Executive Summary

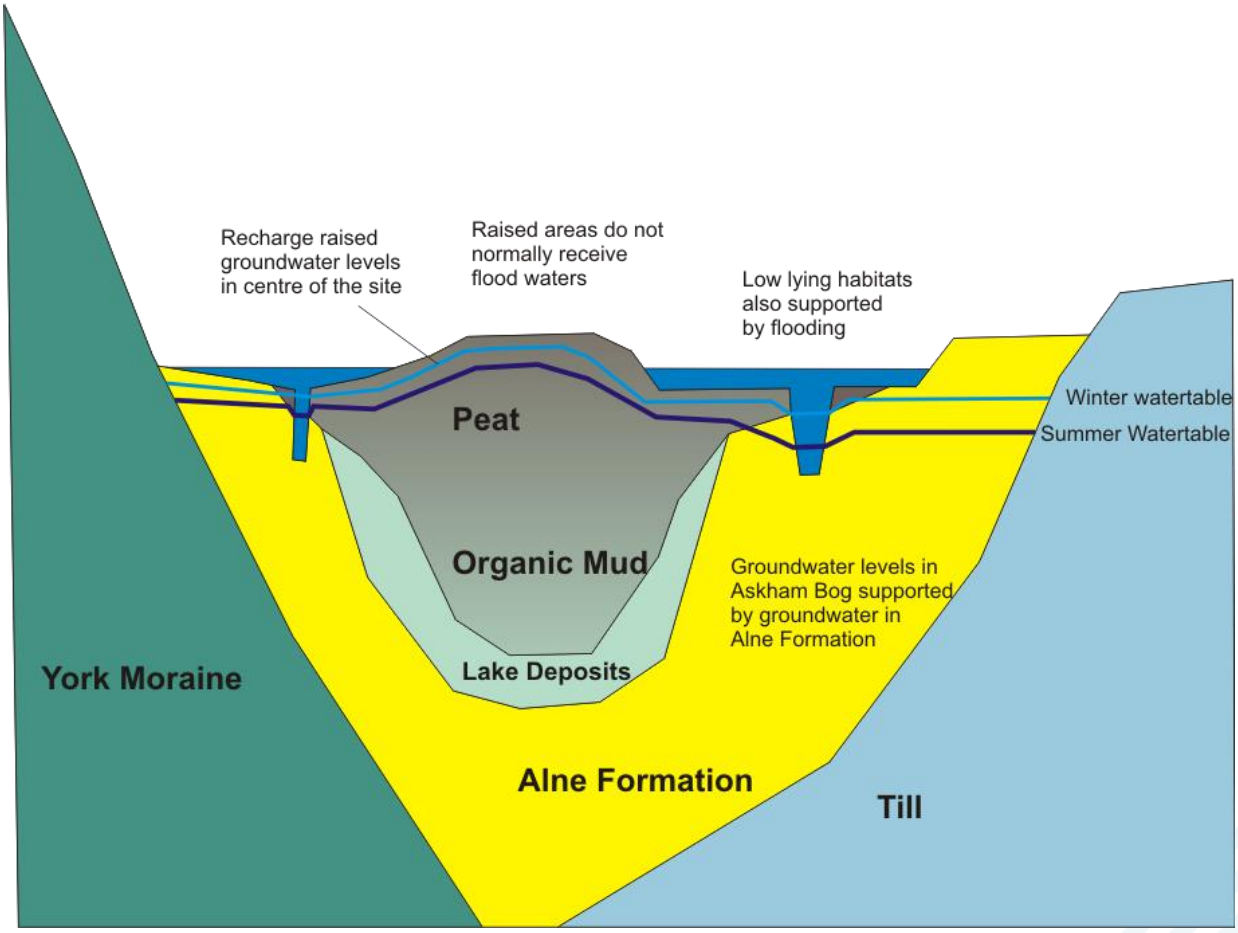
JBA Consulting (JBA) was appointed by the Yorkshire Wildlife Trust (YWT) in January 2019, to advise on hydrological matters in connection to the application by Barwood Homes at Moor Lane (Planning Application 18/02687/FULM). The scope of the review was as follows:

- Consider the hydrological and hydrogeological processes that are supporting Askham Bog SSSI and the wider wetland system.
- Consider the documents and assessments submitted in support of the application.
- Undertake an outline assessment of potential development impacts specifically in relation to the hydrology and hydrogeology of the Askham Bog SSSI.

JBA reviewed a range of documents to develop an ecohydrological conceptual model of Askham Bog. This is represented in the figure below and contains the following principal features:

- The bog lies in a depression surrounded by boundary drains.
- The bog developed from the infilling of a post-glacial lake, and is underlain by a series of clays, muds and peat.
- The wetland deposits are surrounded by the Alne Formation.
    - In the valley bottom, this formation is dominated by thick sand deposits.
- In the valley bottom, the Alne Formation and boundary drain show a strong hydraulic connectivity.
- High groundwater levels in the peat body are supported water levels in the boundary drains and Alne Formation by two mechanisms:
    - Where the peat body is contained within lake bed deposits, a high groundwater table in the Alne Formation, limits the rate of lateral groundwater movement through the lake deposits
    - Where peat or peaty deposit (and especially thin deposits), lie directly on the Alne Formation, high groundwater levels in the Alne Formation limit/stop the vertical loss of water out of the peat deposits.
- On higher areas of the bog, shallow groundwater is supported by direct precipitation inputs. This results in lower nutrient conditions.
- On the low-lying habitats, flooding from the boundary drains and/or groundwater inputs from the Alne Formation bring nutrients/minerals into the area, which support the habitat types present in these areas.

Eco-hydrological Conceptual Model of Askham Bog



The main issue with the applicant's hydrological assessment is that it is based on a misunderstanding of how Askham Bog is supported. It assumes there is limited connectivity between the development site and the bog - "Monitoring work has proven that there is no groundwater connectivity between the Site and the SSSI" (Paragraph 12.87 of the ES). The eco-hydrological conceptual model presented above indicates that this assumption amongst others (e.g. the role of flooding) is incorrect. As a result, the assessment upon which this is based is critically flawed and cannot be relied upon to identify significant impacts.

In addition to the applicant's assessments being flawed, this review has identified several important impact mechanisms. These mainly relate to the function of the attenuation basin that would border the SSSI. The attenuation basin may have the following effects:

- Reduced flooding of habitats dependent on regular flooding;
- Cut off any run-off from the entering the boundary drain when the basin levels drop below the normal set/control level;
  - E.g. after a drought, the attenuation basin will have to adequately fill, before any run-off can supply the site.
- Generally lower the groundwater levels, through increased evaporation effects

In addition, groundwater level monitoring indicates that without a liner, the attenuation basins are likely to dry out.

Overall, the review shows that the assessments supporting the application are critically flawed and cannot be relied upon to identify significant impacts. JBA's review however indicates there are a range of potential impact mechanisms created by the proposed development that could detrimentally affect the eco-hydrological conditions of Askham Bog.

1 Introduction

My name is Alex Jones and I am a Chartered Geologist specialising in hydrogeology. I have a MSc in Environmental Hydrogeology and a BSc (Hons) in Environmental Science. I am a consultant hydrogeologist by profession, with particular experience in the hydrology and hydrogeology of wetland systems including their conceptualisation and restoration.

I am currently employed as a Chartered Senior Hydrogeologist at JBA Consulting within the company's Groundwater Team. I have 10 years of continuous professional experience in consultancy within the field of environmental and engineering hydrogeology. My specialist fields in relation to the assessment in this report relates to hydrogeology and eco-hydrology.

Over the course of my career I have advised clients on environmental risk related issues, particularly in relation to assessing the hydrological functioning of wetlands and the evaluation of development impacts for developers, regulators and other public bodies. I have also designed peatland restoration schemes in England and Scotland. This includes producing the developed design for a £2.9million Water Level Management Plan to restore the eco-hydrological conditions of the Thorne, Crowle and Goole Moors SSSI, and forms part of a SAC, NNR and SPA, the largest extent of lowland raised mire in England (1,918 hectares). I have also worked on many other smaller peat wetland sites. I was recently invited by Natural England to talk at a conference on lowland peat restoration.

2 Scope and Purpose of Review

JBA Consulting (JBA) was appointed by the Yorkshire Wildlife Trust (YWT) in January 2019, to advise on hydrological matters in connection to the application by Barwood Homes at Moor Lane (Planning Application 18/02687/FULM).

This document takes the form of a review of the application, the scope of which is to:

- Consider the hydrological and hydrogeological processes that are supporting Askham Bog SSSI and the wider wetland system.
- Consider the documents and assessments submitted in support of the application.
- Undertake an outline assessment of potential development impacts specifically in relation to the hydrology and hydrogeology of the Askham Bog SSSI.

The document is structured as follows:

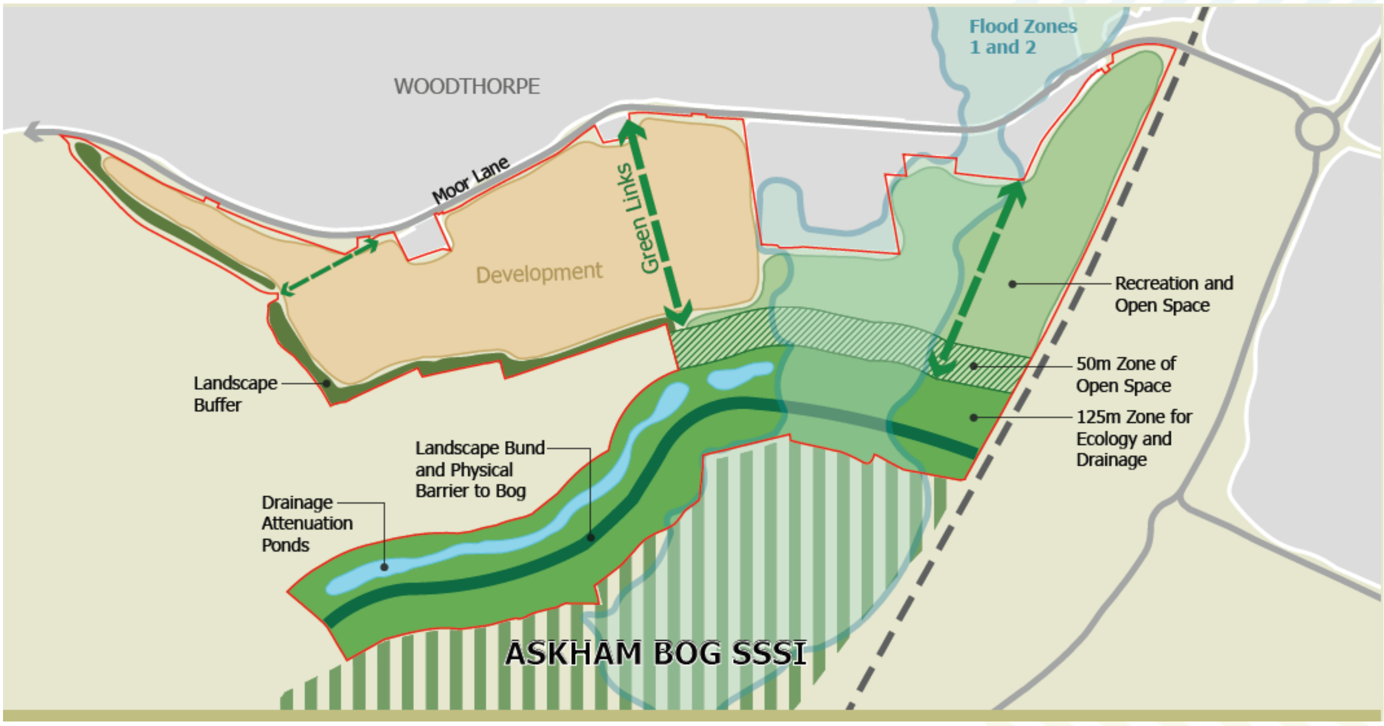
- Description of the development and the SSSI,
- An environmental baseline description of the site and the SSSI,
- Development of an eco-hydrological conceptual model of the SSSI,
- Comparison of JBAs understanding of how the SSSI is supported compared to that of the applicant,
- Review of the applicant's assessments in light of JBAs eco-hydrological conceptual model,
- Identification of potential impact mechanisms of the development.

A critical review of the assessments presented in the application, and the information upon which it is based, is presented in the Appendices.

2.1 The Development

The development site is 40.05ha. The housing will be in north-west of the site, the west will contain a series of green spaces (allotments, sports pitches, etc.), and the south along the boundary of Askham Bog will contain an attenuation basin and landscape bund.

Figure 2-1: Concept Diagram for Landscape and Ecology



2.2 Askham Bog

Askham Bog SSSI was first notified in 1961. The site citation states the following:

> *Askham Bog is the remnant of a valley-mire which formed between two ridges of glacial moraine in the Vale of York just southwest of the City. Base-rich ground-water draining the moraines has led to the development of a rich-fen community which demonstrates stages in seral succession to fen woodland. In the central areas there is a poor-fen community, thought to represent incipient raised-bog, where vegetation has grown above the influence of the ground-water and conditions have become acidic through the leaching action of rain-water and the growth of bog mosses Sphagnum spp.*
>
> *The present habitats are considered to be secondary, raised-bog having largely replaced the original fen before peat-cutting in the Middle Ages brought the vegetation back within the influence of base-rich ground-water with the consequent reversion to fen conditions.*

3 Baseline Environmental Setting

This baseline section aims to present sufficient information to develop an eco-hydrological conceptual model of Askham Bog SSSI in order to understand how the development may affect the eco-hydrological controls on the bog and the features of interest within it.

3.1 Hydrology and Topography

Figure 3-1 shows the topography of Askham Bog and the proposed development site. The box below presents a figure from the FRA (Appendix 13 of the Environment Statement (ES)) detailing the names of the main watercourses.

Askham Bog SSSI lies in a topographic hollow. The northern edge of the SSSI is Askham Bog Drain, and forming the southern boundary is Pike Hill Drain. These join at the eastern edge of the bog and discharge to Holgate Beck. At the north-west corner of the development site, Holgate beck discharges to an internal drainage board pumping station.

The development site lies on rising ground to the north-east of the SSSI.

Between the railway line and Holgate Beck is an area of raised ground formed by a historic landfill.

Two shallow domes (up to 0.5m high) occur of Askham Bog, these are surrounded by lower lying areas on the boundary.

