A47 Wansford to Sutton Dualling

Scheme Number: TR010039

Volume 6
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Appendix 13.4 - Groundwater assessment

APFP Regulation 5(2)(a)

Planning Act 2008

Infrastructure Planning (Applications: Prescribed
Forms and Procedure) Regulations 2009

July 2021

Infrastructure Planning

Planning Act 2008

The Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009

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Development Consent Order 202[x]

ENVIRONMENTAL STATEMENT APPENDICES
Appendix 13.4 - Groundwater assessment

Regulation Number:	Regulation 5(2)(a)
Planning Inspectorate Scheme Reference	TR010039
Application Document Reference	TR010039/APP/6.3
BIM Document Reference	HE551494-GTY-EWE-000-RP-LE-30005
Author:	A47 Wansford to Sutton Project Team, Highways England

Version	Date	Status of Version
Rev 0	July 2021	Application Issue

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1. Introduction

1.1.1. This appendix report supports Chapter 13 (Road Drainage and Water Environment) of the Environmental Statement (ES) (**TR010039/APP/6.1**). It provides a hydrogeological conceptual model for the Proposed Scheme and its study area, based on a ground investigation undertaken in the current stages of the Proposed Scheme, and the necessary groundwater-specific environmental assessments as described in the Design Manual for Roads and Bridges (DMRB) LA113 Road Drainage and the Water Environment (Highways England, 2020). These assessments identify potentially significant impacts and inform the assessment of significant effects presented in Chapter 13 (Road Drainage and the Water Environment) (**TR010039/APP/6.1**), which follows the assessment methodology described in LA104 Environmental Assessment and Monitoring (Highways England, 2019).

1.1.2. The study area encompasses groundwater and surface water features that could be affected by the Proposed Scheme. The study area is based on professional judgement to ensure that effects are sufficiently identified. It comprises a 1km corridor surrounding the Proposed Scheme boundary. The groundwater study area is shown in Annex A Location Plan.

1.2. Scheme overview

1.2.1. Chapter 2 (The Proposed Scheme) of the Environmental Statement (**TR010039/APP/6.1**) provides a detailed description of the Proposed Scheme. The overall aim of the Proposed Scheme is to alleviate traffic flow issues between Wansford and Sutton by upgrading to dual carriageway and by constructing a slip road between the A1 southbound and the A47 eastbound carriageways, to effectively bypass the junction. The Proposed Scheme includes the following below-ground structures and infiltration features, which are shown in Annex A Location Plan:

- New drainage design including two infiltration ponds and filter drains discharging to ground
- Sacrewell Farm underbridge (S05)
- Wansford NMU underpass (S02)

1.2.2. Key potential construction and operation effects upon the water environment include:

- Changes to groundwater levels and / or flow through groundwater control during construction, and through redirection and / or reduction of lows around permanent subsurface structures

- Contamination of groundwater by generation of suspended solids, direct contact with construction materials, or polluted construction run off
- Contamination of surface water by discharge of dewatering volumes, if required
- Discharge of metalloid and organic compounds from road drainage to surface water and groundwater.

1.3. Aims and Objectives

1.3.1. This report aims to;

- provide a hydrogeological conceptual model and identify key direct and indirect receptors within the study area,
- identify construction and operation activities specific to the Proposed Scheme that have the potential to impact on the groundwater environment,
- present simple qualitative assessments to identify which activities may result in a significant impact, and therefore require further consideration and / or mitigation.

1.3.2. The report is set out in the following structure to achieve these aims:

- Chapter 2 presents the hydrogeological baseline conditions, based on ground investigation results and other freely available sources of information, to provide a conceptual model and identify receptors, in line with the Groundwater Levels and Flows assessment method set out in LA113.
- Chapter 3 provides details of construction and operation activities and a description of the potential hydrogeological impact, prior to mitigation.
- Chapter 4 assesses the significance of risk to receptors in line with the assessment methods as set out in LA113 (Groundwater Dependent Terrestrial Ecosystems (GWDTE), Routine runoff and groundwater quality and spillage assessments).
- Chapter 5 summarises the activities that may result in a potentially significant impact, prior to mitigation, and that are taken forward for further consideration in the assessment of significant effects in Chapter 13 (Road Drainage and the Water Environment) of the ES (**TR010039/APP/6.1**).

1.4. Data sources

1.4.1. This technical report has been produced utilising the following sources of information:

- British Geological Survey (BGS) 1:50,000 and 1:625,000 superficial and bedrock geological maps (British Geological Survey, 2021a)
- DEFRA's 'Magic' interactive map (DEFRA, 2021)

- Environment Agency (EA) Catchment Data Explorer (Environment Agency, 2021a)
- Highways Agency Drainage Data Management System (HADDMS), Drainage Data Management System v5.12. (Highways England, 2021)

1.4.2. Additional information was requested from the EA for the study area in March 2020 and has also been summarised, where appropriate, in the report:

- Licensed groundwater and surface water abstractions
- Consented discharges

1.4.3. The following information was requested from the three local authority areas that the study area falls within in June 2020:

- Unlicensed groundwater and surface water abstractions
- Unlicensed consented discharges to groundwater and surface water

Ground investigation

1.4.4. A 2018 geotechnical and geo-environmental investigation was undertaken around the A47 Wansford to Sutton dualling scheme.

1.4.5. The objective of the investigation was to obtain information on the ground and groundwater conditions relating to the preliminary design of the proposed highways development, which included improvement works to the existing A47 / A1 junction. The investigation comprised cable percussive boreholes, dynamic sample boreholes, trial pits and dynamic probes. Soakaway infiltration testing, groundwater level monitoring, and laboratory testing of soil and groundwater was also undertaken. Since the ground investigation (GI) was undertaken the position of the proposed A47 realignment has moved northwards between Sutton Heath Road and Upton Road. A supplementary GI is planned for the next stage of the Proposed Scheme to confirm ground conditions in this area.

1.4.6. There is a total of 19 boreholes that have been completed for groundwater monitoring.

1.4.7. Five infiltration tests were completed during the ground investigation works.

1.4.8. Groundwater levels were initially recorded over a three-month period following the completion of initial fieldwork, with additional groundwater level monitoring undertaken between September 2020 and February 2021.

1.4.9. Groundwater quality analyses were completed 14 samples collected on 15 November 2018.

2. Hydrogeological baseline conditions

2.1. Topography and drainage

2.1.1. The site is located adjacent and inline to the existing A47 single carriageway between the A47 / A1 junction, at Wansford and the existing A47 / Castor / Upton roundabout, north of Sutton. Topography falls towards the east from a high of 30maOD in the west to a low of 11maOD at Wittering Brook, adjacent to the Sutton Heath Road junction. From here there is a slight rise to approximately 20maOD where it broadly remains for the rest of the route. Topography from the north slightly slopes towards the River Nene.

2.1.2. The River Nene is present immediately to the south of the Proposed Scheme and meanders from the south to flow in an eastwards direction between the A1 and Sutton Heath Road before flowing south-eastwards and away from the A47. Several watercourses traverse or adjoin the site. These generally flow from north to south, with the exception of Mill Stream, which flows from west to east beneath the A1 to join Wittering Brook, a tributary of the River Nene. There are also a number of springs and ponds in the study area. In particular there are ponds adjacent to Mill Stream at Sacrewell Farm, and also to the south of the River Nene.

2.2. Geology

2.2.1. The bedrock and superficial geology within the study area is described in detail below. The superficial geology is shown in Annex A Location Plan.

Head

2.2.2. Head deposits are present along the route of Mill Stream, and in particular where this crossed the A1, and also beyond the eastern extents of the Proposed Scheme. The head deposits are described as generally poorly sorted and comprise clay, silt, sand and gravel, with occasional inclusions of peat. Head deposits were encountered in one borehole during ground investigation works in the west of the study area in BH02 adjacent to the A1 / Great North road on approach to the A47 intersection. The deposits are described as cohesive in the form of firm grey silty clay.

Alluvium

2.2.3. Granular and cohesive alluvium is present along the route of River Nene and the Wittering Brook, and is present beneath the Proposed Scheme to the west of Sutton Heath Road junction, as proven by BH30 during ground investigation works. Alluvium was also encountered in TP11, TP12 on the north bank of the River Nene adjacent to the sewage Anglian Water pumping station. Granular alluvium was encountered as sand and sandy gravel. Cohesive alluvium was encountered as gravelly sandy locally silty clay (Sweco, 2020). Alluvium deposits were encountered at depths between 0.3 to 1.2mbGL (BH30), 0.3 to 2.3mbGL (TP11) and 0.1 to 2.1mbGL (TP12), indicating the alluvial deposits are greatest adjacent to the River Nene.

River Terrace Deposits

2.2.4. River terrace deposits are generally present on the inner sides of meanders of the River Nene and to the west of Wittering Brook. They are generally present along the Proposed Scheme, except to the west of the sewage Anglian Water pumping station and a small area near the Sutton Heath Road junction. The river terrace deposits were encountered as interbedded granular and cohesive material during ground investigation works. Granular river terrace deposits were encountered as silty or clayey gravelly sand or sandy gravel. Cohesive river terrace deposits were encountered as gravelly sandy locally silty clay and occasionally clayey silt (Sweco, 2020). River terrace deposits ranged in thickness between 0.4m (BH33) and 5.6m (BH40) with an average thickness of 2.6m. The maximum depth recorded is 5.9mbGL (BH40).

Rutland Formation

2.2.5. The youngest, uppermost bedrock lithology encountered under the proposed alignment is the Rutland Formation of the Great Oolite Group, which is a sedimentary rock composed of sandstones, siltstones, and fireclays, and occasionally containing rootlets. The formation was noted in boreholes in the eastern end of the study area (BH36, 37, 37A, 38, 40 and 41). The depth of the Rutland Formation was not proven during GI works, with a maximum thickness of 3.6m observed in BH38. The Rutland Formation was encountered at depths between 0.3mbGL (TP30) and 8.1mbGL (BH38) and is generally overlain by river terrace deposits.

Lincolnshire Limestone Formation

2.2.6. The Lincolnshire Limestone Formation of the Inferior Oolite Group includes the Upper Lincolnshire Limestone Member and the Lower Lincolnshire Limestone Member. This is found generally beneath the whole of the Proposed Scheme, with the exception of a small central section where this has been eroded by the River Nene and Wittering Brook to expose the older Grantham Formation and Lias Group. The Lower Lincolnshire Limestone Member comprises flat bedded, oolitic limestone with marl partings. The Upper Lincolnshire Limestone Member comprises coarse grained oolites, which are thought to have infilled channels in the older, lower limestone. The two members were considered together in the Ground Investigation Report (Sweco, 2020). Lincolnshire Limestone deposits ranged in thickness from 0.6m (TP26) to 11.7m (BH32) with an average thickness of 4.7m.

Grantham Formation

2.2.7. The Grantham Formation of the Inferior Oolite Group underlies the Lincolnshire Limestone Formation where present across the site. It is a sedimentary rock, comprising white and grey leached silts and sands, and dark grey clays, often containing rootlets and lignitic debris. The Grantham Formation ranges in thickness from 0.5m (BH01) to 7.58m (BH33) with an average thickness of 3.8m. The maximum observed depth of the Grantham Formation was 16.9mbGL (BH32) and the BGS Lexicon indicates the Grantham Formation thickness is typically 2m to 5m but can be up to 15m thick in channels (BGS, 2021b).

Whitby Mudstone Formation

2.2.8. The oldest unit encountered during the ground investigation is the Whitby Mudstone Formation, part of the Lias Group. It is sedimentary bedrock, described by the BGS (BGS, 2021b) as comprising grey mudstones and shales with bands of phosphatic and limestone nodules. The Lias Group were typically encountered at a shallow depth where underlying made ground or superficial deposits, generally along the route of the River Nene and Wittering Brook. Elsewhere, the Lias Group is found underlying Lincolnshire Limestone and Grantham Formation deposits. The thickness of the Lias Group ranged between 1.35m (BH19) and 14.59 (BH14A). The maximum depth that the Whitby Mudstone Formation was recorded at was 25.94mbGL (BH32). The base of the formation was not encountered. The BGS lexicon indicates that the Whitby Mudstone Formation may be up to 120m thick (BGS, 2021b).

2.3. Hydrogeology

Aquifer designations

2.3.1. Table 1 summarises Environment Agency aquifer designations along with their approximate extents within the study area.

Table 1 Aquifer designations

Geological Unit	Group	EA Aquifer Designation	Approximate Extents
Head	Pleistocene & recent	Secondary (undifferentiated) aquifer	Towards western end of scheme Encountered in BH2 adjacent to the A1 / A47 junction
Alluvium		Secondary A aquifer	Present along the Nene valley to the south of the A47, and beneath Wittering Brook, to the west of Sutton Heath Road
River terrace deposits		Secondary A aquifer	Generally present to the east of the Sacrewell Farm access road junction, with exception of one small area around the Sutton Heath Road junction
Rutland Formation	Great Oolite Group	Secondary B aquifer	Towards eastern end of scheme (overlain by river terrace deposits)
Upper Lincolnshire Limestone	Inferior Oolite Group	Principal aquifer	Small outcrop area around A1/A47 junction
Lower Lincolnshire Limestone		Principal aquifer	Outcrops around Sacrewell Farm access road junction and east of Sutton Heath Road junction
Grantham Formation		Secondary (undifferentiated) aquifer	Present around Sacrewell Farm access road junction and east of Sutton Heath Road junction. Generally overlain by alluvium or river terrace deposits. One small outcrop area to the west of Sutton Heath Road junction
Whitby Mudstone	Lias Group	Unproductive strata	Assumed present across the entire area, generally overlain by the Inferior Oolite, except along the River Nene and Wittering Brook, where it is overlain by superficial deposits.

