lying, with LiDAR DTM showing heights between approximately 4.8m AOD and 8.6m AOD. The site is generally flat, with an average gradient of 1 in 120 (0.8%) sloping from the south-east to the north-west. The slope in the northern part of the site is generally steeper than in the southern part of the site. The site boundary and local topography are presented below in B5.1.

7.1.3 Current land use

The land is currently use for agricultural purposes and historical mapping indicates land use on site has not changed since at least 1888.

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
    - Farmland/agricultural
- East
    - Industrial estate
    - Supermarket
- South
    - Residential
- West
    - Farmland/agricultural with reservoir and golf course beyond.

7.1.4 Surface water hydrology

There are no surface water bodies or historically mapped surface water bodies within the site boundary.

Notable surface water bodies outside of the site boundary include;

- A drainage ditch marks the western boundary of the site.
- There are a series of man-made reservoirs to the northwest of the site (approx. 400 m to the nearest one). These are largely modern structures built between 2005 and 2018.
- The English Channel is located approximately 1 km to the east of the site.

7.1.5 Geology and soils

Information on the soils and geology of the site and surrounding area has been derived from the Cranfield Soil and Agrifood Institute Soilscapes online viewer, 1:50,000 BGS geology mapping (Sheet 317/332: Chichester and Bognor), and the BGS online borehole archive.

Soils

The soils across the entire site are classified as type 6, which are described as freely draining slightly acid loamy soils with a loamy texture. Typically, these soils drain to local groundwater and rivers.

Superficial geology

The superficial deposits mapped across the extent of the site comprise River Terrace Deposits (undifferentiated) SAND, SILT and CLAY.

Bedrock geology

The vast majority of the site is underlain by the Earnley Sand Formation, which is comprised largely of Glauconitic silty sands and sandy silts. The Marsh Farm Formation is mapped across the far southern extent of the site. The Marsh Formation comprises Laminated clay; wavy to lenticular-bedded sand interbedded with clay in equal proportions; and fine- to medium-grained sparsely glauconitic sand with laminae and intercalations of clay.

Summary of site geology

A summary of the local superficial and bedrock geology is shown in Table 7-1.

Table 7-1: Summary of local geology

Age	Group	Formation	Description	Thickness
Quaternary	Superficial Deposits	River Terrace Deposits (Undifferentiated)	Sand and gravel, locally with lenses of silt, clay.	Up to 24m**
Eocene	Bedrock	Marsh Farm Formation	Laminated clay; wavy to lenticular-bedded sand interbedded with clay in equal proportions; and fine- to medium-grained sparsely glauconitic sand with laminae and intercalations of clay.	12 - 13.5m*
		Earnley Sand Formation	Sands and Siltsilty sand, silty clay and sandy clayey silt, glauconitic, bioturbated, locally calcareous.	22-25m*
Source: *BGS Online Lexicon **BGS Borehole Log				

7.1.6 Hydrogeology

Aquifer designation

The geological strata summarised in the Geology and Soils section have been assessed for their hydrogeological properties. Aquifer designations have been collated via DEFRAs online Magic Map.

The superficial deposits on site are classified as secondary A aquifer. Secondary A aquifers are 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.

Both the Marsh Farm Formation and the Earnley Sand Formation directly underlying the site are also classified as Secondary A Aquifers.

Groundwater source protection zones

The site is not located within 10 km of a groundwater source protection zone.

Aquifer vulnerability

Groundwater vulnerability mapping shows that groundwater beneath the site is designated as having 'medium-high' vulnerability with no 'soluble rock risk' (DEFRAs Magic Map).

Groundwater flow, springs and issues

The general regional groundwater gradient can be expected to reflect the local topography, with baseflow towards the west.

Aquifer properties

Table 7-2 presents the aquifer properties at the site.

Table 7-2: Summary of aquifer properties

Formation	Description	Thickness	Properties
River Terrace Deposits	Sand and gravel, locally with lenses of silt, clay.	Up to 24m	May form local aquifer High Permeability Intergranular Flow
Marsh Farm Formation	Dominated by laminated clays; wavy to lenticular-bedded sand interbedded with clay in equal proportions; and fine- to medium-grained sparsely glauconitic sand with laminae and intercalations of clay.	12 - 13.5m	Aquitard Low permeability Fracture Flow
Earnley Sand Formation	Sands and Siltsilty sand, silty clay and sandy clayey silt, glauconitic, bioturbated, locally calcareous.	22-25m	Mixture of aquifer and aquitard properties, may differ locally Moderate-Low Permeability Intergranular flow

7.2 Groundwater constraints assessment

The following section builds on the geology, hydrology and topography data collated in the previous sections to form a desk-based review into possible groundwater related development constraints across the site. Possible groundwater constraints have been described in Section 2.

7.2.1 Hydrogeological indicators of a high groundwater table

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

Superficial deposits

The superficial deposits mapped across the extent of the site comprise River Terrace Deposits (undifferentiated) SAND, SILT and CLAY.