Figure 3-1: Topography of Askham Bog, the Development Site and Surrounding Area

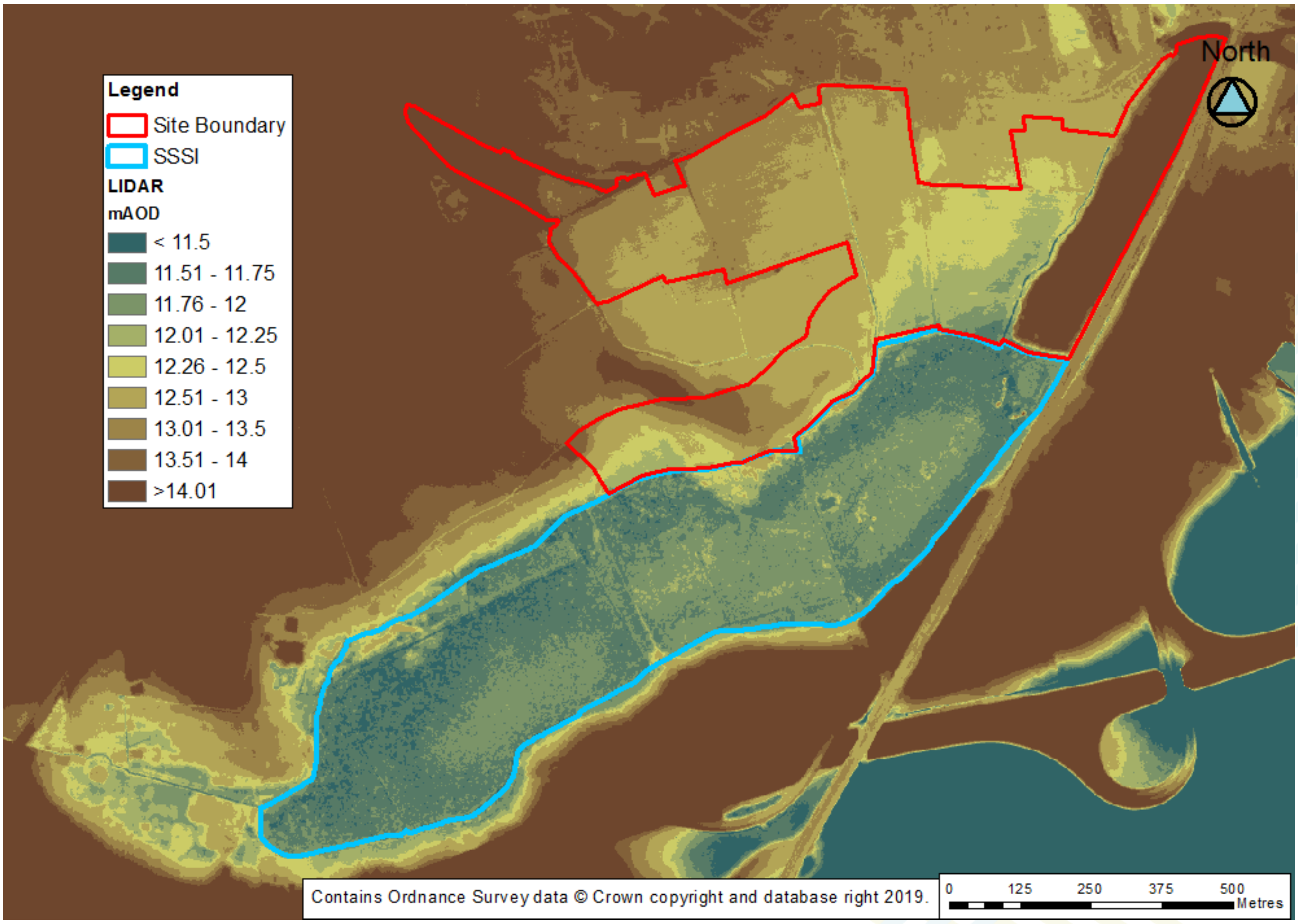
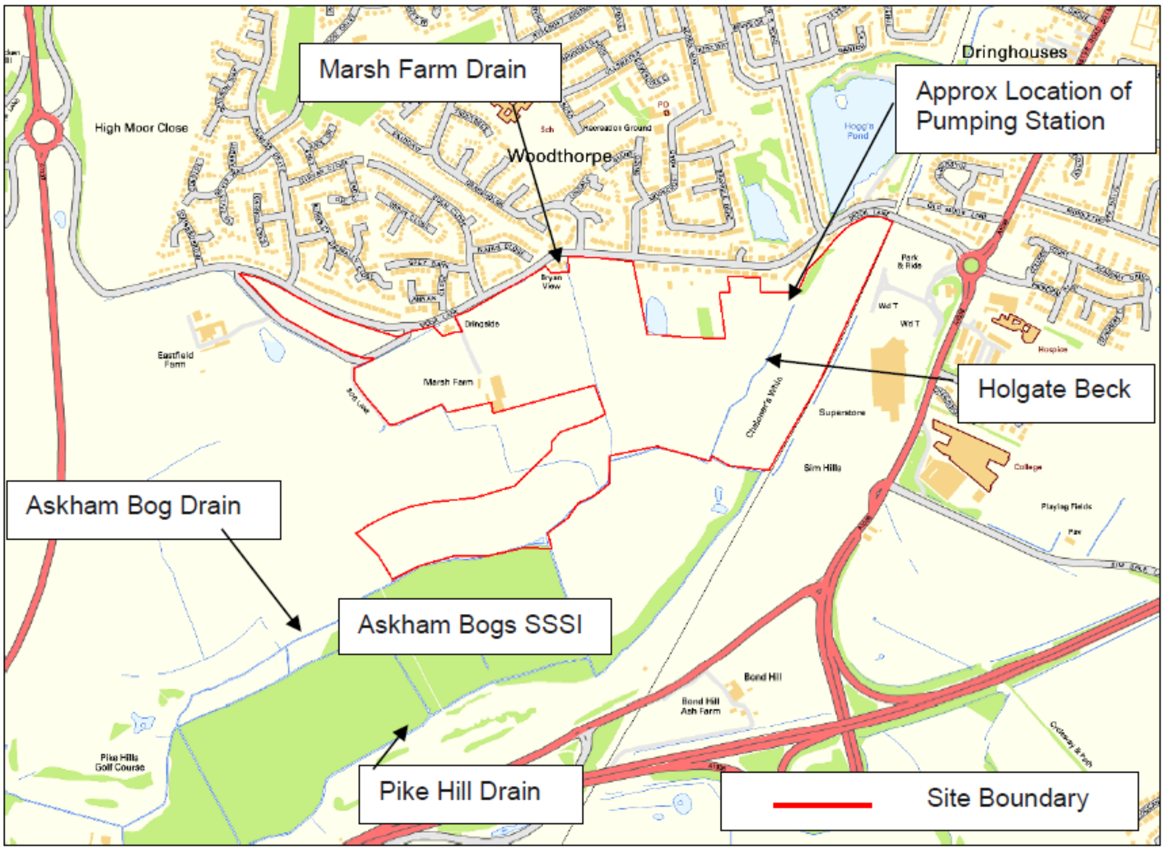


Figure 2.1 from the FRA (PBA 2018)



3.2 Geology and Site Development

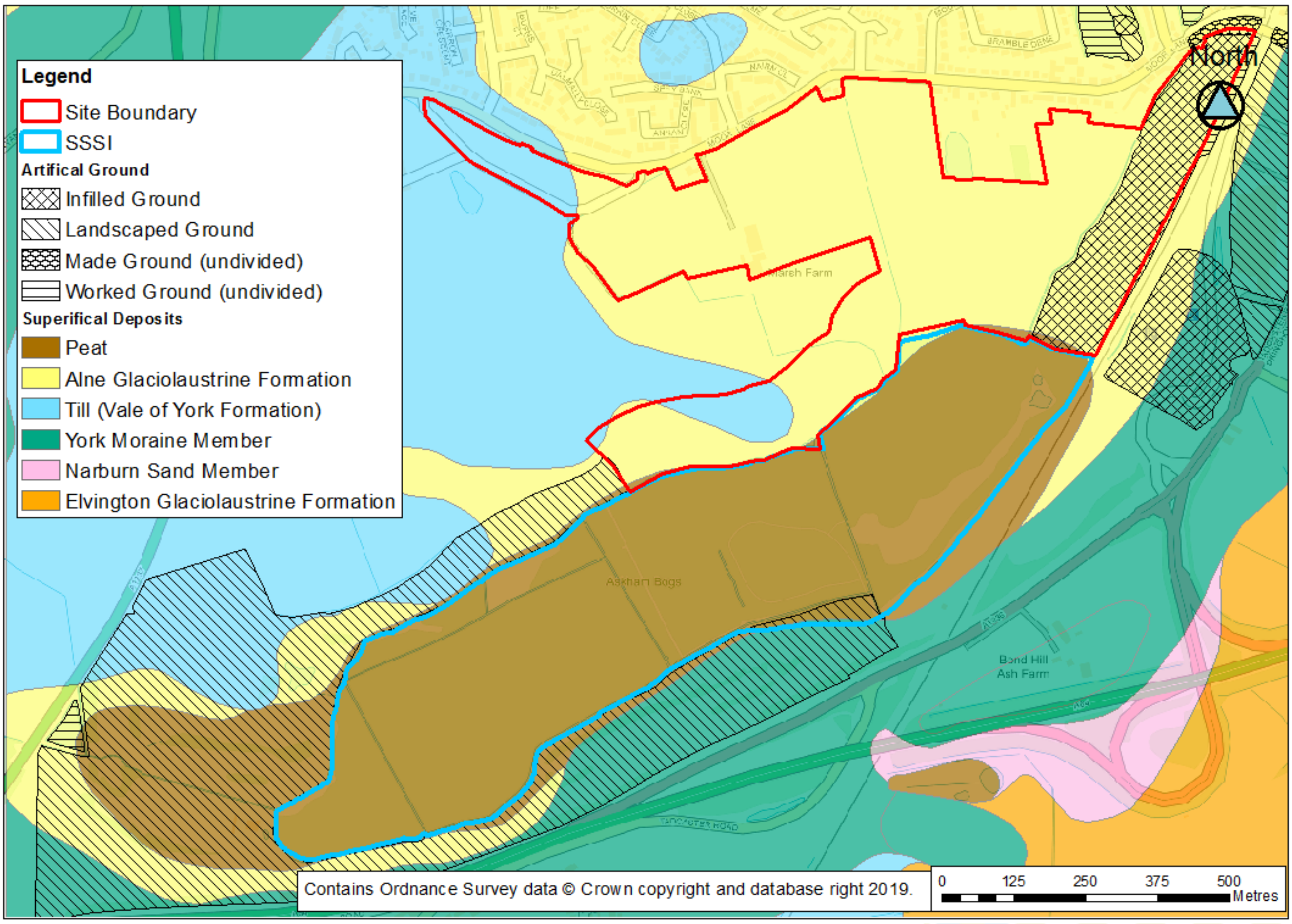
The geology of Askham Bog and the development site is complex. The table below summarises the geological units present. The distribution of the superficial units across the area is shown in Figure 3-2.

Table 3-1: Geological Unit Summary

Age	Formation / Member / Group	Description	Thickness	Location
Quaternary	Peat	Varied due to complex history of the site. Some areas thin and oxidised, other areas deep and amorphous	0-2m+	Thin peat around the edge of Askham bog Thickens towards centre and west of the bog.
	Lacustrine /Fen Deposits	Deposits laid down as lake transitioned to fen. Deepest deposits are lake bed clays and change into organic rich mud	0-4m	Within the Askham bog basin. Extents in some areas smaller (or larger) than the peat, as the wetland extends beyond the lake area
	Alne Formation	Glaciolacustrine deposits described by the BGS as	0-8m+ Thinner on	Underlies the Askham Bog basin and the

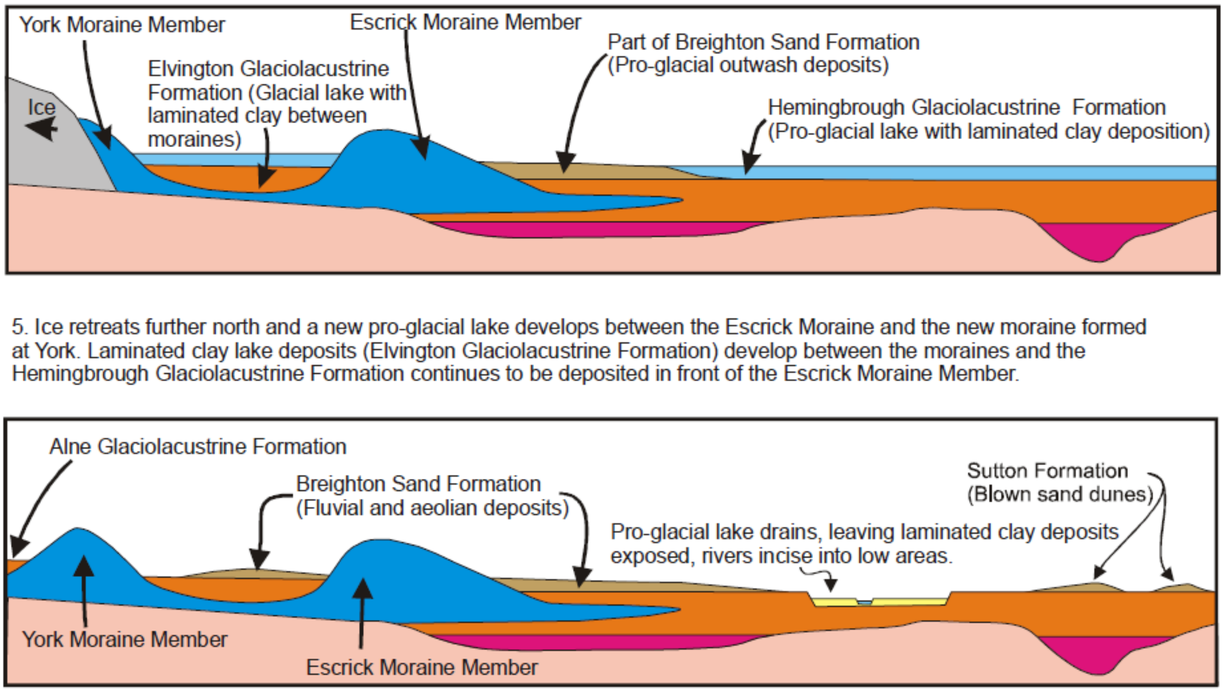
Age	Formation / Member /Group	Description	Thickness	Location
		Clay and Silty. However, in valley it is dominated by Medium SAND in the borehole logs	higher ground and thickness in the valley bottom	majority of the development site
	Till	Site investigations show it to be gravelly CLAY	10+	On high ground of the site and under the Alne Formation
	York Moraine	Clayey Gravelly SAND	10+	Forms the ridge that lies to the south and west of Askham Bog
Triassic	Sherwood Sandstone Group	Sandstone		Circa 20m+ below ground surface
Sources; BGS Mapping, applicants Site Investigation, Ove (2003), BGS (2003).				