2.3.2. Principal aquifers are strata that have high intergranular and/or fracture permeability, and as such usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale.

2.3.3. Secondary A aquifers are permeable layers capable of supporting water supplied at a local, rather than strategic scale, and in some cases, form an important source of baseflow to rivers.

2.3.4. Secondary B aquifers are predominantly lower permeability layers which may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering. These are generally the water-bearing parts of the former non-aquifers.

2.3.5. Secondary (undifferentiated) aquifers are classified as such due to the formation previously having been designated as both a minor aquifer and non-aquifer (now defined as Secondary A and Secondary B respectively) in different locations, due to variable characteristics of the rock type. As such Secondary (undifferentiated) aquifers are likely to contain lower permeability layers and perched aquifers.

2.3.6. Unproductive strata are rock layers or superficial deposits with low permeability that have negligible significance for water supply or river baseflow (Environment Agency, 2021b).

2.3.7. The bedrock and superficial aquifers have a combined groundwater vulnerability classification of high risk in areas where there is limited cover of superficial deposits and the Lower Lincolnshire Limestone is exposed. This is found in the vicinity of the A1/A47 junction in the west of the site and along Sutton Heath Road in the east. Areas of medium to high risk are associated with exposure of the Grantham Formation in the west of the site and the Upper Lincolnshire Limestone in the east. Areas of medium to low risk are associated with cover of alluvium and river terrace deposits in the vicinity of the River Nene. Soluble rock risk is associated with the Limestone bedrock under the site.

Groundwater levels and flows

Regional groundwater level monitoring

2.3.8. The nearest EA groundwater level monitoring boreholes are located within the Sutton Heath and Bog SSSI to the north of the Proposed Scheme and west of Sutton Heath Road. There are three monitoring boreholes, two of which monitor the Lincolnshire Limestone and one that monitors the superficial sands and gravels. Data has been provided by the EA for between March 1998 and March 2020. Details of the monitoring boreholes and a summary of water levels is provided in Table 2.

Table 2 Summary of EA groundwater level monitoring within Sutton Heat and Bog SSSI

Borehole Reference Number	NGR	Monitoring Horizon	1998 - 2020 Water levels (maOD)		
			Minimum	Average	Maximum
3/032	509070 300040	Lincolnshire Limestone	14.25	15.42	22.18
3/034	509030 300230	Lincolnshire Limestone	17.95	18.67	20.23
8/913	508840 300060	Superficial sands and gravels	11.13	11.61	12.02

2.3.9. A hydrograph summarising these EA groundwater levels is given below in Figure 1. There is a period of spurious data from BH3/032 in from April 2018 to June 2019, which has been interpreted to be erroneous data. Figure 2 highlights that long-term groundwater levels within the Lincolnshire Limestone have been relatively stable with a very slight downwards trend and a seasonal range in the order of 1m. Groundwater levels in the superficial sands and gravels follow a similar, albeit muted, pattern and with a seasonal range of around 0.6 – 0.8m.

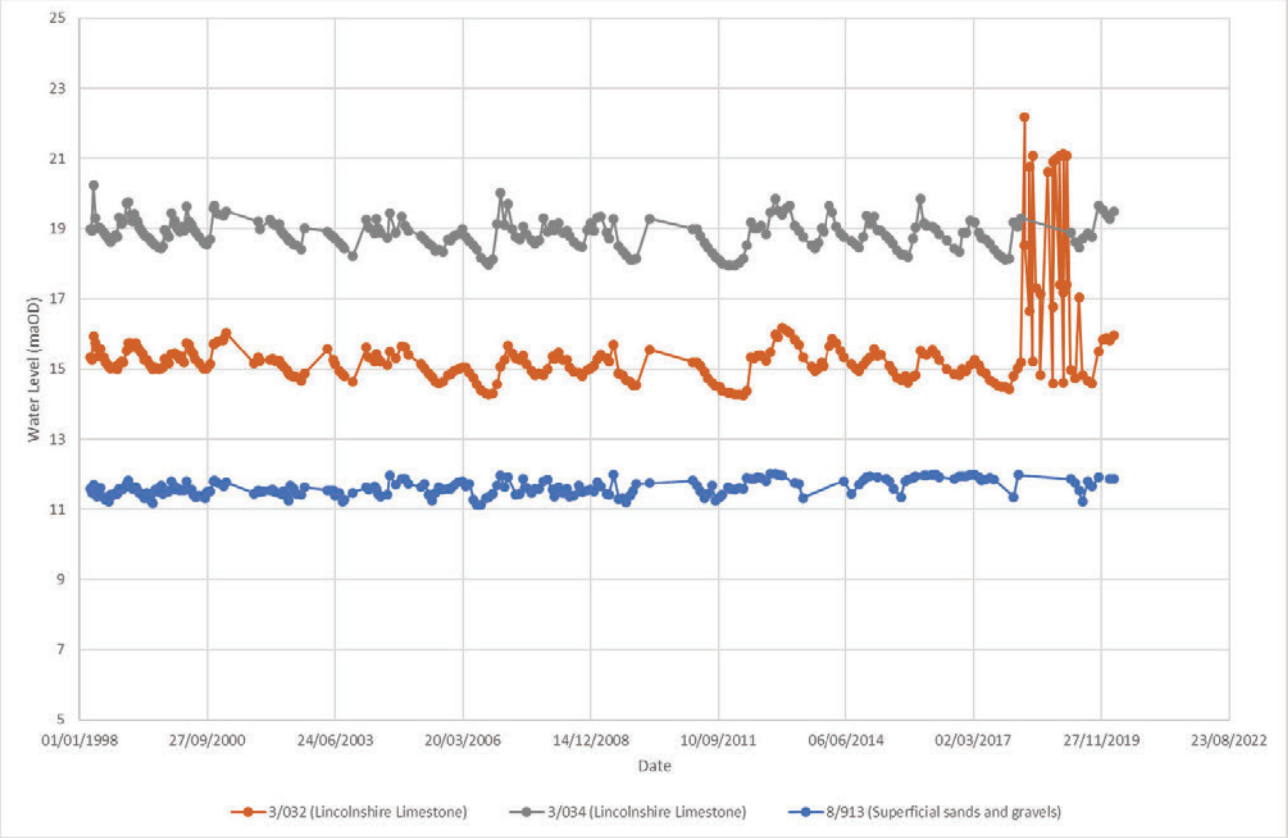

Figure 1 EA monitoring boreholes at Sutton Heath and Bog SSSI, 1998 to 2020.

Site groundwater level monitoring

2.3.10. Groundwater was encountered within 21 exploratory holes during drilling, with strikes associated mainly with the Lincolnshire Limestone Formation and Grantham Formation, but also the Lias Group. 19 exploratory boreholes were fitted with 50mm diameter standpipe installations to monitor groundwater levels. Groundwater level monitoring data was collected during and post fieldwork between September 2018 and January 2019 and also between September 2020 and February 2021, as summarised in Table 3 and presented in Figure 2.

2.3.11. The majority of boreholes monitoring bedrock aquifers have installations that are screened over several horizons (BH3A, BH6, BH7, BH9, BH11, BH13, BH18, BH20, BH27 and BH37A). Where this is the case, groundwater levels are broadly found to be close to the top of, and within, the Grantham Formation across the study area, however. Table 3 highlights that groundwater levels are generally close to ground level across the Proposed Scheme.

Table 3 Groundwater level monitoring summary (September 2018 to January 2019, September 2020 to February 2021)

Borehole Reference Number	Ground Elevation (m aOD)	Response Zone Depths (m bDAT)	Monitoring Horizon	Min GW level (m bGL)	Min GW level (m aOD)	Date	Max GW level (m bGL)	Max GW level (m aOD)	Date
BH01A	19.38	1 – 2.7	Grantham Formation	1.35	18.03	24/01/19	0.00	19.38	15/01/21
BH03A	28.59	1.5 – 12.0	Upper Lincolnshire Limestone, Grantham Formation & Lias Group	8.42	20.17	25/09/18	7.21	21.38	19/02/21
BH06	29.59	1.5 – 6.0	Lower Lincolnshire Limestone & Grantham Formation	DRY	DRY	All visits except (25/09/18)	6.05	23.54	15/01/21
BH07	29.45	1.5 – 10.5	Upper Lincolnshire Limestone, Grantham Formation & Lias Group	6.7	22.75	21/12/18	5.57	23.88	19/02/21
BH09	18.38	3.5 – 9.0	Lower Lincolnshire Limestone, Grantham Formation & Lias Group	5.16	13.22	03/10/18	3.44	14.94	17/09/18
BH11	21.09	1.5 – 7.5	Lower Lincolnshire Limestone, Grantham Formation & Lias Group	DRY	DRY	03/09/20 & 12/10/20	2.47	18.79	19/02/21
BH13	27.54	1.0 – 6.7	Lower Lincolnshire Limestone & Grantham Formation	DRY	DRY	10/18, 11/18 and 01/19	6.45	21.09	19/02/21
BH16	27.61	8.5 - 20	Lias Group	8.62	18.99	11/10/18	6.35	21.26	12/12/18
BH18	26.32	1.5 – 10.5	Lower Lincolnshire Limestone & Grantham Formation[1]	6.75	19.57	21/12/18	5.74	20.58	19/02/21
BH20	22.32	1.5 – 7.5	Lower Lincolnshire Limestone & Grantham Formation	5.1	17.22	24/01/19	3.91	18.41	19/02/21
BH24	12.32	6.5 – 15.0	Lias Group	3.26	9.06	06/11/18	1.37	10.95	19/02/21
BH26	15.66	3.3 – 15.0	Lias Group	4.3	11.36	21/12/18	2.59	13.07	19/02/21

BH27	14.07	5.0 – 15.0	Whitby Formation & Lias Group	5.3	8.77	03/10/18	4.28	9.79	19/02/21
BH29	9.87	1.0 – 3.1	Lower Lincolnshire Limestone	2.15	7.72	03/10/18	0.41	7.72	15/01/21
BH33	18.88	6.4 – 12.4	Northampton Sand Formation	8.4	10.48	24/01/19	6.45	12.43	19/02/21
BH34	24.02	14.5 – 25.5	Lias Group	25.67	-1.65	06/11/18	6.59	17.43	15/01/21
BH36	19.54	0.6 – 2.8	River Terrace Deposits	DRY	DRY	All visits except (06/11/18)	2.75	16.79	06/11/18
BH37A	19.32	2.5 – 5.0	Rutland Sand Formation and Northampton Sand Formation	DRY	DRY	09/18, 10/18, 01/1, 09/20 and 10/20.	2.52	16.80	05/09/18
BH39	16.93	2.0 – 5.5	River Terrace Deposits	DRY	DRY	09/18, 10/18 and 12/18	4.76	12.17	19/02/21

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[1] Rutland Formation in BH18 interpreted to be Grantham Formation in the GIR (Sweco, 2020)

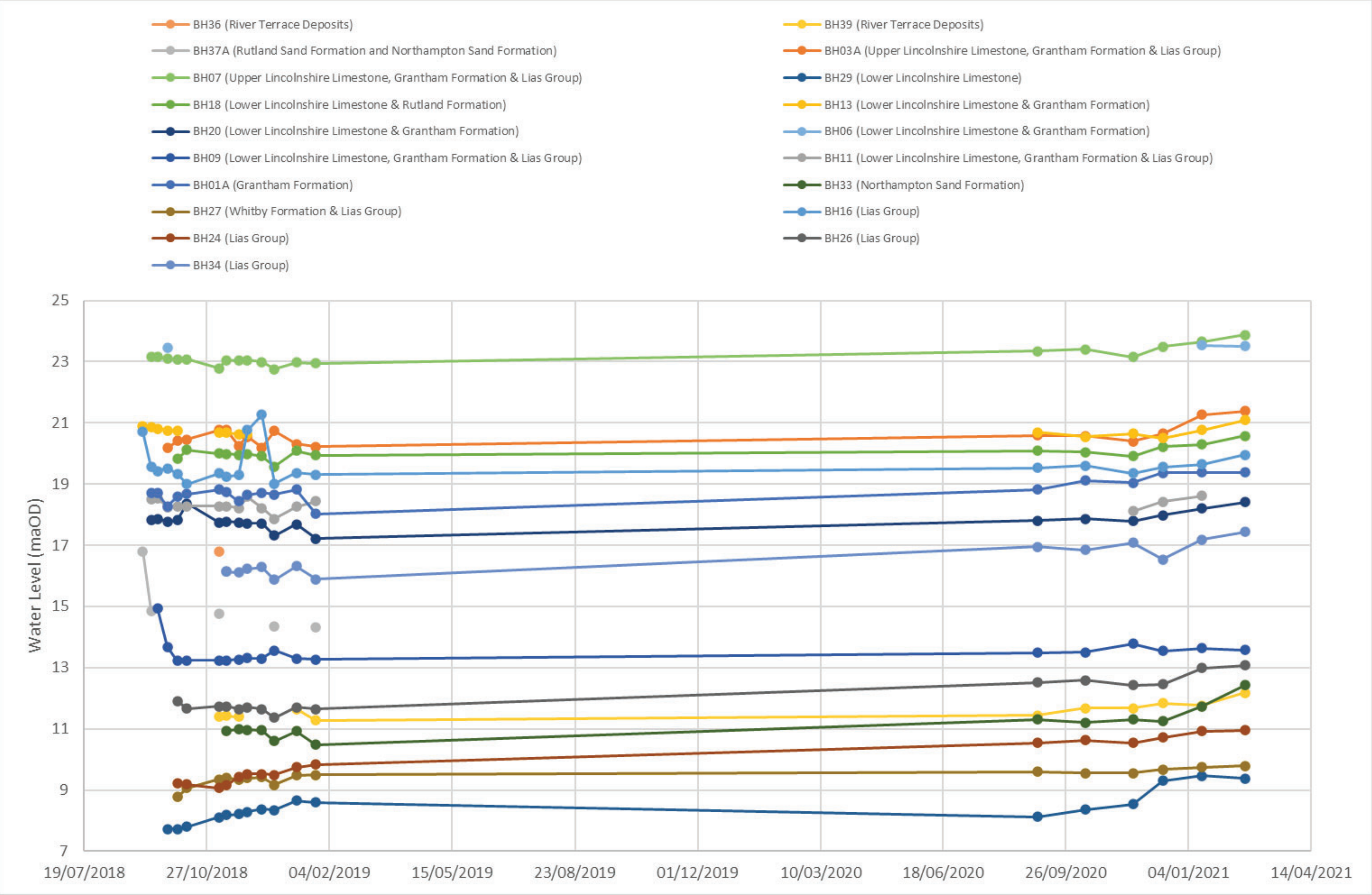

Figure 2 Groundwater level monitoring hydrograph from 2018 ground investiga ion and subsequent monitoring visits. Full list of monitored units is given above in Table 3.

