Haweswater Aqueduct Resilience Programme - Proposed Bowland Section

Environmental Statement

Volume 4

Appendix 7.2: GWDTE Assessment

June 2021

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Project No:	B27070CT
Document Title:	Proposed Bowland Section Environmental Statement Volume 4 Appendix 7.2: GWDTE Assessment
Document Ref.:	LCC_RVBC-BO-TA-007-002
Revision:	0
Date:	June 2021

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1. Overview

1) This appendix follows the UK Technical Advisory Group (UKTAG) guidance[1] to identify, prioritise and assess the impacts of the Proposed Bowland Section on Groundwater Dependent Terrestrial Ecosystems (GWDTEs).

2) This appendix only discusses potential impacts on groundwater flows and quality that support ecosystems. Other impacts on vegetation and habitats are discussed in Chapter 9A: Terrestrial Ecology.

3) In some instances, the ecological sites listed in Chapter 9A: Terrestrial Ecology have been grouped together within this assessment to form one larger GWDTE site. In most cases, this is due to the habitats being of similar nature, geographically connected, and/or hydrologically linked. Where this is the case, this is clearly stated in the relevant habitats and vegetation sections for each site.

4) The overarching GWDTE assessment area is defined as a 200 m buffer (as shown in Annexe A: Site Specific Figures for CSMs of this appendix) in all directions around the surface works for the Proposed Bowland Section (see Chapter 7: Water Environment). Within this assessment area, the zone of influence of dewatering for the nearest shaft has been used as a buffer around all surface works items as a way of prioritising those sites which could experience significant direct or indirect effects as a result of the Proposed Bowland Section, and which would require the creation of individual Conceptual Site Models (CSMs). This is referred to as the refined GWDTE assessment area.

5) As shown on Figure 7.7, there are eight sites which lie within the refined GWDTE assessment area for the Proposed Bowland Section, for which individual CSMs have been developed. Potential additional GWDTEs that lie outside of the priority area for assessment and which do not have individual CSMs are listed in Section 2.9.

6) Further details on the approach adopted to identify GWDTEs, the information and data available for their assessment, their prioritisation and value attribution, and the limitations associated with the assessment are provided in Chapter 7: Water Environment, to which this report forms an appendix.

[1] UKTAG (2005) Draft Protocol for Determining "Significant Damage" to a "Groundwater Dependant Terrestrial System".

2. Design Evolution

7) Section 3 describes the potential impacts that could occur as a result of the Proposed Bowland Section, including during the enabling, construction, commissioning and operation phases.

8) However, reducing potential impacts on ecological receptors and GWDTEs has already been encompassed into the various stages of design development (where possible).

9) It is therefore important to capture and record the design considerations made to date, which are of relevance to GWDTEs, including:

- Design iterations that have reduced the footprint of the Newton-in-Bowland Compound in the south, including the proposed access road, which has been re-designed to minimise direct impacts as much as feasibly possible
- Use of existing roads to provide access to the Lower Houses Compound in the north. This has removed the need to construct new access roads in alternative locations.

10) The design at the Lower Houses Compound, Newton-in-Bowland Compound and associated shafts is however constrained by a number of factors:

- The access road proposed, which requires a connected circuit as there is not enough room to accommodate traffic volumes to the east due to the steep topography (Newton-in-Bowland Compound only)
- The steep topography which limits the compound location, footprint and access
- The level of the existing Haweswater Aqueduct
- The need to keep the proposed shaft some distance away from the existing aqueduct
- The complex connections required
- The exact connection point to the existing Haweswater Aqueduct, which is hard to determine at this stage and requires a degree of flexibility
- The requirement for suitable access, providing a gradual gradient to accommodate heavy plant and machinery.

11) As a result of these constraints, no further design options could be identified to minimise the impacts to GWDTEs.

12) However, Chapter 7: Water Environment records additional mitigation measures proposed to further reduce the potential impacts predicted to the identified GWDTEs.

3. Site Specific GWDTE Assessments

3.1 Lower House Cottage

3.1.1 Site Setting, Topography and Hydrological Catchment

13) The site comprises a small patch of land located 100 m southwest of Lower House Cottage. An access track runs along the site's northern boundary.

14) The site forms part of a steep valley side that slopes northeast towards the River Hindburn Main River. The elevation of the site ranges from 172 metres above Ordnance Datum (mAOD) in the south to 168 mAOD in the northeast.

15) Two river valleys are located either side of the site. Cod Gill Ordinary Watercourse flows northeast in the valley situated along the northern boundary of the site.

16) The hydrological catchment for Lower House Cottage extends approximately 470 m southwest where the ground reaches an elevation of around 200 mAOD.

3.1.2 Soils and Geology

17) Soils at the site are described as slowly permeable seasonally wet acid loamy and clayey soils with impeded drainage[2].

18) Geological mapping indicates that the northern third of the site is underlain by superficial deposits of glacial till, comprising clay, sand and gravel[3]. Superficial deposits are shown to be absent from the rest of the site. Bedrock is the Claughton Member, belonging to the Silsden Formation, and typically comprises interbedded shaly siltstone and sandstone.

19) There was GI[4] (see Chapter 7: Water Environment) available close to the site at the time of writing. The nearest available historical borehole record is located 145 m northeast (Annexe A)3. As shown in Table 3.1, a layer of clay was recorded underlying topsoil to a depth of 2 metres below ground level (mbgl). At this depth, a light grey shale bedrock was encountered, which from 13 mbgl alternated with sandstone bands to the borehole completion depth of 60 mbgl.

20) This is consistent with the mapped superficial and bedrock geology at the borehole's location. A similar lithology profile is expected in the north of the site, with no superficial cover in the centre and south.

[2] http://www.landis.org.uk/soilscapes/
Cranfield Soil and Agrifood Institute (2020) *Soilscapes viewer*. [Online] Available from: URL. [Accessed: July 2020].
[3] http://mapapps2.bgs.ac.uk/geoindex/home.html
British Geological Survey (2020a) *Onshore GeoIndex*. [Online] Available from: URL. [Accessed: July 2020].
[4] Draft unchecked GI package received by end of April 2020 (data freeze).

Table 3.1: Historical Borehole Records Close to Lower House Cottage

Borehole ID	Relation to site	Top (mbgl)	Base (mbgl)	Lithology Description
SD66NW8	145 m northeast	0	1.20	Topsoil
		1.20	2.00	Clay
		2.00	13.00	Light grey shale
		13.00	60.00	Alternating between dark and light grey shale with sandstone bands

3.1.3 Groundwater

21) There are no Environment Agency (EA) or British Geological Survey (BGS) groundwater monitoring locations or GI borehole data available close to the site at the time of writing to provide an indication of groundwater seeps, strikes, or rest water levels. In addition, given that the historical borehole record is located 145 m from the site, and at a lower elevation, extrapolating groundwater levels from the borehole's location is unlikely to provide an accurate representation of groundwater levels at the site.

22) Lower House Cottage was added to the assessment following an update to habitat mapping that took place after hydrogeological walkover surveys had been completed. Consequently, this site has not been surveyed.

23) BGS data suggest that the site is not susceptible to groundwater flooding[5]. However, there is potential for groundwater flooding to occur at surface level, and / or to property or infrastructure situated below ground level in areas surrounding the site, which broadly correlate with areas where glacial till is expected to be present.

24) There are no springs shown on Ordnance Survey maps close to the site. However, the presence of shallow groundwater cannot be ruled out, particularly given the high potential for groundwater flooding to occur in areas surrounding the site. Localised baseflow contributions are also expected to Cod Gill, from groundwater flowing northwards in the bedrock and superficial aquifers (where present). If the topography drops sufficiently in the vicinity of the watercourse, then at times, the water table may intersect, or approach the ground surface in the north of the site.

3.1.4 Habitats and Vegetation

25) A Phase 1 Habitat Survey was carried out for the site by Bowland Ecology Ltd. in April 2020[6]. No National Vegetation Classification (NVC) or Scotland & Northern Ireland Forum for Environmental Research (SNIFFER) WFD95 Wetland Typology surveys were undertaken at the site. A detailed description of the data collected, and methodologies used for the ecology surveys in the Proposed Bowland Section is provided in Chapter 9A: Terrestrial Ecology.

26) The Phase 1 Habitat Survey classified the entire site as a marsh / marshy grassland habitat type, surrounded by poor semi-improved grassland.

27) Marsh / marshy grassland habitats can often form GWDTEs in the right hydroecological setting. This is considered in the CSM section below, where a groundwater dependency is assigned to the site considering all available information, including geology, groundwater level information, habitats etc.

28) There are no ecological designations present within the site.

[5] British Geological Survey (2020b) Susceptibility to groundwater flooding. A dataset provided by Groundsure Limited.
[6] Bowland Ecology Ltd. (2020a) TR3 Phase 1 Habitat Assessment Report. A report produced for United Utilities PLC.

3.1.5 Initial Conceptual Site Model

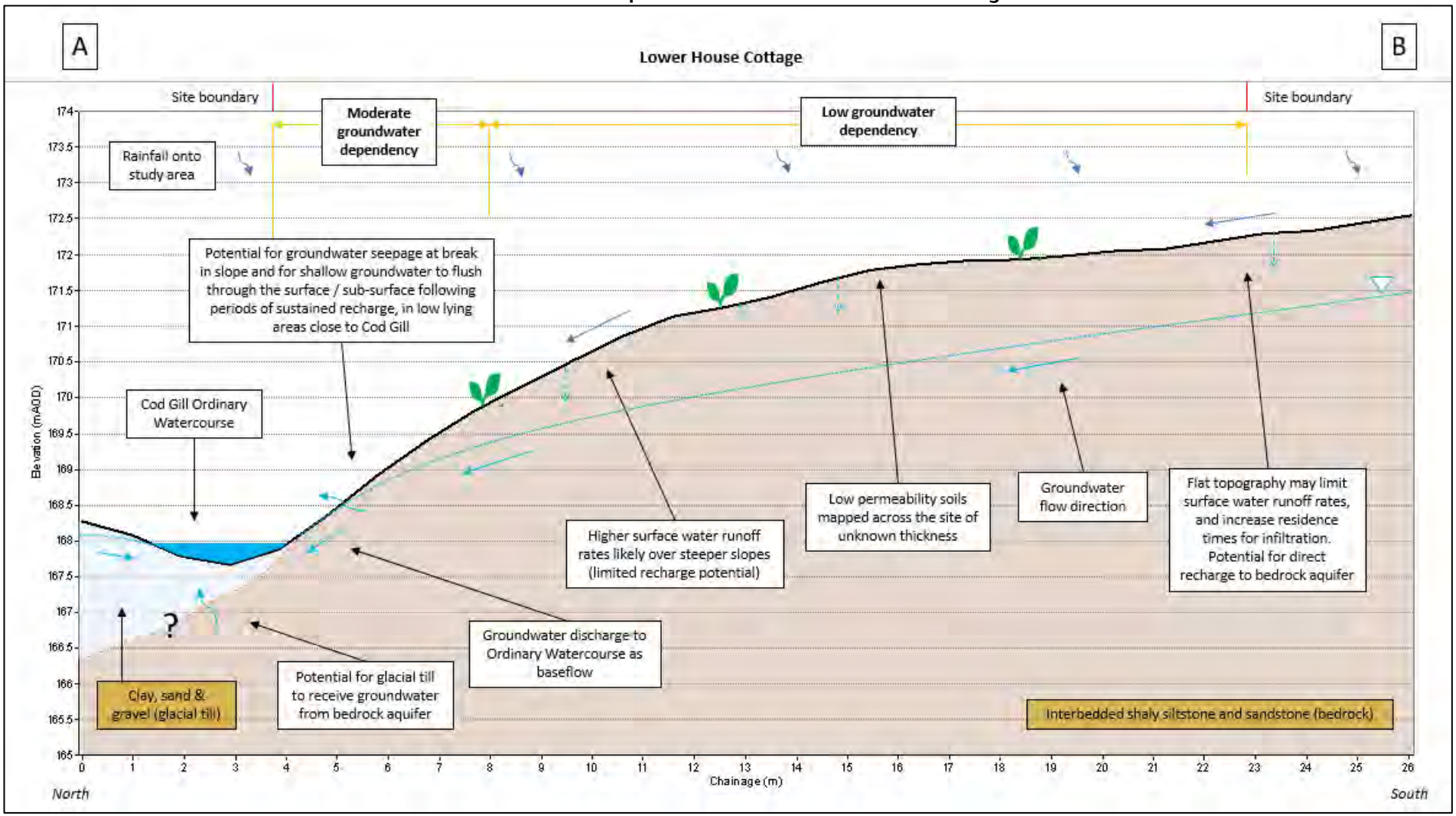
29) Illustration 1 shows a conceptualised cross-section running north to south through the centre of the site (Section A-B). The CSM highlights the indicative movement of groundwater and surface water through the site, and interpreted groundwater dependencies supporting vegetation and habitats.

30) Where superficial deposits are thin or absent, the bedrock aquifer is able to receive direct recharge inputs. The low permeability soils in the surrounding area may limit infiltration (and recharge) rates to a degree, depending on the exact lithology and thickness of the soil profile. But the break in slope that is present in the centre of the site provides potential for shallow groundwater emergence, as it follows the topography and flows northeast towards Cod Gill. Following periods of rapid or sustained recharge to the bedrock aquifer, the water table may intersect, or approach the ground surface, in the north of the site, such that the marsh habitats and vegetation in this location are expected to be moderately groundwater dependent.

31) Further up the hillside, there are no sudden changes in topography, no springs shown on Ordnance Survey maps, and no site-specific hydrogeological data to suggest that groundwater levels are particularly shallow in this location. However, given the data gaps present, GWDTEs cannot be ruled out. The southern half of the site is therefore classified as having a low groundwater dependency.

32) Annexe A shows the classification of groundwater dependency at the site. Given that there are no ecological designations at the site, according to Chapter 7: Water Environment, the sensitivity of the GWDTE is medium to low.

Illustration 1: Conceptual Site Model for Lower House Cottage



3.1.6 Assessment of Effects

33) The site lies 5 m northeast of the Lower Houses Compound at its closest point (Annexe A), and downgradient in terms of groundwater flow.

Enabling Works

34) The site is located outside the estimated dewatering zone of influence for the attenuation pond (see Chapter 7: Water Environment) and, although downgradient, it lies 160 m northeast of the activity. As shown in Table 3.2, no impacts on groundwater flows and levels at the site due to dewatering are therefore predicted.

35) Groundwater flow disturbance could occur within the compound area due to compaction-related construction activities and earthworks that do not require dewatering, i.e. topsoil stripping and construction of the temporary and permanent access tracks. Topsoil stripping would involve excavation to a maximum depth of 0.5 m and may not intercept groundwater. If groundwater flows were disturbed, however, given that the site lies immediately downgradient of the works area, the impact on groundwater flows and levels at the site could be moderate. This would result in a Moderate or Slight significance of effect, depending on the groundwater dependency of areas.

36) Ground disturbance due to topsoil stripping, vegetation clearance and excavation could also impact on groundwater quality, due to mobilisation of suspended solids and associated solutes (see Chapter 7: Water Environment). As the proposed works would reach a maximum depth of 0.5 m, significant migration of suspended solids is unlikely, due to the filtering effect of aquifer material. In addition, the Construction Code of Practice (CCoP) includes embedded mitigation measures associated with controlling silt pollution. However, there is potential for a minor magnitude change in groundwater quality at the site, due to groundwater flow directions and the potential contaminant pathways between the works area and the site. This would result in a Slight or Neutral significance of effect, depending on the groundwater dependency.

37) The CCoP also refers to guidance on Pollution Prevention measures, including the development of a Construction Environmental Management Plan (CEMP). The migration of contaminants from the compound area as a result of accidental spills and leaks of fuels and chemicals (including cement and sewage) would likely lead to a minor magnitude change in groundwater quality at the site, resulting in a Slight or Neutral significance of effect, depending on the groundwater dependency of areas.

Construction Phase

38) The site lies outside of the estimated dewatering zone of influence for the shaft and although downgradient, the site is located 165 m northeast of this activity. Given the distance, no impacts on groundwater flows and levels at the site due to shaft dewatering are therefore predicted.

39) Construction of the open-cut connection would also likely require dewatering. However, the site lies 20 m downgradient of the estimated zone of influence for this activity. Consequently, the impact on groundwater flows supporting GWDTEs at the site would likely be negligible, with any groundwater flow disturbances equilibrating upgradient of the site boundary. This would result in a Neutral significance of effect.

40) The magnitude of change on existing groundwater quality at the site, due to mobilisation of suspended solids and / or accidental spills and leaks is expected to be minor. Considering the embedded mitigation measures referred to in the CCoP, should contaminants within shallow groundwater from the works area reach the site, this would result in a Slight or Neutral significance of effect, depending on the groundwater dependency of different areas within the site.

Operation Phase

41) The below ground shaft structure has the potential to permanently alter localised groundwater flows and levels within the compound area. However, the shaft would be located 190 m upgradient of the site and so no impacts to groundwater flows and levels at the site are predicted.