Low lying areas

The surface water flood map presented below Appendix B5.20 indicates areas of the site where water is liable to pool. It is evident that the surface water flood map closely reflects surface topography. It is evident from the surface water flood map that there are only a few very small areas in the south-eastern corner of the site where surface water is likely to pool. Overall, it should be expected that any surface water runoff will flow to the west towards the boundary ditch. There are only very small areas of low surface water flood risk indicating that local drainage can cope with surface water flows and the duration of flooding is likely to be limited.

The Flood Zones presented in figure B5.3 highlights areas at risk of flooding from rivers and sea. It is clear that the site sits above the fluvial and tidal flood zone and is not considered to be at risk of flooding from fluvial or tidal sources.

7.2.2 Bedrock level

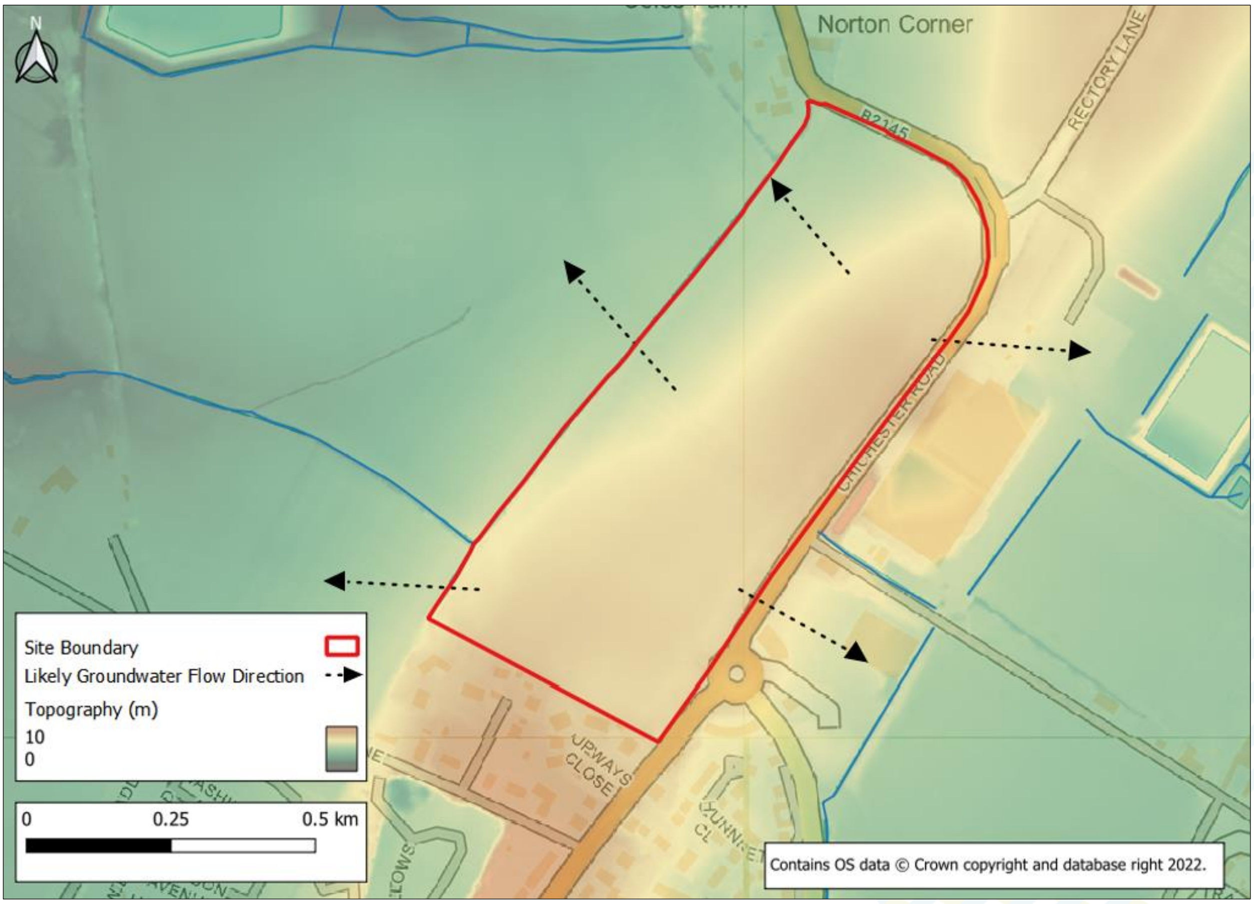
The majority of the site is likely covered by relatively thick superficial deposits.

No springs have been identified on the site that originate from discharges from the bedrock aquifer.

7.2.3 Groundwater movement

Figure 7-1 below highlights the likely direction of local groundwater movement based on available topographic data. It is evident that that the site sits on a ridge, which will act as a local groundwater divide. As such, the site receives little groundwater input.

Figure 7-1: Direction of local groundwater movement



7.3 Groundwater flooding analysis

The following section summarises the main groundwater constraints associated with the development of the site. This assessment is based on analysis of the local geology, hydrology, topography and the implementation of high-resolution groundwater flood mapping. The difference between clearwater flooding and alluvial groundwater flooding is described in Section 2.1.