Discussion of groundwater level monitoring

Superficial deposits

2.3.12. Boreholes monitoring the river terrace deposits in the study area (BH36 and BH39) recorded maximum groundwater levels of between 2.75mbGL (16.79maOD) and 4.76mbGL (12.17maOD) and with a total range in levels of around 0.4m.

2.3.13. In comparison, the long term seasonal range in groundwater levels in borehole 8/913 at Sutton Heath and Bog SSSI is around 0.6 to 0.8m, suggesting that the seasonal maximum groundwater level has the potential to be up to 0.4m higher.

Rutland Formation

2.3.14. There is one borehole installation monitoring the Rutland Formation (BH37A), in the east of the study area, and adjacent to Sutton Drift. This is generally dry with intermittent groundwater levels recorded in the winter period at an approximate depth of ~5mbGL (14.3maOD). However, as the response zone ends at 5.10mbGL it is likely that groundwater levels are generally below the base of the installation. Groundwater levels recorded at this location in the Rutland Formation are in the order of 2m lower than in the overlying river terrace deposits.

Lincolnshire Limestone Formation

2.3.15. Only one borehole installation was screened in the Lincolnshire Limestone alone (BH29), which is situated in a low-lying area near the confluence between the Wittering Brook and River Nene. Groundwater levels recorded in this borehole are the shallowest in the bedrock within the study area, ranging between 2.15mbGL (7.72maOD) and 0.41mbGL (9.46maOD). Elsewhere, where boreholes are installed with response zone across multiple horizons, the Lincolnshire Limestone Formation is found to be dry.

2.3.16. A number of springs and issues are present in the area, which coincide with the contact point between the base of the Lincolnshire Limestone Formation and the underlying Grantham Formation of Whitby Formation. This is discussed further in the following section on surface water – groundwater interactions.

Grantham Formation

2.3.17. Groundwater levels across the site are generally found to coincide with the top of the Grantham Formation. The majority of boreholes monitoring the Grantham Formation also monitor the Lincolnshire Limestone Formation and sometimes also the Lias Group. The cross section through the Sacrewell Farm access road show presented in Figure 3 illustrates, however, that irrespective of the length of the response zone, groundwater levels generally coincide with the top of the Grantham Formation. It is likely that the Grantham Formation is in hydraulic continuity with the overlying Lincolnshire Limestone. Further cross sections are included in Annex B. 2020 GIR geological cross sections.

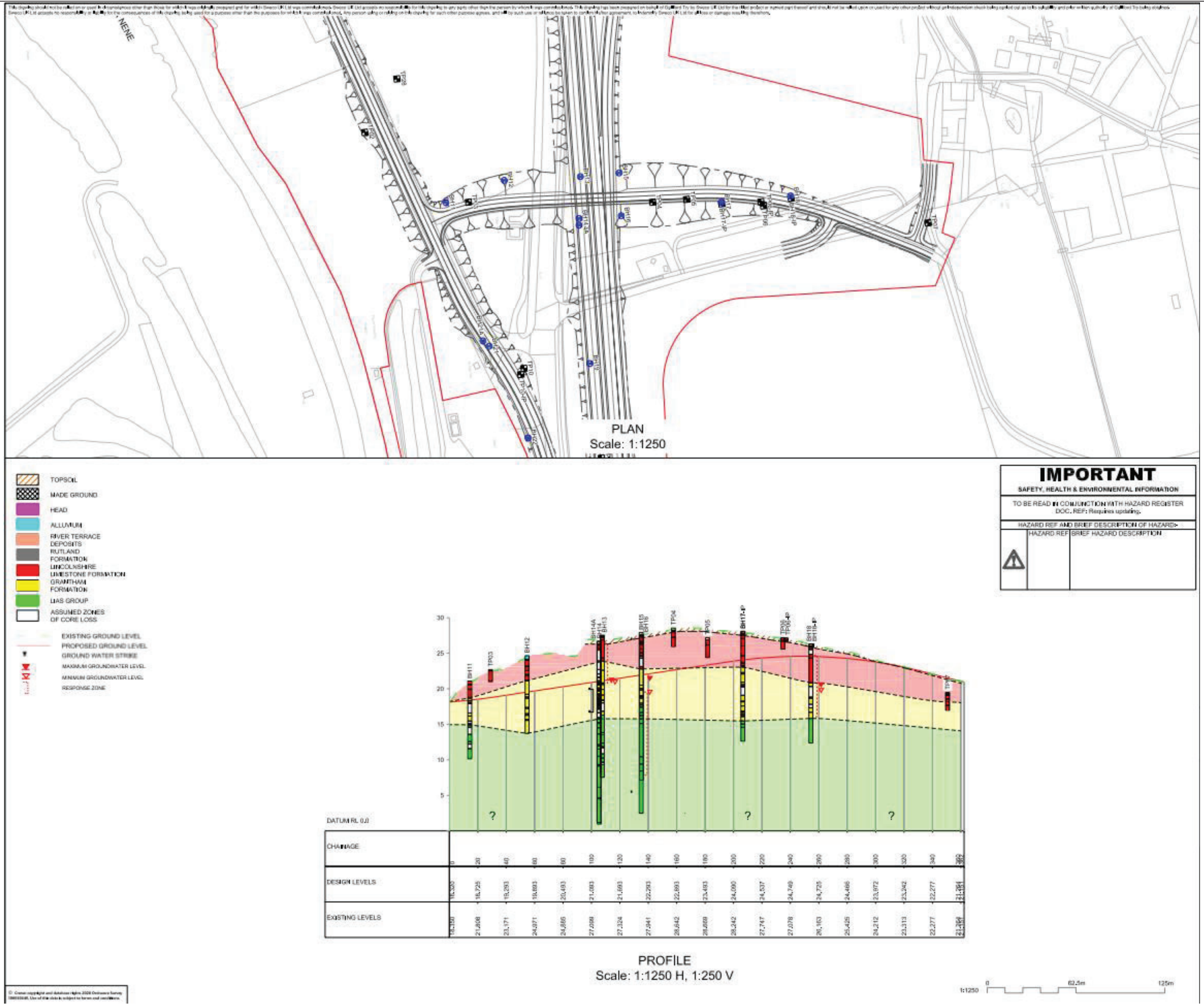

Figure 3 Cross section through the Sacrewell Farm access road

2.3.18. Groundwater levels within the Grantham Formation generally range between 2.5 and 7.3mbGL (17.2 and 23.5maOD) along the A47 route, although at the point where the A1 crosses Mill Stream (BH01A) groundwater levels are closer to ground level (0 – 1.35mbGL; 18 – 19.4mAOD). It is likely that groundwater levels are generally controlled by springs issuing from the upper boundary of the Grantham Formation, although groundwater levels also appear to fall towards the River Nene. Adjacent to watercourses such at Mill Stream and Wittering Brook, groundwater levels in the Grantham Formation are also likely to be controlled by surface water as noted by baseflow contributions discussed below.

Lias Group

2.3.19. Five boreholes monitored the fissured Lias Group (BH16, BH24, BH26, BH27 and BH34).

2.3.20. Groundwater levels in the Lias Group appear to be influenced by proximity to the River Nene. Lias Group boreholes closest to the river (BH24, BH25 and BH27) have recorded groundwater levels ranging between 1.4 and 5.3mbGL (8.8 and 13mAOD). Further away from the river, however, groundwater levels have been recorded in the Lias Group at between 6.35 and 8.62mbGL (15.9 and 21.3mAOD). Groundwater levels in the Lias Group are generally lower than adjacent groundwater levels in the Grantham Formation.

Surface water – groundwater interactions

2.3.21. In response to the Scoping Report, the Environment Agency provided details of their hydrogeological conceptualisation of groundwater – surface water interactions at Sutton Heath and Bog SSSI (see Annex C). Investigations undertaken by the EA indicate that in this area the Lincolnshire Limestone Formation outcrops, giving way to the underlying Grantham Formation and Whitby Formation at the western boundary of the SSSI. Groundwater modelling in this area indicates a downwards groundwater flow direction. The Lincolnshire Limestone Formation is recharged by rainfall, and infiltration through the limestone aquifer is likely to be rapid due to its permeable nature. Groundwater subsequently discharges as springs downslope at the boundary of the Lincolnshire Limestone Formation and the Grantham Formation/Whitby Mudstone Formation, further confirming the high permeability nature of the Lincolnshire Limestone Formation. This conceptualisation is likely to apply to other springs in the area observed at the base of the Lincolnshire Limestone Formation.

2.3.22. The Environment Agency also provided information from their groundwater model on interactions between groundwater and surface water for Mill Stream and Wittering Brook under wet, dry and average recharge scenarios. This is summarised below in Table 4.

Table 4 Summary of baseflow recharge modelling from the EA

Periods of rainfall	Flow type	Mill Stream	Wittering Brook
Dry	Stream flow	0.5 – 5 Ml/d	>5 Ml/d
	Baseflow	<0.1 Ml/d	<0.1 Ml/d
Average	Stream flow	5 – 50 Ml/d	>50 Ml/d
	Baseflow	<0.5 Ml/d	<0.5 Ml/d
Wet	Stream flow	>50 Ml/d	>50 Ml/d
	Baseflow	Up to 1 Ml/d	<0.5 Ml/d

2.3.23. The Environment Agency concluded that in all scenarios the watercourses do not lose water to ground. This is supported by vertical flow volume predictions, which suggest a small volume of upward leakage from the superficial deposits (where present) and from the bedrock into the superficial deposits along the watercourse routes. Modelling also confirmed that groundwater levels should be close to ground level in the Mill Stream and Wittering Brook area.

2.3.24. The River Nene has a baseflow index of 0.6 at Wansford (UKCEH, 2021) indicating that there is a moderate baseflow supply from groundwater. This is likely from underlying the superficial deposits (alluvium) and as such may be indirectly fed by the bedrock aquifers, either via seasonal springs discharging at the contact between the Lincolnshire Limestone Formation and Grantham Formation or Whitby Mudstone Formation, or via upwards hydraulic gradients from underlying bedrock, where this is permeable.

Aquifer properties

2.3.25. The properties of the aquifer define its capacity to release water and the ability of groundwater flow to be transmitted with ease.

2.3.26. The results of the infiltration tests from the ground investigation are presented in Table 5, below. These show that the river terrace deposits have an infiltration rate in the region of 3×10^{-2} to 1×10^{-1}m/s. Results for the weathered Lincolnshire Limestone Formation are lower in the range of 2 to 9×10^{-5}m/s.

2.3.27. The Lincolnshire Limestone is noted by the (Griffiths *et al.*, 2006) as having low primary intergranular porosity and permeability, in the range of 10^{-4}m/d (10^{-9}m/s) and high secondary permeability resulting from fracturing of tectonic origin which is enhanced by karstic weathering. Griffiths *et al.*, 2006 indicate that transmissivity within the Lincolnshire Limestone can range from 100 to 250m^2/day when unconfined and 2000 to 10000 m^2/day when confined.

2.3.28. Groundwater flow within the Lincolnshire Limestone Formation may therefore be dependent on fracture flow, and the hydraulic conductivity is therefore highly dependent on the presence, orientation and interconnectivity of fracturing. The infiltration test results are, however, within the likely range of hydraulic conductivity for a fractured limestone but there is potential that permeability could be higher.

Table 5 Summary of soakaway infiltration tests from the ground investigation

Trial Pit	Depth (mBGL)	Response zone formation	Minimum Infiltration Rate (m/s)	Associated structure?
TP14	1.44	Weathered Lower Lincolnshire Limestone Formation	1.92×10^{-5}	
TP27	1.50	Weathered Upper Lincolnshire Limestone Formation	8.96×10^{-5}	
TP28	1.50	Weathered Lower Lincolnshire Limestone Formation	4.27×10^{-5}	Infiltration basin F (design depth of 1.30mbGL)
TP29	1.46	River Terrace Deposits	2.82×10^{-2}	Infiltration basin L (design depth of 1.75mbGL)
TP30	1.46	River Terrace Deposits	1.16×10^{-1}	

2.3.29. Small scale dissolution features were noted in ground investigation boreholes within the main body of the Lincolnshire Limestone Formation (Sweco, 2020). This suggests there may be localised areas where the secondary permeability may be several orders of magnitude higher than those recorded in infiltration tests.

2.3.30. The Rutland Formation is a secondary B aquifer and the Grantham Formation is a secondary undifferentiated aquifer which are both likely to have lower intergranular permeability than the overlying Lincolnshire Limestone, but may also be controlled by the presence of fractures. The underlying Whitby Mudstone Formation is likely to have a low intergranular permeability but may store water where fractured or fissured.