42) The open-cut construction method proposed for the connection structure means that the trench would be backfilled with arisings or a granular bedding material. Depending on the nature of the backfill material, a preferential groundwater flowpath or barrier to groundwater flow could be created. The backfilled excavation would be located 45 m upgradient of the site, and any localised disturbances to groundwater flows would likely equilibrate up-gradient of the site, such that no impacts on groundwater levels and flows supporting the GWDTE are expected.

43) In addition, given the nature of the topography in this area, groundwater flowpaths are unlikely to be routed from the proposed permanent access track to the site, which lies across the hillside from this asset. Hence no long-term impacts to the GWDTE are expected from minor and localised groundwater disturbances associated with the below ground element of the road.

Summary

44) A summary of the potential impacts to the site is provided in Table 3.2.

Table 3.2: Summary of Effects to Lower House Cottage

Groundwater Dependency	Ecological Designation	Sensitivity	Effect Type	Phase	Magnitude of Impact	Significance of Effect
Moderate to low	None	Medium to low	Attenuation pond dewatering (groundwater levels / flows)	Enabling	No impact	No effect
			Shaft dewatering (groundwater levels / flows)	Construction	No impact	No effect
			Open-cut connection dewatering (groundwater levels / flows)	Construction	Negligible	Neutral
			Intercept flows in short term, including ground compaction (groundwater levels / flows)	Enabling	Moderate Adverse	Moderate
			Accidental leaks / spills, of fuels and chemicals, including cement and sewage (groundwater quality)	Enabling / Construction	Minor Adverse	Slight
			Mobilisation of suspended solids (groundwater quality)	Enabling / Construction	Minor Adverse	Slight

Groundwater Dependency	Ecological Designation	Sensitivity	Effect Type	Phase	Magnitude of Impact	Significance of Effect
			Intercept flows in long term, i.e. loss of aquifer storage, backfilling materials, and ground settlement in superficial deposits (groundwater levels / flows)	Operation	No impact	No effect

3.2 Lower House Cottage West

3.2.1 Site Setting, Topography and Hydrological Catchment

45) The site comprises a narrow strip of land, trending north-south, and located approximately 300 m west of the Lower House Cottage site. This site also forms part of the River Hindburn's steep valley side.

46) The site broadly follows the 185 mAOD contour and lies perpendicular to the general topographic gradient, which drops steeply towards the northeast. The site does, however, slope gently northwards due to its length, with the elevation of the site ranging from 189 mAOD in the south to 181 mAOD in the north.

47) According to Ordnance Survey maps, an unnamed Ordinary Watercourse issues immediately south of the site, flows north through the centre of the site, and exits via its northern boundary.

48) The hydrological catchment for Lower House Cottage West extends approximately 250 m west, where the ground reaches an elevation of 195 mAOD.

3.2.2 Soils and Geology

49) Soils at the site are described as slowly permeable seasonally wet acid loamy and clayey soils with impeded drainage[7].

50) Geological mapping indicates that the site is underlain by glacial till, comprising clay, sand and gravel[8]. Bedrock is shown to be the Claughton Member, comprising interbedded shaly siltstone and sandstone.

51) No GI data[9] was available (see Chapter 7: Water Environment) close to the site at the time of writing. The nearest historical borehole record lies 125 m northwest of the site, but there is no geological information contained within the borehole log to verify published geological mapping[8].

3.2.3 Groundwater

52) There are no EA or BGS groundwater monitoring locations, or GI boreholes available close to the site to provide an indication of groundwater seeps, strikes, or rest water levels. In addition, the nearest historical borehole record does not provide any groundwater level information.

53) The site was added to the assessment following an update to habitat mapping that took place after hydrogeological walkover surveys had been completed. Consequently, this site has not been surveyed.

54) BGS data suggest that there is limited potential for groundwater flooding to occur at the site and in the surrounding area[10].

[7] Cranfield Soil and Agrifood Institute (2020) *op. cit.*
[8] British Geological Survey (2020a) *op. cit.*
[9] Draft unchecked GI package received by end of April 2020 (data freeze).
[10] British Geological Survey (2020b) *op. cit.*

3.2.4 Habitats and Vegetation

55) A Phase 1 Habitat Survey was carried out for the site by Bowland Ecology Ltd. in April 2020[11]. No NVC or SNIFFER surveys were undertaken at the site (see Chapter 9A: Terrestrial Ecology for a detailed description of the data collected, and methodologies used for the ecology surveys in the Proposed Bowland Section).

56) As shown in Annexe A, the site is dominated by marsh / marshy grassland habitats, surrounded by expanses of improved grassland to the north, and poor semi-improved grassland in the south.

57) There are no ecological designations present within the site.

3.2.5 Initial Conceptual Site Model

58) The CSM shown in Illustration 2 highlights the indicative movement of groundwater and surface water through a west-east section of the site (Section A-B).

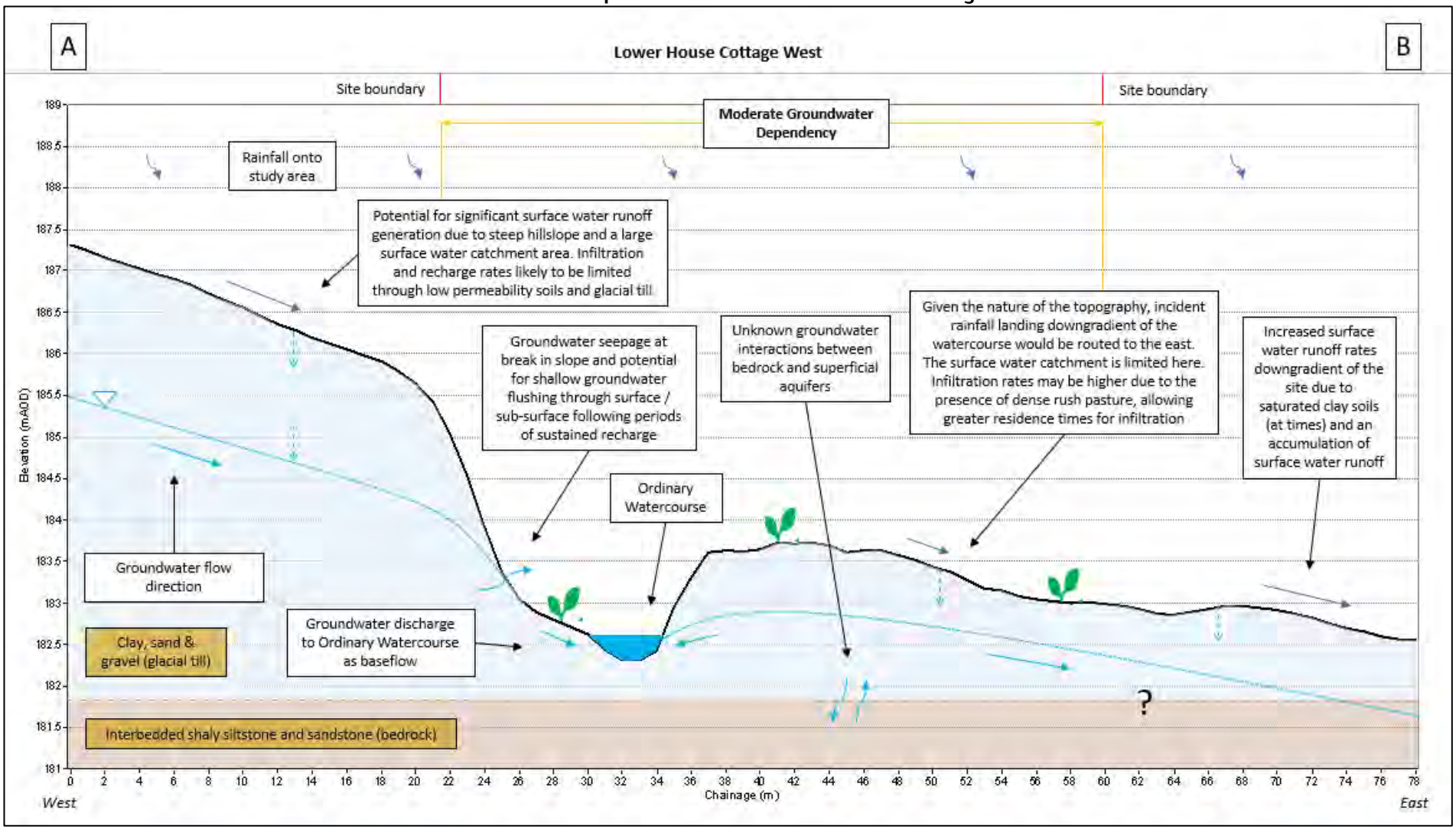
59) Within the site boundary and upgradient of the Ordinary Watercourse, there is a sudden drop in the topography, such that the water table may intersect the ground surface and promote shallow groundwater emergence, in the form of groundwater seepages. Overland flows would also be routed towards the northeast and may accumulate along the edges of the watercourse channel prior to discharge. The marsh habitat on the watercourse's upgradient side is therefore expected to be fed by a combination of both groundwater and surface water inputs and is assessed as having a moderate groundwater dependency.

60) Downgradient of the Ordinary Watercourse, the topography flattens and any ponded surface water present (following rainfall events), would have longer residence times for infiltration, meaning that recharge rates through the glacial till may be higher here compared to other parts of the catchment. With the Ordinary Watercourse intercepting surface water runoff from the west, the area immediately downgradient of the watercourse channel forms the head of a new catchment, and groundwater contributions to the marsh habitat will be an important sustaining mechanism in times of limited or no rainfall. Further downslope, as surface water runoff rates begin to increase and larger flowpaths can develop, less infiltration is expected, and the water table would likely lower compared to the ground surface. The area of marsh habitat immediately downgradient of the Ordinary Watercourse is therefore also considered to have a moderate groundwater dependency.

61) Annexe A shows the classification of groundwater dependency at the site. In accordance with Chapter 7: Water Environment, the sensitivity of potential GWDTEs at the site is medium.

[11] Bowland Ecology Ltd. (2020a) *op. cit.*

Illustration 2: Conceptual Site Model for Lower House Cottage West



3.2.6 Assessment of Effects

62) The site lies 25 m northwest of the Lower Houses Compound at its closest point, and cross-gradient in terms of groundwater flow. Cod Gill Ordinary Watercourse flows northeast between the site and the compound area.

Enabling Works

63) The site lies outside of the estimated dewatering zone of influence for the attenuation pond and does not lie downgradient of the activity. No impacts on groundwater flows or levels at the site due to dewatering are therefore predicted (see Table 3.3).

64) Groundwater flow disruptions caused by earthworks activities (i.e. ground compaction and settlement, topsoil stripping, and construction of the access tracks) are expected to be minor and localised. Given that the site is situated cross-gradient of the compound in terms of groundwater flow, and that Cod Gill may capture shallow groundwater flows from the works area, no impact on groundwater levels and flows at the site are predicted.

65) Similarly, any changes to groundwater quality within the compound due to accidental leaks or spills of fuels and chemicals, or mobilisation of suspended solids during topsoil stripping and vegetation clearance, are not expected to impact groundwater quality at the site.

Construction Phase

66) The site lies outside of the estimated dewatering zones of influence for the proposed shaft and open-cut connection and does not lie downgradient of these activities. Therefore, no impacts on groundwater levels and flows at the site due to construction phase dewatering are predicted.

67) Considering the embedded mitigation measures referred to in the CCoP, in conjunction with the groundwater flow direction in the area, no impacts on groundwater quality at the site are predicted.

Operation Phase

68) There are no permanent below ground structures proposed within the vicinity of the site to locally alter groundwater levels and flows supporting GWDTEs. No impacts to the site are therefore predicted.

Summary

69) A summary of the potential impacts to the site is provided in Table 3.3.

Table 3.3: Summary of Effects to Lower House Cottage West

Groundwater Dependency	Ecological Designation	Sensitivity	Effect Type	Phase	Highest Magnitude of Impact	Highest Significance of Effect
Moderate	None	Medium	Attenuation pond dewatering (groundwater levels / flows)	Enabling	No impact	N/A
			Shaft dewatering (groundwater levels / flows)	Construction	No impact	N/A
			Open-cut connection dewatering (groundwater levels / flows)	Construction	No impact	N/A

Groundwater Dependency	Ecological Designation	Sensitivity	Effect Type	Phase	Highest Magnitude of Impact	Highest Significance of Effect
			Intercept flows in short term, including ground compaction (groundwater levels / flows)	Enabling / Construction	No impact	N/A
			Accidental leaks / spills, of fuels and chemicals, including cement and sewage (groundwater quality)	Enabling / Construction	No impact	N/A
			Mobilisation of suspended solids (groundwater quality)	Enabling / Construction	No impact	N/A
			Intercept flows in long term, i.e. loss of aquifer storage, backfilling materials, and ground settlement in superficial deposits (groundwater levels / flows)	Operation	No impact	N/A

3.3 Park House Lane

3.3.1 Site Setting, Topography and Hydrological Catchment

70) The site comprises two verges either side of a 65 m long section of Park House Lane and lies 35 m southeast of Lower House Cottage. The site slopes gently from an elevation of 164 mAOD in the southwest to 160 mAOD in the northeast. There is a topographic depression either side of the road, which is assumed to act as highway drainage for surface water runoff.

71) The site is situated along the River Hindburn's steep valley side, located between Cod Gill Ordinary Watercourse to the north, and an unnamed Ordinary Watercourse to the south (140 m and 120 m from the site, respectively). Both watercourses follow the topography and flow northeast towards the Main River.

72) The hydrological catchment for the site extends approximately 350 m southwest, where the ground reaches an elevation of around 183 mAOD.

3.3.2 Soils and Geology

73) Soils at the site are described as slowly permeable seasonally wet acid loamy and clayey soils with impeded drainage[12].

74) Geological mapping indicates that the site is underlain by superficial deposits of glacial till[13]. Bedrock at the site is shown to be the Claughton Member, comprising interbedded shaly siltstone and sandstone.

75) There was no GI data[14] available (see Chapter 7: Water Environment), close to the site at the time of writing. The historical borehole record reported in relation to Lower House Cottage lies 65 m northwest of the site13 and is also relevant to this assessment. Lithological information from this borehole record is summarised in Table 3.1. Its location is shown on Figure 7.4.

76) Topsoil and clay were recorded to a depth of 2 mbgl, overlying a light grey shale. From 13 mbgl, the bedrock comprised interbedded shale and sandstone bands to the borehole completion depth of 60 mbgl. This is consistent with published geological mapping in this area, and a similar geology (both superficial and bedrock) is expected beneath the site, although potential for local variations exist across the site and the surrounding area.

3.3.3 Groundwater

77) There are no EA or BGS groundwater monitoring locations, or GI boreholes available close to the site to provide an indication of groundwater seeps, strikes, or rest water levels. However, the nearby historical borehole record lies at a similar elevation to the site and shows that groundwater was struck during drilling at a depth of 21 mbgl in the bedrock aquifer, with no seeps or strikes recorded in the glacial till.

78) Park House Lane was added to the assessment following an update to habitat mapping that took place after hydrogeological walkover surveys had been completed. Consequently, this site has not been surveyed.

79) Regional-scale BGS data show that there is potential for groundwater flooding to occur to property or infrastructure situated below ground level at the site[15]. Whilst this is not consistent with groundwater strike information recorded in the historical borehole record, the presence of localised perched groundwater, potentially in silt / sand lenses confined by clay layers in the glacial till cannot be ruled out.

80) Locally, groundwater is likely to flow to the northeast towards the River Hindburn. If small and localised perched aquifers do exist within the till, groundwater flowpaths may be discontinuous.

3.3.4 Habitats and Vegetation

81) A Phase 1 Habitat Survey was carried out for the site by Bowland Ecology Ltd. in April 2020[16]. No NVC or SNIFFER surveys were undertaken at the site (see Chapter 9A: Terrestrial Ecology for a detailed description of the data collected, and methodologies used for ecology surveys in the Proposed Bowland Section).

82) The Phase 1 Habitat Survey classified the entire site as a marsh / marshy grassland habitat type, predominantly surrounded by improved grassland.

83) There are no ecological designations present within the site.