7.3.1 Clearwater groundwater flooding

Groundwater flood maps

It is evident from the Geosmart groundwater flood map presented in Appendix B5.25 that the site is considered to be at negligible risk from groundwater flooding.

According to the JBA groundwater flood map in Appendix B5.26 there is a risk of groundwater lying close to the surface across the site but with no areas of emergence.

The area appears to be highlighted as having a negligible risk of groundwater flooding (despite being underlain by permeable sands and gravel deposits) as the entire allocation is on top of a ridge.

7.3.2 Alluvial groundwater flooding

Extensive alluvial groundwater flooding is most likely to occur in the following situations:

- River valleys or coastal floodplains 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".

Although there are high permeability River Terrace deposits on site they are not in contact with the alluvial floodplain of the larger watercourses and rivers in the area. Whilst they are potentially affected by adjacent sea levels, the tidal variation and existing mean sea level make it unlikely that tide levels will affect groundwater flood risk at the site (as any groundwater flows induced by sea levels would be of a transitory nature). Therefore, it is unlikely that the site is at risk from alluvial groundwater flooding.

7.3.3 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.

7.4 Conclusions and mitigation strategy considerations

7.4.1 Summary

Section 7.3 identifies whether the site may be subject to groundwater flooding mechanisms. This section assesses the potential, if necessary for mitigation and the likely scale of that mitigation.

The table below outlines the main considerations when assessing groundwater flood risk and the potential for simple mitigation.

Table 7-3: Main groundwater flooding constraints

Questions	Explanation	Answer
What groundwater flood risk zone is the allocation in?	The GeoSmart V2.2 flood map should be used as an initial indicative screening tool categorises groundwater flood risk into four classes. 1- High risk, 2- Moderate risk, 3 - low risk, 4 - negligible risk.	All class 4 - Negligible risk. and Groundwater levels are between 0.025m and 0.5m below the ground surface in the 100-year return period flood event.
Is the site vulnerable to clearwater flooding?	Clearwater flooding 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).	No but the area my get relatively saturated in very wet periods.
Is the site vulnerable to alluvial groundwater flooding?	Alluvial groundwater flooding is most likely to occur in: • 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".	No
Does the site receive groundwater from a relatively large groundwater catchment?	If there is a large groundwater catchment, groundwater inputs may be harder to manage through drainage	No
Are the main groundwater discharge boundaries (ditches, rivers, lakes) within surface water or fluvial flood zones?	If yes, there may be periods when these discharge boundaries will be overwhelmed with surface water and will not function to suppress the groundwater watertable	No
Are there discharge boundaries potentially outside of the control of the allocation?	Groundwater level may change in future.	No
Are there areas of the site lower than the lowest point of the banktop of the drain/river network?	If yes, then alluvial groundwater flooding may be a potential mechanism as water in the neighbouring surface water body could be higher than the surface of the site	No

This initial assessment indicates that overall, the risk of groundwater flooding on site is negligible. It should be noted that this assessment does not consider underground structures such as basements.

7.4.2 Climate change

For low lying locations on the coastal flood plain the potential effects of rise in mean sea level could be influential with respect to the performance of local drainage systems, water level management and groundwater flood levels. Accordingly at such locations it is appropriate to perform a more detailed assessment within the Flood Risk Assessment to understand the potential magnitude of such effects so that any modifications required to water level management or site drainage arrangements can be identified.