Groundwater quality

2.3.31. Surface water, groundwater and leachate quality sampling was carried out as part of the 2019 ground investigation and is presented in the Ground Investigation Report (Sweco, 2020). It was noted that when compared to Drinking Water Standards (DWS) for groundwater there were marginal exceedances of Ammoniacal Nitrogen (BH24 and 26) and Boron (BH24, BH26, BH27 and BH34). Additional groundwater quality sampling, completed in

October 2020, identified exceedances of chloride (BH1A, BH3A, BH24, BH26 and BH29). A summary of the sampling results of key road drainage pollutants, including copper, zinc and chloride are provided in Table 6.

Table 6 Summary of groundwater results from 2020 groundwater quality monitoring

Location	Depth (mbGL)	Date	Total Copper (µg/l)	Total Zinc (µg/l)	Total Cadmium (µg/l)	Total Chloride (mg/l)	Fluoranthene (ug/l)	Pyrene (ug/l)	Total of 16 PAH's (total) (ug/l)
BH1A	0.27	12/10/2020	1.7	13	<0.080	360	<0.1	<0.1	<2.0
BH3A	8.02		3.8	6.7	<0.080	640	<0.1	<0.1	<2.0
BH16	8.01		2.1	4.2	<0.080	56	<0.1	<0.1	<2.0
BH18	6.27		<1.0	7.5	<0.080	93	<0.1	<0.1	<2.0
BH20	4.45		<1.0	2.9	<0.080	38	<0.1	<0.1	<2.0
BH07	6.05	13/10/2020	<1.0	12	<0.080	190	<0.1	<0.1	<2.0
BH09	4.88		1.7	3.6	<0.080	170	<0.1	<0.1	<2.0
BH24	1.69	14/10/2020	2.8	1.5	<0.080	410	<0.1	<0.1	<2.0
BH26	3.07		2.1	2.9	<0.080	400	<0.1	<0.1	<2.0
BH27	4.52		<1.0	3.8	<0.080	95	<0.1	<0.1	<2.0
BH29	1.51		<1.0	3.6	<0.080	320	<0.1	<0.1	<2.0
BH33	7.67	13/10/2020	<1.0	2.2	<0.080	240	<0.1	<0.1	36
BH34	7.17		<1.0	7	<0.080	24	<0.1	<0.1	36
Limit of Detection			**1**	**1**	**0.08**	**1**	**0.1**	**0.1**	**2**

2.3.32. BGS baseline reporting for the Lincolnshire Limestone (Griffiths *et al.*, 2006) indicates that there is significant variability in groundwater quality across the principal aquifer and that baseline quality is best represented by a range rather than any single value. However, they did note that in much of the unconfined aquifer 'baseline' conditions will have been modified by anthropogenic influences and high nitrates and elements indicative of pollution (such as sulphate and chloride) may be elevated.

2.4. Groundwater resources

Groundwater abstractions

2.4.1. The site is not within any source protection zones for groundwater abstraction.

2.4.2. There are no licensed or unlicensed groundwater abstractions within the 1km study area, although there are two unlicensed abstractions just outside the western extent of the study area. These are to the west and south-west of the A1 as shown in Annex A Location plan. These likely abstract from the Lower Lincolnshire Limestone based on local borehole records and 1:50,000 geological mapping (BGS, 2021a).

Consented discharges to groundwater

2.4.3. The are no recorded consented discharges to groundwater within 1km of the study area.

2.5. Designations

Water Framework Directive

2.5.1. The aquifers underlying the application site are included in:

- Welland Limestone Unit A groundwater body (GB40501G445900) within the Welland Limestone Unit A operational catchment
    - Coincides with presence of the Lincolnshire Limestone Formation in the western half of the study area and around the Sutton Heath Road junction.
- Nene Mid Lower Jurassic Unit groundwater body (GB40502G402400) within the Nene Mid Lower Jurassic Unit operational catchment
    - Found in the middle of the site where the Grantham Formation and Whitby Mudstone Formation cross the A47, and generally follows the route of the River Nene.
- Northampton Sands groundwater body (GB40501G445500) within the Northampton Sands operational catchment
    - Found to the east of Sutton and where the Rutland Formation is present.
- Welland Limestone Unit A groundwater body (GB40501G445900) within the Welland Limestone Unit A operational catchment
    - Coincides with presence of the Lincolnshire Limestone Formation in the western half of the study areas and around the Sutton Heath Road junction.

2.5.2. All of the groundwater bodies are found within the Anglian GW management catchment (Environment Agency, 2021a). Details of the groundwater bodies are summarised in Table 7.

2.5.3. The Nene Mid Lower Jurassic Unit and Northampton Sands groundwater bodies have ‘Good’ Chemical and Quantitative status from 2019 cycle 2 assessment.

2.5.4. The Welland Limestone Unit A groundwater body has ‘Poor’ Chemical and ‘Good’ Quantitative status from 2019 cycle 2 assessment. The Chemical status is limited by the Chemical Drinking Water Protected Area and General Chemical Test criteria, which both scored poorly as a result of pollution associated with waste treatment and disposal in the form of landfill leaching. Objectives are to achieve ‘Good Chemical Status by 2027 by natural recovery.

Table 7 Summary of WFD groundwater bodies within the study area (Environment Agency, 2021b)

Category	Details		
Water body ID	GB40502G402400	GB40501G445500	GB40501G445900
Water body Name	Nene Mid Lower Jurassic Unit	Northampton Sands	Welland Limestone Unit A
Operational Catchment	Nene Mid Lower Jurassic Unit operational catchment	Northampton Sands operational catchment	Welland Limestone Unit A operational catchment
Management Catchment	Anglian GW Management Catchment	Anglian GW Management Catchment	Anglian GW Management Catchment
River Basin District	Anglian	Anglian	Anglian
Overall Classification (Cycle 2 – 2019)	Good	Good	Poor
Current Quantitative status (Cycle 2 – 2019)	Good	Good	Good
Current Chemical Quality (Cycle 2 – 2019)	Good	Good	Poor
Chemical Objective	Good (by 2015)	Good (by 2015)	Good (by 2027)
Protected Areas	Drinking Water Protected Area • Nene Mid Lowe Jurassic Unit, UKGB40502G402400 Nitrates Directive • Lincolnshire Limestone, G69 • Northampton Sands, G165	Drinking Water Protected Area • Northampton Sands, UKGB40501G445500 Nitrates Directive • Bedford Great Oolite, G74 • Lincolnshire Limestone, G69 • Northampton Sands, G165	Drinking Water Protected Area • Welland Limestone Unit A, UKGB40501G445900 Nitrates Directive • Lincolnshire Limestone, G69

Groundwater Dependent Terrestrial Ecosystems

2.5.5. Designated sites which are potentially hydraulically linked to the study area are included in this assessment.

2.5.6. There are no Ramsar sites, Special Areas of Conservation (SAC), Special Protection Areas (SPA), Local Nature Reserves (LNR) or National Nature Reserves (NNR) within the 1km study area.

Priority Habitats

2.5.7. Lowland Meadow Priority Habitats are located along the River Nene and the floodplain to the south. Lowland fens receive water and nutrients from the underlying soil, rock and groundwater. They are recognised as a priority habitat under the UK Biodiversity Action Plan (Joint Nature Conservation Committee, 2016). The following Priority Habitats have been identified;

- A Lowland Fen (TG 0812899399) is located on the south bank of the River Nene immediately east of A1 carriageway and west of a small track that comes off the A1 and heads north-east. It is underlain by, and likely fed by, river terrace deposits
- A Lowland Fen (TG 0742899346) is located on the other side of this track and includes the River Nene and an area on the south bank. This continues towards Sutton Drift to the east. It is underlain by, and likely fed by, alluvium and river terrace deposits

2.5.8. A county wildlife site (Sutton Marshes North CWS) has been identified within the study area which is associated with both fen habitats listed above. As there is likely hydrogeological connection between the Proposed Scheme and these groundwater dependent terrestrial ecosystems, these are considered further in the Groundwater Dependent Terrestrial Ecosystems assessment. Other county wildlife sites within the study area contain either woodland or flood meadow wet grassland habitats that are not considered to be groundwater dependent terrestrial ecosystems.

SSSIs

2.5.9. Within the 1km study area there are three Sites of Special Scientific Interest (SSSI). These are:

- Sutton Heath and Bog SSSI (Natural England, 1983) found on the north side of the A47 adjacent to Sutton Heath Road in the middle of the study area
- Wansford Pasture SSSI (Natural England, 1985) approximately 0.5km south-west of the A1 / A47 junction
- West, Abbot's and Lound Woods (Natural England, 1987) approximately 0.6km to the west of the A1, near the northern extent of the Proposed Scheme boundary

2.5.10. Sutton Health and Bog SSSI sits directly on the Lincoln Limestone Formation outcrop, giving way to the underlying Grantham Formation and Whitby Mudstone to the western boundary. As discussed in the Surface water – groundwater interactions section, the EA believe the bog is likely to be entirely rainfall-dependent with rapid rainfall infiltration through the Lincolnshire Limestone Formation, which re-emerges as springs downslope at the boundary of the Lincolnshire Limestone Formation and the Grantham Formation/Whitby Mudstone Formation.

2.5.11. Wansford Pasture SSSI is noted as overlying an outcrop of the Lower Lincolnshire Limestone on the upper part of its south-facing slope. Springs and a flush are noted at the junction with the Lower Lincolnshire Limestone and beds of the “Upper Estuarine Series exposed below” (Natural England, 1985). This is interpreted as the Grantham Formation (previous known as the Lower Estuarine Series). The springs flow eastwards towards the River Nene and as such the Wansford Pasture SSSI is not considered to be down-gradient of the Proposed Scheme.

2.5.12. West, Abbot’s and Lound Woods SSSI is designated for its woodland habitat and is not considered to be groundwater dependent. Therefore, it has not been taken forward for further assessment.

2.6. Groundwater flooding

2.6.1. BGS records indicate that most of the site to the east of Wansford East Roundabout is susceptible to groundwater flooding of properties situated below ground level. In addition, several areas are susceptible to groundwater flooding at surface, generally coincident with the location of watercourses (Wittering Brook and the River Nene).

2.7. Climate change

2.7.1. The climate change projections do not affect the overall annual recharge volumes for groundwater, although the groundwater recharge season is likely to be shorter and more intense, leading to more variable groundwater levels and a greater drought vulnerability (Environment Agency, 2019).

2.8. Summary of findings

2.8.1. This section provides a summary of findings in the form of a hydrogeological model, and highlights uncertainties relating to the datasets considered.

Hydrogeological conceptual model

2.8.2. The default study area comprises a 1km buffer zone of the Proposed Scheme based on professional judgement of the groundwater flow pathways this is considered appropriate.

2.8.3. The study area is found within the Nene Mid Lower Jurassic Unit (GB40502G402400) groundwater body (overall classification 2019 – Good), the Northampton Sands (GB40501G445500) groundwater body (overall classification 2019 – Good) and Welland Limestone Unit A (GB40501G445900) groundwater body (overall classification 2019 – Poor). These are all within the Anglian GW Management Catchment.

2.8.4. Groundwater monitoring indicates that the main bedrock aquifer units in the study area are the Lincolnshire Limestone Formation, where saturated, and the Grantham Formation. Groundwater was also observed within the Whitby Mudstone Formation.

2.8.5. The Lincolnshire Limestone Formation principal aquifer appears to be mostly unsaturated within the study area. Groundwater modelling indicates that in areas of higher ground and away from watercourses, the Lincolnshire Limestone Formation is recharged by rainfall and rapid infiltration due to its permeable nature results in downwards groundwater flow Groundwater subsequently discharges as springs at the contact point between the Lincolnshire Limestone Formation and the underlying Grantham Formation / Whitby Mudstone Formation and flow towards either the Mill Stream, Wittering Brook or the River Nene. This highlights its importance as a source of water for superficial deposits beneath the River Nene, and ultimately also the River Nene. The permeability of the Lincolnshire Limestone Formation was recorded to be in the order of 2 to 9 x 10^{-5}m/s in infiltration testing.

2.8.6. Groundwater levels in the area are controlled by springs emerging from the base of Lincolnshire Limestone Formation, and possibly also fracturing within the top of the Grantham Formation. Groundwater levels within the Grantham Formation generally range between 2.5 and 7.3mbGL (17.2 and 23.5maOD). Groundwater levels are found to be much closer to ground at the northern extents of the Proposed Scheme, adjacent to Mill Stream, where groundwater levels are likely to be controlled by surface water due to baseflow contributions from groundwater into the stream. The Lincolnshire Limestone Formation and Grantham Formation are likely to be in hydraulic continuity, although the Lincolnshire Limestone Formation is significantly more permeable. Similarly, the overlying Rutland Formation is also assumed to be in hydraulic continuity with the Lincolnshire Limestone Formation.

2.8.7. To the east of Sutton Heath Road, groundwater has been identified within the Rutland Formation at depths of 5mbGL or deeper. Groundwater levels in the overlying river terrace deposits range between 2.75 and 4.76mbGL, although may be up to 0.4m higher.

2.8.8. Permeability in the superficial deposits is likely variable depending on local characteristics. Infiltration tests conducted in the river terrace deposits obtained results in the range of $3x10^{-2}$ to $1x10^{-1}$ m/s which is considered to be a high result for sands and gravels (Freeze & Cherry, 1979).

2.8.9. Groundwater quality results from the 2019 ground investigation indicate elevated ammoniacal nitrogen and boron, which may be reflective of anthropogenic influences on the unconfined aquifer.

2.8.10. A source protection zone (SPZ) 2 (Outer Protection Zone) is found along the northern boundary of the Study Area. This is associated with groundwater abstractions to the North of the Proposed Scheme.

2.8.11. There are no licensed abstractions within the study area. Two unlicensed groundwater abstractions, below 20m^3/day, are noted the study area. These are to the west and south-west of the A1 and likely abstract from the Lower Lincolnshire Limestone.