[12] Cranfield Soil and Agrifood Institute (2020) *op. cit.*
[13] British Geological Survey (2020a) *op. cit.*
[14] Draft unchecked GI package received by end of April 2020 (data freeze).
[15] British Geological Survey (2020b) *op. cit.*
[16] Bowland Ecology Ltd. (2020a) *op. cit.*

3.3.5 Initial Conceptual Site Model

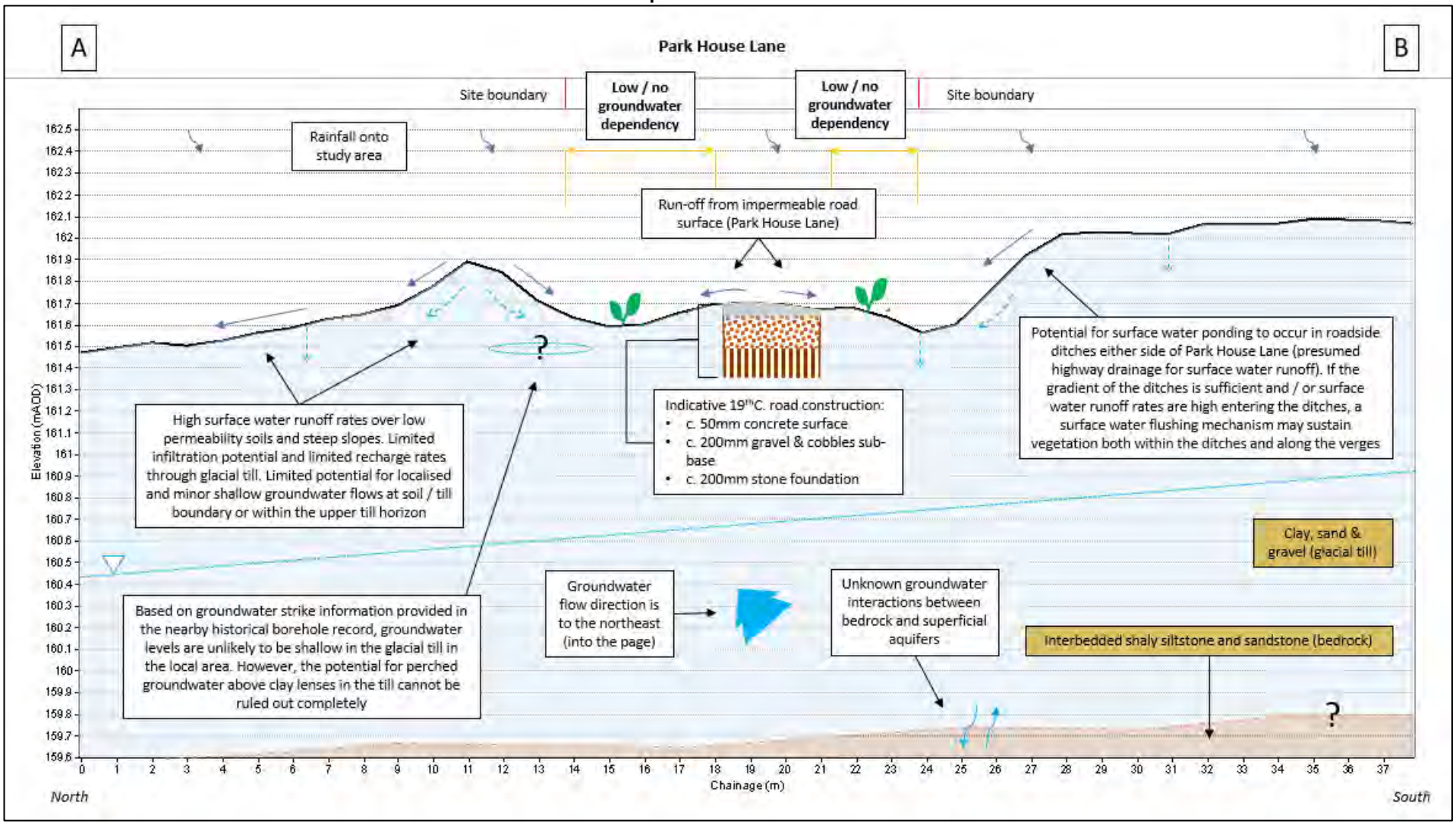
84) Illustration 3 shows a conceptualised cross-section running north to south through the centre of the site (Section A-B). The CSM highlights the indicative movement of groundwater and surface water through the site, as well as interpreted groundwater dependencies supporting vegetation and habitats.

85) The marsh / marshy grassland habitats are aligned with the road verges and ditches on either side of Park House Lane, which are assumed to be drainage features for managing surface water runoff. It is likely, therefore, that these areas receive significant surface water inflows from the road surface and the surrounding hillside, which may form an important sustaining mechanism for these habitats.

86) In the general area, infiltration is likely to be limited by clay soils and surface water runoff rates are expected to be high. There is potential, however, for limited groundwater flows to occur within the more permeable horizons of the glacial till, in the form of localised perched aquifers. However, contributions to the habitats on Park House Lane are expected to be minor (if present) and given the likelihood for surface water to pond within the road verges, the areas of marsh habitat on Park House Lane are considered to have a low groundwater dependency.

87) Annexe A shows the distribution of groundwater dependency at the site. Given the absence of ecological designations at the site, the sensitivity of the GWDTE is low according to Chapter 7: Water Environment.

Illustration 3: Conceptual Site Model for Park House Lane



3.3.6 Assessment of Effects

88) The site lies immediately downgradient of the proposed permanent access road for the Lower Houses Compound. The main compound area and associated works items are located more than 110 m southeast of the site.

Enabling Works

89) The site lies outside of the estimated dewatering zone of influence for the attenuation pond and 350 m northeast of the activity. No impacts on groundwater flows and levels at the site due to dewatering are therefore predicted (see Table 3.4).

90) Groundwater flow disturbance could occur from construction of the permanent access track immediately south of the site. Topsoil stripping would be limited to a maximum depth of 0.5 m, but ground compaction of superficial deposits from use of the road by haulage vehicles could create a barrier to shallow groundwater flows sustaining the site from the southwest. Groundwater flow disturbances at the site are expected to be minor but permanent. Given the localised nature of the perched aquifers that may partially sustain GWDTEs at the site (if present), this would result in a Neutral significance of effect.

91) Topsoil stripping and vegetation clearance activities could cause changes to groundwater quality due to mobilisation of suspended solids and associated solutes. As the proposed topsoil stripping would reach a maximum depth of 0.5 m, significant migration of suspended solids is unlikely, due to the filtering effect of aquifer material. In addition, considering the embedded mitigation measures in the CCoP, associated with controlling silt pollution, there is potential for a minor magnitude change in groundwater quality at the site. This is due to groundwater flow directions and the potential contaminant pathways between the access track and the site, which cannot be ruled out completely. This would result in a Neutral significance of effect.

92) Accidental spills or leaks of fuels and chemicals from the access track area have the potential to introduce contaminants into the groundwater environment. The embedded mitigation measures contained within the CCoP would significantly reduce the likelihood of an incident. However, if a spill or leak did occur, this would lead to a minor adverse impact on groundwater quality for the GWDTE present, resulting in a Neutral significance of effect.

Construction

93) The site lies outside of the estimated dewatering zones of influence for the proposed shaft and open-cut connection and is located more than 200 m northeast of these activities. No construction phase dewatering impacts at the site are therefore expected.

94) As the temporary access track would lie adjacent to, and upgradient of the southern boundary of the site, any ground compaction caused by heavy haulage vehicles and plant could create a barrier to groundwater flows from the southwest. This would represent a long-term impact. However, as the shallow groundwater flows sustaining the GWDTE are expected to be very localised and minor, within perched aquifer lenses, any changes to upgradient groundwater flows would likely lead to a minor magnitude change at the site. This would result in a Neutral significance of effect.

95) The magnitude of change on existing groundwater quality at the site, due to mobilisation of suspended solids and / or accidental spills and leaks is expected to be minor. Considering the embedded mitigation measures referred to in the CCoP, should contaminants within shallow groundwater from the works area reach the site, this would result in a Neutral significance of effect.

Operation

96) The only permanent feature close to the site would be the access road connecting Park House Lane to the new permanent connection and nearby ancillary infrastructure. No impacts on groundwater flows, levels and quality are expected at the site from this asset during the operational phase.

Summary

97) A summary of the potential impacts to the site is provided in Table 3.4.

Table 3.4: Summary of Effects to Park House Lane

Groundwater Dependency	Ecological Designation	Sensitivity	Effect Type	Phase	Highest Magnitude of Impact	Highest Significance of Effect
Low	None	Low	Attenuation pond dewatering (groundwater levels / flows)	Enabling	No impact	N/A
			Shaft dewatering (groundwater levels / flows)	Construction	No impact	N/A
			Open-cut connection dewatering (groundwater levels / flows)	Construction	No impact	N/A
			Intercept flows in short term, including ground compaction (groundwater levels / flows)	Enabling / Construction	Minor Adverse	Neutral
			Accidental leaks / spills, of fuels and chemicals, including cement and sewage (groundwater quality)	Enabling / Construction	Minor Adverse	Neutral
			Mobilisation of suspended solids (groundwater quality)	Enabling / Construction	Minor Adverse	Neutral
			Intercept flows in long term, i.e. loss of aquifer storage, backfilling materials, and ground settlement in superficial deposits (groundwater levels / flows)	Operation	No impact	N/A

3.4 Gamble Hole Farm Pasture

3.4.1 Site Setting, Topography and Hydrological Catchment

98) Gamble Hole Farm Pasture is situated on moderately sloping ground between a plateau to the northeast and watercourses to the south and west. The elevation of the site ranges from 166 mAOD in the northeast to 148 mAOD in the southwest.

99) Dan Clough lies immediately north of the site and forms a steep north-south trending ravine. Heaning Brook Ordinary Watercourse issues at the base of the ravine (65 m north of the site), flows south along the site's western boundary and then turns southwest, where it eventually discharges into the River Hodder Main River 800 m southwest of the site. There is a small catchment divide in the southeast of the site, which marks the source of two unnamed Ordinary Watercourses. One Ordinary Watercourse flows northwest along the site's southern boundary and discharges into Heaning Brook in the west of the site. A second Ordinary Watercourse flows southeast, also along the site's southern boundary, and discharges into the River Hodder 400 m southeast of the site.

100) The total hydrological catchment for the site includes several sub-catchments to the northwest, northeast, and east, with the largest extending approximately 950 m northwest to the top of the plateau, where the ground reaches an elevation of 245 mAOD.

101) A hydrogeology walkover survey was undertaken at the site in March 2020. During the walkover, two assets were identified in the northeast and southeast of the site, understood to be Private Water Supplies (PWS). Potential impacts on these assets (identified as PWS3-13 and PWS-15) are discussed in Chapter 7: Water Environment.

3.4.2 Soils and Geology

102) Soils in the northwest of the site are described as slowly permeable seasonally wet acid loamy and clayey soils with impeded drainage[17]. Loamy and clayey floodplain soils, with naturally high groundwater, are present throughout the remainder of the site.

103) Geological mapping indicates that most of the site is underlain by superficial deposits of glacial till, comprising clay, sand and gravel[18], with a small strip of alluvium in the northwest. Superficial deposits are thought to be absent from the northeast and southeast of the site.

104) Bedrock at the site is predominantly the Hodder Mudstone Formation, comprising mudstone with subordinate limestone, siltstone and sandstone18. The exception is the north-western tip of the site, which is underlain by the Chatburn Limestone Formation, typically comprising packstone limestones with chert lenses, and subordinate calcareous mudstones and siltstones. The two formations are separated by an east-west trending fault which cuts across the bedrock in the far north of the site.

105) There are two historical borehole records within the northwest and southeast of the site. However, they note the presence of springs and provide no lithological information to verify published geological mapping at these locations. GI data[19] were available for a borehole located approximately 160 m northeast of the site (see Chapter 7: Water Environment). Information of relevance to this assessment is summarised in Table 3.5, with the borehole location shown on Figure 7.4.

106) Layers of sandy gravelly clay were encountered in the GI borehole to a depth of at least 1.20 mbgl. The presence of glacial till is consistent with published geological mapping at this location, and a similar thickness of glacial till may be expected at Gamble Hole Farm Pasture, given its location at the edge of the mapped extent of these deposits. Limestone bedrock was encountered at a depth of 1.70 mbgl. The borehole was drilled just south of the Chatburn Limestone / Hodder Mudstone boundary but based on the lithology identified in TR3_4B_BH021, the limestone bedrock may extend slightly further south than published sources show, and this may be similar at the site.

[17] Cranfield Soil and Agrifood Institute (2020) *op. cit.*
[18] British Geological Survey (2020a) *op. cit.*
[19] Draft unchecked GI package received by end of April 2020 (data freeze).

Table 3.5: GI Borehole Records Close to Gamble Hole Farm Pasture

Borehole ID	Relation to site	Top (mbgl)	Base (mbgl)	Lithology Description
TR3_4B_BH021	160m northeast	0	0.50	Soft to firm light brown mottled orange slightly sandy locally sandy slightly gravelly CLAY. Sand is fine to coarse. Gravel is subangular fine to medium of limestone.
		0.50	1.00	Soft brown slightly sandy gravelly CLAY. Sand is fine to coarse. Gravel is subangular fine to coarse of limestone.
		1.00	1.20	Soft to firm light brown slightly sandy slightly gravelly CLAY. Sand is fine to coarse. Gravel is subangular fine to coarse of limestone.
		1.20	1.70	*No description available due to insufficient recovery of material.*
		1.70	2.43	Strong thinly laminated to thinly bedded dark grey to grey LIMESTONE. Frequent fossil fragments including crinoids and corals (<8mm).
		2.43	3.15	*No description available due to insufficient recovery of material.*
		3.15	4.00	Strong thinly laminated to thinly bedded dark grey to grey LIMESTONE. Frequent fossil fragments including crinoids and corals (<15mm).
		4.00	4.60	*No description available due to insufficient recovery of material.*
		4.60	5.00	Weak to moderately weak thinly laminated to very thinly bedded grey to dark grey LIMESTONE. Locally frequent fossil debris including crinoids and corals (<3mm).
		5.00	5.45	*No description available due to insufficient recovery of material.*
		5.45	6.30	Weak to moderately weak very thinly to thinly bedded dark grey LIMESTONE. Frequent fossil debris (<10mm) including crinoids and corals.
		6.30	8.43	Medium strong to strong thinly laminated to medium bedded grey to light grey LIMESTONE. Frequent fossil debris (<6mm) including crinoids and corals fragments.
		8.43	9.10	*No description available due to insufficient recovery of material.*
		9.10	10.33	Strong thinly laminated to very thinly bedded light grey to grey LIMESTONE. Frequent fossil debris including corals (<8mm) and crinoids (<5mm).
		10.33	11.62	Moderately weak thickly laminated to very thinly bedded dark grey calcareous silty MUDSTONE with locally frequent fossil debris including crinoid fragments (<8mm).
		11.62	13.00	Strong thinly to medium bedded dark grey LIMESTONE with weak to moderately weak thickly laminated to thinly bedded dark grey calcareous mudstone. Frequent fossil crinoid fragments (<6mm).
		13.00	13.54	*No description available due to insufficient recovery of material.*
		13.54	15.50	Strong thinly to medium bedded grey to dark grey partially to distinctly weathered LIMESTONE with extremely weak thinly

Borehole ID	Relation to site	Top (mbgl)	Base (mbgl)	Lithology Description
				laminated to thickly laminated brown to orange brown calcareous mudstone. Mudstone is weathered to a residual soil.
		15.50	15.92	*No description available due to insufficient recovery of material.*
		15.92	18.09	Moderately weak to medium strong thinly laminated to very thinly bedded light grey to dark grey locally clayey LIMESTONE with weak to moderately weak thinly to thickly laminated dark grey calcareous mudstone. Frequent fossil debris including crinoids and coral fragments (<6mm).
		18.09	18.30	Weak to moderately weak dark grey calcareous MUDSTONE.
		18.30	19.50	*No description available due to insufficient recovery of material.*
		19.50	22.85	Weak thinly laminated to very thinly bedded dark grey calcareous MUDSTONE. Occasional fossil fragment debris of mainly crinoid fragments (<12mm x 8mm).

3.4.3 Groundwater

107) There are no EA or BGS groundwater monitoring locations nearby. In addition, the available GI borehole is located 160 m from the site, and at a higher elevation, so extrapolating groundwater levels from the borehole's location is unlikely to provide an accurate representation of groundwater levels at the site.

108) The two historical borehole records in the northwest and southeast of the site, however, both recorded the presence of springs in these locations[20], as indicated on Figure 7.4

109) A hydrogeological walkover survey was undertaken at the site in March 2020, which generally noted the presence of boggy ground conditions and many areas of standing water across the site. Multiple springs were also identified (Annexe A), which included a group of three springs with significant flows, that were found to be upwelling through the base of a pond in the west of the site. A spring with moderate flow was also found in the northeast, which marked the source of a small unnamed Ordinary Watercourse and tributary of Heaning Brook.

110) Two springs were noted in the south and centre of the site – the spring furthest to the west was thought to be tufa-forming, with calcite deposits observed along the edges of ditches flowing southwest towards Heaning Brook. The second spring in this area was seen to be discharging to the nearby tributary of Heaning Brook, but it is possible that this could have been a land drainage pipe outfall.

111) In the southeast of the site, water was found to be flowing from a fenced off area, understood to be PWS-15. It is unknown whether the flowing water observed was from the PWS spring, or an area of separate groundwater emergence. A spring was also identified just outside of the site boundary in the southeast of the site.