8 Site AL7 – Highgrove Farm

8.1 Environmental setting

8.1.1 Introduction

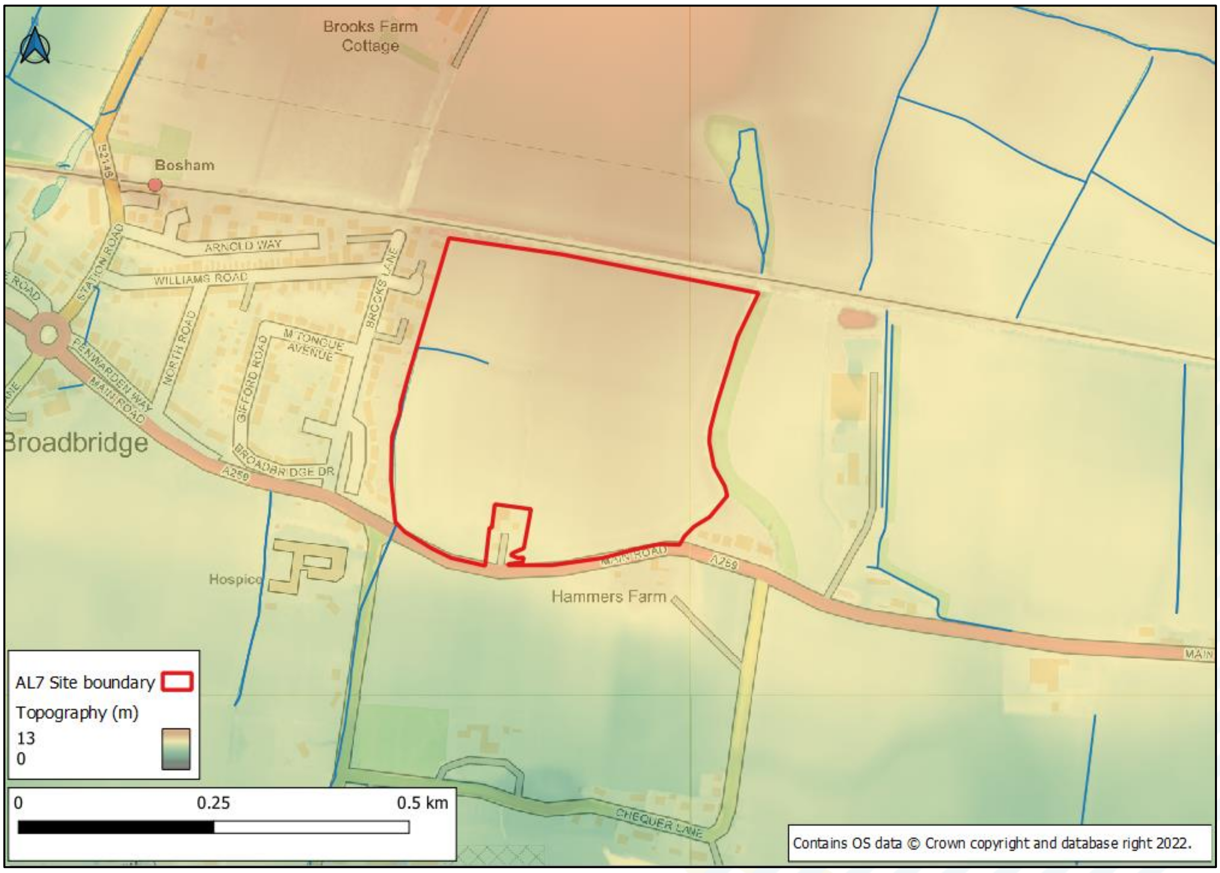
The following section presents an understanding of the environmental setting of the site and the local area, including aspects such as the topography, hydrology, geology and hydrogeology. This information provides an important baseline for the groundwater constraints.

8.1.2 Location and topography

The site covers a total area of 14.5 ha and is located approximately 4 km to the west of Chichester (site NGR: SU 81765 05052).

The site has historically been used for agriculture and exhibits a gradient to the southwest, dipping towards the A259. There is a maximum elevation of 12m AOD in the northeast corner and a topographic minimum of 8m AOD in the southwest corner (Figure 8-1).

Figure 8-1: Site topography



8.1.3 Current land use

The proposed development site is bound by agricultural land to the north and east. The western extent is bound by a small watercourse and residential properties and the southern boundary is defined by the A249.

8.1.4 Surface water hydrology

There are no major surface water bodies mapped within or close to the site boundary. There is a small watercourse along the western boundary which flows south towards the road.

The LiDAR also indicates the presence of drain structures along the northern and eastern boundaries.

8.1.5 Geology and soils

Overview

Information on the soil and geology of the site was derived from the Soilscapes Online Viewer by Cranfield University, BGS Geoindex, BGS borehole records and previous ground investigations. The geology beneath the site is summarised in Table 8-1.

Soils

The soil covering the site is classified as:

- Soil type 22: covers most of the site and is described as loamy soils with naturally high groundwater which typically drains to local shallow groundwater.
- Soil type 6: covers the most southerly extent of the site and is described as freely draining slightly acid loamy soils with a loamy texture. Typically, these soils drain to local groundwater and rivers.

Superficial geology

Based on BGS mapping, the entire site is covered by Quaternary river terrace deposits, comprising of undifferentiated sand, silt and clay.

It is evident from previous ground investigations the quaternary deposits are up to around 3 m thick and there are also lenses of gravel within the superficial material.

Bedrock geology

The bedrock geology of the site comprises of

- Lambeth Group: underlays most of the area and exhibits vertically and laterally variable sequences mainly of clay, some silty or sandy, with some sands and gravels.
- London Clay: outcrops in the northwest corner of the field and mainly comprises of bioturbated or poorly laminated, blue-grey/grey-brown, slightly calcareous, silty clay.
- White Chalk Subgroup: underlays the southern extent of Highgrove Farm, adjacent to the A259.

Summary of site geology

A summary of the local superficial and bedrock geology is shown in Table 8-1.