2.8.12. Groundwater dependent terrestrial ecosystems within the study area comprise a County Wildlife Site (Sutton Meadows North) associated with lowland fen priority habitats along and to the south of the River Nene and two SSSI's (Wansford Pasture SSSI and Sutton Heath and Bog SSSI). Wansford Pasture SSSI is not considered to be directly down-gradient of the Proposed Scheme, however.

Receptors

2.8.13. The main direct groundwater receptors within the study area are as follows:

- The main direct groundwater receptors within the study area are:
  - Aquifer units of the Nene Mid Lower Jurassic Unit groundwater body and the Welland Limestone Unit A comprising:
    - Lincolnshire Limestone
    - Grantham Formation
  - Superficial aquifers including the Northampton Sands groundwater body comprising:
    - Alluvium
    - River Terrace Deposits
    - Rutland Formation
- The main indirect groundwater receptors within the study area are:
  - Two unlicensed groundwater abstractions believed to take from the Lower Lincolnshire Limestone.
  - Designated sites associated with groundwater dependent terrestrial ecosystems (GWDTEs), including:
    - Sutton Heath and Bog SSSI
    - Wansford Pasture SSSI
    - Sutton Meadows North CWS
  - Surface water features supplied by groundwater:
    - River Nene, Mill Stream and Wittering Brook

Limitations and uncertainty

2.8.14. This groundwater assessment is constrained by the information available; the ground investigation has provided comprehensive data relating to the geology and hydrogeology within the Site (the Proposed Scheme boundary), but data is limited outside of this. The data collected may therefore not necessarily fully represent the regional hydrogeological conditions, particularly with respect to hydraulic gradients and direction of groundwater flow.

2.8.15. Since the GI was undertaken the position of the proposed A47 realignment has moved northwards between Sutton Heath Road and Upton Road. There is therefore limited information directly between the Proposed Scheme in this area. Other areas, such a proposed below-ground structures, may also require further investigation and monitoring to ascertain accurate hydraulic properties and groundwater level ranges in order to better understand any groundwater control measures and subsequent impacts of construction. Further details of construction methods will also be required to assess the associated potential dewatering requirements.

2.8.16. In addition, whilst over a year of groundwater level monitoring data has been collected, there is the possibility that this does not reflect long term seasonal maximums and minimums.

2.8.17. Further limitations in the datasets used include the extents of the groundwater flooding susceptibility dataset, which is limited to a 500m corridor around the existing road, and restricted location descriptions for unlicensed groundwater abstractions due to General Data Protection Regulations.

3. Potential impacts

3.1.1. The key intrusive structures that may have an impact on groundwater are the Sacrewell Farm underbridge (S05) and the Wansford NMU underpass (S02). The indicative maximum construction depth for the Sacrewell Farm underbridge is 6.5mbGL (19.5maOD) and for Wansford NMU underpass is 5.5mbGL (11.43maOD). These are subject to confirmation following confirmatory GI, however.

3.1.2. The key road drainage features that may have an impact on groundwater quality are two infiltration ponds and filter drains discharging to ground. Infiltration pond INF F is located to immediately to the south-west of the Sacrewell Farm underbridge, and INF L is located to the south of the A47, adjacent to the junction with Sutton Drift. Filter drains are extensive throughout the Proposed Scheme. Furthermore, the outfall for road drainage at the northern tie in for the Sutton Heath slip road is expected to drain to a ditch adjacent to the Sutton Heath and Bog SSSI boundary.

3.1.3. Other elements of the road construction are also considered, including site compounds and utilities diversions in the study area. Site compounds are proposed adjacent to Sacrewell Farm and to the east of Sutton Heath and Bog SSSI.

3.1.4. The locations of the key structures and road drainage features are presented in the location plan in Annex A.

3.1.5. A simple hydrogeological assessment of the construction and operational activities relating to these structures is presented in Table 8 and Table 9.

3.1.6. Sichardt empirical calculations have been used to estimate the potential radius of influence from excavations required for the Sacrewell Farm underbridge (S05) and the Wansford WCH underpass (S02), which are anticipated to intersect groundwater. The results of these calculations are presented in Annex F Sichardt calculations of Radius of Influence. The radius of influence at the Sacrewell Farm underbridge (S05) is 87m and at the Wansford WCH underpass (S02) is 72m, using a worst case permeability of 5.80×10^{-4} m/s for both. The permeability is based on transmissivity values confirmed by the BGS (Griffiths *et al.*, 2006) across the entire unconfined Lincolnshire limestone and is likely to be an overestimate for permeability within the Grantham Formation on site. These will both be reinvestigated following supplementary GI being completed at the structure locations.

3.1.7. The use of the Sichardt formula is discussed within the Environment Agency's guidance document Hydrogeological Impact Appraisal for Dewatering

Abstractions (2007). Whilst the formula provides an estimate of the radius of influence, it is limited due to not being consistent with the principle of the impact of an abstraction spreading until it has captured sufficient water (EA, 2007). Therefore, the radius of influence results is a preliminary assessment of risk to nearby receptors. The radius of influence will be considered further at the detailed design stage following completion of the baseline groundwater level monitoring and the supplementary ground investigation.

3.1.8. Intercepting groundwater may necessitate groundwater control measures to be incorporated in the construction methodology and operation design. Temporary dewatering will be subject to licensing, which requires a detailed Hydrogeological Impact Assessment (HIA) to be undertaken. The potential dewatering requirements will be considered further at the detailed design stage following completion of the baseline groundwater level monitoring and the supplementary ground investigation.

Table 8 Summary of potential impacts to groundwater receptors resulting from construction activities associated with the Proposed Scheme

Activity	General Description of Potential Impact	Structure	Direct Receptor	Indirect receptor	Site specific potential impact	Potential impact?
Construction						
Drainage from construction areas, including site compounds	Removal of topsoil during construction works has the potential to increase the vulnerability of underlying aquifers. Accidental spillages / leakage of construction materials in such areas may result in contamination of groundwater	Site compounds adjacent to Sacrewell Farm,	Lincolnshire Limestone Formation, Grantham Formation	River Nene, associated priority habitats, Sutton Meadows North CWS and Sutton Heath and Bog SSSI	Site compound overlies areas of high groundwater vulnerability risk where there is little, or no, cover of superficial deposits.	Yes
		Site compound adjacent to Sutton Heath road & Sutton Heath slip road	Rutland Formation	River Nene	Site compound and slip road overlie areas of high groundwater vulnerability risk where this is no cover of superficial deposits.	Yes
		Infiltration basin INF L	River terrace deposits	Rutland Formation River Nene	Infiltration basin overlie areas of medium - high groundwater vulnerability risk, where the secondary A aquifer is at surface.	Yes
Drainage from construction areas, including excavations and cuttings	Excavations reduce the thickness of unsaturated zone above the receptor aquifer, thus increasing its vulnerability to groundwater contamination risks as a result of accidental spillages / leakage	Sacrewell Farm underbridge (S05), Wansford NMU underpass (S02)	Lincolnshire Limestone Formation, Grantham Formation,	River Nene, associated priority habitats, Sutton Meadows North CWS and Sutton Heath and Bog SSSI	A significant proportion of the unsaturated thickness will be removed at S05 and potentially S02 which will increase the vulnerability of the underlying aquifer at both locations.	Yes
Excavations, including underpass and infiltration basin construction	Potential for contamination of groundwater through direct contact with contaminated construction materials	Sacrewell Farm underbridge (S05), Wansford NMU underpass (S02)	Lincolnshire Limestone Formation, Grantham Formation	River Nene, associated priority habitats, Sutton Meadows North CWS and Sutton Heath and Bog SSSI	S02 and S05 are likely to intercept a saturated aquifer unit during construction.	Yes
	Potential for contamination of groundwater through creation of pathways between potentially contaminated ground & underlying aquifers	Sacrewell Farm underbridge (S05), Wansford NMU underpass (S02)	Lincolnshire Limestone Formation, Grantham Formation	River Nene, associated priority habitats, Sutton Meadows North CWS and Sutton Heath and Bog SSSI	No excavations intercept contaminated land.	No
	Groundwater control requirements during any excavation works (including construction of cuttings and underpasses) resulting in a reduction in local groundwater levels and therefore a loss of	Sacrewell Farm underbridge (S05), Wansford NMU underpass (S02)	Lincolnshire Limestone Formation, Grantham Formation	River Nene, associated priority habitats, Sutton Meadows North CWS and Sutton Heath and Bog SSSI	There is a risk that Lincolnshire Limestone/Grantham Formation groundwater may be intercepted during the construction of S05 and S02, and therefore groundwater control may be required. This may have a direct impact on spring flows to the River Nene and also other indirect receptors within the radial zone of influence. At S05, the minimum design level is 19.5maOD, and the maximum local groundwater level at BH16 is 21.3maOD.	Yes

Activity	General Description of Potential Impact	Structure	Direct Receptor	Indirect receptor	Site specific potential impact	Potential impact?
Construction						
	groundwater flow / resource to nearby receptors				Therefore, the cutting may require a minimum 1.8m drawdown. The radius of influence was calculated to be 87m. At S02, the minimum design level is 11maOD, and the maximum observed local groundwater level at BH31 is 11.09maOD. As the borehole is not directly adjacent to the structure a worst case 1m minimum drawdown has been calculated for. The radius of influence was calculated to be 72m. Groundwater control measures will need to be considered. This may be through dewatering but due to the proximity to the River Nene other groundwater control methods may also need to be considered. Further ground investigation is scheduled to confirm likely inflow rates to the excavation. Abstractions and subsequent discharges associated with temporary dewatering may divert water from one groundwater or surface water catchment to another.	
	Construction dewatering discharges may contain suspended solids and may therefore result in contamination of receiving waterbody	Sacrewell Farm underbridge (S05)	River Nene (dependent upon discharge point)	Priority habitats (dependent on discharge point)	Dewatering discharge points and any treatment requirements to be confirmed following confirmatory GI.	Yes

Table 9 Summary of potential impacts to groundwater receptors resulting from operational activities associated with the Proposed Scheme

Activity	General Description of Potential Impact	Structure	Direct Receptor	Indirect receptor	Site specific potential impact	Potential impact?
Operation						
Routine road runoff and accidental spillages discharging to infiltration basins.	Routine road drainage (including accidental spillages collected by road drainage) may result in contamination of receiving aquifer	Infiltration basin INF F Filter drains west of Sutton Heath Road	Lincolnshire Limestone Formation, river terrace deposits (where present)	Grantham Formation, River Nene and associated priority habitats	Infiltration features discharging to the Lincolnshire Limestone Formation may impact springs flowing towards the River Nene.	Yes
		Road drainage outfall to east of Sutton Heath and Bog SSSI	Lincolnshire Limestone Formation	Wittering Brook	Road drainage at the northern tie in of the Sutton Heath slip road discharges via an outfall to a ditch along the eastern boundary of the Sutton Heath and Bog SSSI. Road drainage is likely to infiltrate into the Lincolnshire Limestone Formation at this location. As such road drainage has the potential to impact on water quality within the Lincolnshire Limestone Formation, the springs that discharge from it, and ultimately the Wittering Brook.	Yes
		Filter drains at northern extents of A1 slip road	Lincolnshire Limestone Formation	Grantham Formation Mill Stream	Filter drains are present at the location where the A1 passes over Mill Stream. In this location, springs issuing from the base of the Lincolnshire Limestone Formation discharge to Mill Stream.	Yes
		Infiltration Basin L Filter drains on A47 east of Sutton Heath Road	River terrace deposits	Rutland Formation River Nene	Infiltration features discharging to a secondary A aquifer	Yes
		Filter drains on Sutton Heath slip road	Rutland Formation	Wittering Brook River Nene	Groundwater conditions and flow pathways not fully understood in this area and are subject to supplementary GI. Further assessment of filter drains in this area required at Stage 5. It is assumed that the Rutland Formation may be in hydraulic continuity with the underlying Grantham Formation and therefore a pathway exists between the Rutland Formation and the Wittering Brook and River Nene.	Yes
Increase in impermeable area	Reduction in aquifer recharge due to increase in impermeable area from roads, embankments and bunding	New road layout	Lincolnshire Limestone Formation, Grantham Formation	N/A	Within the area where aquifers outcrop there is a limited increase in impermeable area in relation to the extents of the outcrop.	No
Permanent subsurface drainage of cuttings / underpasses	Permanent drainage may result in a local reduction in groundwater levels around the structure	Sacrewell Farm underbridge (S05), Wansford NMU underpass (S02)	Lincolnshire Limestone Formation, Grantham Formation	River Nene, associated priority habitats, Sutton Meadows North CWS and Sutton Heath and Bog SSSI	Underpasses are anticipated to encounter groundwater in the base of the excavation and therefore require permanent drainage. However, the likely zone of influence is small (calculated at S05 to be 87m and at S02 to be 72m). Any resulting alteration of groundwater levels is likely to be seasonal but may affect spring flows from the Lincolnshire Limestone Formation.	Yes

Activity	General Description of Potential Impact	Structure	Direct Receptor	Indirect receptor	Site specific potential impact	Potential impact?
Operation						
Permanent placement of below-ground impermeable structures i.e. piles, underpasses	Redirection of flows around permanent underground structures, resulting in groundwater mounding and a reduction in groundwater flows immediately down-gradient of the underpass.	Sacrewell Farm underbridge (SO5), Wansford NMU underpass (S02)	Lincolnshire Limestone Formation, Grantham Formation	N/A	Underpasses intercept the Lincolnshire Limestone and the top of the Grantham Formation and piles intercept the saturated Grantham Formation. The likely groundwater flow direction is perpendicular to the underpass - groundwater likely to flow around the underpass box and associated piles. Furthermore, permanent subsurface drainage will remove the potential risk of groundwater mounding.	No

4. Risk assessment

4.1. Introduction

4.1.1. Infiltration to ground has been included in the drainage design. Groundwater quality and routine runoff assessments have been completed for infiltration basins INF F and INF L and for filter drains across the Proposed Scheme. These assessments are discussed in Section 4.2.