Figure 3-2: Superficial Geology of the Development Site and Askham Bog



The complex geology is a result of the pattern of retreating and advancing glaciers in the last ice age[1]. Askham Bog itself formed in a hollow by the retreat of the last glacier. This retreating glacier left the York Moraine, which forms the ridge to the south and west of the site. Behind the York moraine, a glacial lake formed, the material deposited in that lake is called the Alne Formation (see Figure 3-3). The BGS describes it as clay and silt deposits, however a review of the borehole logs in Appendix EDP 4 in Appendix 10.1 Historic Environment Baseline of the Environmental Statement (ES), show that the Alne Formation is dominated by sandy deposits in this area (see Section 3.2.2 for a more detailed description). Till forms the high ground to the west of the site, the same borehole logs show it to be dominated by gravelly CLAY.

Figure 3-3: Schematic Model of the Creation of the York Moraine and Alne Formation (From BGS 1999)



Askham Bog formed from the infilling of a late-glacial lake, within the Alne Formation. A succession of habitats occurred within the hollow, leaving behind a complex series of deposits. These are described in the paragraph below and shown in Figure 3-4 (from Ove 2003):

> *About one-third of the basin has been filled by late-glacial lake clay (layer 2), with an organic band (layer 3) that Fitter and Smith attributed to an interstadial, a relatively brief warmer period. Above the clay there is a thick layer of organic mud consisting of the remains of aquatic plants (layer 4). The open water stage in the site's development was brought to an end by the spread of reedswamp and the build-up of fen peat (layer 5). The growth of the peat above the maximum water level led to acidification, and possibly to a transition to raised mire (see Section 5.4.2). An unknown quantity of raised mire peat (layers 6 and 7) may have been removed for fuel during the 18th and*

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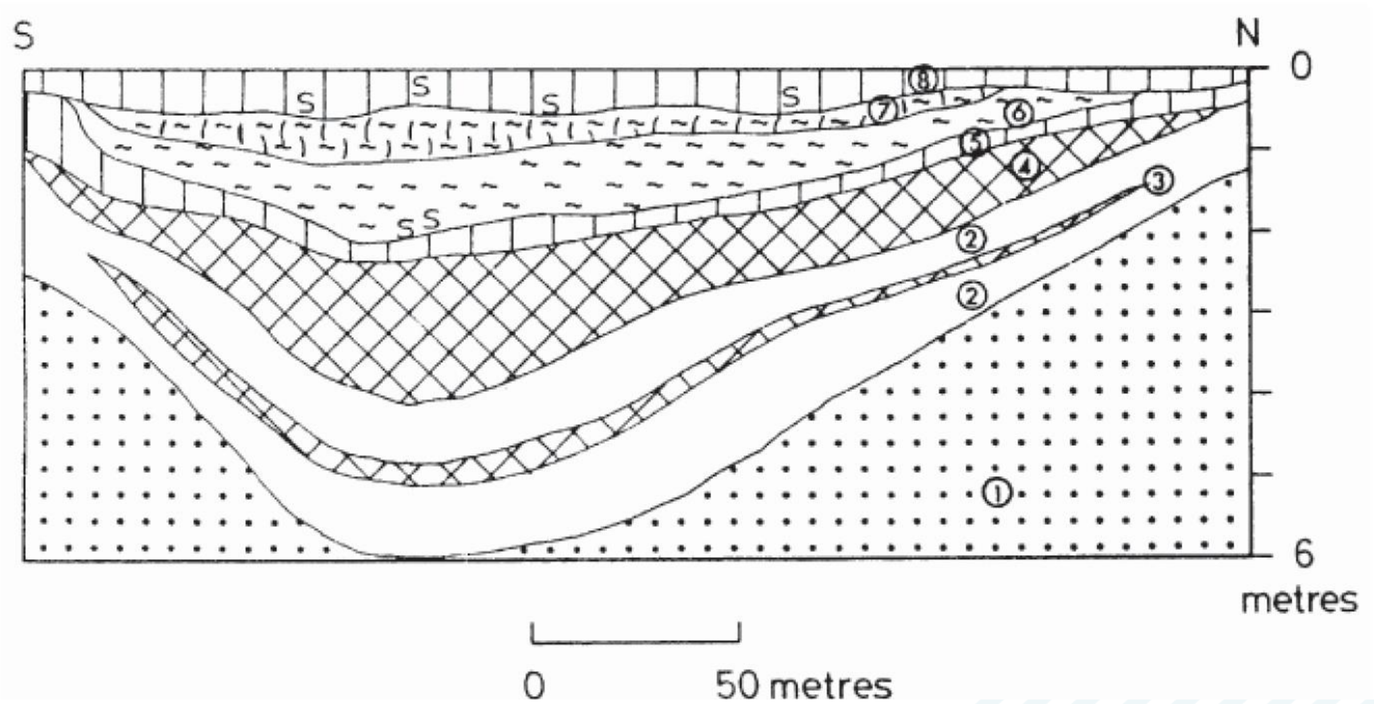
1 BGS (1999) Field Guide to the Glacial Evolution of the Vale of York Internal Report IR/04/106

early 19th Centuries, but sampling of the remaining acid peat shows that surrounding woodland was dominated by alder, indicating that the base-rich margins of the site, which could have been much more extensive than at present, may have consisted of fen carr. A return to fen conditions, perhaps as a result of increased flooding after peat-digging ended, has led to an almost complete cover of fen peat (layer 8).

In summary, the deposits beneath the bog, within the lake area, transition from clays, to organic rich muds to peat. Along the northern border of the site, there are areas where the peat lies directly on the Alne Formation.

Figure 3-4 Fitter and Smith (1979) Cross Section through Askham Bog (from Ove 2003)



3.2.1 Bog Development

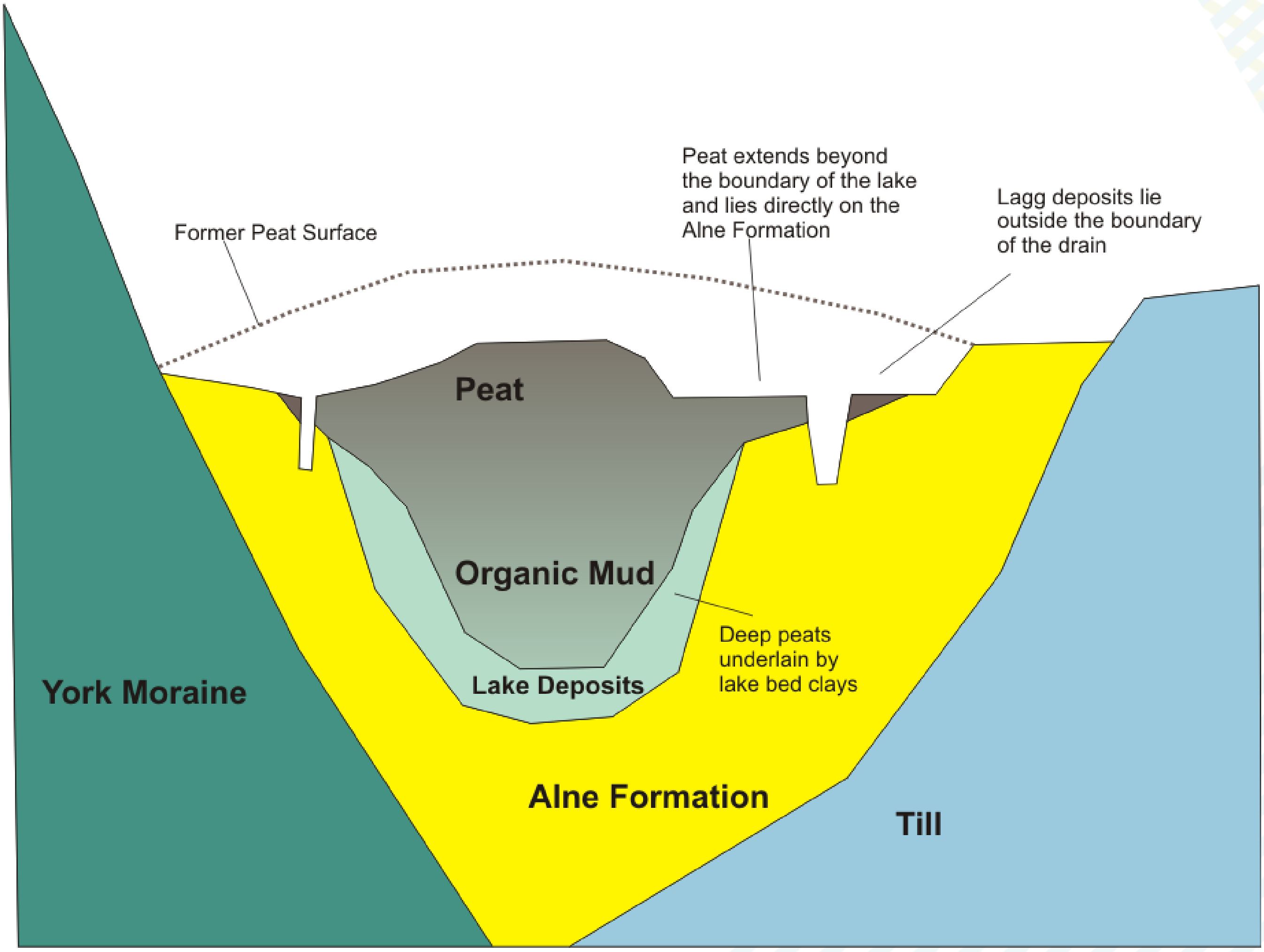
The development of the bog can be summarised as following (based on Ove, 2003) (please note this is a simplification):

- Several glaciers passed over the area,
- The last formed the York Moraine,
- In the hollow behind the moraine was a large lake formed which deposited the Alne Formation (locally sandy in nature),
- The large lake disappeared and within the Alne Formation a smaller lake formed,
- This lake slowly filled in with clays, and organic rich muds,
- Once sufficiently full, fen habitats took hold and peat accumulation started,
- The peat extended beyond the boundary of the old lake directly onto the Alne Formation,
- Peat accumulated so much that the growth level raised above the surrounding area, reducing flooding of the centre of the site. This reduced the nutrients feeding the habitats, leading them to change,

- Peat extraction occurred up until the 18th Century lowering the ground surface and changing the habitats,
- Wastage of peat through drainage at the edge, and/or the accumulation of peat in the centre, has led to centre of the site being domed.

The key deposits and features of the development of the bog are shown in the diagram below.

Figure 3-5: Diagram showing the Bog Development



3.2.2 Alne Formation

The ES chapter (Paragraph 11.50) describes the superficial deposits of the site as following: "The natural deposits were typically described as sandy slightly gravelly clay with occasional silt, sand and peat layers". This is based on "previous ground investigation". In Appendix 11 of the ES the following is also added. " In the south-eastern corner of the site, there was between 4m and >7m of sand present, beneath the Made Ground."

The table below provides a review of the sand deposits in the borehole logs in Appendix 10 of the ES. It shows that sand deposits of varying thicknesses are widespread within the Alne Formation. It also indicates that in the valley bottom the sand deposits are relatively thick (see Figure 3-6 and Figure 3-7).

Table 3-2: Sand Deposits in the Alne Formation

Exploration Location	Sand thickness (m)
BH06/06	1
BH14/07	4.2
BH14/08	7+
BH14/10	0.5
TP14/04	0.7+ (over 2 bands)
TP14/05a	1.5+
TP14/06a	2.05+

Figure 3-6: Site Investigation Locations, Superficial geology mapping and annotations