Table 8-1: Summary of local geology

Age	Group	Formation	Description	Thickness
Quaternary	Superficial Deposits	River Terrace deposits	Sand and gravel, locally with lenses of silt, clay or peat.	At least 3 m*
Palaeogene	Thames Group	London Clay	The London Clay mainly comprises bioturbated or poorly laminated, blue-grey or grey-brown, slightly calcareous, silty to very silty clay, clayey silt and sometimes silt, with some layers of sandy clay.	At least 8 m"
	Lambeth Group	Reading Formation	Vertically and laterally variable sequences mainly of clay, some silty or sandy, with some sands and gravels, minor limestones and lignites and occasional sandstone and conglomerate.	At least 18 m, with thicknesses recorded up to 30 m"
Upper Cretaceous	Chalk	White Chalk Subgroup	Chalk with flints. With discrete marl seams, nodular chalk, sponge-rich and flint seams throughout.	At least 18 m"
Data source: BGS Borehole logs*				

8.1.6 Hydrogeology

Aquifer designation

The aquifer designations for the area have been collated using DEFRA's Magic Map application are classified as:

- Superficial deposits and Lambeth Group: Secondary A, meaning 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. These are generally aquifers formerly classified as minor aquifers.
- White Chalk: Principal aquifer, meaning layers of rock or drift deposits that have high intergranular and/or fracture permeability - meaning they usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale. In most cases, principal aquifers are aquifers previously designated as major aquifers.

Groundwater source protection zones

There is a Zone I source protection zone is located 70 m to the east of the development area. There are also two further Zone I SPZs located 1 km and 1.8 km to the northwest of the site. All source protection zones are located upgradient of the proposed development site.

Aquifer vulnerability

Groundwater vulnerability mapping shows that groundwater beneath the site is designated as having 'medium' to high' vulnerability with a 'soluble rock risk' over the Lambeth Group. The Chalk is designated as 'Medium' vulnerability with a 'soluble rock risk'

Groundwater flow, springs and issues

The general regional groundwater gradient can be expected to reflect the local topography, with baseflow towards the Bosham Channel in the southwest and any man-made drains. It is possible that groundwater levels within the superficial deposits may be influenced by variations in surface water levels in the drains.

There are currently no springs mapped within the site boundary and there has been no historical reporting of groundwater emergence. It is unclear whether the water level along the watercourse is reflective of local groundwater.

Aquifer properties

The properties of the aquifers underlying Highgrove Farm are:

- River terrace deposits
- Moderately to highly permeable deposits.
- The Lambeth Group:
- Highly variable lithology; mottled clay and silt. Fine to medium grained sand in layers and channels.
- The variation of the hydraulic conductivity at any one locality is likely to be between 2 and 60 m/d, with a tendency to increase towards the top of the deposit. A representative average value is about 20 m/d but the aquifer typically provides low yields.
- The Reading Formation is sometimes in hydraulic continuity with the underlying Chalk aquifer.
- White Chalk Subgroup:
- Principal aquifer in UK which is up to 450 m thick and yields 50 to 100 L/s from large diameter boreholes and up to 300 L/s from adited systems. The aquifer is considered to produce hard to very hard, good quality water.

8.1.7 Environmental designations

There is one major designated site at least 1 km from Highgrove Farm:

- Chichester Harbour, which is designated as:
- Site of Special Scientific Interest (SSSI)
- Special Protection Area (SPA)
- Ramsar designation

The entire area around Chichester Harbour, immediately south of the A259, is defined as an Area of Outstanding Natural Beauty.

8.2 Groundwater constraints assessment

The following section builds on the geology, hydrology and topography data collated in the previous sections to form a desk-based review into possible groundwater related development constraints across the site. Possible groundwater constraints have been described in Section 2.

8.2.1 Hydrogeological indicators of a high groundwater table

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

8.2.2 Superficial deposits

Alluvium (river terrace deposits) across the site is likely to be an indicator of a perennially or semi perennially high water table.

The current watercourse adjacent to the western boundary of the site likely acts to locally control the water table in this area.

8.2.3 Low lying areas

The Environment Agency's surface water flood map 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, with low lying areas more likely to intercept the local water table or collected perched water when over low permeability deposits.

The Environment Agency's Flood Map for Planning shows the site is unlikely to be at risk of flooding from rivers and see and therefore alluvial flooding.