4.1.2. Groundwater dependent terrestrial ecosystems (GWDTEs) have been identified as receptors to construction and operation activities. These are therefore considered further in Section 4.3.

4.2. Groundwater quality and routine runoff assessment

Simple assessment

4.2.1. Groundwater quality and runoff risk assessments were completed for all catchments containing filter drains and infiltration basins to assess the risk of impact upon groundwater quality from routine runoff. This assessment is based on the ‘source-pathway-receptor’ model, as per Appendix C of LA 113.

4.2.2. Road drainage catchments are shown in Annex D. Filter drains are proposed along the A1 – A47 eastbound slip road (catchments A, B, E and F), the A47 east and westbound (catchments F, H, I, J, L and P), the Sacrewell Farm access road (catchment K) and the Sutton Heath slip road and junction with the existing Sutton Heath Road (catchments L, M and N). Infiltration basins are also included in catchments F and L as the final point of discharge for road drainage.

4.2.3. Input parameters were derived from ground investigation data and publicly available information. These are in line with the conceptualisation outlined above in Section 2.8 and are summarised below in Table 10. Where no information is available, for example along the Sutton Heath slip road (catchments L, M and N), worst case assumptions have been made to give a conservative result. Results are summarised in Table D.1 (Annex D) and show that infiltration of untreated routine road runoff presents a medium risk to groundwater in all catchments. This is primarily due to the depth to the water table and low organic matter content in the unsaturated zone.

Table 10 Summary of HEWRAT risk assessment input parameters

Input parameter	Detail
Traffic flow	AADT model data. This is generally <50,000 for each catchment, with the exception of catchments F and L (>50,000 and <100,000)
Rainfall depth (annual averages)	Average based on warm/dry climatic region from nearest UK rainfall monitoring site (Huntingdon; <740mm).
Drainage area ratio	Determined as 'drainage area of road'/'active surface area of infiltration device', where the surface area is that part of the device through which most downward discharge will occur. <50 selected for catchments with either filter drains or infiltration basins.
Infiltration method	"continuous" selected to reflect overall dimensions of filter drains For catchments where the final discharge point is via infiltration basin (catchments F and L), "region" is selected.
Unsaturated zone	A conservative estimate of the depth to water table was based on groundwater monitoring data available for the monitoring boreholes from the ground investigation. "<5m" selected for all catchments, with exception of Catchments B, E and F, where ">5 and <15m" selected.
Flow type	"Flow dominated by fractures/ fissures" selected where infiltration features discharge to the Lincolnshire Limestone Formation (catchments A, B, E, F, H and K). "Mixed fracture and intergranular flow" selected where discharge to river terrace deposits and/or underlying fractured bedrock (catchments I, J, L and P) "Dominantly intergranular flow" where discharge to the Rutland Formation (catchments M & N)
Unsaturated zone clay content	Particle size distribution results were available for a number of ground investigation borehole samples across the Proposed Scheme. The result was selected based on the underlying geology (<1% for Lincolnshire Limestone Formation and Rutland Formation, <15% for river terrace deposits).
Organic carbon	SOM results range between 0.2 and 2.5% SOM for all samples - conservative approach adopted by selecting <1% for discharges to bedrock and >1% and <15% for discharges to river terrace deposits
Unsaturated zone soil pH	Soil pH <=8 for majority of samples from unsaturated zone

Detailed assessment

4.2.4. As the HEWRAT assessment for infiltration to ground produced a medium risk result, consultation was undertaken with the Environment Agency, in line with the assessment guidance. Initial consultation with the Environment Agency on 11 November 2020 focused on the infiltration basins, and the Environment Agency confirmed that their key concerns were as follows:

- That shallow groundwater levels may reduce the potential effectiveness of the infiltration basins, should groundwater mounding occur, for example
- Spillage containment should be included for the infiltration features

4.2.5. The potential effectiveness of the infiltration features, in terms of infiltration capacity and potential for groundwater mounding has been commented on below. The drainage network includes filter drains and/or gullies and pollution control valves upstream of the infiltration basins to capture pollutants. The efficacy of the filter drains as an integral part of the road drainage treatment train, specifically for discharges that outfall to surface waterbodies has also been assessed within the HEWRAT routine runoff assessment for surface water (Volume 3, Appendix 13.3 (Water quality assessment)) (**TR010039/APP/6.3**).

Infiltration capacity

4.2.6. Infiltration basin F is underlain by the Lincolnshire Limestone Formation and infiltration basin L is underlain by river terrace deposits and the Rutland Formation. The depth to water table at each infiltration structure has been estimated based on the nearest available groundwater monitoring borehole. The water table at Infiltration basin F is approximately 6.7mbGL (BH13) and at Infiltration basin L is approximately 4.4 to 5.0 mbGL (BH37A).

4.2.7. Permeability rates for both the Lincolnshire Limestone Formation and river terrace deposits was tested during the GI and found to be acceptable for infiltration to ground. Permeability rates for the Lincolnshire Limestone Formation are expected to be at least $2x10^{-5}$ m/s, although is potentially higher due to fracture flow. Permeability rates for the river terrace deposits are expected to be at least 2×10^{-2}m/s. Due to the high anticipated permeabilities of the Lincolnshire Limestone Formation and the river terrace deposits, groundwater mounding below the infiltration basins is not anticipated.

4.2.8. Where filter drains are present in locations with similar ground conditions to the infiltration basins, these are also considered unlikely to affected by groundwater mounding. Groundwater levels in catchment A, where the A1 crosses Mill Stream, are particularly shallow and have been recorded to be at ground level. Unlined filter drains in this area pose a particular risk in terms of groundwater mounding.

4.2.9. Filter drains are also present along the Sutton Heath slip road where the Rutland Formation outcrops. Although no permeability tests were undertaken in Rutland Formation, this is expected to have a relatively low permeability due to its Secondary B aquifer status. Furthermore, there is no groundwater level monitoring data available away from the A47, and therefore there is no data available along the Sutton Heath slip road. Whilst groundwater monitoring of the Rutland Formation at BH37A suggests that groundwater levels adjacent to the A47 may be at around 5mbGL, the depth to the water table is likely to be greater further north on areas of higher ground away from the River Nene. Filter drains in this area will be reassessed following collection of additional groundwater level and permeability information in the supplementary GI.

Summary of risk to groundwater

4.2.10. The detailed assessment on infiltration capacity highlights that whilst the infiltration basins pose a medium risk to groundwater, groundwater mounding is unlikely to be issue due to the highly permeable nature of the Lincolnshire Limestone Formation and river terrace deposits.

4.2.11. Filter drains also pose a medium risk to groundwater across the Proposed Scheme. Where groundwater levels are particularly shallow, such as in catchment A on the A1 adjacent to Mill Stream, there is a risk of groundwater mounding beneath the filter drains. There is limited information of the infiltration capacity in the area surrounding the Sutton Heath slip road, which is to be reassessed following supplementary GI. In the absence of this information, it is assumed that groundwater mounding may occur.

4.2.12. Filter drains at the northern extents of the Sutton Heath slip road have the potential to discharge untreated road drainage into the Sutton Heath and Bog SSSI with limited potential for natural attenuation within the unsaturated zone.

4.2.13. Due to the risks identified from infiltration through the base of filter drains, their inclusion in the drainage design should be reviewed at detailed design stage and, should no other solution be identified, the filter drains should be lined with an impermeable barrier to ensure that they can provide primary treatment without posing a risk of discharging untreated road drainage directly to groundwater. Where filter drains are required for subsurface drainage, such as Sacrewell Farm underbridge, road runoff should be isolated from the filter drains, and conveyed to the drainage system via carrier drains.

4.3. Spillage assessment

4.3.1. Spillage containment is included in the drainage design, further details of which are provided in the Volume 3, Appendix 13.2 Drainage Strategy (**TR010039/APP/6.3**). The risk to groundwater quality from spillage during operation of the Proposed Scheme was assessed using the methodology outlined in Appendix D of LA113.

4.3.2. Results from the spillage assessments completed for catchments discharging to infiltration basins are presented in Annex E and show that the infiltration basins passed the accidental spillage assessment with the results indicating that drainage area would have <0.5% annual risk of pollution.

4.3.3. Spillage assessments for all other catchments where the final discharge point is to a surface waterbody are presented in Volume 3, Appendix 13.3 (Water quality). The outfall passed the accidental spillage assessment with the results indicating that the drainage area would have <0.5% annual risk of pollution.

4.4. GWDTE Assessment

4.4.1. Identified groundwater dependent terrestrial ecosystems (GWDTE) have been assessed following the methodology set out in LA 113 to determine hydrogeological links with the Proposed Scheme, the importance of each GWDTE, the magnitude of any potential impact on the GWDTE and thereby the overall significance of risk to the GWDTE.

4.4.2. Designated sites with a potential hydrogeological link to the study area have been identified based on professional judgement. These are Sutton Meadows North CWS directly south of the River Nene within the study area, the Sutton Heath and Bog SSSI situated to the north side of the A47 adjacent to Sutton Heath Road in the middle of the site and Wansford Pasture SSSI situated approximately 0.5km to the south-west of the A1 / A47 junction.

Potential hydrogeological link between the Proposed Scheme and GWDTE

Sutton Meadows North CWS

4.4.3. Sutton Meadows North CWS is underlain by superficial geology of alluvium and river terrace deposits. Although the superficial deposits are underlain by Whitby Mudstone Formation bedrock, there may be a hydraulic link with the Lincolnshire Limestone and the Grantham Formation underlying the Proposed Scheme via springs issuing from the base of the Lincolnshire Limestone Formation and which feed into superficial deposits and ultimately the River Nene. Ordnance survey mapping does not show any springs in the area immediately surrounding the Sacrewell Farm underbridge (S05), and between this and the Sutton Meadows North CWS. This should be confirmed by a water features survey, however.

Wansford Pasture SSSI

4.4.4. Groundwater flow in the study area is primarily towards the south, as shown in the Geological Section in Figure 3. As noted in section 2.5.11 the citation for Wansford Pasture SSSI states that springs exist at the junction of the Lincolnshire Limestone and the underlying formations. Wansford Pasture SSSI is approximately 950m to the east of Sacrewell Farm underbridge (S05) and 1800m to the east of the Wansford NMU underpass (S05). The calculated radius of influence for the underpasses (see Section 3 and Annex F) are significantly smaller and therefore the risk to this designated site from temporary dewatering or permanent subsurface drainage is negligible.

Sutton Heath and Bog SSSI

4.4.5. As discussed above in 2.5.10, the Sutton Heath and Bog SSSI is underlain by the Lincolnshire Limestone Formation and is considered to be a groundwater dependent ecosystem that is primarily rainfall fed. Due to the highly permeable nature of the Lincolnshire Limestone Formation, however, any road drainage discharging to unlined drainage ditches is likely to infiltrate into the Lincolnshire Limestone Formation and therefore has the potential to affect the water quality of the springs and the Wittering Brook, to which the springs discharge. As such this potential linkage must be considered in the impact assessment.

4.4.6. Sutton Heath and Bog SSSI is situated 800m to the west of the Sacrewell Farm underbridge and is therefore outside of the potential zone of influence for temporary dewatering and permanent road drainage for this structure (see Annex F). The site is situated only 30m to the north of the Wansford NMU underpass, however, and it is possible that temporary dewatering and permanent road drainage could impact upon groundwater levels and flow and groundwater quality at the site. In particular dewatering may reduce spring flow and baseflow to Wittering Brook.

4.4.7. The zone of influence calculations are generally conservative and in addition are based on worst case estimates of drawdown requirements and hydraulic conductivity, however. It is likely that any impact will be limited to the very southern extents of the designated site. Due to changes to road alignment in this area, a supplementary ground investigation is required to confirm ground conditions directly beneath the underpass structure. A water features survey will also be required to confirm the locations of springs and seepages in the southern area of the SSSI. Dewatering requirements, and their subsequent potential impact will be reviewed when further site specific information is available.

Assessment of GWDTE importance

4.4.8. Table 11 presents the overall importance for the GWDTEs. This is taken as highest of the ‘flora and fauna’ and ‘habitat’ receptors, based on SSSI citations (Natural England, 1985, 1988, 1993) and UKTAG guidance for national vegetation classification (UKTAG, 2009).

Table 11 Summary of GWDTE classification and importance based on flora and fauna, and habitat receptors

GDTWE	Flora and fauna receptor	Flora and fauna importance	Habitat receptor	Habitat importance	Overall importance
Sutton Meadows North CWS	Not surveyed	N/A	Local Site – County Wildlife Site Biodiversity Action Plan Priority Habitat	Moderate	Moderate
Wansford Pasture SSSI	M13 – Schoenus nigricans – Juncus subnodulosus mire	High	SSSI	High	High
Sutton Heath and Bog SSSI	M24 – Molinia caerulea – Cirsium dissectum fen meadow	Medium	SSSI	High	High

Assessment of potential impacts and establishment of risk to GWDTE

4.4.9. Based on identified hydrogeological impacts summarised in Tables 8 and 9, it is possible that construction activities and operation of the Proposed Scheme could result in a reduction in groundwater quantity and quality which may negatively impact upon the GWDTE sites listed above. A summary of these activities, resulting impacts and the overall risk to GWDTE sites is given below in Table 12.