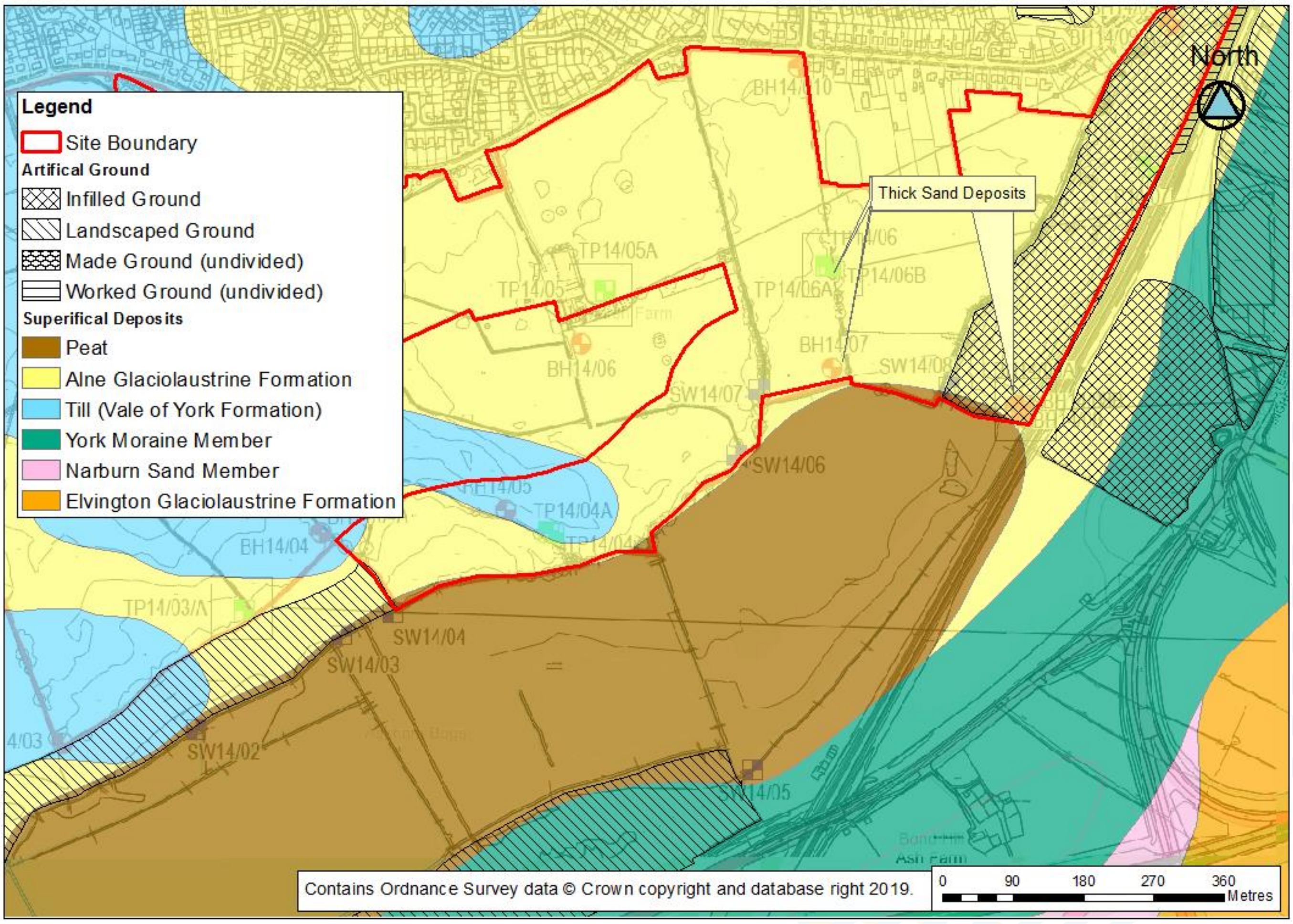
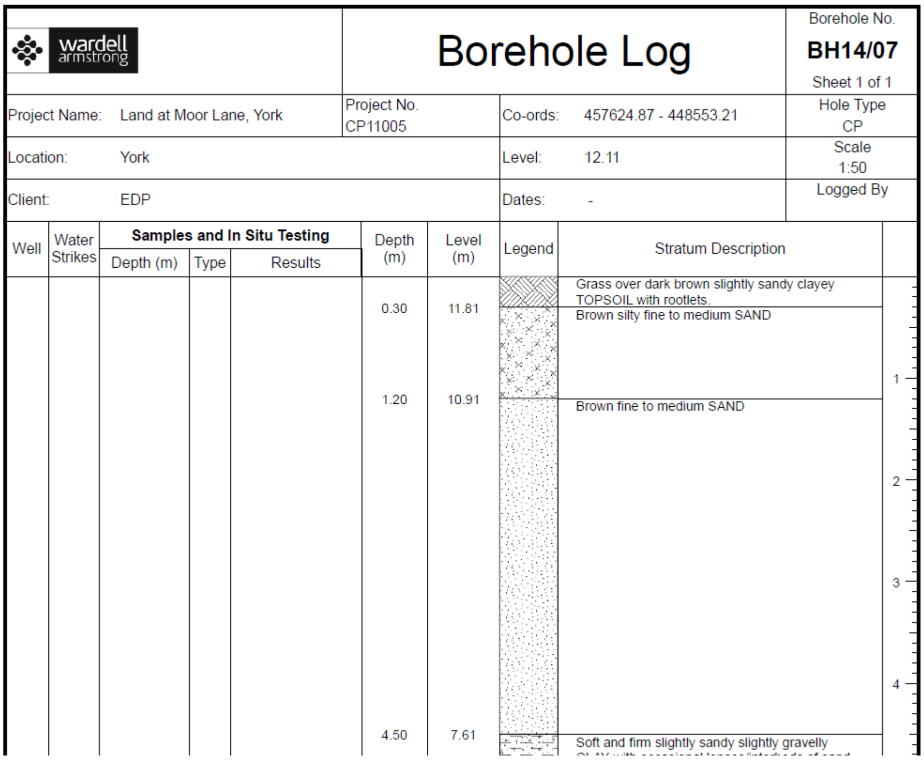


Figure 3-7: Borehole Log BH14/07



3.3 Hydrogeology

The table below presents the hydrogeological units present on the development site and peat bog.

Table 3-3: Hydrogeological Units

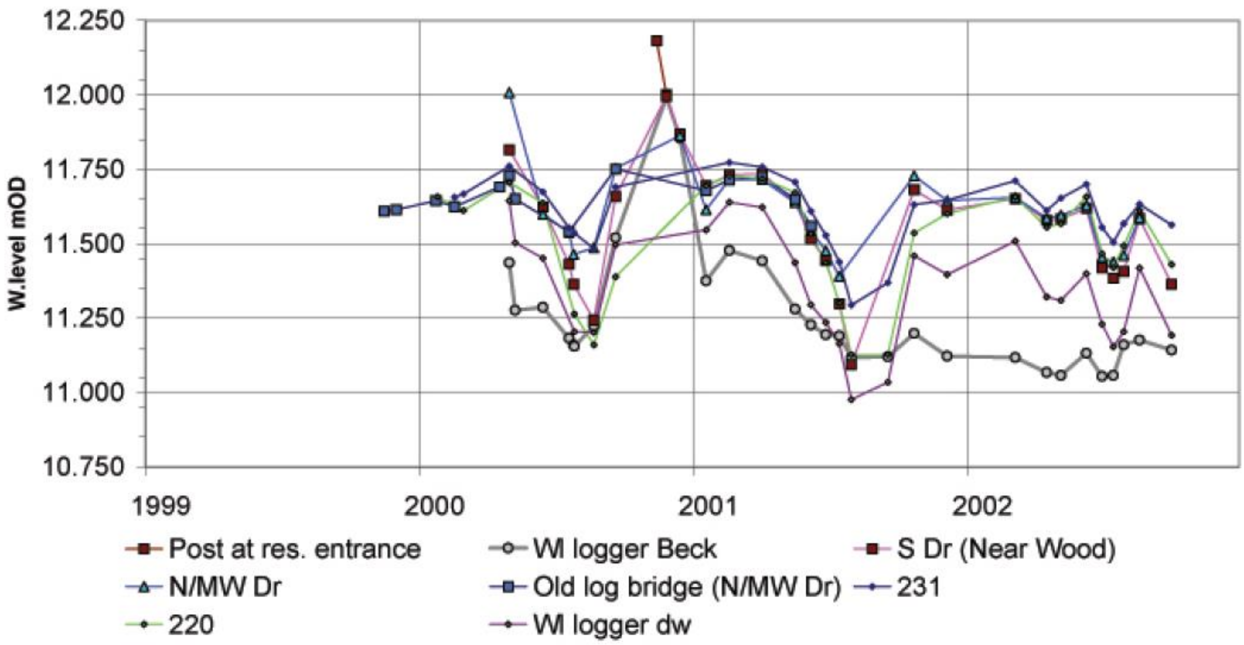
Formation / Member /Group	Description	Location	Permeability
Peat	Varied due to complex history of the site. Some areas thin and oxidised, other areas deep and amorphous	Thin peat around the edge of Askham bog Thickens towards centre and west of the bog.	Relatively Low permeability
Lacustrine /Fen Deposits	Deposits laid down as lake transitioned to fen. Deepest deposits are lake bed clays and change into organic rich mud	Within the Askham bog basin. Extents in some areas smaller than the peat, as the wetland extends beyond the lake area	Low permeability
Alne Formation	Glaciolaustrine deposits described by the BGS as Clay and Silty. However, in one part of the site it is dominated by Medium SAND in the logs	Underlies the Askham Bog basin and the majority of the development site	Variable High permeability in areas of where sand dominates
Till	Site investigations	On high ground of the site and	Relatively Low

Formation / Member /Group	Description	Location	Permeability
	show it to be gravelly CLAY	under the Alne Formation	permeability
York Moraine	Clayey Gravelly SAND	Forms the ridge that lies to the south and west of Askham Bog	Highly permeable
Sherwood Sandstone Group	Sandstone	At depth	Highly Permeable

3.3.1 Peat hydrogeology

Peat forms when plant material does not fully decay in anaerobic conditions. Anaerobic conditions can develop when the ground is waterlogged. The continued existence of peat depends upon its ability to retain water. Water level monitoring (Ove 2003) suggests that much of the bog is fully saturated in winter, but water levels drop by 0.5-0.75m over the summer.

Figure 3-8: Water Level Monitoring from Near Wood (Ove 2003)



3.4 Hydrogeology of the Alne Formation and interactions with Askham Bog Drain

This section focuses on the area shown in Section 3.2.2, where the valley floor of the site contains thick sand deposits adjacent to the bog.

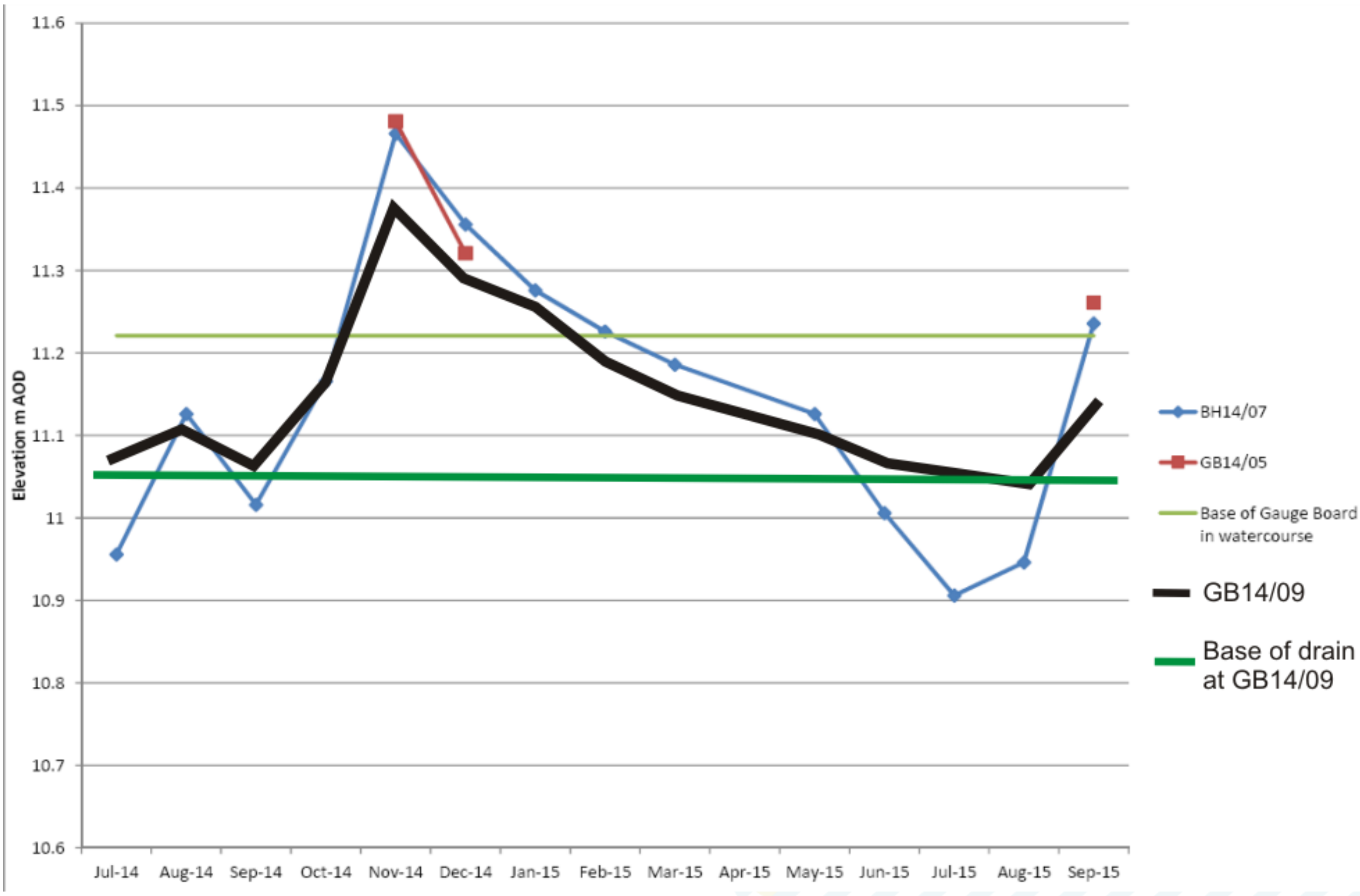
Figure 3-9 is a composite hydrograph based on data presented in Peter Brett Associates (PBA) technical note (29/10/2015) in Appendix 12 of the ES. It presents the water level record at BH14/07 against the nearest gaugeboard in Askham Bog Drain with a significant number of monitoring records. It clearly shows that the groundwater levels in the Alne

Formation sand at this location and the water level in the drain have a similar pattern. The conclusion from this is that groundwater level in the Alne Formation in the valley floor and the boundary drain has a good hydraulic connectivity. This conclusion differs from the PBA technical note (29/10/2015) in Appendix 12 of the ES, which states:

> *When the water level data between adjacent groundwater monitoring boreholes and surface water monitoring locations is compared, the pattern of the data does not indicate that there is direct hydraulic continuity between the surface water and groundwater across the site.*

However, this appears to be the result of not identifying the thick sand deposits in the base of the valley in the assessment nor plotting water levels at BH14/07 against a good record of water levels in the Askham Bog Drain.