112) The locations of the observed springs broadly correlate with BGS data, which show that there is potential for groundwater flooding to occur at surface level, and / or to property situated below ground level in the centre and west of the site[21]. In the east, there is limited potential for groundwater flooding to occur, with some small areas that are not considered to be susceptible to groundwater flooding in the far southeast.

113) The presence of several springs, boggy ground conditions and BGS susceptibility data suggest that groundwater levels are generally shallow across the site.

[20] British Geological Survey (2020a) *op. cit.*
[21] British Geological Survey (2020b) *op. cit.*

3.4.4 Habitats and Vegetation

114) Gamble Hole Farm Pasture is designated as a Biological Heritage Site[22]. The citation describes the site as comprising 'an area of wet, semi-natural, neutral grassland with springs and flushes'.

115) A Phase 1 Habitat Survey was carried out for the site by Bowland Ecology Ltd. in June 2019[23], which was supplemented with a standard NVC survey in September 2019[24]. A detailed description of the data collected, and methodologies used for the ecology surveys can be found in Chapter 9A: Terrestrial Ecology.

116) NVC data show that the whole site is dominated by an M22 Juncus subnodulosus – Cirsium palustre fen meadow vegetation type, that is spring fed and base rich. This plant community is classified by the UKTAG guidance as having a high groundwater dependency[25].

3.4.5 Initial Conceptual Site Model

117) Illustration 4 shows a conceptual cross-section running southwest to northeast through the west of the site (Section A-B). The CSMs highlight the indicative movement of groundwater and surface water through the site, and guideline groundwater dependencies supporting vegetation and habitats.

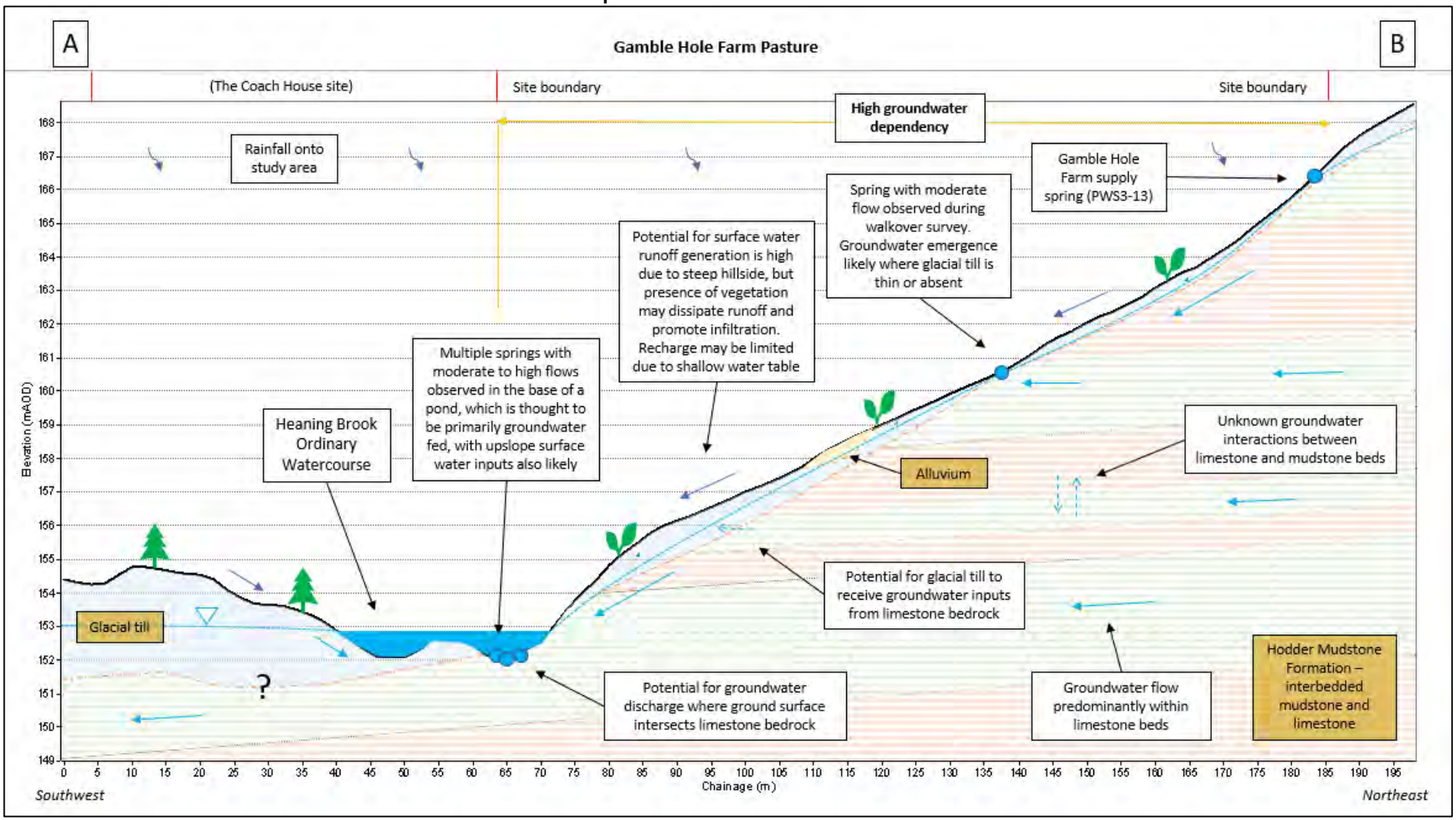
118) The shallow subsurface is expected to comprise of a relatively thin (less than 2 m thick) layer of glacial till. Groundwater within the till is likely to flow downslope to the south and southwest towards Heaning Brook and its tributary. Recharge to the superficial aquifer is thought to be from a combination of direct recharge to the till, as well as base-rich groundwater from the underlying limestone beds. The limestone is likely to support preferential groundwater pathways between confining mudstone interbeds.

119) There is evidence of groundwater reaching the surface in several locations. This flushing of groundwater is expected to be a key process to sustain moderate and highly groundwater dependent vegetation at the site. The presence of the fen habitat, and evidence of base-rich groundwater emergence suggests that the site has a high groundwater dependency.

120) Annexe A shows the groundwater dependency at the site. Given the non-statutory designation present at the site, in accordance with Chapter 7: Water Environment, the sensitivity of the GWDTE is high.

[22] Biological Heritage Sites Partnership (2003). Gamble Hole Farm Pasture. Lancashire County Council, The Wildlife Trust for Lancashire, Manchester and North Merseyside, Natural England.
[23] Bowland Ecology Ltd. (2020a) *op. cit.*
[24] Bowland Ecology Ltd. (2019) TR3 NVC Report. A report produced for United Utilities PLC.
[25] UKTAG (2009) op. cit.

Illustration 4: Conceptual Site Model for Gamble Hole Farm Pasture



3.4.6 Assessment of Effects

121) The centre and east of the site lie within the footprint of the Newton-in-Bowland Compound. The temporary access track bisects the site in its centre and the proposed portal lies 7 m east of the site at its closest point.

Enabling Works

122) The site lies outside of the estimated dewatering zone of influence for the attenuation pond and is not downgradient of the activity. Therefore, no impacts on groundwater flows or levels at the site are predicted (see Table 3.6).

123) Groundwater flow disturbance could occur within the compound area due to compaction-related construction activities and earthworks, such as topsoil stripping (excavation to a maximum depth of 0.5 m) and construction of the temporary access track (with associated excavations of up to 1 m deep). This would result in a site-wide shallow dewatering effect and the impact on groundwater flows and levels within the site would be direct and major within the footprint of the compound. This would result in a Large significance of effect. It should also be noted that topsoil stripping and vegetation clearance could lead to a complete loss of GWDTE habitats. This is assessed separately within Chapter 9A: Terrestrial Ecology.

124) Ground disturbance, for e.g. due to topsoil stripping and vegetation clearance, could also impact groundwater quality due to mobilisation of suspended solids. Implementation of the embedded mitigation measures referred to in the CCoP would significantly reduce the likelihood of suspended solids causing a deterioration in groundwater quality at the site. However, given the consequence of such an event occurring, the risk remains high, and the migration of suspended solids to the GWDTE would result in a moderate impact on groundwater quality at the site due to the direct nature of the works footprint. This would result in a Moderate significance of effect.

125) Accidental spills and leaks of fuels and chemicals have the potential to introduce contaminants into groundwater sustaining GWDTE habitats at the site. The embedded mitigation measures contained within the CCoP would significantly reduce the likelihood of an incident. However, if a spill or leak did occur, this would lead to a moderate impact on groundwater quality at the site, resulting in a Moderate significance of effect.

Construction

126) The estimated dewatering zone of influence for the proposed portal extends across most of the eastern half of the site, and a significant drawdown in groundwater levels is expected in areas of high sensitivity. This represents a direct and major adverse impact to groundwater levels and flows in the east of the site, which would result in a Very Large significance of effect. The western half of the site lies along the edge of the estimated dewatering zone of influence, and the impact to groundwater levels and flows in this part of the site would likely be minor, with significant groundwater inflows expected to be unaffected from the contributing catchment to the north.

127) Excavations for the multi-line connection and overflow would also likely require dewatering and would cause a moderate drawdown of groundwater levels within the compound area. The far southeast corner of the site lies within the footprint of the connection excavation and the estimated zone of influence for dewatering extends some 30 m into the site's southeast corner. Consequently, groundwater flows supporting the habitat in this part of the site would also experience a direct and major impact on groundwater flows and levels due to dewatering, resulting in a Large significance of effect. Aside from the area located immediately downgradient of the estimated dewatering zone of influence, the remainder of the site is likely to experience negligible to no impacts on groundwater flows.

128) As the temporary access track bisects the site, any ground compaction caused by heavy haulage vehicles and plant, could create a local barrier to groundwater flows from the west and northeast. This would represent a direct impact to shallow groundwater levels and flows, with a major magnitude change expected in the centre of the site. Although the contributing groundwater catchment upgradient of the

site is large, effects with a Large significance are anticipated in the site's centre due to the direct nature of the works footprint.

129) There are several embedded mitigation measures contained within the CCoP for managing silt pollution (for suspended solids transport), and leaks and spills of fuels and chemicals. However, these measures only reduce the likelihood of contaminating groundwater, and do not affect the severity or consequence of an event occurring. Should groundwater become contaminated within the upgradient works footprint, or from use of the temporary access track, the impact on groundwater quality throughout the centre and east of the site would be minor, resulting in a Slight significance of effect. The exception is the far west of the site, which lies cross-gradient of the works area and would likely experience negligible to no impacts on groundwater quality.

Operation

130) Excavations for the portal, multi-line connection and overflow structures, would need to be backfilled with arisings or a granular bedding material. Depending on the nature of the backfill material, a preferential groundwater flowpath or barrier to groundwater flow could be created. Since the southeast corner of the site falls directly within the footprint of the multi-line connection excavation, a moderate adverse impact on groundwater flows and levels in this part of the site is predicted. This would result in a Moderate significance of effect. Elsewhere, within the centre and east of the site, there may be minor but localised impacts on groundwater flows, propagating downgradient from the portal and connection areas, which would result in a Slight significance of effect. No long-term impacts are expected in the west of the site.

Summary

131) A summary of the potential impacts to the site is provided in Table 3.6.

Table 3.6: Summary of Effects to Gamble Hole Farm Pasture

Groundwater Dependency	Ecological Designation	Sensitivity	Effect Type	Phase	Highest Magnitude of Impact	Highest Significance of Effect
High	BHS	High	Attenuation pond dewatering (groundwater levels / flows)	Enabling	No impact	N/A
			Portal dewatering (groundwater levels / flows)	Construction	Major adverse	Very Large
			Open-cut connection dewatering (groundwater levels / flows)	Construction	Major Adverse	Large
			Overflow dewatering (groundwater levels / flows)	Construction	Major Adverse	Large
			Intercept flows in short term, including ground compaction (groundwater levels / flows)	Enabling / Construction	Major Adverse	Large

Groundwater Dependency	Ecological Designation	Sensitivity	Effect Type	Phase	Highest Magnitude of Impact	Highest Significance of Effect
			Accidental leaks / spills, of fuels and chemicals, including cement and sewage (groundwater quality)	Enabling	Moderate Adverse	Moderate
			Mobilisation of suspended solids (groundwater quality)	Enabling	Moderate Adverse	Moderate
			Intercept flows in long term, i.e. loss of aquifer storage, backfilling materials, and ground settlement in superficial deposits (groundwater levels / flows)	Operation	Moderate Adverse	Moderate

3.5 The Coach House

3.5.1 Site Setting, Topography and Hydrological Catchment

132) The site comprises two areas of woodland to the east and southeast of The Coach House, and immediately west of Gamble Hole Farm Pasture. An access track to The Coach House separates the two woodland areas.

133) Heaning Brook forms the eastern boundary of the northern sub-site and separates the site from Gamble Hole Farm Pasture. Ordnance Survey maps show that a small unnamed Ordinary Watercourse issues in the north of the northern sub-site and flows east, where it discharges into Heaning Brook. The brook then enters a culvert beneath the access track to The Coach House and turns southwest, where it flows along the western boundary of the southern sub-site. Upgradient of the culvert is the confluence of Heaning Brook and its tributary which flows in from Gamble Hole Farm Pasture.

134) Both sub-sites lie on relatively flat or gently sloping land, with the elevation ranging from 155 mAOD in the northern sub-site to 146 mAOD in the southern sub-site.

135) The total hydrological catchment for the site includes two sub-catchments, which extend approximately 900 m northwest (and where the ground reaches an elevation of 245 mAOD), and 195 m southeast, to the southern boundary of Gamble Hole Farm (where the elevation reaches 160 mAOD).

3.5.2 Soils and Geology

136) Soils at the northern sub-site are described as slowly permeable seasonally wet acid loamy and clayey soils with impeded drainage[26]. At the southern sub-site, loamy and clayey floodplain soils with naturally high groundwater are described.

137) Geological mapping indicates that the northern sub-site is underlain by glacial till, comprising clay, sand and gravel[27]. The southern sub-site is shown to be underlain by alluvium, with glacial till likely to be

[26] Cranfield Soil and Agrifood Institute (2020) *op. cit.*
[27] British Geological Survey (2020a) *op. cit.*

present at depth. Bedrock at both sub-sites is the Hodder Mudstone Formation, comprising mudstone, with subordinate limestone, siltstone and sandstone.

138) There are no available historical borehole records close to the site to verify published geological mapping[28]. There was no GI data[29] available (see Chapter 7: Water Environment) close to the site at the time of writing.

3.5.3 Groundwater

139) There are no EA or BGS groundwater monitoring locations, historical borehole records, or GI boreholes available close to the site to provide an indication of groundwater seeps, strikes, or rest water levels.

140) The site was added to the assessment following an update to habitat mapping that took place after hydrogeology walkover surveys had been completed. Consequently, no hydrogeological survey was undertaken.

141) BGS data suggests that there is potential for groundwater flooding to occur at surface level within both sub-sites, and to property or infrastructure situated below ground level in the far northwest of the northern sub-site[30].

3.5.4 Habitats and Vegetation

142) A Phase 1 Habitat Survey, later supplemented with a high-level NVC and SNIFFER WFD95 Wetland Typology survey[31], were carried out for the site by Bowland Ecology Ltd. in June 2019 and May 2020[32], respectively. A detailed description of the data collected, and methodologies used for the ecology surveys can be found in Chapter 9A: Terrestrial Ecology.

143) All ecological survey data of relevance to this assessment are presented in Table 3.7, along with the groundwater dependencies assigned by the UKTAG guidance[33].

Table 3.7: UKTAG Derived Groundwater Dependency for Vegetation Encountered at The Coach House

Phase 1 Habitat Type	Ecology Site ID / Location	WFD95 Wetland Type	High-level NVC Community	Groundwater Dependency[33]
A1.1.1 – Semi-natural broad-leaved woodland	TR3.GW10	1b – Other wet woodland	W7	High to moderate
F1 - Swamp	TR3.GW9	5 - Swamp	S7	Moderate

144) The northern sub-site comprises an area of wet woodland habitat, within a larger expanse of semi-natural broad-leaved woodland habitat. The high-level NVC survey identified W7 Alnus glutinosa-Fraxinus excelsior-Lysimachia nemorum woodland vegetation, which, according to the UKTAG guidance, has a high to moderate groundwater dependency33.

145) The southern sub-site comprises an area of swamp habitat, dominated by S7 Carex acutiformis swamp vegetation. This plant community has a moderate groundwater dependency33.

146) There are no ecological designations present within the site.