Table 12 Summary of overall risk to GWDTE

Impact type	Activity	Description of potential impact	Sites	Magnitude of impact on a GWDTE	Overall risk to GWDTE
Groundwater quantity • Groundwater flow / flux • Groundwater level • Soil saturation / soil moisture	Excavations, including underpass construction	The distance between the underpass S02 excavation and Sutton Heath and Bog SSSI is 30m. Other GWDTEs are outside of the worst case radius of influence from dewatering. Removal of groundwater from the aquifer has the potential to impact on groundwater levels in the immediate area surrounding excavation, and also on groundwater supply to down-gradient receptors. Any dewatering activities resulting in abstractions of >50m^3 will be subject to further impact assessments and consultation with the EA. Dewatering rates or alternative groundwater control measures to be confirmed following supplementary ground investigation and an abstraction licence will be applied	Sutton Meadows North CWS Sutton Heath and Bog SSSI	Minor adverse	Moderate risk

Impact type	Activity	Description of potential impact	Sites	Magnitude of impact on a GWDTE	Overall risk to GWDTE
		for following further hydrogeological impact assessments.			
	Permanent subsurface drainage of cuttings / underpasses	The distance between the underpass S02 excavation and Sutton Heath and Bog SSSI is 30m. Other GWDTEs are outside of the worst case radius of influence from permanent road drainage. Permanent drainage may result in a local reduction in groundwater levels around the structure and a potential reduction in supply to Sutton Meadows North CWS. This will be reassessed upon completion of further ground investigation and finalisation of drainage design, although likely to be seasonal.	Sutton Meadows North CWS Sutton Heath and Bog SSSI	Minor adverse	Moderate risk
Groundwater quality as a result of construction activities • Nutrients (Nitrate / Phosphate) • Metalloid and organic compounds	Drainage from construction areas including site compounds, excavations and cuttings.	Removal of topsoil during construction works and/or a reduction in the thickness of the unsaturated zone has the potential to increase the vulnerability of underlying aquifers. Accidental spillages / leakage of construction materials in such areas may result in contamination of groundwater which in turn has the potential to reduce groundwater quality supplied to Sutton Meadows North CWS and Sutton Heath and Bog SSSI.	Sutton Meadows North CWS Sutton Heath and Bog SSSI	Minor / Moderate	Moderate risk
	Excavations, including underpass construction	Potential for contamination of groundwater through direct contact with contaminated construction materials which has the potential to migrate to Sutton Meadows North CWS and Sutton Heath and Bog SSSI.	Sutton Meadows North CWS Sutton Heath and Bog SSSI	Moderate	Moderate risk

Impact type	Activity	Description of potential impact	Sites	Magnitude of impact on a GWDTE	Overall risk to GWDTE
	Discharge of metalloid and organic compounds to groundwater from proposed road drainage to both surface water and groundwater	Road drainage generally discharges to Lincolnshire Limestone (Principal aquifer) and River Terrace Deposits (Secondary A aquifer). Any pollution (including accidental spillages) in routine runoff may have the potential to migrate to Sutton Meadows North CWS and Sutton Heath and Bog SSSI.	Sutton Meadows North CWS Sutton Heath and Bog SSSI	Moderate	Moderate risk

Assessment outcomes and actions

4.4.10. Prior to any mitigation the risk to GWDTE sites is moderate. A number of activities that may have a moderate risk impact upon the identified GWDTEs are based on worst case assumptions and are subject to further investigation during the supplementary GI, for example dewatering and permanent drainage risks at both the Sacrewell Farm underbridge and the NMU underpass. Should groundwater control be required for construction of the underpasses, isolation techniques should be considered in preference to dewatering, to limit impacts to the GWDTEs. In addition water features surveys should be undertaken to confirm the presence of springs within the radius of influence of any dewatering activities or permanent drainage, and groundwater level monitoring should be undertaken before, during and after construction.

4.4.11. The discharge of metalloid and organic compounds to groundwater from the proposed road drainage will be mitigated through the use of impermeable liners in filter drains.

4.4.12. Potential impacts upon the groundwater quality of the identified GWDTEs such as discharges from construction areas or direct contact with contaminated equipment in excavations is mitigated via best practise mitigation measures set out in the Environment Management Plan. No further detailed assessment is therefore required.

5. Conclusions

5.1.1. This section summarises the activities that may result in a potentially significant impact, prior to mitigation, and are therefore taken forward for further consideration in the assessment of significant effects in Chapter 13 of the ES (Road Drainage and the Water Environment) (**TR010039/APP/6.1**):

- Construction activities:
  - Drainage of construction areas including excavations, cuttings and site compounds
  - Excavations, including construction of underbridges and infiltration basins
  - Dewatering activities associated with construction of underbridge
- Operation activities:
  - Drainage to infiltration basins and filter drains discharging to ground
  - Subsurface drainage for the underbridge and underpass structures

5.1.2. The groundwater levels and flows assessment identified the following receptors for consideration in the assessment of significant impacts:

- The main direct groundwater receptors within the study area are:
  - Aquifer units of the Nene Mid Lower Jurassic Unit, the Welland Limestone Unit A and the Northampton Sands groundwater bodies comprising:
    - Lincolnshire Limestone
    - Grantham Formation
    - Rutland Formation
  - Superficial aquifers comprising:
    - Alluvium
    - River Terrace Deposits
- The main indirect groundwater receptors within the study area are:
  - Designated sites associated with groundwater dependent terrestrial ecosystems (GWDTEs), including:
    - Sutton Heath and Bog SSSI
    - Sutton Meadows North CWS
  - Surface water features supplied by groundwater:
    - River Nene, Mill Stream and Wittering Brook
- The following features are not considered further, as they are not directly down-gradient or within the radius of influence of any construction or operation activities:

- Two unlicensed groundwater abstractions believed to take from the Lower Lincolnshire Limestone
- Wansford Pasture SSSI

5.1.3. As the Groundwater quality and runoff risk simple assessment (HEWRAT groundwater assessment) identified that discharges to ground have an overall risk rating of medium, a further detailed assessment was carried out. This was based on consultation with the Environment Agency and focussed on infiltration capacity. The detailed assessment confirmed an acceptable infiltration capacity beneath infiltration basins. Due to the risks identified from filter drains, their inclusion in the drainage design should be reviewed at detailed design stage and, should no other solution be identified, the filter drains should be lined with an impermeable barrier. Where filter drains are required for subsurface drainage, such as Sacrewell Farm underbridge, road runoff should be isolated from the filter drains, and conveyed to the drainage system via carrier drains.

5.1.4. For the infiltration basins, the maximum overall spillage risk score is <0.5% indicating there is negligible spillage risk.

5.1.5. The GWDTE assessment considered potential hydraulic links between the Proposed Scheme and designated sites within the radius of influence of construction and operation activities. The assessment has concluded moderate risk. It is anticipated that the supplementary GI, water features surveys, groundwater monitoring, road drainage mitigation and other best practice mitigation included in the Environment Management Plan will confirm and/or address risks to the GWDTEs however.

6. References

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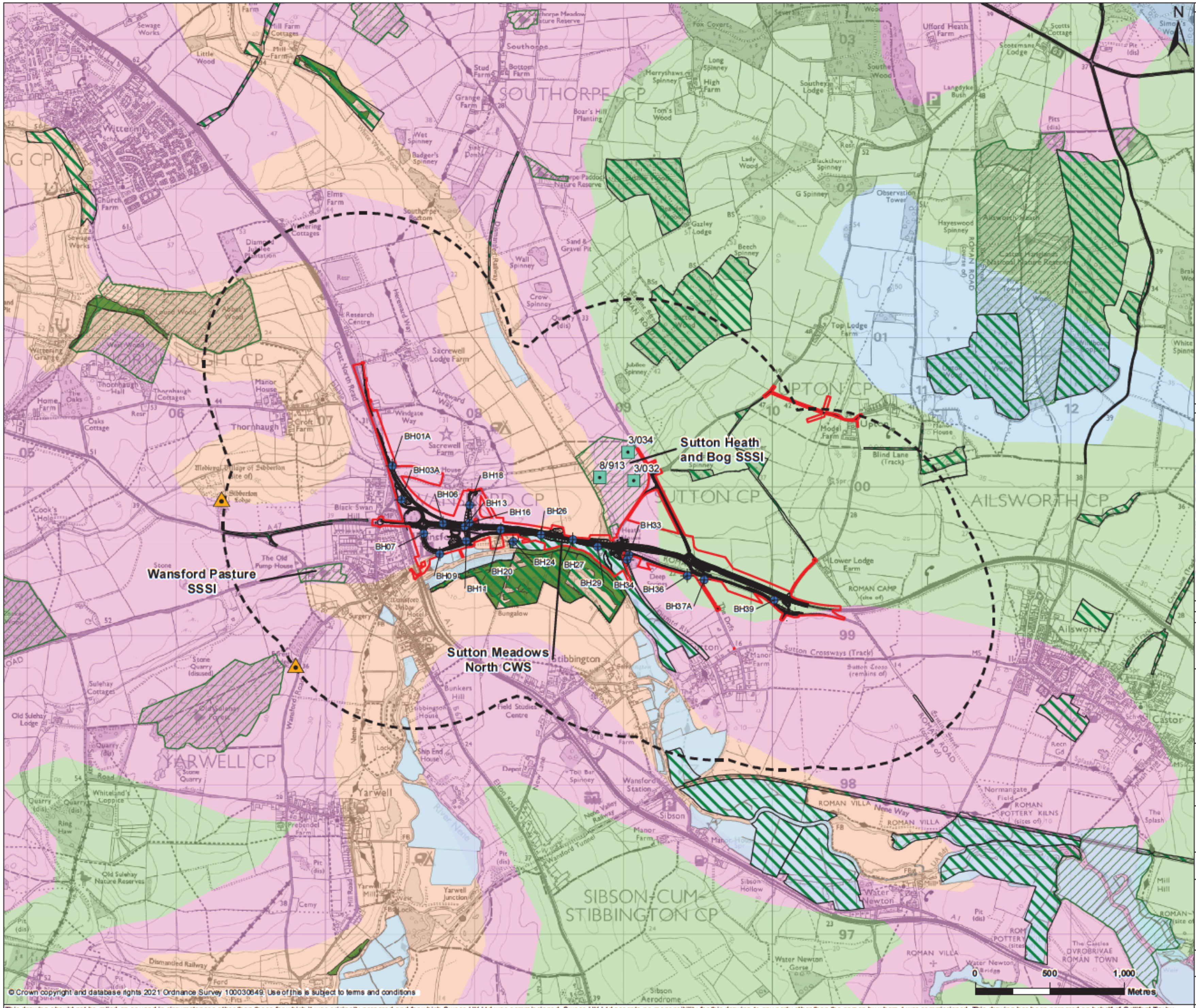
Annex A. Location plan



LEGEND

- 🟥 Proposed Scheme Boundary
- — Proposed Scheme Design
- ⬚ 1km Study Area
- ▣ Environment Agency - Groundwater monitoring points
- ▲ Unlicensed groundwater abstractions
- ⊕ Ground Investigation Boreholes
- ▨ County wildlife site

Statutory designated sites

- ▨ Site of special scientific interest (SSSI)

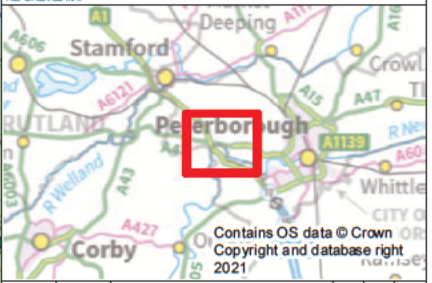
Priority Habitat

- ■ Coastal and floodplain grazing marsh
- ■ Lowland fens

BGS Bedrock Geology (1:625k)

- ■ Kellaways Formation and Oxford Clay Formation
- ■ Great Oolite Group (Rutland Formation)
- ■ Inferior Oolite Group (Upper Lincolnshire Limestone Formation, Lower Lincolnshire Limestone Formation, Grantham Formation and Northampton Sand Formation)
- ■ Lias Group (Whitby Formation)