Figure 3-9: Hydrograph of BH14/07 and GB14/09



3.5 Groundwater Levels in Alne Formation supporting groundwater levels within Askham Bog

The detailed geological cross sections in Figure 3-10 are based on the following sources (the line of the cross sections are shown in Figure 3-11):

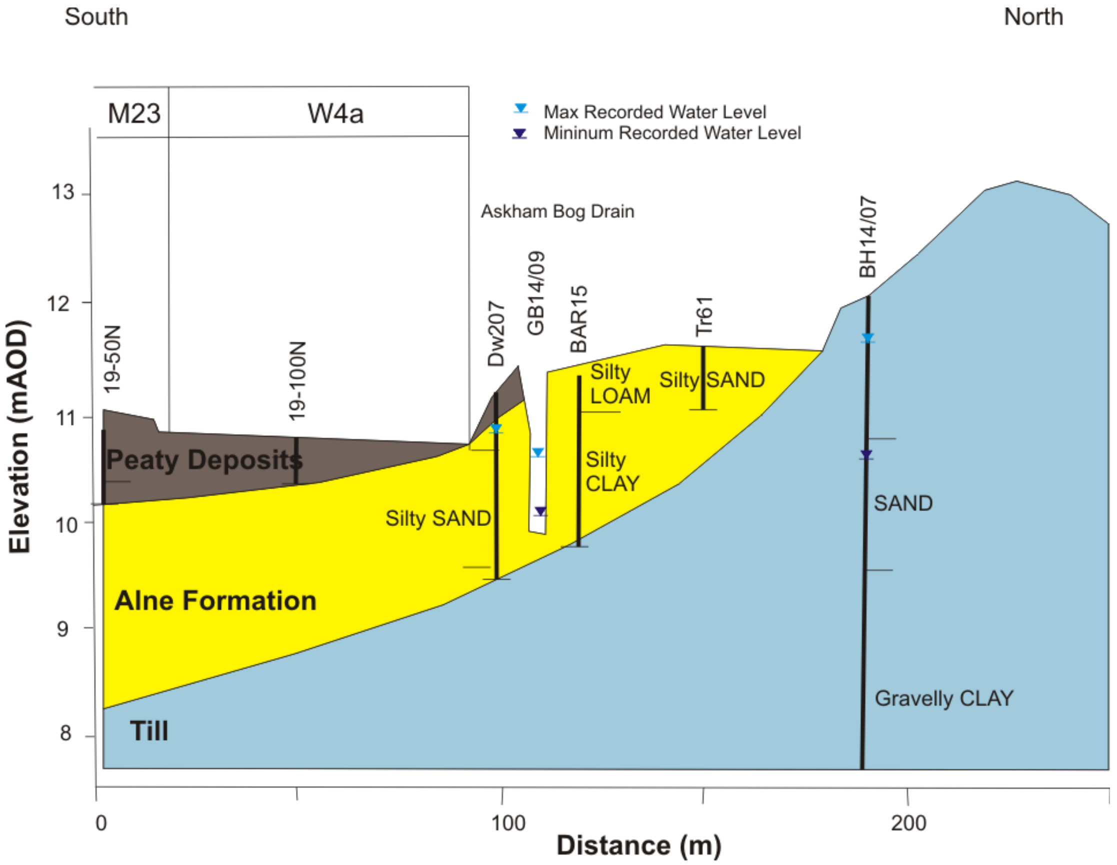
- Logs and water level records presented in the application including archaeological trial pit logs,
- Logs in WWT (2013), Investigating the hydrological relationship between the Moor Lane site and Askham Bog SSSI,
- Data in Ove (2003).

The cross sections can be used to illustrate two conditions where the water levels in the Alne Formation and the boundary ditch (which have been shown to be connected) support groundwater levels in the peat bog, namely:

1 The first cross section shows that, where the peat body is contained within lake bed deposits, a high groundwater table in the Alne Formation, limits the rate of lateral groundwater movement through the lake deposits.

2 The second cross section shows where peat or peaty deposit (and especially thin deposits), lie directly on the Alne Formation, high groundwater levels in the Alne Formation limit/stop the vertical loss of water out of the peat deposits.

Figure 3-10: Geological Cross Sections with Water levels



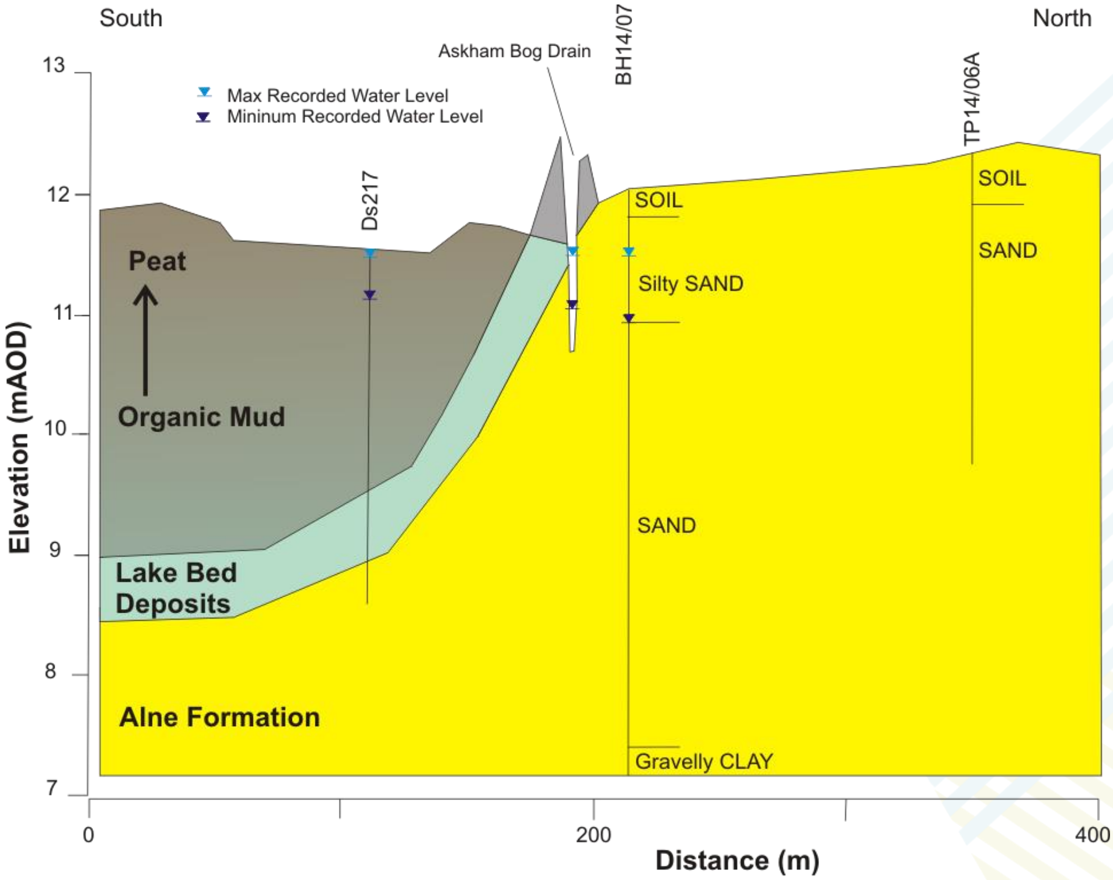
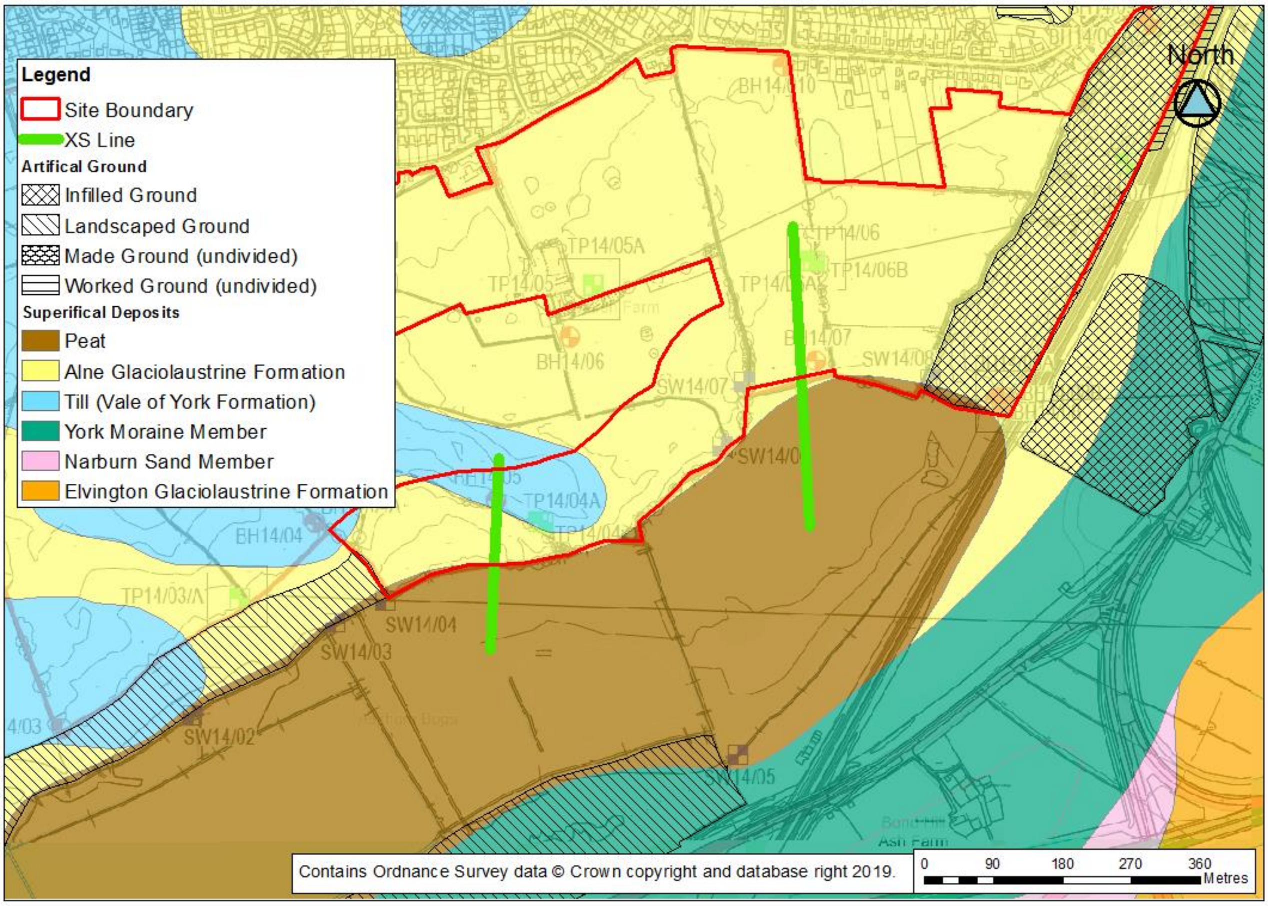


Figure 3-11: Line of Geological Cross Sections



3.5.1 Comparison of Understanding with the Applicant's Assessment

As shown in the section above, the groundwater levels in Askham Bog are dependent on levels in the boundary drain and the Alne Formation. The applicant's assessment presents a different understanding.

Paragraph 13.30 of the ES states the following:

> *Previous studies include the 'Eco-hydrological Assessment of the Moor Lane Site on the Adjacent SSSI', WWT Consulting (2013 and the 'Yorkshire Wildlife Trust Askham Bog Restoration Project Technical Report' (Ove Arup, 2003). Both make the conclusion that Askham Bogs is critically dependent on precipitation for water supply rather than surface water runoff or groundwater inputs.*

The last statement "Askham Bogs is critically dependent on precipitation for water supply rather than surface water runoff or groundwater inputs" appears to be misunderstood by the ES. It is agreed that the quality of shallow groundwater across much of the site, is dependent on precipitation. The shallow watertable on higher parts of the site is low in nutrients, as this water comes from direct precipitation. However, water levels in the Alne Formation and boundary ditch play a crucial role in supporting the high groundwater levels within the peat. If these are not high, the peat will drain and water levels in the peat will drop.

The discrepancies which arise between the conceptual understanding presented here and that outlined by the applicant, in terms of data gaps which have been identified in this review, are discussed in more detail in Appendix B. The inconsistencies between the conceptual understanding given here and that of the applicant are documented in Appendix C.

4 Eco-hydrological Conditions

A National Vegetation Community (NVC) survey was conducted by Ecological Surveys in 2011. The results are shown in Figure 4-1 (Note. M habitats = mires, S = swamp and W = woodland). Table 4-1 presents the UKTAG classification NVC communities based on their dependence on groundwater[2]. Together they show that the communities in low lying areas are classified highly dependent on groundwater (e.g. M22d, M23, W4a). To an extent this may also suggest that these habitats are dependent on minerals/nutrients brought into the area from flooding. The pattern of groundwater dependent habitats and flood extents are similar (see Figure 4-2). In these areas of flooding, are significant areas of wet woodland, with a *Carex elongata* understorey. This species is of particular importance to the designation of the SSSI.

On the higher domed ground, the groundwater dependent communities are replaced by less dependent communities such as M27, S4b, S5. As they are above areas of normal flooding, these are dependent on precipitation. Though as noted in Section 3.5.1, they are also dependant on the high-water levels in surrounding ground to ensure they do not drain.