[28] British Geological Survey (2020b) op. cit.
[29] Draft unchecked GI package received by end of April 2020 (data freeze).
[30] British Geological Survey (2020b) *op. cit.*
[31] SNIFFER (2009) WFD95: A Functional Wetland Typology for Scotland – Project Report. Edinburgh, SNIFFER.
[32] Bowland Ecology Ltd. (2020b) TR3 GWDTE Habitat Assessment Report. A report produced for United Utilities PLC.
[33] UKTAG (2009) *op. cit.*

3.5.5 Initial Conceptual Site Model

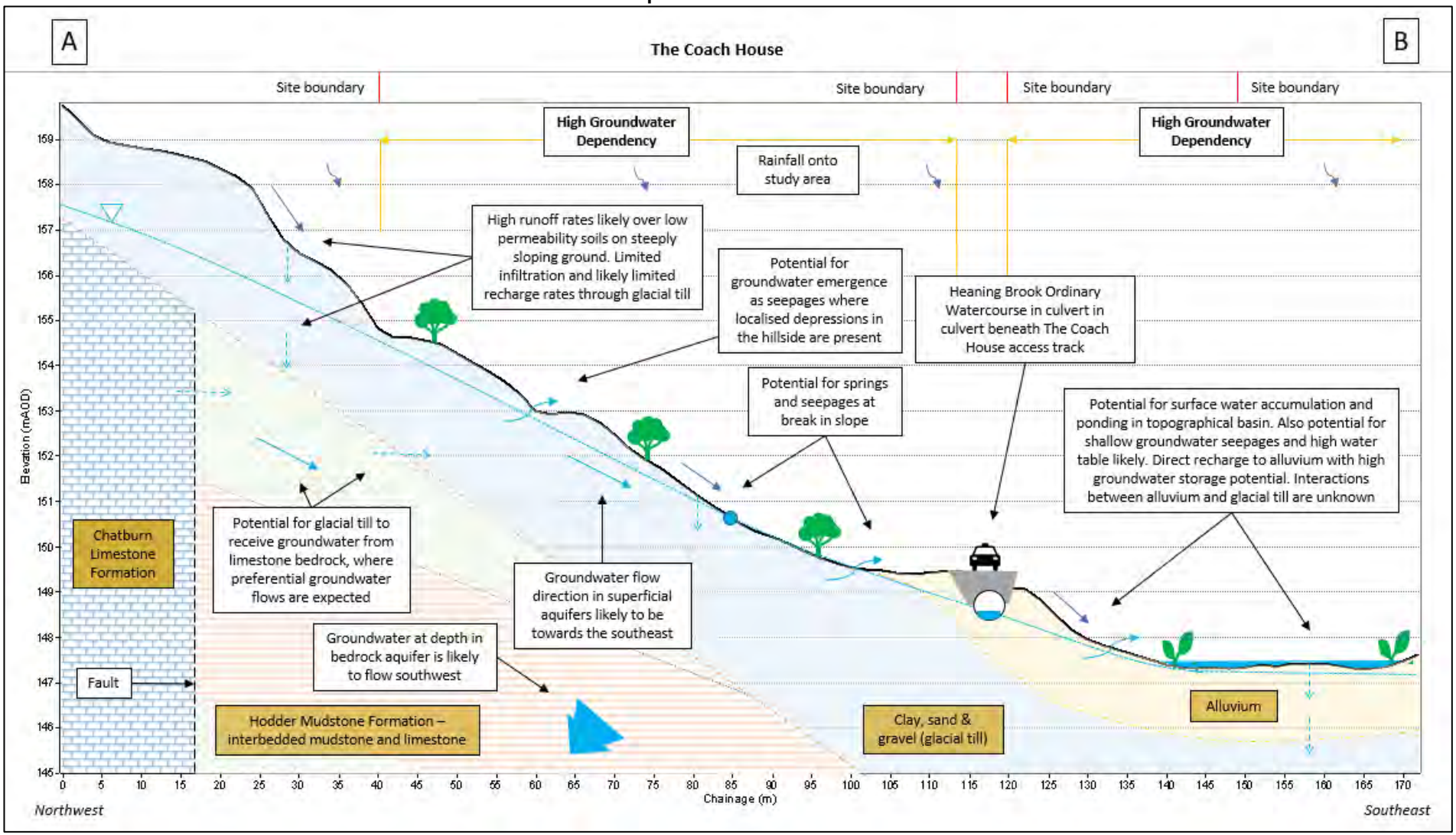
147) Illustration 5 shows a conceptualised cross-section running northwest to southeast through the centre of the site (Section A-B). The CSM highlights the indicative movement of groundwater and surface water through the site, and interpreted groundwater dependencies supporting vegetation and habitats.

148) In the northern sub-site, infiltration is likely to be limited by low permeability soils and steep topography. There are steps in the topographic profile, however, where surface water runoff may be able to accumulate for short periods of time and directly recharge the glacial till. The till may also receive groundwater inputs from the underlying bedrock, particularly from the limestone beds where preferential groundwater flow paths are expected to be confined between lower permeability mudstone bands. Shallow groundwater within the glacial till is expected to flow downslope towards the southeast. Where the water table approaches the ground surface, i.e. where the topographic steps in the hillside are present, there is potential for shallow groundwater flows to flush through the surface and sub-surface to sustain GWDTEs at the site. Therefore, the northern sub-site is considered to have a high groundwater dependency.

149) At the southern sub-site, the alluvium is expected to be largely saturated, with groundwater levels close to the ground surface for prolonged periods of time. Groundwater flow is likely to be to the southwest, at a shallow gradient. The topography at the sub-site forms a basin where surface water runoff from the steeply sloping ground to the north can also accumulate, but infiltration within the basin may be limited by the high groundwater level. The swamp habitat identified in the southern sub-site is therefore also considered to have a high groundwater dependency.

150) Annexe A shows the groundwater dependency at the site. Given that there are no ecological designations present at the site, according to Chapter 7: Water Environment, the sensitivity of the GWDTE is medium.

Illustration 5: Conceptual Site Model for The Coach House



3.5.6 Assessment of Effects

151) At its closest point, the southern sub-site lies 5 m west of the Newton-in-Bowland Compound (Annexe A). The northern sub-site is located 35 m northwest of the compound area and across-gradient in terms of groundwater flow. Heaning Brook Ordinary Watercourse separates the northern sub-site from the compound.

Enabling Works

152) The site lies outside of the estimated dewatering zone of influence for the attenuation pond and is not downgradient of the activity. Therefore, no impacts on groundwater flows or levels at the site are predicted (see Table 3.8).

153) Topsoil stripping and vegetation clearance activities within the compound area, along with construction of the temporary access track, are unlikely to disturb groundwater flows at the northern sub-site, which lies across-gradient from the works areas. Topsoil stripping within the compound footprint would lie just outside, but upgradient of the southern sub-site. Given the likely groundwater flow directions in this area, alterations to groundwater flows may propagate downgradient to this location, causing moderate impacts to groundwater flows at the southern sub-site. This would result in a Moderate significance of effect.

154) The southern sub-site lies across-gradient from the temporary access track and would therefore not experience any alterations to groundwater flows, for e.g. due to topsoil stripping (excavation to a maximum depth of 0.5 m), construction of the temporary access track (with associated excavations of up to 1 m deep), and ground compaction effects during its use.

155) Ground disturbance due to topsoil stripping, vegetation clearance and excavation could also impact groundwater quality at the site due to mobilisation of suspended solids. Implementation of the embedded mitigation measures referred to in the CCoP would significantly reduce the likelihood of suspended solids entering the groundwater environment. However, given the consequence of such an event occurring, a high risk remains, and the potential for contaminant pathways to exist between the compound area and the southern sub-site, means that migration of suspended solids to the GWDTE would result in a minor adverse impact on groundwater quality. This would result in a Slight significance of effect. No impacts on groundwater quality are predicted at the northern sub-site.

156) Accidental spills and leaks of fuels and chemicals have the potential to introduce contaminants into groundwater sustaining GWDTE habitats at the site. The embedded mitigation measures contained within the CCoP would significantly reduce the likelihood of an incident. However, if a spill or leak did occur, this would also lead to a minor adverse impact on groundwater quality at the southern sub-site, resulting in a Slight significance of effect. No impacts on groundwater quality are predicted at the northern sub-site.

Construction

157) The site lies outside of the calculated dewatering zone of influence and approximately 200 m downgradient of the proposed portal. Given the distance, no impacts on groundwater flows are expected, with all dewatering impacts predicted to equilibrate upgradient of the site boundary.

158) The site also lies outside of the estimated dewatering zones of influence for the proposed open-cut connection and overflow structures and does not lie downgradient of these activities.

159) Therefore, no impacts on groundwater levels and flows at the site due to construction phase dewatering are predicted.

160) In addition, no impacts on groundwater quality are expected at the site during the construction phase. This is because all works activities that could introduce suspended solids, and / or fuels and chemicals into the groundwater environment, are located across-gradient and at least 80 m southeast of the site.

Operation

161) There are no permanent below ground structures or backfilled excavations within close proximity of the site. No operational phase impacts to groundwater levels, flows or quality at either sub-site are therefore predicted.

Summary

162) A summary of the potential impacts to the site is provided in Table 3.8.

Table 3.8: Summary of Effects to The Coach House

Groundwater Dependency	Ecological Designation	Sensitivity	Effect Type	Phase	Highest Magnitude of Impact	Highest Significance of Effect
Moderate	None	Medium	Attenuation pond dewatering (groundwater levels / flows)	Enabling	No impact	N/A
			Portal dewatering (groundwater levels / flows)	Construction	No impact	N/A
			Open-cut connection dewatering (groundwater levels / flows)	Construction	No impact	N/A
			Overflow dewatering (groundwater levels / flows)	Construction	No impact	N/A
			Intercept flows in short term, including ground compaction (groundwater levels / flows)	Enabling	Moderate Adverse	Moderate
			Accidental leaks / spills, of fuels and chemicals, including cement and sewage (groundwater quality)	Enabling	Minor Adverse	Slight
			Mobilisation of suspended solids (groundwater quality)	Enabling	Minor Adverse	Slight
			Intercept flows in long term, i.e. loss of aquifer storage, backfilling materials, and ground settlement in superficial deposits (groundwater levels / flows)	Operation	No impact	N/A

3.6 Dunsop Bridge Road

3.6.1 Site Setting, Topography and Hydrological Catchment

163) The site comprises an irregularly shaped northeast-southwest trending area of land, located 35 m south of Dunsop Bridge Road, and approximately 400 m southwest of the village of Newton-in-Bowland.

164) The site slopes gently to the south, towards the River Hodder Main River, from an elevation of 145 mAOD in the far north, to 128 mAOD in the south. The site shares its southern boundary with the River Hodder North site.

165) Ordnance Survey maps show an unnamed Ordinary Watercourse that issues from a spring in the north of the site. The watercourse flows south and then southeast through the centre of the site, before turning southwest and flowing along the southern site boundary. The watercourse exits the site via its southwest corner and enters the River Hodder North site.

166) The hydrological catchment for the site extends some 500 m northwest, where the ground reaches an elevation of around 190 mAOD.

3.6.2 Soils and Geology

167) Soils across most of the site are described as slowly permeable seasonally wet acid loamy and clayey soils with impeded drainage[34]. In the south of the site, soils are described as loamy and clayey floodplain soils with naturally high groundwater.

168) Geological mapping indicates that the site is underlain by superficial deposits of glacial till[35]. Overlying the glacial till in the south of the site, where the two elongated strips of land extend from the main site area, are river terrace deposits, comprising sand and gravel. Bedrock is shown to be the Hodder Mudstone Formation, comprising predominantly mudstone with subordinate limestone, siltstone and sandstone.

169) There are no available historical borehole records close to the site to verify published geological mapping35. There was no GI data[36] available (see Chapter 7: Water Environment) at the time of writing.

3.6.3 Groundwater

170) There are no EA or BGS groundwater monitoring locations, historical borehole records, or GI boreholes available close to the site to provide an indication of groundwater seeps, strikes, or rest water levels.

171) This site was added to the assessment following an update to habitat mapping that took place after hydrogeology walkover surveys had taken place. Consequently, this site has not been surveyed from a groundwater perspective.

172) An ecology survey was however carried out by Bowland Ecology Ltd. in July 2020[37] (see Section 3.6.4), which noted the presence of a groundwater seepage face in the northeast of the site, and a spring, which marked the source of the unnamed Ordinary Watercourse in the north. Three springs were also observed in the west of the site, thought to be tufa-forming, and several lime-rich springs were noted in the south, flowing into the unnamed Ordinary Watercourse, which was also lined with tufa deposits.

173) The presence of springs and seepages is consistent with BGS data, which shows that there is potential for groundwater flooding to occur to property or infrastructure situated below ground level throughout the site[38]. The observed shallow groundwater emergence, BGS flood susceptibility data, and the site's location on the edge of the floodplain of a Main River, means that groundwater levels are likely to be generally shallow at the site.

[34] Cranfield Soil and Agrifood Institute (2020) *op. cit.*
[35] British Geological Survey (2020a) *op. cit.*
[36] Draft unchecked GI package received by end of April 2020 (data freeze).
[37] Bowland Ecology Ltd. (2020b) *op. cit.*
[38] British Geological Survey (2020b) *op. cit.*

3.6.4 Habitats and Vegetation

174) Phase 1 Habitat, high-level NVC, and SNIFFER WFD95 Wetland Typology surveys[39], were carried out by Bowland Ecology Ltd. in May 2020 and July 2020[40], respectively. A detailed description of the data collected, and methodologies used for the ecology surveys can be found in Chapter 9A: Terrestrial Ecology.

175) Marsh / marshy grassland habitat was recorded in the northeast of the site, dominated by MG10 Holcus lanatus-Juncus effusus rush-pasture. According to the UKTAG guidance, this plant community has a moderate groundwater dependency[41].

176) Surrounding the unnamed Ordinary Watercourse in the north of the site was a basic flush habitat associated with tufa-forming springs. The habitat extended from the north of the site to the southeast, in a thin strip of land, following the Ordinary Watercourse. As the watercourse reaches the River Hodder North site, it turns southwest, and a second strip of basic flush habitat was identified adjacent to the tufa-lined watercourse channel, with several lime-rich springs discharging into it. Within this second strip of flush habitat were M27 Filipendula ulmaria-Angelica sylvestris mire, M37 Cratoneuron commutatum-Festuca rubra spring, and S7 Carex acutiformis swamp vegetation communities, with varying groundwater dependencies41.

177) A large expanse of acid / neutral flush habitat was recorded in the west / southwest of the site, occupied by M23 Juncus effusus / acutiflorus-Galium palustre rush-pasture, and MG10 Holcus lanatus-Juncus effusus rush-pasture vegetation. These plant communities have a high to moderate, and moderate groundwater dependency, respectively41.

178) There are no ecological designations present within the site.

179) Phase 1 habitat, high-level NVC, and wetland typology data for the site are presented in Table 3.9, along with the groundwater dependencies assigned by the UKTAG guidance (where possible)[41].