8.2.4 Bedrock level

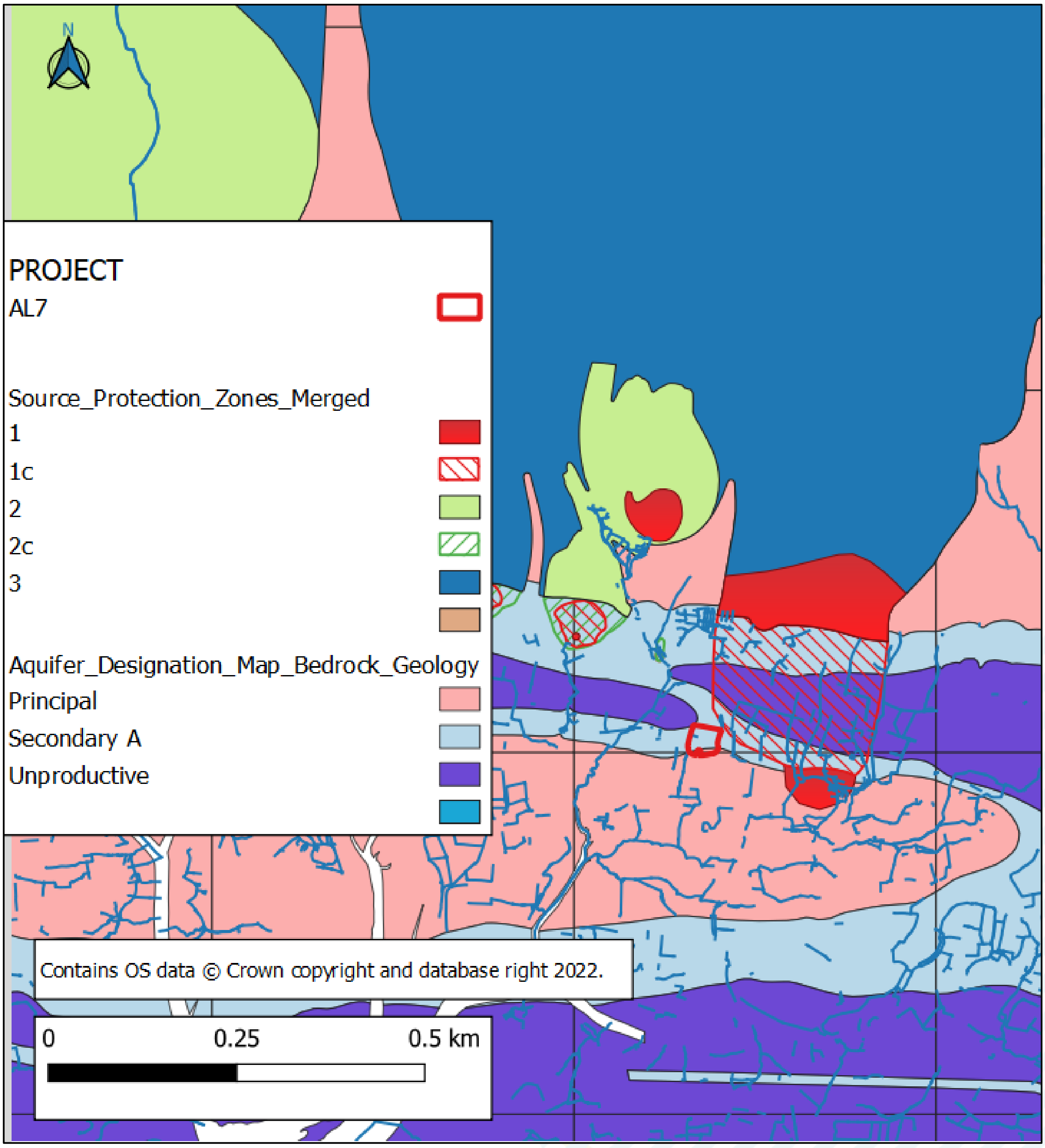
The majority of the site is likely covered by relatively thick superficial deposits.

No springs have been identified on the site, based on desk based studies, that originate from discharges from the bedrock aquifer.

8.2.5 Groundwater catchment

Figure 8-2 shows Source Protection Zones and Bedrock Aquifer Designations in the local area. This shows that there is regional flow from the chalk outcrop (pink) to the north, under the unproductive strata (purple) to the chalk outcrop on the south of the site. Therefore, there is a large groundwater catchment for the chalk aquifer.

Figure 8-2: Source Protection Zones and Bedrock Aquifer Designations



8.3 Groundwater flooding analysis

The following section summarises the main groundwater constraints associated with the development of the site. This assessment is based on analysis of the local geology, hydrology, topography and the implementation of high-resolution groundwater flood mapping. The difference between clearwater flooding and alluvial groundwater flooding is described in Section 2.1.

8.3.1 Clearwater flooding

The groundwater flood map generated by the GeoSmart model for the site is presented in Figure 8-3.

The groundwater flood risk ranking across the site demonstrates (Figure 8-3):

- The majority of the site comes under class 4, which signals that there is a negligible risk of groundwater flooding.
- The southeast corner is classified as 2, which suggests a moderate risk of groundwater flooding in this area.
- The southwest corner is predicted to be class 1, suggesting that there is a high risk of groundwater flooding in this area. This area is likely to be of a high category compared to the rest of the site due to underlying the chalk.

The boundary to the west is associated with a small watercourse, where groundwater levels were monitored in 2016-2017. The water levels were observed to be shallow, reaching 0.2 mbgl in January 2017, following winter rainfall. Ongoing monitoring would be recommended as there is a possibility of local groundwater emergence.