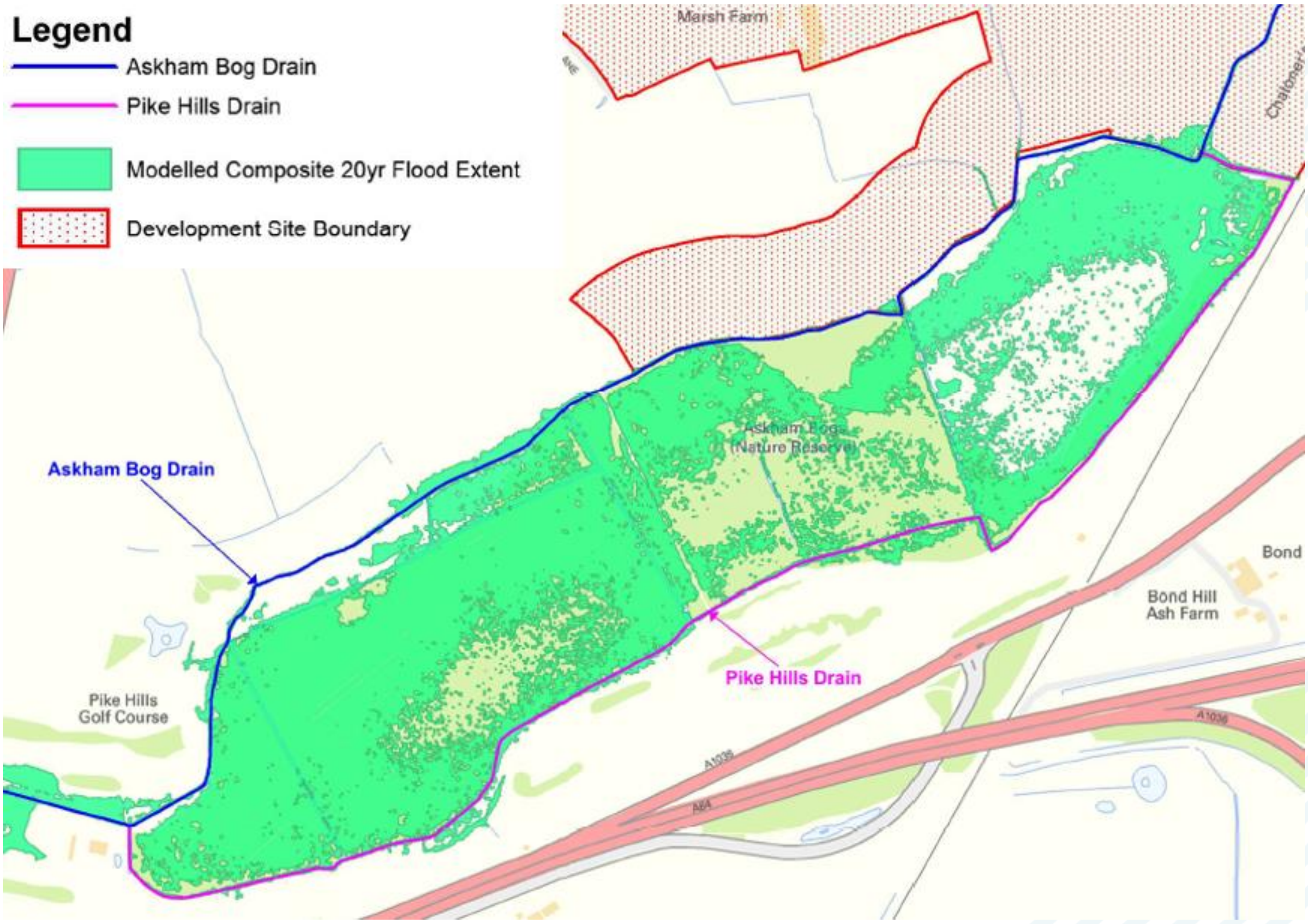
2 https://www.wfduk.org/resources%20/risk-assessment-groundwater-dependent-terrestrial-ecosystems

Figure 4-1: NVC Survey (Ecological Surveys 2011)

Table 4-1: Groundwater Dependency of NVC Communities on Askham Bog

NVC Community	Groundwater Dependency Classification
M22d *Juncus subnodulosus-Cirsium palustre* fen meadow *Iris pseudacorus* subcommunity	1
M23 *Juncus effusus/acutiflorus-Galium* palustre rush mire	1
M25 *Molinia caerulea-Potentilla erecta* mire	2
M27 *Filipendula ulmaria-Angelica sylvestris* mire	2
S4b P*hragmites australi*s reed bed *Galium palustre* subcommunity	3
S5 *Glyceria maxima* swamp	3
W10 - *Quercus robur-Pteridium aquilinum-Rubus fruticosus* woodland	N/A
W2 *Salix cinerea-Betula pubescens-Phragmites australis* woodland	2
W4a *Betula pubescens-Molinia caerulea* woodland	1
W5 *Alnus glutinosa-Carex paniculata* woodland	2
Dependence of community/ habitat on groundwater. Note. Dependency classification: 1=High, 2=moderate, 3=low	

Figure 4-2: 20yrs Return Period Flood Modelled Extent from Askham Bog Drain (from Appendix 13 of the ES)

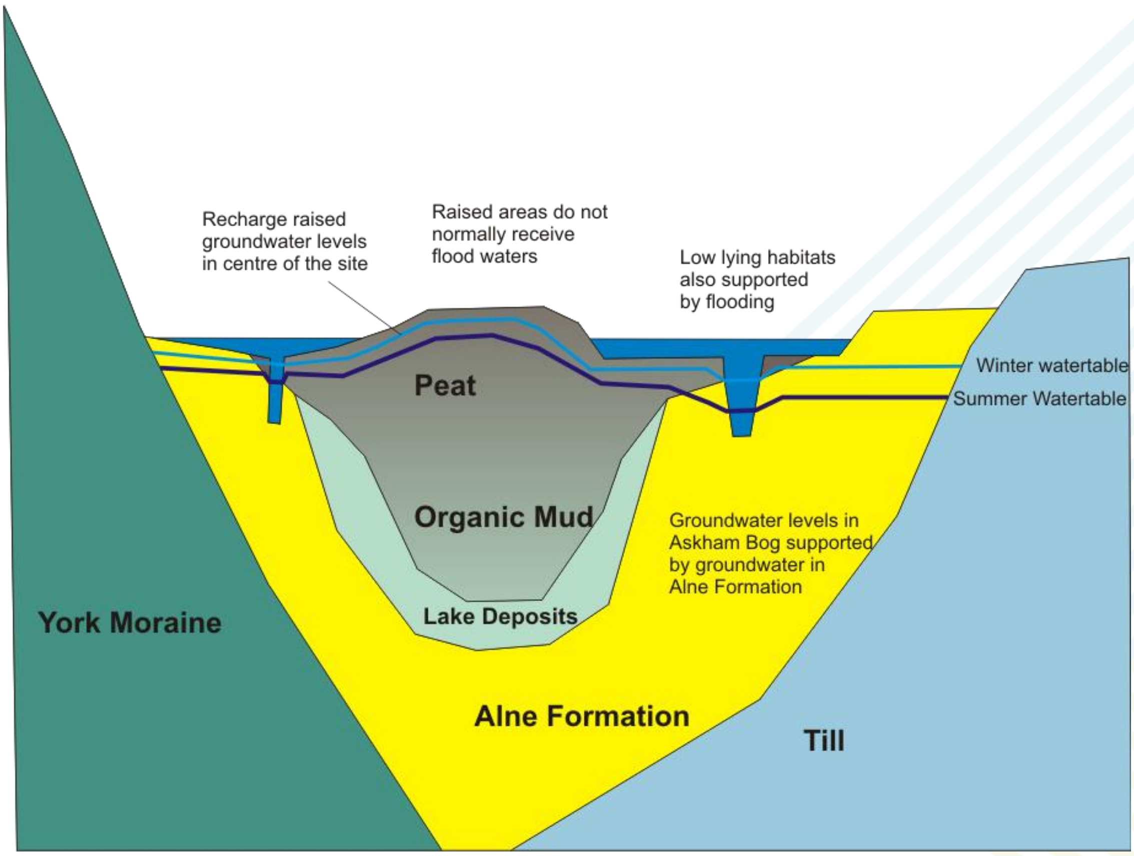


5 Ecohydrological Conceptual Model of Askham Bog

Based on the baseline description developed above, an ecohydrological conceptual model of Askham Bog has been developed. It is shown in Figure 5-1 and has the following features:

- The bog lies in a depression surrounded by boundary drains.
- The bog developed from the infilling of a lake, and is underlain by a series of clays, muds and peat.
- The wetland deposits are surrounded by the Alne Formation.
  - In the valley bottom, this formation is dominated by thick sand deposits.
- In the valley bottom, the Alne Formation and boundary drain show a strong hydraulic connectivity.
- High groundwater levels in the peat body are supported by water levels in the boundary drains and Alne Formation by two mechanisms:
  - Where the peat body is contained within lake bed deposits, a high groundwater table in the Alne Formation, limits the rate of lateral groundwater movement through the lake deposits
  - Where peat or peaty deposit (and especially thin deposits) lie directly on the Alne Formation, high groundwater levels in the Alne Formation limit/stop the vertical loss of water out of the peat deposits.
- On higher areas of the bog, shallow groundwater is supported by direct precipitation inputs. This results in lower nutrient conditions.
- On the low-lying habitats, flooding from the boundary drains and/or groundwater inputs from the Alne Formation bring nutrients/minerals into the area, which support the habitat types presents in these areas.

Figure 5-1: Eco-hydrological Conceptual Model of Askham Bog



6 Overview of Applicants Impact Assessment

The ecohydrological model developed shows how Askham Bog is supported. This can be used to identify if and how the development might change the water supply mechanisms that support the bog. As a result, any robust assessment should attempt to answer the following questions:

- Will the development affect groundwater levels in the sands of the Alne Formation in the valley bottom?
- Will the development affect water levels in the boundary drain?
    - Either through changes in run-off or by lowering of groundwater levels in the Alne Formation.
- Will the development affect flooding of the bog?

None of these have been addressed in the application's assessments.

The issue with the applicant's hydrological assessment is that it is based on a misunderstanding of how Askham Bog is supported. It assumes there is limited connectivity between the development site and the bog - "Monitoring work has proven that there is no groundwater connectivity between the Site and the SSSI" (Paragraph 12.87 of the ES). The eco-hydrological conceptual model presented in Section 5 indicates that this assumption amongst others (e.g. the role of flooding) is incorrect. As a result, the assessment upon which this is based is critically flawed and cannot be relied upon to identify significant impacts.

Without a good understanding of how the bog functions, the assessments have not identified key impact mechanisms. A number of these are explored in more detail below, and further evaluation is provided in Appendix D.

In addition, the assessment methodology used to undertake the impact assessment, and determine the significance of potential effects, is considered to be limited, and a review of the applicant’s approach to assessment methodology is given in Appendix A.

6.1.1 Potential Impacts

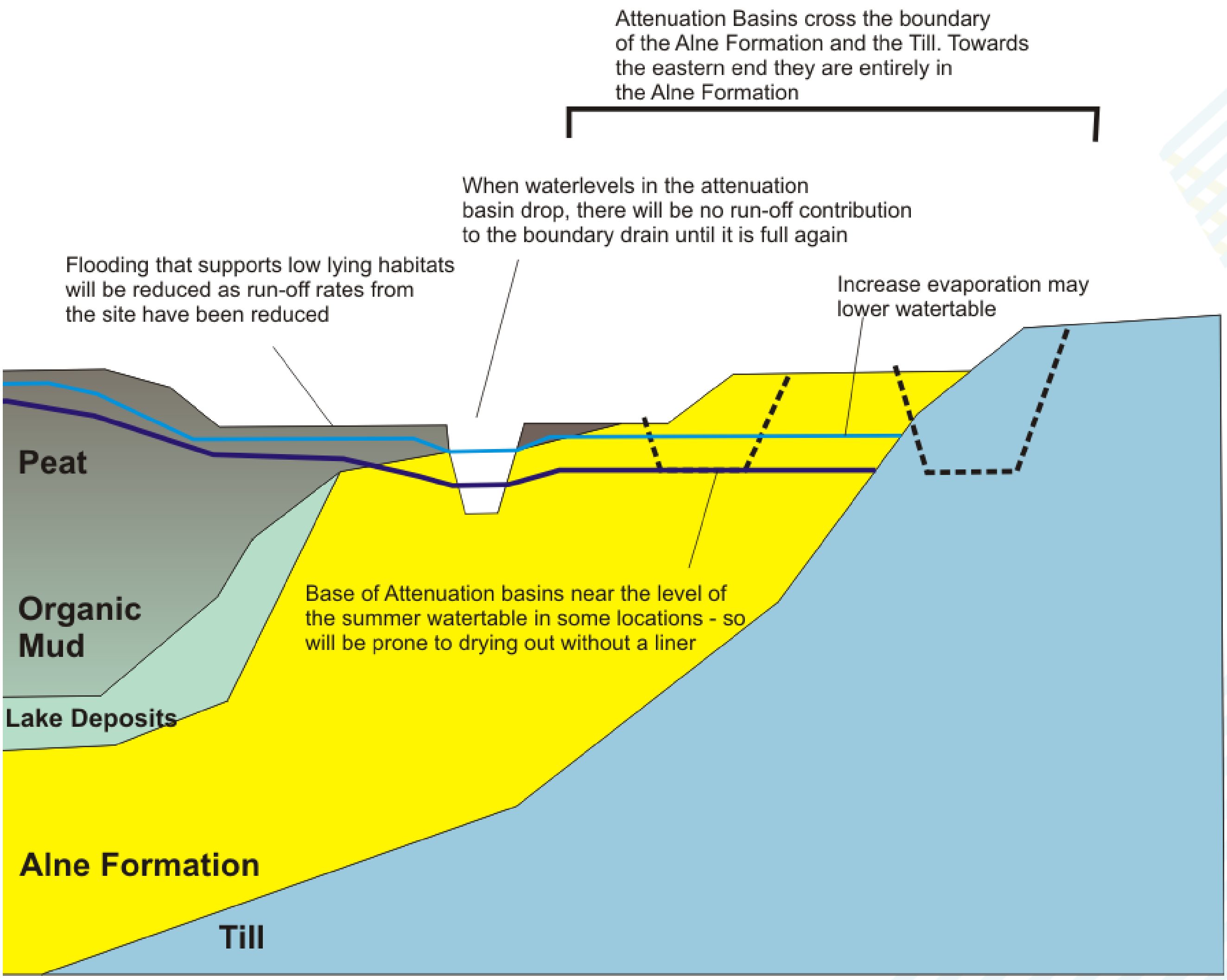
It is not the aim of this report to present a full eco-hydrological impact assessment of the effects of the proposed development on Askham Bog. However, through the development of the ecohydrological conceptual model, several important impact mechanisms have been identified. These are presented in Table 6-1 and Figure 6-1.

Table 6-1: Impact Mechanism Discussion

Eco-hydrological Control	Discussion	Impact
Attenuation Basin - Flooding	Periodic flooding is critical to the low-lying habitats of the bog. A 3.1 l/s/ha QBAR greenfield run-off rate (the run-off rate that has been calculated to be equalled or exceeded each year) from the site is presented in the FRA (Appendix 13.1 of the ES). The peak run-off rate from the attenuation basin is however "limited to 1.4l/s/ha". This is described as having the following impact: "Proposed surface water management strategy represents betterment through reducing the peak discharge rates into the receiving system" Reducing peak run-off rates to less than half what they were before, could have a significant impact on how Askham Bog	Flooding of habitats dependent on periodic flooding will decrease

	floods, and affect the habitats which are dependent on that type of periodic flooding.	
Attenuation Basin - groundwater	Site investigation indicates that the eastern attenuation basin will cut through thick sand deposits. The groundwater level range monitored in that area (BH14/07) suggests that the summer minimum level will be at or close to the base of the proposed attenuation basin. If the basin is not lined, it is likely to be prone to drying out in the summer. If it is lined, the basins will affect summer run-off from the site to the boundary drain (see table line below). If the basins are not lined, they will be directly connected to the watertable. The increase in evaporation through the construction of the basins, may generally lower the water table in the area, and water levels in the boundary ditch.	Basins may be prone to drying out. Increase evaporation may lower the groundwater table in the Alne formation and water levels Askham Bog Drain
Attenuation Basin -Surface water	When water levels drop below "normal level" in the attenuation basin, run-off from the development site to the boundary drain will cease. This may have significant impact to the quality and pattern of run-off entering the Askham Bog Drain. For example, if the attenuation base dries out in a dry period, no run-off from the site will enter Askham Bog Drain from the site, until the "normal level" is reached and water can flow out of the outfall chamber. This would exacerbate the effects of droughts on the bog	Basins will cut-off run-off entering the boundary drain, if/when water levels fall in the attenuation basin.