[39] SNIFFER (2009) *op. cit.*
[40] Bowland Ecology Ltd. (2020b) *op. cit.*
[41] UKTAG (2009) *op. cit.*

Table 3.9: UKTAG Derived Groundwater Dependency for Vegetation Encountered at Dunsop Bridge Road

Phase 1 Habitat Type	Ecology Site ID / Location	WFD95 Wetland Type	High-level NVC Community	Groundwater Dependency[41]
B5 – Marsh / marshy grassland	TR3.GW3	2a – Marshy grassland	MG10	Moderate
E2.2 – Basic flush	TR3.GW2	3b – Tufa-forming spring	M36	High
	TR3.GW4	3b – Tufa-forming spring	M27	Moderate to low
			M37	High
			S7	Moderate
	No ID given – narrow strip around watercourse in the centre of the site	N/A	N/A	N/A
E2.1 – Acid / neutral flush	TR3.GW1	3d – Seepage / flush	M23	High to moderate
			MG10	Moderate

3.6.5 Initial Conceptual Site Model

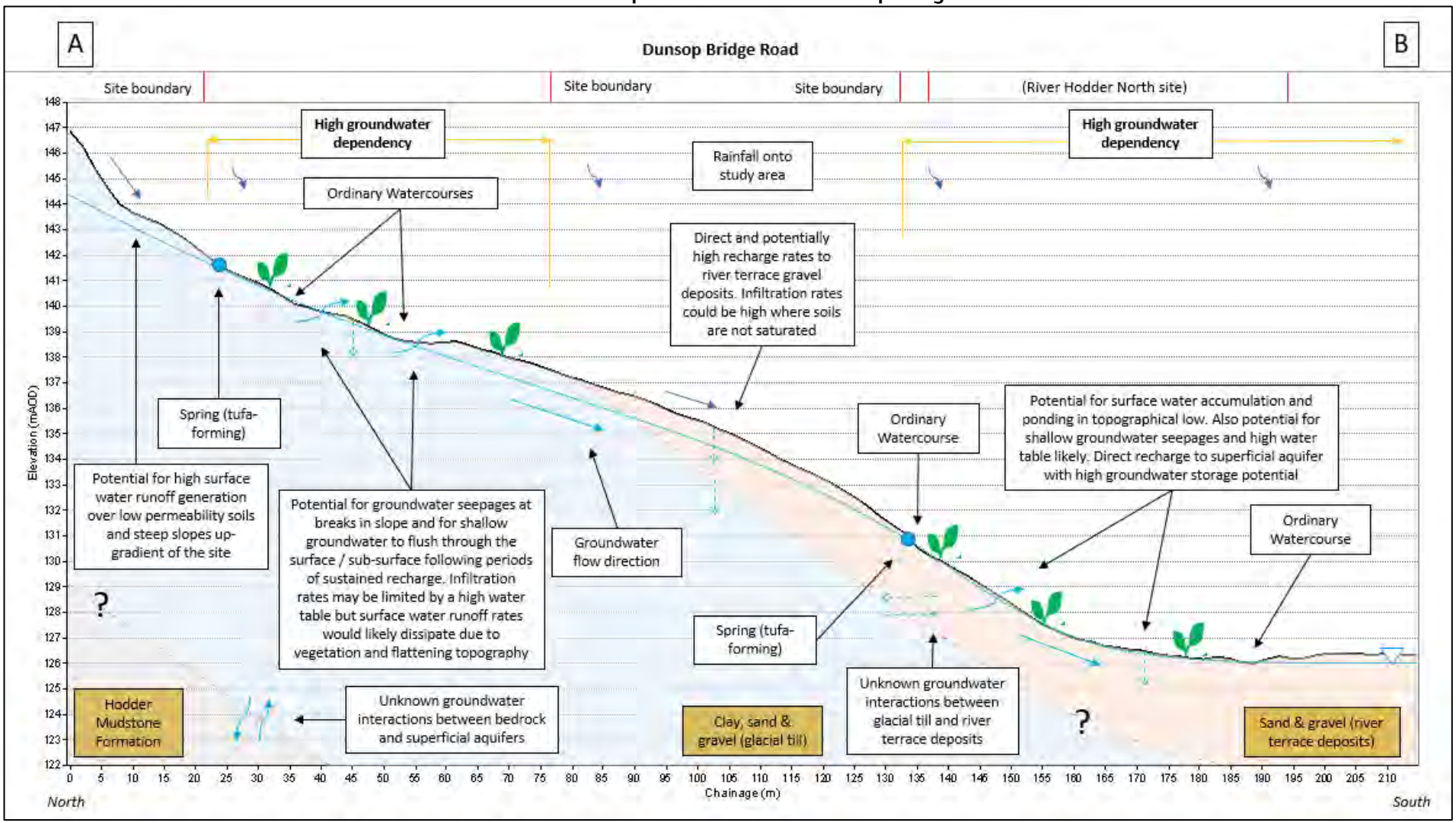
180) Illustration 6 shows a conceptualised cross-section running north to south through the centre of the site (Section A-B). The CSM highlights the indicative movement of groundwater and surface water through the site, and interpreted groundwater dependencies supporting vegetation and habitats.

181) Shallow groundwater is generally expected to flow southwards within the glacial till and river terrace deposits towards the unnamed Ordinary Watercourse, and / or River Hodder. Groundwater levels are expected to be shallow throughout most of the site, with the drop in topography in the north promoting shallow groundwater emergence in the form of spring lines and seepages. Given the nature of the topography in this area, there is potential for a flushing mechanism through the surface / shallow subsurface which can support moderate to highly groundwater dependent vegetation at the site. Downgradient of the spring lines and seepages, the site is therefore considered to have a high groundwater dependency.

182) Upgradient of the break in slope, and areas of observed groundwater emergence, groundwater levels are likely to be slightly deeper, but still fairly shallow, such that the far northeast and northwest of the site are considered to have a moderate groundwater dependency.

183) Annexe A shows the distribution of groundwater dependency at the site. According to Chapter 7: Water Environment, the sensitivity of the GWDTE is medium.

Illustration 6: Conceptual Site Model for Dunsop Bridge Road



3.6.6 Assessment of Effects

184) The main Newton-in-Bowland Compound lies 300 m west of the site. The proposed compound access area lies immediately south and downgradient of the site.

Enabling Works

185) The site lies outside of the estimated dewatering zone of influence for the attenuation pond and is not downgradient of the activity. Therefore, no impacts on groundwater flows or levels at the site due to dewatering are predicted (see Table 3.10).

186) Groundwater flow disturbance could occur due to compaction-related construction activities and earthworks that do not require dewatering, i.e. topsoil stripping and construction of the temporary access track. Topsoil stripping would involve excavation to a maximum depth of 0.5 m, along the southern boundary of the site. Although this excavation depth is limited, groundwater levels are expected to be at surface level in this location, and the activity may create localised upgradient dewatering effects that extends into the south of the site. Minor impacts on groundwater flows are therefore expected, resulting in a Slight significance of effect for the south of the site, with no impacts expected throughout the remainder of the GWDTE.

187) Ground disturbance due to topsoil stripping and vegetation clearance could also impact groundwater quality at the site due to mobilisation of suspended solids. Similarly, accidental spills and leaks of fuels and chemicals have the potential to introduce contaminants to groundwater sustaining GWDTE habitats at the site. However, due to a combination of the embedded mitigation measures referred to in the CCoP, along with the site being located upgradient of the temporary access works area, no impacts on groundwater quality are expected at the site.

Construction

188) The site lies outside of the calculated dewatering zones of influence for the proposed portal, open-cut connections and overflow structures. Therefore, no impacts on groundwater levels and flows at the site due to construction phase dewatering are predicted.

189) In addition, the proposed access road lies 20 m downgradient of the site boundary, and no impacts on groundwater quality (i.e. from a release of suspended solids and / or leaks of fuels and chemicals) are therefore expected at the site.

Operation

190) There are no permanent below ground structures proposed within the vicinity of the site to locally alter groundwater levels and flows supporting GWDTEs. No impacts to the site are therefore predicted.

Summary

191) A summary of the potential impacts to the site is provided in Table 3.10.

Table 3.10: Summary of Effects to Dunsop Bridge Road

Groundwater Dependency	Ecological Designation	Sensitivity	Effect Type	Phase	Highest Magnitude of Impact	Highest Significance of Effect
High to moderate	None	Medium	Attenuation pond dewatering (groundwater levels / flows)	Enabling	No impact	N/A
			Portal dewatering (groundwater levels / flows)	Construction	No impact	N/A
			Open-cut connection dewatering (groundwater levels / flows)	Construction	No impact	N/A
			Overflow dewatering (groundwater levels / flows)	Construction	No impact	N/A
			Intercept flows in short term, including ground compaction (groundwater levels / flows)	Enabling	Minor adverse	Slight
			Accidental leaks / spills, of fuels and chemicals, including cement and sewage (groundwater quality)	Enabling	Negligible	Neutral
			Mobilisation of suspended solids (groundwater quality)	Enabling	Negligible	Neutral
			Intercept flows in long term, i.e. loss of aquifer storage, backfilling materials, and ground settlement in superficial deposits (groundwater levels / flows)	Operation	No impact	N/A

3.7 River Hodder North

3.7.1 Site Setting, Topography and Hydrological Catchment

192) The River Hodder North site comprises an east-west trending low-lying area of land, that forms part of the floodplain for the River Hodder Main River. The elevation of the site ranges from 135 mAOD in the northeast, to 123 mAOD in the west, adjacent to the River Hodder. The village of Newton-in-Bowland lies 500 m northeast, and the Dunsop Road Bridge site is present immediately to the north.

193) An unnamed Ordinary Watercourse and tributary of the River Hodder issues in the northeast corner of the site. The watercourse then flows west, along the site's southern boundary, and discharges into the River Hodder in the northwest of the site. The unnamed Ordinary Watercourse from the Dunsop Bridge Road site flows southwest adjacent to the site's northern boundary. Ordnance Survey maps show this second watercourse 'sinks' in the centre of the site, close to the northern boundary.

194) The hydrological catchment for the site extends some 550 m north where the ground reaches an elevation of around 190 mAOD.

3.7.2 Soils and Geology

195) Soils at the site are described as loamy and clayey floodplain soils with naturally high groundwater[42].

196) Geological mapping indicates that alluvium is present in the south and far southwest of the site, comprising clay, silt, sand and gravel[43]. River terrace deposits are also mapped across most of the site and likely underlie the alluvium. Glacial till is expected at depth beneath the river terrace deposits, based on the mapped geology of the wider area.

197) Bedrock is the Hodder Mudstone Formation, comprising mudstone with subordinate limestone, siltstone and sandstone. A northwest-southeast trending fault cuts across the bedrock in the west of the site.

198) There are no available historical borehole records close to the site to verify published geological mapping[44]. There was no GI data[45] available (see Chapter 7: Water Environment) close to the site at the time of writing.

3.7.3 Groundwater

199) There are no EA or BGS groundwater monitoring locations, historical borehole records, or GI boreholes available close to the site to provide an indication of groundwater seeps, strikes, or rest water levels.

200) This site was added to the assessment following an update to habitat mapping that took place after hydrogeology walkover surveys had taken place. Consequently, this site has not been surveyed from a groundwater perspective.

201) An ecology survey was, however, carried out by Bowland Ecology Ltd. in May 2020[46] (see Section 3.7.4). Three springs were identified in the northeast of the site that marked the source of the unnamed Ordinary Watercourse that flows along the site's southern boundary. A spring was also observed in the centre of the site, flowing into a second Ordinary Watercourse, where groundwater seepages were seen along the channel sides. These springs were thought to be tufa-forming, with tufa deposits noted along the edges of the watercourse channels in the northeast and centre of the site.

202) The presence of these springs is consistent with BGS data, which show that there is potential for groundwater flooding to occur to property or infrastructure situated below ground level in the northeast of the site[47]. There is also potential for groundwater flooding to occur at surface level in the south and west of the site.

[42] Cranfield Soil and Agrifood Institute (2020) *op. cit.*
[43] British Geological Survey (2020a) *op. cit.*
[44] British Geological Survey (2020a) *op. cit.*
[45] Draft unchecked GI package received by end of April 2020 (data freeze).
[46] Bowland Ecology Ltd. (2020b) *op. cit.*
[47] British Geological Survey (2020b) *op. cit.*

203) Given that the site lies within the floodplain of a Main River, soils at the site are described as having naturally high groundwater, the presence of multiple springs, and the susceptibility of the site to groundwater flooding, groundwater levels are generally expected to be shallow at the site.

3.7.4 Habitats and Vegetation

204) A Phase 1 Habitat Survey was carried out by Bowland Ecology in May 2020[48], supplemented with a high-level NVC survey in conjunction with the SNIFFER WFD95 Wetland Typology methodology[49]. A detailed description of the data collected, and methodologies used for the ecology surveys can be found in Chapter 9A: Terrestrial Ecology.

205) Phase 1 Habitat, high-level NVC, and wetland typology data for the site are presented in Table 3.11, along with the groundwater dependencies assigned by the UKTAG guidance (where possible)[50].

Table 3.11: UKTAG Derived Groundwater Dependency for Vegetation Encountered at River Hodder North

Phase 1 Habitat Type	Ecology Site ID / Location	WFD95 Wetland Type	High-level NVC Community	Groundwater Dependency[50]
E2.2 – Basic flush	TR3.GW5	3b – Tufa-forming spring	M36	N/A
	TR3.GW7	3b – Tufa-forming spring	M27	Moderate to low
			M37	High
	No ID given – along the northern boundary of the site	N/A	N/A	N/A
E3 – Fen	TR3.GW6	4 – Fen	S7	Moderate
B5 – Marsh / marshy grassland	No ID given – patches in the east and west of the site	N/A	N/A	N/A
B6 – Poor semi-improved grassland	No ID given – throughout large parts of the site	N/A	N/A	N/A

206) In the far northeast of the site, a small area of basic flush habitat was identified, associated with spring-fed ditches. M27 Filipendula ulmaria-Angelica sylvestris mire and M37 Cratoneuron commutatum-Festuca rubra spring vegetation types were found to dominate in this area, which, according to the UKTAG guidance[51], have moderate to low, and high groundwater dependencies, respectively. Two smaller areas of basic flush habitat were recorded in the centre of the site, the largest of which was associated with a spring-fed ditch and groundwater seepages, that were supporting a series of moss vegetation types in this area.

207) An area of fen habitat was recorded in the centre of the site, close to the southern boundary. This habitat was dominated by S7 Carex acutiformis swamp vegetation, which has a moderate groundwater dependency51.

208) Areas of marsh / marshy grassland habitat were recorded throughout the site, including in the west around the tributary of the River Hodder, immediately upgradient of its confluence. The remainder of the site is classified as poor semi-improved grassland habitat.

[48] Bowland Ecology Ltd. (2020a) *op. cit.*
[49] SNIFFER (2009) *op. cit.*
[50] UKTAG (2009) *op. cit.*
[51] UKTAG (2009) *op. cit.*

209) There are no ecological designations present within the site.

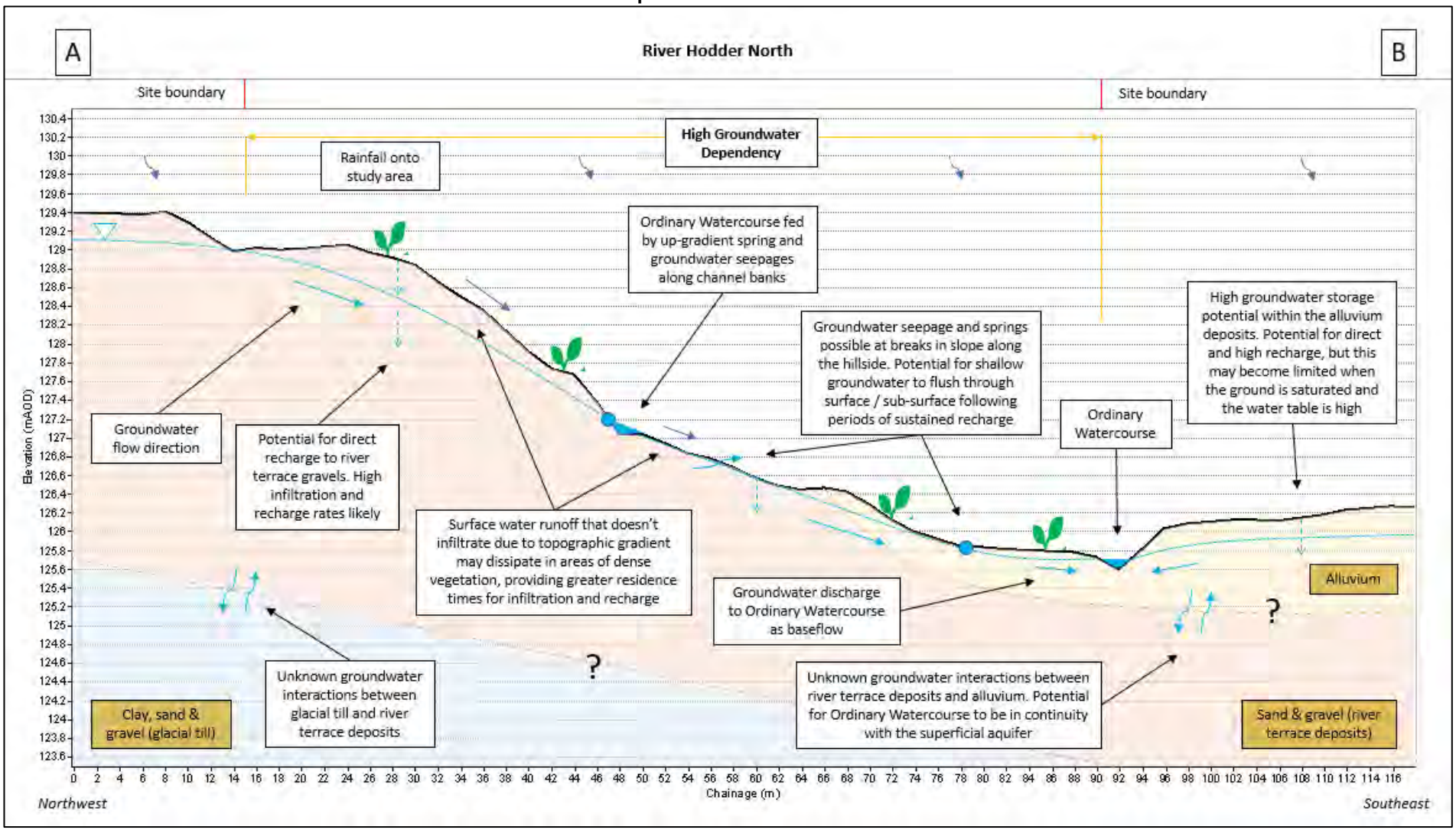
3.7.5 Initial Conceptual Site Model

210) Illustration 7 shows a conceptualised cross-section running northwest to southeast through the centre of the site (Section A-B). The CSM highlights the indicative movement of groundwater and surface water through the site, and guideline groundwater dependencies supporting vegetation and habitats.