Figure 8-3: Geosmart Groundwater flood risk mapping

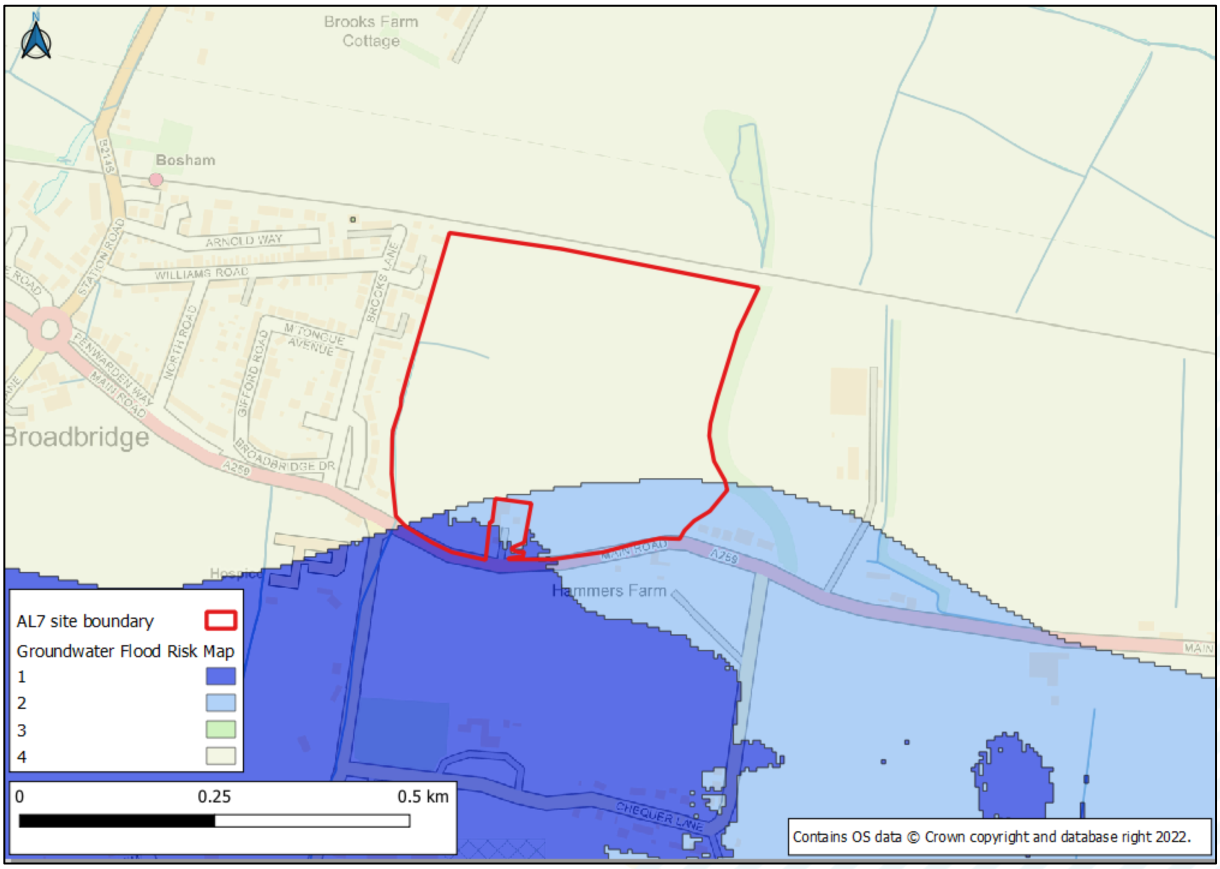
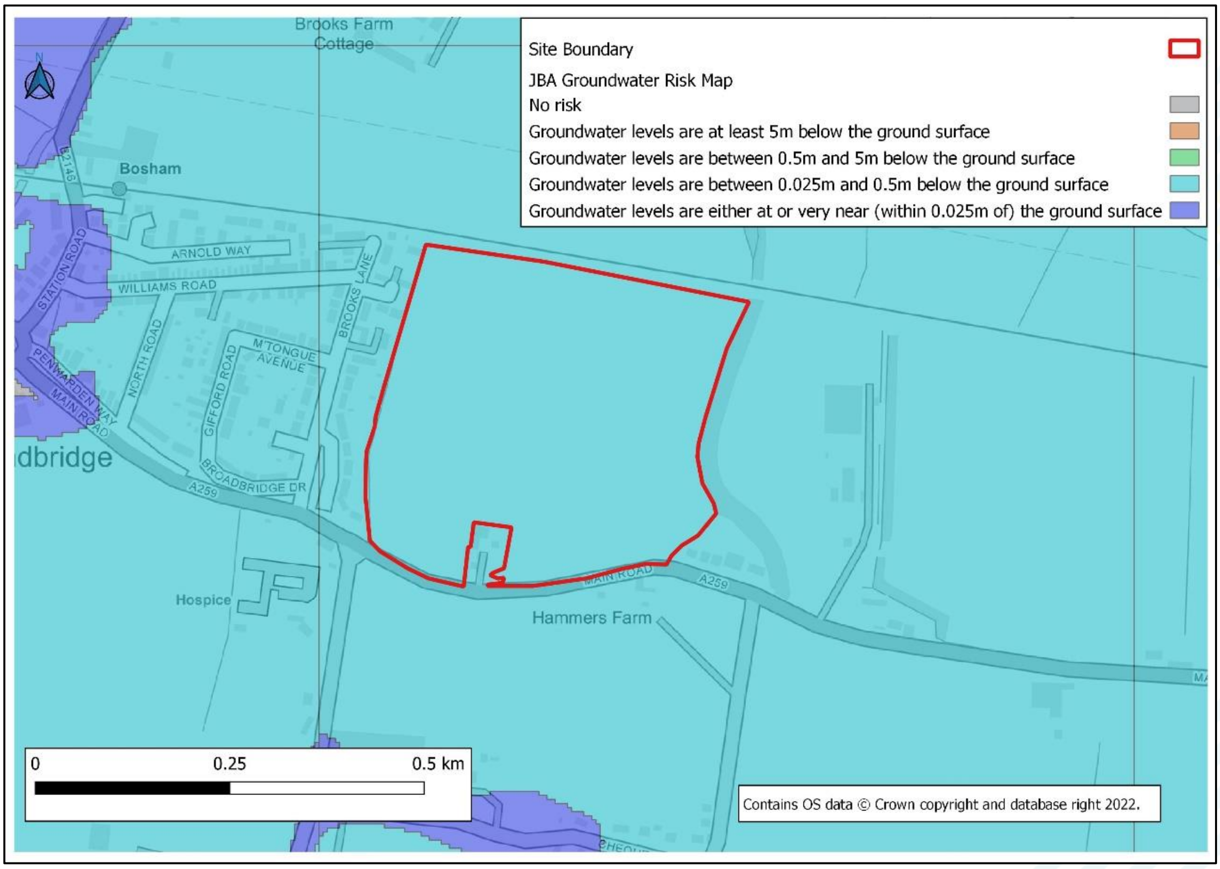