Figure 6-1: Impact Mechanism Conceptual Model



The assessment above has been able to illustrate a series of possible impact mechanisms from the development. These have not been adequately assessed by the applicant, and therefore until these have been, there are significant limitations in their assessments. This means that currently the information provided is not suitable to allow decision makers to understand the significant impacts of the scheme.

7 Conclusions

Overall, the review shows that the assessments supporting the application are critically flawed and cannot be relied upon to identify significant impacts. JBA's review however indicates there are a range of potential impact mechanisms crated by the proposed development that could detrimentally affect the eco-hydrological conditions of Askham Bog.

Appendices

The following appendices outlines a technical review of the applicant's submission.

A Assessment Methodology

This section considers how the assessments have been presented in the application. This critique stands alongside the consideration that the assessments did not correctly identifying potential impact mechanism from the site to the bog. This occurred by not firstly understanding the eco-hydrological conditions supporting the SSSI (see Section 6).

A.1 Document Structure

Consideration of the eco-hydrological impacts on Askham Bog are not well presented in the application. Elements are spread across several documents:

- Appendix 12.1 of the ES presents a short Hydrogeological Review from 2014.
- Appendix 12.2 of the ES presents a technical note on groundwater and surface water monitoring.
- The main hydrogeological impact assessment is presented in Chapter 12 of the ES.

Each document acts as an addendum to the last, with no one document presenting the applicant's full understanding. It would have been preferable for the appendices to contain a full hydrogeological risk assessment (see Section A.3) outlining all the pertinent baseline information and the risk assessment process. This could have then been synthesised in the main ES chapter. By not doing this, the assumptions used in the assessments are not always obvious.

A.2 ES Chapter 12 Assessment Methodology

Chapter 12 of the ES sets out the Significance Criteria. However, it is not shown how sensitivity and magnitude are combined to produce significance. It can only be inferred by the significance criteria examples presented in Table 12.2. None of the examples relate to ecological features of interest. No criteria for the sensitivity classification are presented in the assessment. The sensitivity of Askham Bog has been ascribed as ‘medium’ within the "Residual Effects Summary" table (Table12.3). However, Askham Bog is not identified as a separate receptor. Instead, paragraph 12.22 states that it has been included with a receptor called "Waterbodies and Surface Water (Askham Bogs, Askham Bog Drain, Pike Hill Drain, Marsh Farm Drain and other IDB watercourses within the site". Given that Askham Bog SSSI is a national designation it is not clear why it has only been given a medium sensitivity.

Overall, it is difficult to follow the logic of the assessment, because:

- a rationale for the sensitivity of Askham Bog is not given,
- Askham Bog is not treated as a separate receptor, and
- how sensitivity and magnitude have been combined to produce significance is not stated.

A.3 Hydrogeological Risk Assessment and Conceptual Models

The issues in the sections above could have been resolved if the ES assessment had been based on a Hydrogeological Risk Assessment (HRA).

Hydrogeological risk assessments are based on the development of a conceptual model, which can be defined as "a synthesis of the current understanding of how the real system behaves, based on both qualitative and quantitative analysis of the field data"[3].

A limited conceptual model is presented in the hydrogeological review in Appendix 12.1 of the ES, with no conceptual cross section provided. In Appendix 12.2 the monitoring is used to update the conceptual model, but this is done through a limited discussion, rather than a full reinstatement of the conceptual model.

Given that the potential impacts of the scheme (changes in recharge and groundwater flow paths) are similar to those of a dewatering activity, the Environment Agency's Hydrogeological Impact Appraisal for dewatering abstractions[3], provides relevant guidance. It states that a Hydrogeological Impact Assessment (HIA)"*must:*

- *be risk-based; that is, the effort and resources used to assess the impacts should be matched to the level of risk of environmental damage.*
- *emphasise the importance of developing a robust conceptual model of the site that is continually reviewed and updated as new information is collected.*
- *be able to distinguish between impacts caused by changes in flow, and those caused by changes in water level, and deal with them appropriately.*
- *result in an appropriate level of on-going monitoring, targeted at the issues of real concern.*
- *if relevant, take into account the mitigation of impacts by the return of water to the groundwater or surface water system.*
- *be able to cope with a variety of spatial scales (regional and local, for example)."*

In contrast to the guidance above, the assessments provided are limited, and poorly structured over several documents. By not continually developing the conceptual model within the three main documents presented, the rationale behind the assessments is not formally laid out or validated.

3 Environment Agency (2007) Hydrogeological impact appraisal for dewatering abstractions

B Document and Data Gaps

The data provided as part of the application appears to have a number of obvious gaps which has both made this review challenging, and also led to a number of unsupported assertions within the application being made by the applicant.

B.1 Previous Studies

The box below is from Chapter 12 of the ES.

Part of Para 12.18 of the ES main body
12.18 The following data has been used to establish the baseline: • Site observations through undertaking a site walkover (undertaken in July 2015); • Topographical survey (May 2014) • Previous studies including - Ove Arup & Partners Ltd, Yorkshire Wildlife Trust Askham Bog Restoration Project, Technical Report, (2003) and WWT Consulting report investigating the hydrological relationship between the Moor Lane site and the Askham Bog SSSI, (October 2013). This report comprises an eco-hydrological assessment of the site and includes a ditch network walkover of the site, a review of the 2003 Ove Arup report and a soil survey.

Neither listed documents from Ove (2003) nor WWT Consulting (2013) are provided by the applicant. By not including them, the only evidence presented regarding the hydrological and hydrogeological interactions between the development site and the SSSI are those presented in the applicant's assessments in Appendix 12 of the ES.

The ES chapter summarises the conclusion of the Ove (2003) and WWT Consulting (2013) reports, and states that "*Both make the conclusion that Askham Bogs is critically dependent on precipitation for water supply rather than surface water runoff or groundwater inputs*." This is used within the assessment to rule out impact mechanism affecting the bog. This summary is, however, a gross oversimplification of the conclusions of the report. For example, the conclusion of WWT (2013)[4] also notes:

> *"Although surface and sub-surface hydrological inputs from the land to the north of Askham Bog are not the primary hydrological input to the Bog they do play a role in maintaining water levels within the Beck. Any development on the land to the north of Askham Bog should ensure drainage designs do not have any detrimental impacts on the Holgate Beck and therefore Askham Bog.* ***To avoid this, water levels in the Holgate Beck and surrounding ditches should be maintained at their current levels by designing sustainable drainage features that mimic the current drainage network and current infiltration processes occurring across the site.****"*

Ove (2003) provides further information on the role of Askham Bog Drain. Section 14.2 of that report states:

> *"Records from dipwells 217 and 220 support the hypothesis that there is groundwater movement towards the Beck in the summer, but that the combination of reduced evaporation and flooding from the Beck sets up a horizontal water level in winter. In*

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4 The WWT 2013 report was provided to the Yorkshire Wildlife Trust during an earlier round of consultation

the dry winter of 2001/2002 Beck water levels did not rise high enough for overbank flow, and water levels in the logged dipwell were significantly lower than those in the other dipwells. This shows that outside the transpiration season the logged dipwell is influenced by Beck water levels, ***and that the zone of significant lateral groundwater movement to and from the Beck is at least 20m wide in this part of the site****."*

And Section 15.2 states:

> *"The Holgate Beck also seems to be a relatively unimportant source of water to the mire, as at current levels it functions mainly as a potential drain rather than as a source of supply. It does sometimes supply the site in periods of flood (generally in winter), but this appears to be more of nuisance value (by maintaining excessively wet conditions and helping to enrich the mire with nutrients) than a useful mechanism for augmenting the summer water table of the mire. Thus, whilst* ***the invert level of the Beck (itself maintained by a pumping station downstream) may possibly help to regulate the mire water table****, it is not an important water source."*

In these sections, the role of the boundary drain in maintaining conditions on the bog is stressed. Although it may not supply groundwater directly to the habitats, it supports groundwater levels in the bog. This understanding is lost in the conclusions of the PBA Technical Note 29th October 2015:

> *"The baseline groundwater and surface water monitoring data collected between July 2014 and September 2015 supports the conclusion of the Hydrogeological Review that the wetland system in the Askham Bog is fed, supported and maintained predominantly by direct precipitation, and not from* the *groundwater and surface waters across the wider Moor Lane site. The data suggests that the degree of hydraulic continuity between groundwater and the surface water features is low or very low, and also that there is normally limited hydraulic continuity between the Holgate Beck and the Askham Beck (unless active water level management takes place via the sluices present). It is recommended that this data and these conclusions be used to define the drainage strategy such that the proposed development does not have any adverse impact on the Askham Bog."*

Our review in Section 6.1.1 shows why it is necessary to understand how Askham Bog Drain supports the bog in order to fully appreciate the potential impacts of the scheme on the bog.

B.2 Natural England's Letter Dated 23rd June 2016

In the correspondence from Natural England (NE) (see box below, taken from Appendix 9.1 of the ES), there is a reference to an NE letter from 23rd June 2016 which is stated to provide "*clarification*" on why "*Natural England does not agree that there is no direct hydrological connectivity*". However, this letter is not provided in the application and, therefore, the rationale of why NE believed this to be the case. Neither is a systematic response to these concerns presented.

Letter from Natural England 19th December 2017 in Appendix 9.1: Baseline Ecology Report
With regard to the section of the Delivery Statement entitled Hydrology and Flood Risk (p7 of the Delivery Statement) Natural England does not agree that there is no direct hydrological connectivity between the site and Askham Bog. We would refer you to our letter dated 23/06/2016 for our clarification on this matter. We are not aware of any direct evidence that indicates that there is a risk from run-off of pesticides or nitrates from the adjacent area of level arable farmland.

It should be noted the letter date 19/12/2017 significantly postdates the last water level monitoring from the site presented in the ES Appendix 12 technical note from 29/10/2015.

This means when it was stated *"Natural England does not agree that there is no direct hydrological connectivity"*, the applicant had been in a position to share with NE the same hydrogeological and hydrological monitoring information provided in this application.

Table 12.1 of the ES reproduced in the box below states: *"NE agreed that there are technical /engineering solutions to mitigate potential hydrological issues associated with the development in this location"*. When the correspondence referred to in the table is reviewed (see next box below), it neither states that the NE agrees with the hydrological/hydrogeological assessments presented, nor that the design presented by the applicant at that time would have no significant impacts on the bog. It only states that there is likely to be a technical/engineering solution to developing the site. It also seems to disagree with the following quote from a PBA letter from the 7th July (assumed to be 2016), which states:

> *"In conclusion, we understand that NE agree that the development can come forward and not impact adversely on the Bog from a hydrological perspective…"*

In response NE states:

> *"Natural England make no comment on whether the application can come forward."*

If the two pieces of NE correspondence presented in this section are taken together it shows that NE:

- Did not believe that there is no hydrological connectivity between the development site and the SSSI,
- Or endorsed the applicant's mitigation designs.

As a result, the "positive response" referred to in Table 12.1 of the ES refers to appears to be very limited in its scope.

Table 12.1 of the ES

Consultee	Date and Time	Comments	Actions
Natural England	2015/2016 July 2018	Reports submitted to NE outlining the hydrological/hydro geological studies undertaken by PBA. The connectivity between the watercourses was validated through a review of water levels and water chemistry/water quality data observed over a 13 month monitoring period and it indicates that under 'normal' flow conditions there is no continuity between groundwater and surface water flows at the site/Askham Bog Drain and the Askham Bogs. NE response to EIA Scoping Opinion – no specific points raised in relation to water quality.	The development of the site will therefore have limited potential to affect water quantity and water quality within the Askham Bogs SSSI under normal conditions. NE agreed that there are technical /engineering solutions to mitigate potential hydrological issues associated with the development in this location – see positive NE response included in Appendix D of the FRA (**Appendix 13.1** of this ES)

Natural England Correspondence in Appendix B of the FRA in Appendix 13.1 of the ES

Sarah Kirby

From: Walsh, James (NE) <James.Walsh@naturalengland.org.uk>
Sent: 25 July 2016 12:57
To: Sarah Kirby; Michael Parkinson
Cc: Rebecca Mitchell; Christian, Simon (NE); Reaney Ruth (NE)
Subject: Moor Lane York - final summary response

Sarah

Thank you for your letter dated 7th July, the final paragraph of which states:

In conclusion, we understand that NE agree that the development can come forward and not impact adversely on the Bog from a hydrological perspective…

Natural England's advice regarding hydrology is as stated in our DAS advice of 23rd June 2016. It should be noted that Natural England make no comment on whether the application can come forward; our advice simply states that there are likely to be technical /engineering solutions to mitigate potential hydrological issues associated with the development in this location.

Kind regards

James Walsh
Lead Adviser
Yorkshire & Northern Lincolnshire Team
Natural England
Lateral
8 City Walk
Leeds
LS11 9AT

Office: 0208 026 8639
Mobile: 07887 625570

B.3 Site Investigation

The full factual site investigation report reference in Appendix 12.2 of the report is not reproduced in the application (see box below).

Appendix 12.2 - Scope of Site Investigations

A preliminary ground investigation focussing on the hydrogeology of the site was carried out between the 28th May 2014 and 6th June 2014, comprising the following;

- Fifteen cable percussion boreholes with groundwater monitoring standpipes installed
- Fourteen machine excavated trial pits
- Soil infiltration and variable head permeability testing
- Groundwater and surface water sampling and geoenvironmental laboratory testing
- Post field work monitoring of surface water and groundwater levels and quality
- A factual report (Allied Exploration and Geotechnics Ltd)

Some of the information is included in the ES appendices but a number of key elements are missing:

- The borehole logs used with the hydrogeological assessments (Chapter 12 and its appendices) are not presented within those appendices. Instead, they are presented in Appendix EDP 4 in Appendix 10.1 Historic Environment Baseline (these are inferred to be the same boreholes from their naming and locations. However, this information is not cross-referenced in Chapter 12).
- The Appendix 10.1 borehole logs give no details of how the monitoring wells at these locations were constructed, nor the date that they were constructed. This limits the usefulness of the groundwater level monitoring information presented in the application, as it is not possible to confirm which lithological units are being monitored.
- The permeability data is not included anywhere in the assessment, nor is it clear which boreholes were tested.