211) Shallow groundwater within the river terrace deposits and alluvium is expected to predominantly flow southwards towards the Ordinary Watercourse along the southern site boundary. Groundwater within the glacial till and underlying bedrock aquifer is likely to flow southwards, at depth, towards the River Hodder. With gently sloping ground throughout most of the site, incident rainfall is likely to infiltrate freely, albeit limited to a degree by antecedent ground conditions and shallow groundwater levels. Recharge to the river terrace deposits and alluvial aquifers is expected to be direct and given the site's setting within a large floodplain, there is potential for these deposits to be in hydraulic continuity with the River Hodder, although this is not certain. Groundwater levels are generally expected to be shallow across the site, sustaining springs and seepages. The site is considered to be highly groundwater dependent.

212) Annexe A shows the distribution of groundwater dependency at the site. Given that there are no ecological designations at the site, according to Chapter 7: Water Environment, the sensitivity of the GWDTE is medium.

Illustration 7: Conceptual Site Model for River Hodder North



3.7.6 Assessment of Effects

213) The entire site, except the far northeast corner, lies within the footprint of the Newton-in-Bowland Compound Access area (Annexe A). The main compound lies 80 m west of the site at its closest point but is separated from the site by an unnamed Ordinary Watercourse which flows south along the compound edge.

Enabling Works

214) The site lies outside of the estimated dewatering zone of influence for the attenuation pond and is not downgradient of the activity. Therefore, no impacts on groundwater flows or levels at the site due to dewatering are predicted (see Table 3.12).

215) Groundwater flow disturbance could occur due to general compaction-related construction activities such as topsoil stripping and construction of the temporary access track. Topsoil stripping would involve excavation to a maximum depth of 0.5 m, but the impacts on groundwater flows and levels would be direct and major throughout the entire site, with the only exception being its far northeast corner. Overall, this would result in a Large significance of effect.

216) Direct impact could occur due to an area of soil storage north of the site. There is no excavation involved with this. This area falls within the temporary access track envelop and therefore any potential soil stripping impacts have already been discussed in the previous paragraph. However additional compaction of the ground could divert groundwater flow therefore causing a reduction of groundwater reaching the north of the site. Due to this, minor temporary impacts are expected at the impacted location and immediately downgradient of the soil storage area, resulting in a slight significance of effect.

217) Ground disturbance due to topsoil stripping, vegetation clearance and excavation could also impact on groundwater quality due to mobilisation of suspended solids. Implementation of the embedded mitigation measures referred to in the CCoP would significantly reduce the likelihood of suspended solids causing a deterioration in groundwater quality at the site. However, given the consequence of such an event occurring, the risk remains high, and migration of suspended solids to the GWDTEs would result in a moderate adverse impact on groundwater quality at the site. This would result in a Moderate significance of effect.

218) Accidental spills and leaks of fuels and chemicals have the potential to introduce contaminants into groundwater sustaining GWDTE habitats at the site. The embedded mitigation measures contained within the CCoP would significantly reduce the likelihood of an incident. However, if a spill or leak did occur, this would lead to a moderate adverse impact on groundwater quality at the site, resulting in a Moderate significance of effect.

219) Measures in the CCoP relating to soil storage would prevent the mobilisation of any contamination and suspended solids. As a result, any impact on groundwater quality supporting is assessed as negligible. This would result in a Neutral significance of impact.

Construction

220) The site lies outside of the calculated dewatering zone of influence for the proposed portal and open-cut excavations (required for the connection structures and overflow). The site is not downgradient of any of these activities and therefore, no impacts on groundwater levels and flows at the site are predicted.

221) As the temporary access track bisects the site, any ground compaction caused by heavy haulage vehicles and plant, could create a barrier to groundwater flows from the north. This would represent a direct impact to shallow groundwater levels and flows, with a major magnitude of change expected throughout the centre of the site. Effects with a Large significance are therefore anticipated due to the direct nature of the works footprint.

222) Considering the embedded mitigation measures contained within the CCoP, for managing silt pollution (for suspended solids transport), and leaks and spills of fuels and chemicals, minor magnitude changes in groundwater quality could be expected at the site from use of the temporary access track during the construction phase. This would result in a Slight significance of effect.

Operation

223) There are no permanent below ground structures proposed within the vicinity of the site to locally alter groundwater levels and flows supporting GWDTEs. No impacts to the site are therefore predicted.

Summary

224) A summary of the potential impacts to the site is provided in Table 3.12.

Table 3.12: Summary of Effects to River Hodder North

Groundwater Dependency	Ecological Designation	Sensitivity	Effect Type	Phase	Highest Magnitude of Impact	Highest Significance of Effect
High to moderate	None	Medium	Attenuation pond dewatering (groundwater levels / flows)	Enabling	No impact	N/A
			Portal dewatering (groundwater levels / flows)	Construction	No impact	N/A
			Open-cut connection dewatering (groundwater levels / flows)	Construction	No impact	N/A
			Overflow dewatering (groundwater levels / flows)	Construction	No impact	N/A
			Soil storage direct impact / compaction (groundwater levels / flows)	Construction	Minor Adverse	Slight
			Intercept flows in short term, including ground compaction (groundwater levels / flows)	Enabling / Construction	Major Adverse	Large
			Accidental leaks / spills, of fuels and chemicals, including cement and sewage	Enabling	Moderate Adverse	Moderate

Groundwater Dependency	Ecological Designation	Sensitivity	Effect Type	Phase	Highest Magnitude of Impact	Highest Significance of Effect
			(groundwater quality)			
			Mobilisation of suspended solids (groundwater quality)	Enabling	Moderate Adverse	Moderate
			Soil storage direct impact (groundwater quality)	Construction	Negligible Adverse	Neutral
			Intercept flows in long term, i.e. loss of aquifer storage, backfilling materials, and ground settlement in superficial deposits (groundwater levels / flows)	Operation	No impact	N/A

3.8 River Hodder South

3.8.1 Site Setting, Topography and Hydrological Catchment

225) The site comprises a small shallow valley adjacent to the River Hodder Main River, which flows southwest along the site's northern boundary. Long Stripes Plantation lies 225 m to the south.

226) The elevation of the site slopes steeply northwest towards the Main River, and ranges from 133 mAOD in the southeast, to 126 mAOD in the northwest.

227) An unnamed ordinary watercourse issues approximately 80 m southeast of the site, flows northwest through the centre of the site and discharges into the River Hodder along the site's northern boundary.

228) The hydrological catchment for the site extends approximately 500 m southeast where the ground reaches an elevation of 177 mAOD.

3.8.2 Soils and Geology

229) Soils at the site are described as loamy and clayey floodplain soils with naturally high groundwater[52].

230) Geological mapping indicates that the site is underlain by superficial deposits of alluvium, comprising clay, silt, sand and gravel[53]. Based on the mapped geology of the wider area, it is likely that the alluvium is underlain by river terrace deposits (comprising sand and gravel), which themselves are underlain by glacial till.

231) Bedrock at the site is shown to be the Hodder Mudstone Formation, comprising predominantly mudstone, with subordinate limestone, siltstone and sandstone.

[52] Cranfield Soil and Agrifood Institute (2020) *op. cit.*
[53] British Geological Survey (2020a) *op. cit.*

232) There are no available historical borehole records close to the site to verify published geological mapping53. There was no GI data[54] available (see Chapter 7: Water Environment) close to the site at the time of writing.

3.8.3 Groundwater

233) There are no EA or BGS groundwater monitoring locations, historical borehole records, or GI boreholes available close to the site to provide an indication of groundwater seeps, strikes, or rest water levels.

234) This site was added to the assessment following an update to habitat mapping that took place after hydrogeology walkover surveys had taken place. Consequently, this site has not been surveyed from a groundwater perspective.

235) BGS data show that there is potential for groundwater flooding to occur to property or infrastructure situated below ground level throughout most of the site[55]. In the far northwest, there is potential for groundwater flooding to occur at surface level, which is also the case for much of the low-lying areas that form part of the River Hodder's floodplain.

236) Given that the site lies adjacent to a Main River, with a small tributary flowing through it, there is potential for shallow groundwater to be flowing through the site to provide baseflow contributions to the two watercourses. Soils at the site are described as having naturally high groundwater, which is consistent with BGS flood susceptibility data, and it is likely, therefore, that groundwater levels at the site are shallow.

3.8.4 Habitats and Vegetation

237) Phase 1 Habitat, high-level NVC, and SNIFFER WFD95 Wetland Typology surveys[56], were carried out for the site by Bowland Ecology Ltd. in May 2020[57]. A detailed description of the data collected, and methodologies used for the ecology surveys can be found in Chapter 9A: Terrestrial Ecology.

238) The site is shown to be dominated by marsh / marshy grassland habitats, with extensive areas of poor semi-improved grassland to the east, west and south. The area of vegetation present within the site was considered too small and degraded to classify with an accurate high-level NVC type. The closest NVC affinity was, however, attributed to MG10b Holcus lanatus-Juncus effusus rush-pasture. Based on UKTAG guidance, this plant community has a moderate groundwater dependency[58].

239) Although there are no ecological designations present within the site, the River Hodder Main River is designated as a Biological Heritage Site[59]. The citation notes that there are three species included in the Provisional Lancashire Red Data List of Vascular Plants[60] that are present along the river banks, and which could therefore be present at the site. In addition, several ground flora species that typically grow in wetter areas are also noted.

240) All available habitat, high-level NVC, and wetland typology data for the site are presented in Table 3.13, along with the groundwater dependencies assigned by the UKTAG guidance[61].

[54] Draft unchecked GI package received by end of April 2020 (data freeze).
[55] British Geological Survey (2020b) *op. cit.*
[56] SNIFFER (2009) *op. cit.*
[57] Bowland Ecology Ltd. (2020b) *op. cit.*
[58] UKTAG (2009) *op. cit.*
[59] Biological Heritage Sites Partnership (2001). River Hodder From Confluence with River Ribble Upstream to Cross of Greet Bridge/Bowland Fells SSSI. Lancashire County Council, The Wildlife Trust for Lancashire, Manchester and North Merseyside, Natural England.
[60] Lancashire County Council (in prep.). Provisional Lancashire Red Data List of Vascular Plants.
[61] UKTAG (2009) *op. cit.*

Table 3.13: UKTAG Derived Groundwater Dependency for Vegetation Encountered at River Hodder South

Phase 1 Habitat Type	Ecology Site ID / Location	WFD95 Wetland Type	High-level NVC Community	Groundwater Dependency
B5 – Marsh / marshy grassland	TR3.GW12	2a – Marshy grassland	MG10b	Moderate

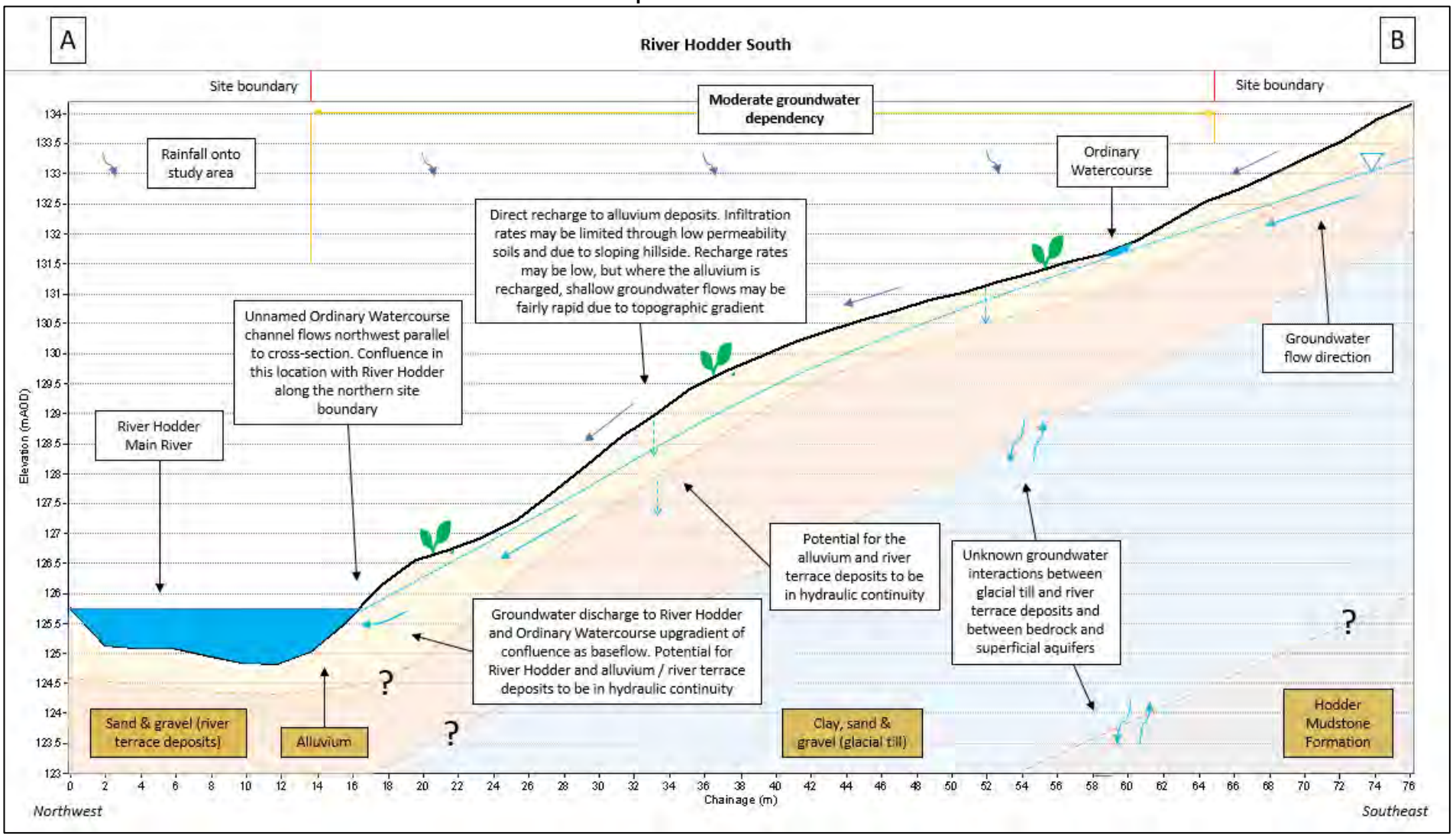
3.8.5 Initial Conceptual Site Model

241) Illustration 8 shows a conceptualised cross-section running northwest to southeast through the centre of the site (Section A-B). The CSM highlights the indicative movement of groundwater and surface water through the site, and guideline groundwater dependencies supporting vegetation and habitats.

242) Shallow groundwater sustaining GWDTEs at the site is expected to be predominantly associated with the alluvial deposits, recharged directly by incident rainfall within the wider catchment. Given the proximity of the site to the River Hodder, there is potential for groundwater stored within the alluvium, along with the underlying river terrace deposits, to be in hydraulic continuity with the Main River, and its tributary within the site. While shallow groundwater may help to support GWDTEs at the site, the steep topography means that groundwater throughflow is likely to be fairly rapid. In a similar manner, the site is also likely to receive significant surface water inputs as overland flows, which may also help to sustain the marsh habitat present. Given the combination of shallow groundwater and surface water inputs, the site is considered to have a moderate groundwater dependency.

243) Annexe A shows the groundwater dependency at the site. Given that there are no ecological designations at the site, according to Chapter 7: Water Environment, the sensitivity of the GWDTE is medium.

Illustration 8: Conceptual Site Model for River Hodder South



3.8.6 Assessment of Effects

244) The site is separated from most of the works area by the River Hodder Main River, which flows west along the northern boundary of the site. A proportion of the proposed access area for the Newton-in-Bowland Compound lies on the same side of the river as the site and is located 90 m northeast at its closest point.

Enabling Works

245) Given its distance, no dewatering impacts associated with the proposed attenuation pond are expected at the site (see Table 3.14). In addition, any groundwater flow disruptions caused by earthworks activities to the north of the River Hodder (i.e. topsoil stripping and construction of the access tracks / haul roads) are not expected to impact the site, as the river likely forms a boundary for groundwater flows.

246) Topsoil stripping and ground compaction associated with the compound access area to the northeast is also unlikely to impact the GWDTE, as the site does not lie downgradient of the works area or in its vicinity.

247) Similarly, any changes to groundwater quality within the compound access area, due to accidental leaks or spills of fuels and chemicals, and / or mobilisation of suspended solids, are not expected to impact groundwater quality at the site.

Construction

248) The site lies outside of the calculated dewatering zones of influence for the proposed portal and open-cut connection and the site is separated from these activities by the River Hodder. Therefore, no impacts on groundwater levels and flows at the site due to construction phase dewatering are predicted.

249) Considering the embedded mitigation measures referred to in the CCoP, in conjunction with the groundwater flow direction in the area and the distance of the site from the proposed access track, no impacts on groundwater quality at the site are also predicted.

Operation

250) There are no permanent below ground structures proposed within the vicinity of the site to locally alter groundwater levels and flows supporting GWDTEs. No impacts to the site are therefore predicted.

Summary

251) A summary of the potential impacts to the site is provided in Table 3.14.