Figure 8-4 shows the JBA Groundwater Flood Risk map. It shows that there is a risk of groundwater being close to the surface across the whole of the site. The south-east of the site is not highlighted as having a higher risk.

Figure 8-4: JBA Groundwater Flood Map



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.

8.3.2 Alluvial groundwater flooding

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".

Although there are permeable River Terrace deposits on site they are not in contact with the alluvial floodplain of a larger watercourses and/or river in the area. Therefore, it is unlikely that the site is at risk from alluvial groundwater flooding.

8.3.3 Historical evidence of groundwater flooding

A review of historical maps highlights any obvious areas which may be prone to local 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 the site's history.

A review of historic maps does not indicate any previously boggy conditions on site, with the fields largely the same as they are at present.

8.4 Conclusions and mitigation strategy considerations

Table 8-2 outlines the main considerations when assessing groundwater flood risk and the potential, if necessary for mitigation and the likely scale of that mitigation

The table below outlines the main considerations when assessing groundwater flood risk and the potential for simple mitigation.

Table 8-2: Main groundwater flooding constraints

Questions	Explanation	Answer
What groundwater flood risk zone is the allocation in?	The GeoSmart V2.2 flood map should be used as an initial indicative screening tool categorises groundwater flood risk into four classes. 1- High risk, 2- Moderate risk, 3 - low risk, 4 - negligible risk.	Mainly Class 4 - Negligible But southern boundary where Chalk subcrops are Class 1 and 2 And Groundwater levels are between 0.025m and 0.5m below the ground surface in the 100-year return period flood event.
Is the site vulnerable to clearwater flooding?	Clearwater flooding 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).	Yes - along the south perimeter of the site in Class 1 and 2 and these areas receive water from a large chalk groundwater catchment The JBA map also indicates there may be a shallow watertable across the rest of the site.
Is the site vulnerable to alluvial groundwater flooding?	Alluvial groundwater flooding is most likely to occur in: • 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".	No. - Although there are moderate permeability river terrace deposits on site they are not in contact with the alluvial floodplain of the larger watercourses and rivers in the area. Therefore, it is unlikely that the site is at risk from alluvial groundwater flooding
Does the site receive groundwater from a relatively large groundwater catchment?	If there is a large groundwater catchment, groundwater inputs may be harder to manage through drainage	Yes - the south perimeter of the site receives water from a large chalk catchment
Are the main groundwater discharge boundaries (ditches, rivers, lakes) within surface water or fluvial flood zones?	If yes, there may be periods when these discharge boundaries will be overwhelmed with surface water and will not function to suppress the groundwater watertable	Yes but these are likely to be short duration, long return period surface water flooding events which would not likely overwhelm the drainage for significant periods.
Are there discharge boundaries potentially outside of the control of the allocation?	Groundwater level maybe change in future	No.
Are there areas of the site lower than the lowest point of the	If yes, then alluvial groundwater flooding may be a potential mechanism as water in the neighbouring surface water body could	No.

banktop of the drain/river network?	be higher than the surface of the site	

The area of high and moderate groundwater flood risk in the south of the site is underlain by chalk, that receives flow from a large groundwater catchment. Simple on site mitigation may not be possible to mitigate groundwater flood risk in this area. The area to the north has negligible groundwater flood risk due to the underlying geology. The site could be zoned to avoid development in the high-risk area, however ongoing monitoring and site investigation would be required to confirm the boundaries of these zones. The following measures should be addressed when formulating site proposals:

- Groundwater monitoring
- Potential zoning of the site limit development in the lowest-lying parts of the site.
- Evaluation of the capacity of local drainage systems to appropriately accommodate and control groundwater flow and level.