C Baseline Summary on Groundwater and Surface Water Monitoring (Appendix 12) Review

Appendix 12.2 of the ES presented a technical note outlining groundwater and surface water monitoring results. This is reviewed in the table below.

Table A 1 - Review of Appendix 12.2

Overview	Discussion
The rationale behind the locations of the monitoring points is not presented	Other than the map, no information is presented on the nature of the locations monitored, or why they were chosen. For example, no information is given for the gaugeboards on the size and role of the drains that were monitored, and whether the gaugeboards were locate in the deepest parts of the drain. In addition, when levels were low it is not clear whether the levels represented flowing water, or water being held in depressions within the drains.
Groundwater units monitored	The construction of the boreholes is not presented anywhere in the application. This means it is not clear which groundwater units are being measured at any given location.
Analysis in the framework of a conceptual understanding of the site	The monitoring analysis is not presented in the framework of a good conceptual understanding of the conditions. This means that review is not informed by understand of if and when surface and groundwater is expected to be connected. For example, it is unlikely that BH14/01 and GB02 (Figure 1 of Appendix 12.2 of the ES) would have a strong connectivity as GB02 appears to be in a small drain on relatively high ground while BH14/01 mainly cuts through low permeability till. However, by not understanding that BH14/07 is on thick sand and only comparing the water level results to a few levels in GB05 (Figure 7 of Appendix 12.2 of the ES), the strong connectivity with levels in Askham Bog Drain (shown in this report in Section 3.4) was missed.
Water Quality Data	The report states: *"The Trilinear Plot indicates that the groundwaters are different in major ion composition, both from the surface waters and from each other, with a wider spread of results, but they are generally richer in calcium cations and carbonate/bicarbonate anions than the surface water. This trend is consistent throughout the monitoring period and does not appear to show distinct seasonal variations."* These differences are not consistently clear across the datasets and, without information on which groundwater units were sampled, it is difficult to draw meaningful conclusions from the information.

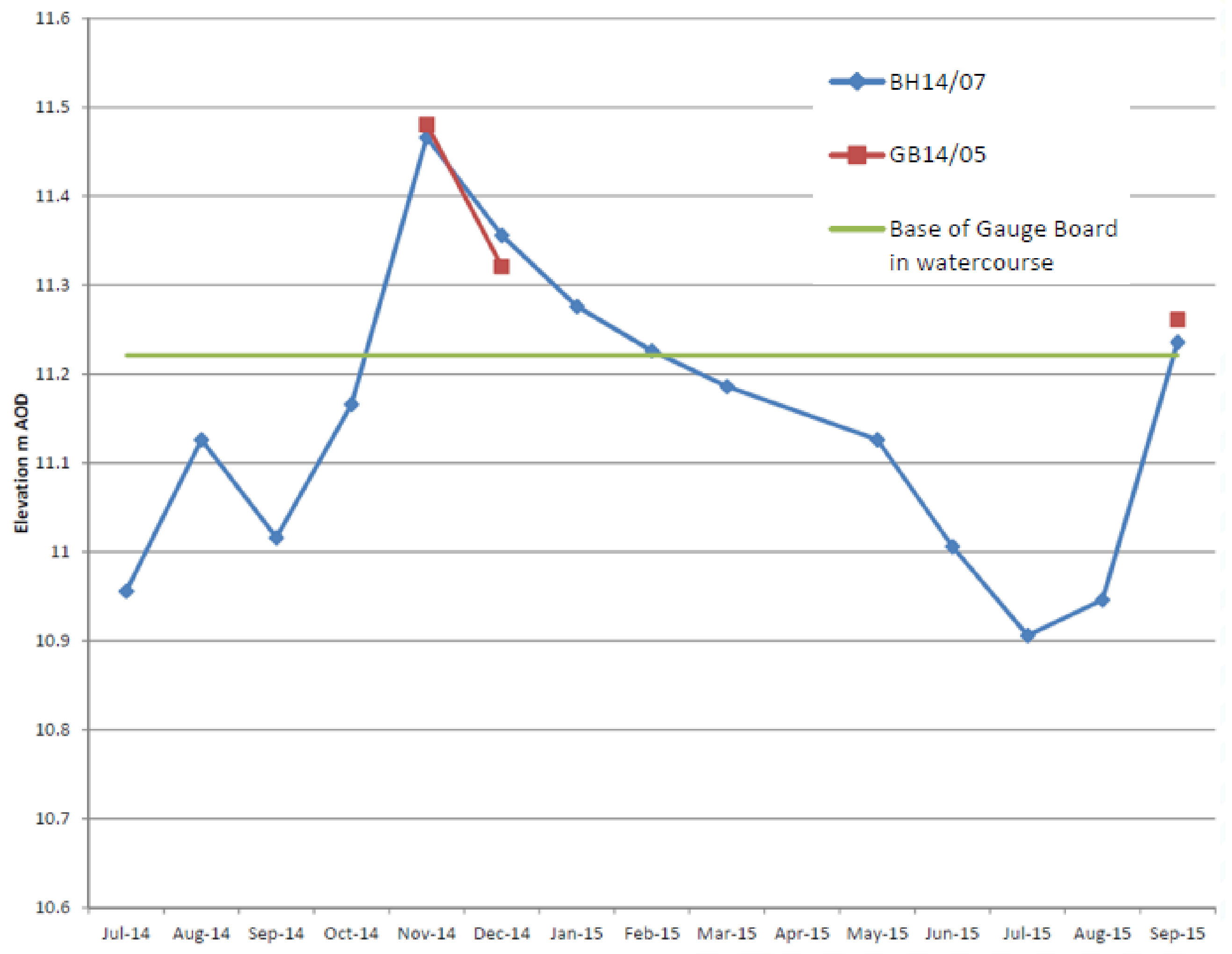
D Impact of the Attenuation Basin

Section 6.1.1 outlines a series of potential impact mechanisms from the development on Askham Bog. The sections below provide further detail on these mechanisms.

D.1 Attenuation Basin and Groundwater

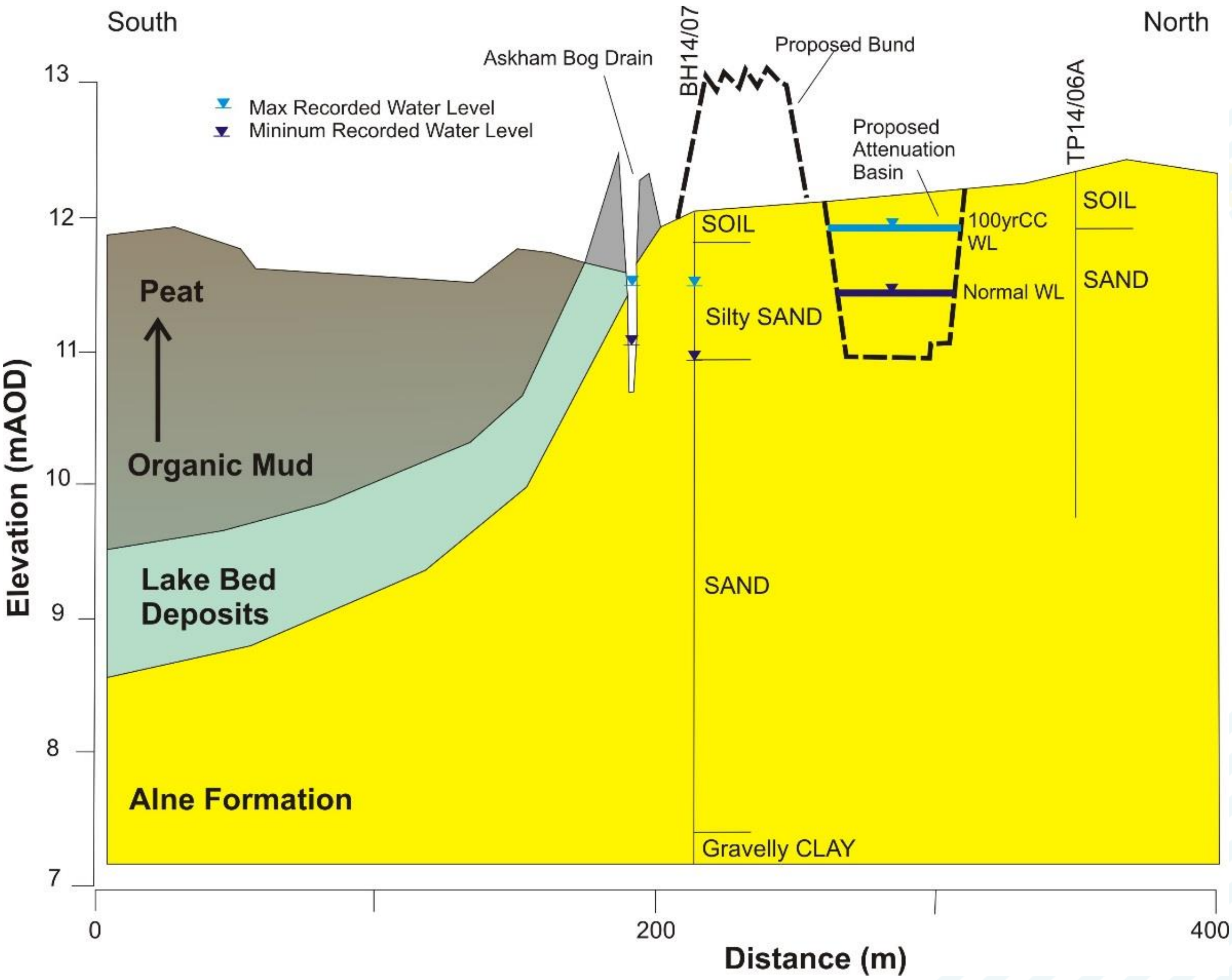
Groundwater level records for BH14/07 (see box below) indicate a minimum groundwater level of circa 10.9mAOD. Met office anomaly data indicates that the summer of 2014 and 2015 were relatively dry[5]. However, there is no reason to assume this minimum level would not be frequently reached in the future.

Figure 7 from Appendix 12.2



5 https://www.metoffice.gov.uk/climate/uk/summaries/anomacts

Figure A 1: Geological Cross Section with Monitored Water levels and the Bund and Attenuation Basin Design



The base of the attenuation basin is designed to lie at 10.92mAOD. The cross section above shows the level of groundwater at BH14/07 relative to the attenuation basin. If the attenuation basin was not lined, then it is likely that it would reflect the groundwater levels in the area. This means the attenuation basin would be prone to drying out, as the minimum recorded groundwater levels are at the base of the attenuation basin.

If the attenuation basin was lined, this may partly resolve the issue of the attenuation basin drying out, but there may be significant impacts on run-off (see section below). It should be noted that the application makes no reference to lining the attenuation basin.

D.2 Attenuation Basin and Surface Water Run-off

No water budget is presented for the attenuation basin to show whether there is sufficient water to supply the attenuation feature, or the variation in water levels that the basin might experience.

If the water levels in the attenuation basin fall below "Normal Levels" run-off will be cut-off from entering the attenuation basin until normal levels are reached again, and water can discharge via gravity from the penstock regulators. The calculation below presents an assessment of how long this would delay run-off entering Askham Bog Drain at the end of a typical summer. It is based on:

- the assumption that there is no/limited lateral groundwater movement in or out of the basin (the discussion in the section above shows this would only be achieved through a liner).
- A simple annual water budget for the area (data in Table A 2).

Table A 2: Average Annual Water Budget for Climate Area 12

Month	Rainfall	Potential Transpiration	Effective Rainfall
1	58	3	55
2	47	10	37
3	39	30	9
4	42	53	-11
5	50	77	-27
6	47	87	-40
7	58	86	-28
8	75	69	6
9	56	43	13
10	51	22	29
11	68	5	63
12	52	1	51
Total	643	486	157
Source MAFF, The Agricultural Climate of England and Wales, 1984			

The water budget above shows that, in a normal summer period, the effective rainfall is - 106mm. With no other inputs or outputs this would lead to the attenuation basin dropping by 10.6cm or a volume of 29,069m^3 (see Table A 3). The annual catchment run-off (31,957m^3) was calculated by multiplying the catchment area by annual rainfall and by the surface percentage run-off. The summer loss of water from the attenuation basin equates to circa 8% of run-off coming off the site in an average year. This means that in a typical year, the attenuation basin may stop run-off entering Askham Bog Drain the for around a month as the attenuation basin fills up. This may be significantly longer during dry years.

Table A 3: Estimate of Run-off Inputs to Attenuation Basin Require to Fill it after a Typical Summer Dry Period

Parameter	Units	Value
Annual Rainfall	mm	643
Catchment Area	m^2	142000
Annual Catchment Rainfall	m^3	91306
Surface Percentage Run-off (SPR)	%	35
Annual Catchment Runoff	m^3	31957.1
Attenuation Basin Area	m^2	24621
Attenuation Basin Summer Loss	m^3	2609.8
Proportion of Annual Catchment Runoff	%	8.2
SPR, catchment and basin sizes from Appendix 13 of the ES		

This calculation is relatively simple and based on several assumptions. However, it aims to provisionally illustrate the potential impact of the attenuation basin on run-off and how a robust water budget, taking into account a range of conditions, would be needed to fully understand the implications of the attenuation basin on run-off inputs into Askham Bog Drain. Nonetheless, it is, sufficient to indicate the cut-off of water inputs for a significant period, when water levels in the boundary drain are at their lowest. This would exacerbate the effects of drought on Askham Bog.

References

BGS (1999) Field Guide to the Glacial Evolution of the Vale of York Internal Report IR/04/106

Ecological Surveys (2011) National Vegetation Classification Survey - Askham Bog

Ove Arup & Partners Ltd (March 2003) Yorkshire Wildlife Trust - Askham Bog Restoration Project - Technical Report

Wildfowl and Wetland Trust (2013), Investigating the hydrological relationship between the Moor Lane site and Askham Bog SSSI