Table 3.14: Summary of Effects to River Hodder South

Groundwater Dependency	Ecological Designation	Sensitivity	Effect Type	Phase	Highest Magnitude of Impact	Highest Significance of Effect
Moderate	None	Medium	Attenuation pond dewatering (groundwater levels / flows)	Enabling	No impact	N/A
			Portal dewatering (groundwater levels / flows)	Construction	No impact	N/A
			Open-cut connection dewatering (groundwater levels / flows)	Construction	No impact	N/A
			Overflow dewatering (groundwater levels / flows)	Construction	No impact	N/A
			Intercept flows in short term, including ground compaction (groundwater levels / flows)	Enabling / Construction	No impact	N/A
			Accidental leaks / spills, of fuels and chemicals, including cement and sewage (groundwater quality)	Enabling / Construction	No impact	N/A
			Mobilisation of suspended solids (groundwater quality)	Enabling / Construction	No impact	N/A
			Intercept flows in long term, i.e. loss of aquifer storage, backfilling materials, and ground settlement in superficial deposits	Operation	No impact	N/A

Groundwater Dependency	Ecological Designation	Sensitivity	Effect Type	Phase	Highest Magnitude of Impact	Highest Significance of Effect
			(groundwater levels / flows)			

3.9 Other Potential GWDTEs

252) In addition to the GWDTEs assessed above, there are three potential sites located in the overarching GWDTE assessment area (see Chapter 7: Water Environment). No CSMs have been developed for these additional sites because they are considered unlikely to experience direct or indirect significant effects as a result of the Proposed Bowland Section. Whilst these potential GWDTEs have not been assessed individually, they are listed in Table 3.15. Annexe A shows their locations.

Table 3.15: Potential Sites in the Overarching GWDTE Assessment Area

Phase 1 Habitat Type	Ecology Site ID / Location	Relation to Scheme / General Comments
B5 (Marsh / marshy grassland)	No ID given	Three small areas of marsh located 40 m south of the Lower Houses Compound
E2.1 (Acid / neutral flush), E3.1 (Valley mire), B5 (Marsh / marshy grassland)	No ID given	Northern part of a large area of connected marsh, flush and fen habitats. Located 185 m south of Lower Houses Compound
F1 (Swamp)	TR3.GW8	Small area of swamp located 115 m southwest of The Coach House and 150 m southwest of the Newton-in-Bowland Compound

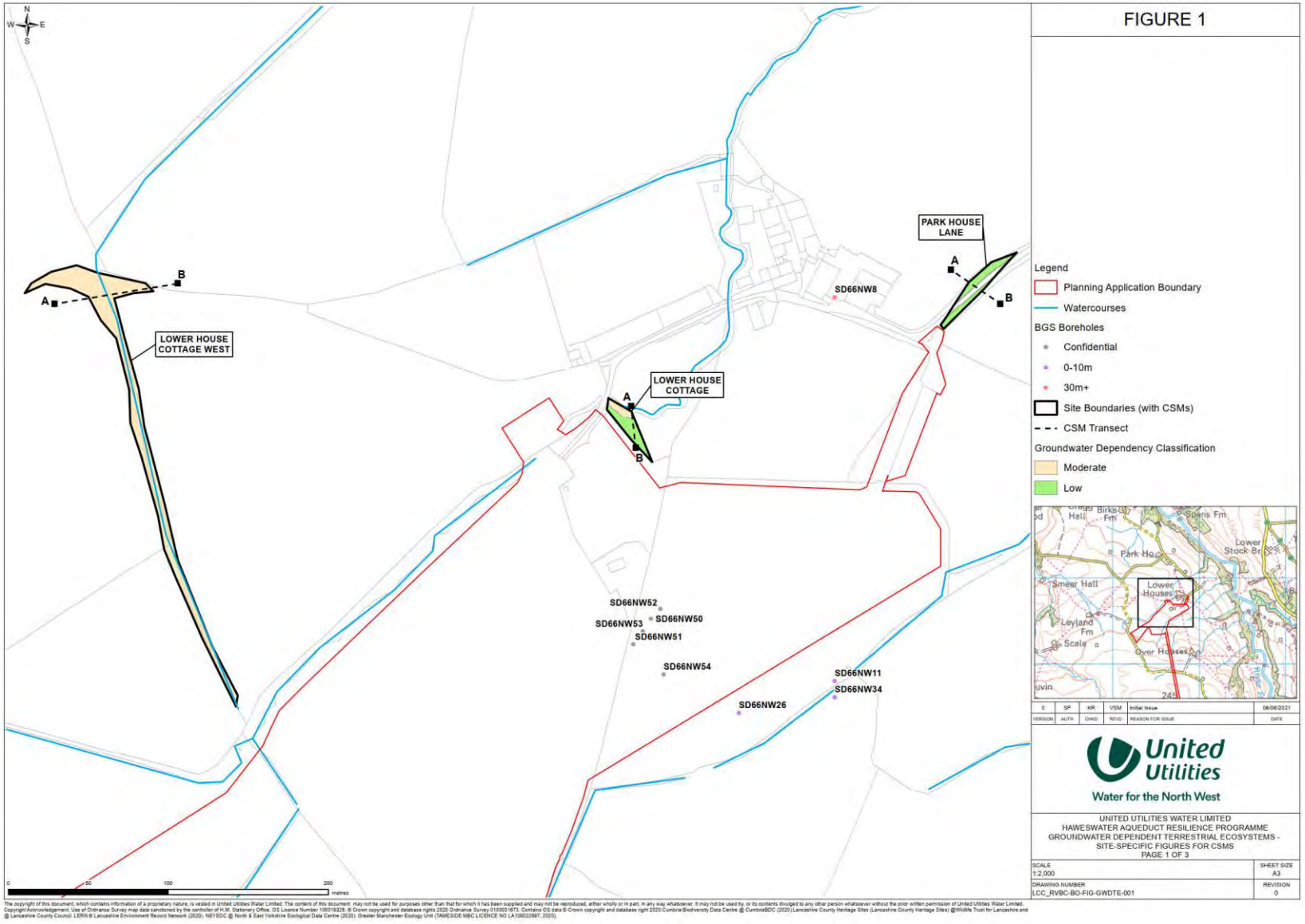
4. Summary of Effects

253) A summary of the initial assessment of groundwater dependency of each GWDTE and the associated magnitudes of impacts to existing groundwater levels, flows, and quality is provided in Table 3.16

Table 3.16: Summary of Effects to GWDTEs for the Proposed Bowland Section

Site	Initial Assessment of Groundwater Dependency	Sensitivity	Highest Magnitude of Impact			Highest Significance of Effect		
			Enabling	Construction	Operation	Enabling	Construction	Operation
Lower House Cottage	Moderate to low	Medium to low	Moderate Adverse	Minor Adverse	No impact	Moderate	Slight	N/A
Lower House Cottage West	Moderate	Medium	No impact	No impact	No impact	N/A	N/A	N/A
Park House Lane	Low	Low	Minor Adverse	Minor Adverse	No impact	Neutral	Neutral	N/A
Gamble Hole Farm Pasture	High	High	Major Adverse	Major Adverse	Moderate Adverse	Large	Very Large	Moderate
The Coach House	High	Medium	Moderate Adverse	No impact	No impact	Moderate	N/A	N/A
Dunsop Bridge Road	High to moderate	Medium	Minor Adverse	No impact	No impact	Slight	N/A	N/A
River Hodder North	High	Medium	Major Adverse	Major Adverse	No impact	Large	Large	N/A
River Hodder South	Moderate	Medium	No impact	No impact	No impact	N/A	N/A	N/A

Annexe A. Site Specific Figures for CSMs



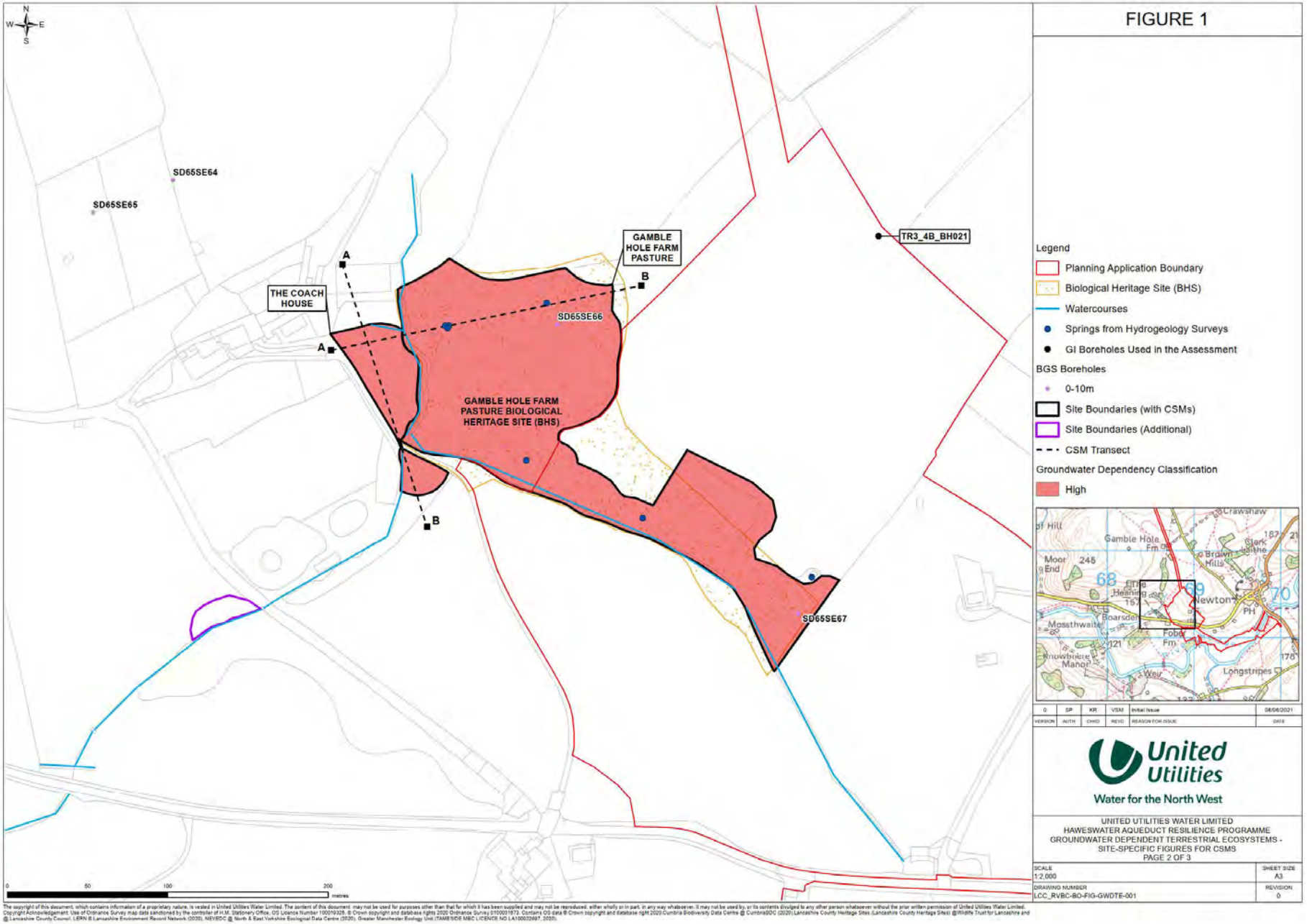


FIGURE 1
SD65SE64
SD65SE65
SD65SE66
SD65SE67
GAMBLE HOLE FARM PASTURE
THE COACH HOUSE
GAMBLE HOLE FARM PASTURE BIOLOGICAL HERITAGE SITE (BHS)
TR3_4B_BH021
A
B
Legend
Planning Application Boundary
Biological Heritage Site (BHS)
Watercourses
Springs from Hydrogeology Surveys
GI Boreholes Used in the Assessment
BGS Boreholes
0-10m
Site Boundaries (with CSMs)
Site Boundaries (Additional)
CSM Transect
Groundwater Dependency Classification
High
United Utilities
Water for the North West
UNITED UTILITIES WATER LIMITED
HAWESWATER AQUEDUCT RESILIENCE PROGRAMME
GROUNDWATER DEPENDENT TERRESTRIAL ECOSYSTEMS - SITE-SPECIFIC FIGURES FOR CSMS
PAGE 2 OF 3
SCALE 1:2,000
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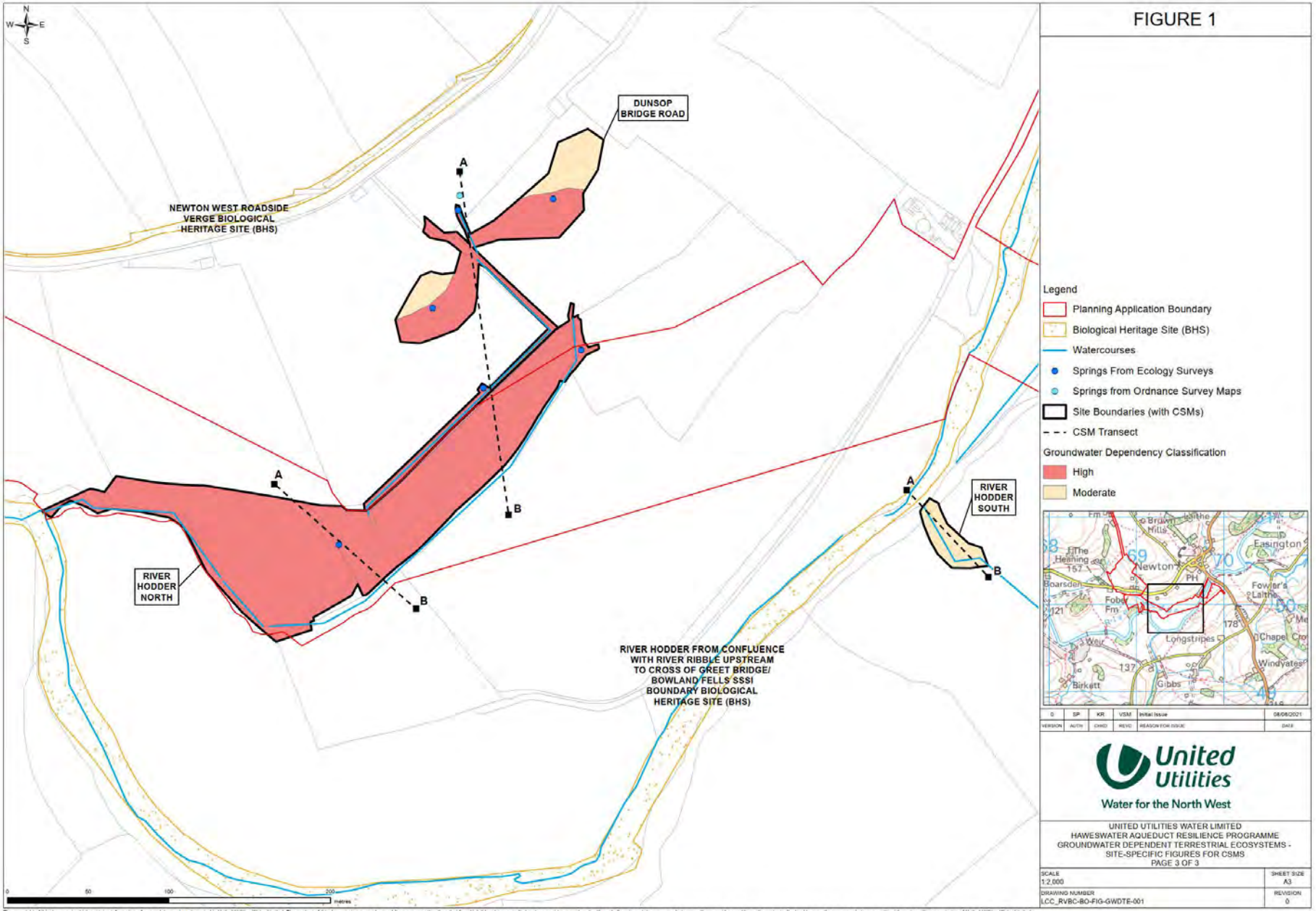
FIGURE 1
DUNSOP BRIDGE ROAD
NEWTON WEST ROADSIDE VERGE BIOLOGICAL HERITAGE SITE (BHS)
RIVER HODDER NORTH
RIVER HODDER SOUTH
RIVER HODDER FROM CONFLUENCE WITH RIVER RIBBLE UPSTREAM TO CROSS OF GREET BRIDGE/ BOWLAND FELLS SSSI BOUNDARY BIOLOGICAL HERITAGE SITE (BHS)
A
B
Legend
Planning Application Boundary
Biological Heritage Site (BHS)
Watercourses
Springs From Ecology Surveys
Springs from Ordnance Survey Maps
Site Boundaries (with CSMs)
CSM Transect
Groundwater Dependency Classification
High
Moderate
United Utilities
Water for the North West
UNITED UTILITIES WATER LIMITED
HAWESWATER AQUEDUCT RESILIENCE PROGRAMME
GROUNDWATER DEPENDENT TERRESTRIAL ECOSYSTEMS - SITE-SPECIFIC FIGURES FOR CSMS
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