REFERENCE MAP



REV	DATE	REVISION NOTE	ORG	CHK'D	APP'D
P01	1 /05/2021	FIRST EDITION	AC	RMC	JB

DESIGNER

SWECO

CONTRACTOR

GallifordTry

CLIENT

highways england

PROJECT TITLE

A47 WANSFORD TO SUTTON

PROJECT STAGE

PCF STAGE 3

DRAWING TITLE

ENVIRONMENTAL STATEMENT
ANNEX A LOCATION PLAN
TR010039/APP/6.2

SUITABILITY

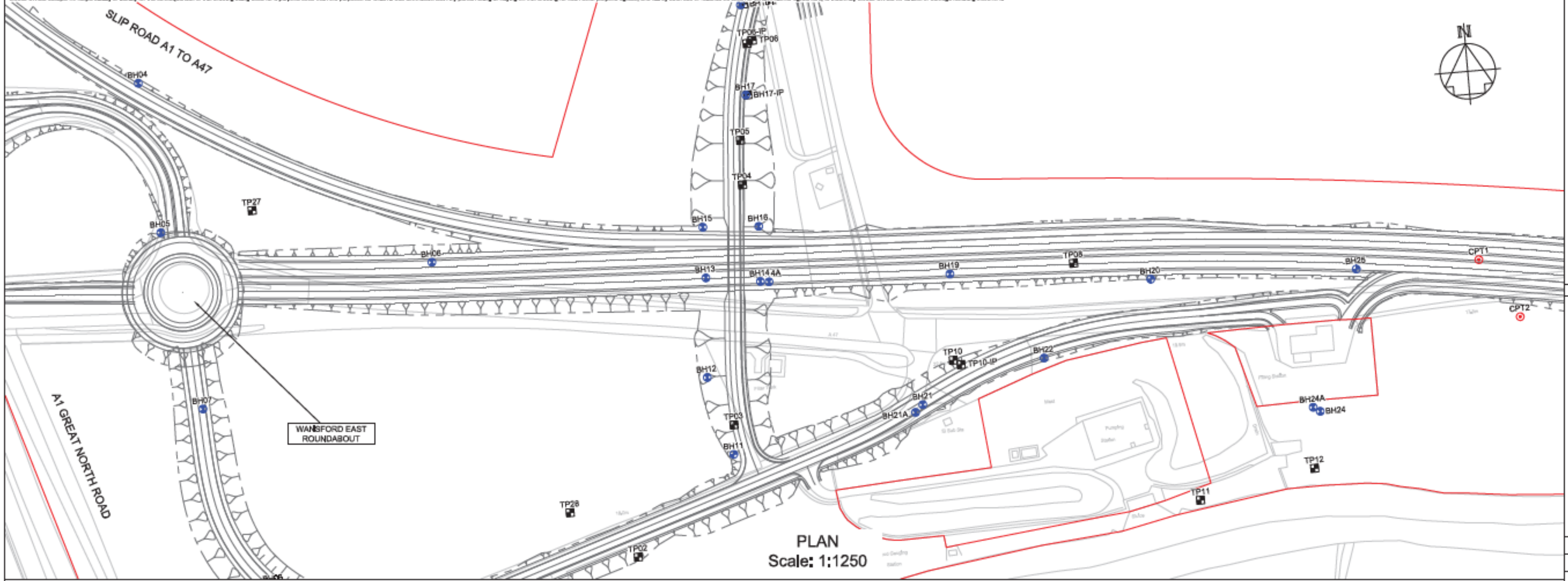
FOR INFORMATION

SHEET SIZE	SCALE	STATUS
A3	1 24,375	S2

DRAWING NUMBER

HE551494-GTY-EGN-000-DR-GI-30073

Annex B. 2020 GIR geological cross section



PLAN
Scale: 1:1250

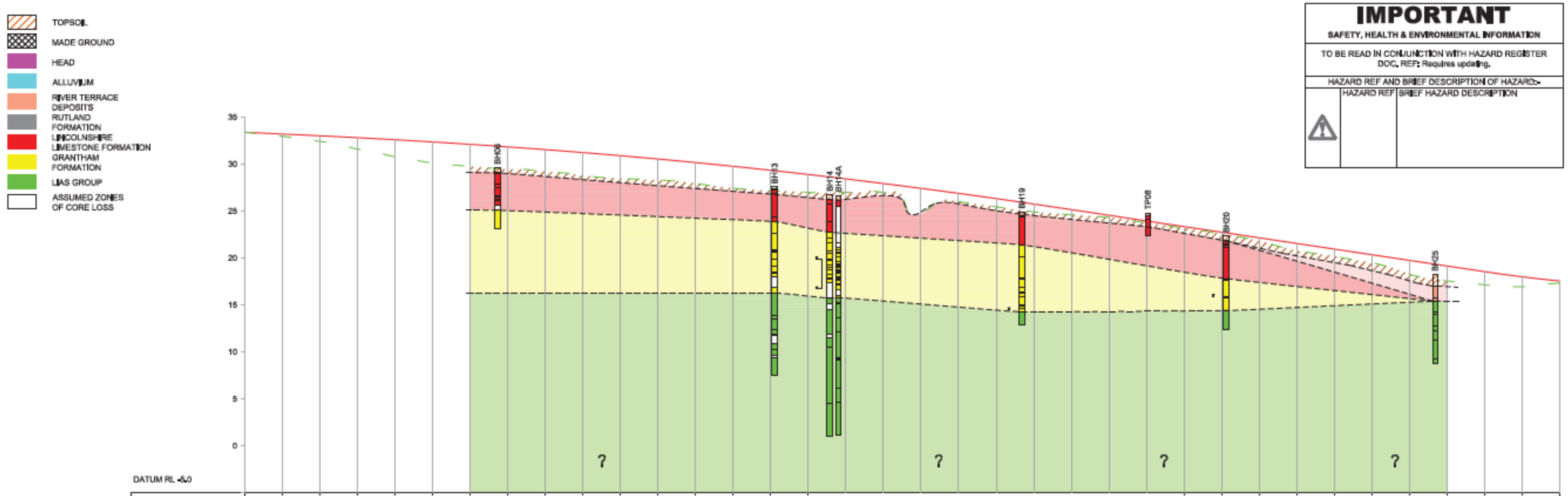
IMPORTANT

SAFETY, HEALTH & ENVIRONMENTAL INFORMATION

TO BE READ IN CONJUNCTION WITH HAZARD REGISTER DOC. REF: Requires updating.

HAZARD REF AND BRIEF DESCRIPTION OF HAZARD:-

HAZARD REF	BRIEF HAZARD DESCRIPTION
⚠	



CHAINAGE	0	20	40	60	80	100	120	140	160	180	200	220	240	260	280	300	320	340
DESIGN LEVELS	33.379	33.179	32.979	32.779	32.574	32.347	32.099	31.829	31.536	31.222	30.886	30.527	30.147	29.745	29.320	28.874	28.408	27.918
EXISTING LEVELS	33.374	32.940	32.398	31.581	30.778	30.115	29.729	29.434	29.186	28.772	28.437	28.298	27.937	27.414	27.155	26.982	26.993	26.866

CHAINAGE	360	380	400	420	440	460	480	500	520	540	560	580	600	620	640	660	680	700
DESIGN LEVELS	27.404	26.869	26.313	25.735	25.138	24.538	23.938	23.338	22.738	22.138	21.538	20.938	20.338	19.738	19.138	18.538	17.986	17.542
EXISTING LEVELS	24.552	25.984	25.447	24.905	24.600	24.310	23.735	23.177	22.551	21.811	20.762	20.158	19.473	18.275	17.550	17.137	16.925	17.338

PROFILE
Scale: 1:1250 H, 1:250 V

1:1250 0 62.5m 125m

NOTES

1: SIDESLOPES: 1:3 CUT, 1:2.5 FILL, 1:2 FILL AT SCHEDULED MONUMENT, SUBJECT TO GEOTECHNICAL INPUT

KEY TO SYMBOLS

●	CABLE PERCUSSIVE BOREHOLE
●	ROTARY CORED BOREHOLE
▣	TRIAL PIT
⊙	CONE PENETRATION TEST
– –	EXISTING GROUND LEVEL
—	PROPOSED GROUND LEVEL
▼	GROUND WATER STRIKE

REV	DATE	REVISION NOTE	ORG	CHK'D	APP'D
P01	09/07/20	Review for comment	GW	EW	MS
P02	02/10/20	First Issue	OT	EWat	MSan
P03	16/10/20	For Review and Issue	OT	MSan	MSan
P04	26/11/20	Issue for Stage Approval	OT	MSan	MSan

DESIGNER
SWECO

CONTRACTOR
GallifordTry

CLIENT
highways england

PROJECT TITLE
A47 WANSFORD TO SUTTON DUALLING

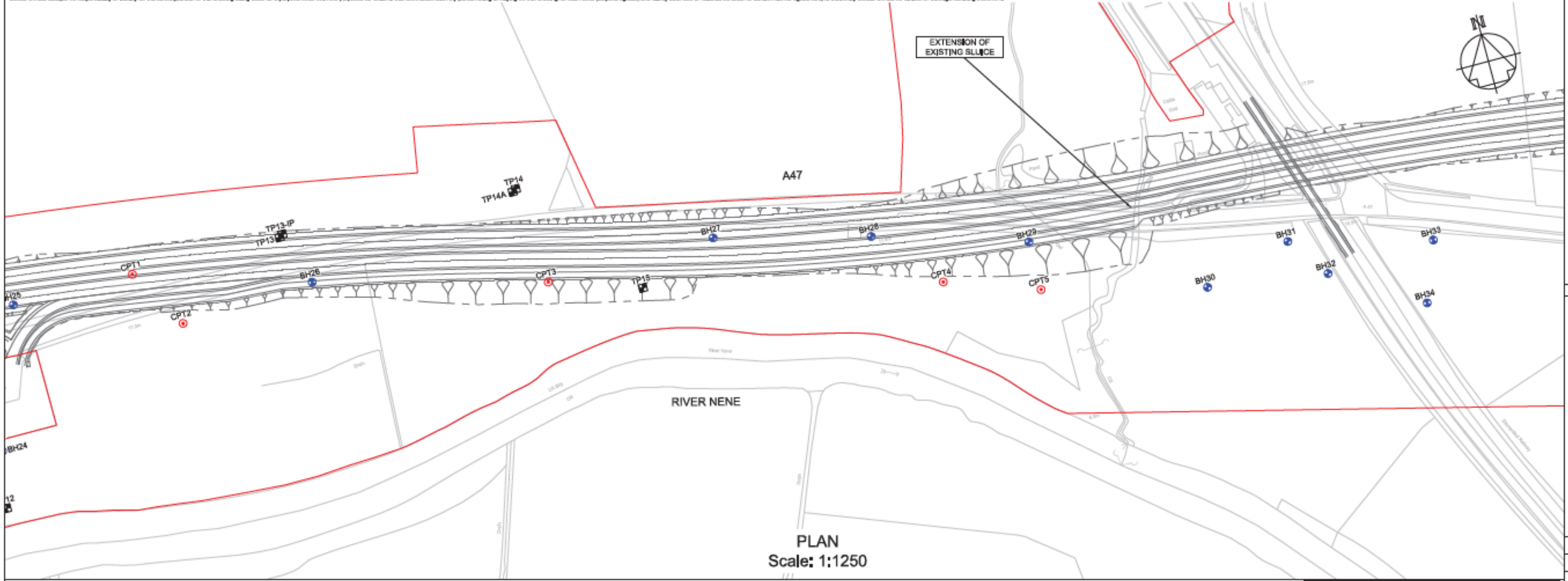
PROJECT STAGE
PCF STAGE 3

DRAWING TITLE
GEOLOGICAL LONGSECTIONS
PLANS & PROFILES
SHEET 1 OF 6

SUITABILITY
SUITABLE FOR REVIEW & COMMENT

SHEET SIZE	SCALE	STATUS	REVISION
A1	1:1250	S3	P04

DRAWING NUMBER
HE551494-GTY-HGT-000-DR-CE-30010



PLAN
Scale: 1:1250

- TOPSOIL
- MADE GROUND
- HEAD
- ALLUVIUM
- RIVER TERRACE DEPOSITS
- RUTLAND FORMATION
- LINCOLNSHIRE LIMESTONE FORMATION
- GRANTHAM FORMATION
- LIAS GROUP
- ASSUMED ZONES OF CORE LOSS

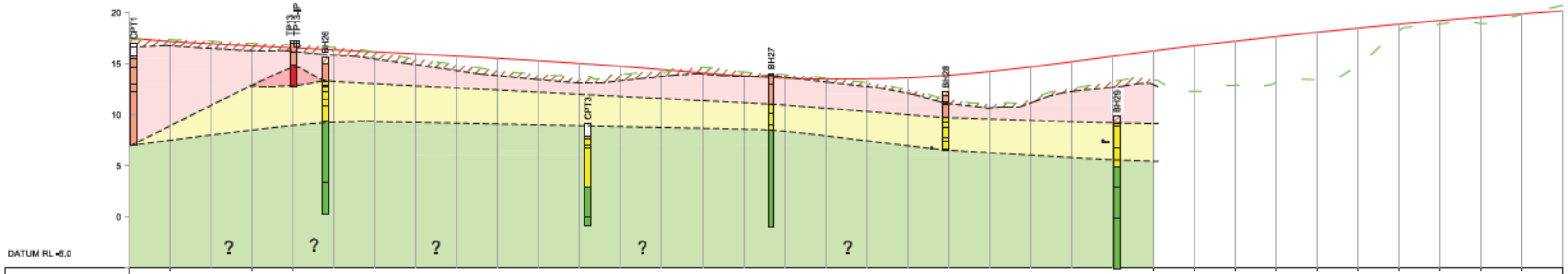
IMPORTANT

SAFETY, HEALTH & ENVIRONMENTAL INFORMATION

TO BE READ IN CONJUNCTION WITH HAZARD REGISTER
DOC. REF: Requires updating.

HAZARD REF AND BRIEF DESCRIPTION OF HAZARD:-

HAZARD REF	BRIEF HAZARD DESCRIPTION
⚠	



CHAINAGE	700	720	740	760	780	800	820	840	860	880	900	920	940	960	980	1000	1020	1040
DESIGN LEVELS	17,542	17,206	16,975	16,775	16,575	16,375	16,175	15,975	15,773	15,554	15,312	15,049	14,763	14,455	14,128	13,820	13,619	13,527
EXISTING LEVELS	17,938	17,387	17,261	17,017	16,866	16,609	16,151	15,485	14,924	14,341	13,982	13,564	13,398	14,217	14,659	14,208	13,950	13,616

CHAINAGE	1060	1080	1100	1120	1140	1160	1180	1200	1220	1240	1260	1280	1300	1320	1340	1360	1380	1400
DESIGN LEVELS	13,544	13,668	13,900	14,240	14,689	15,229	15,763	16,276	16,766	17,234	17,680	18,105	18,507	18,887	19,246	19,582	19,897	20,169
EXISTING LEVELS	13,188	12,509	11,476	11,002	11,494	12,609	13,267	13,440	12,326	12,924	13,191	13,580	14,834	18,247	18,920	18,923	19,856	20,729

PROFILE
Scale: 1:1250 H, 1:250 V

1:1250 0 62.5m 125m

NOTES

1: SIDESLOPES: 1:3 CUT, 1:2.5 FILL, 1:2 FILL AT SCHEDULED MONUMENT, SUBJECT TO GEOTECHNICAL INPUT

KEY TO SYMBOLS

- CABLE PERCUSSIVE BOREHOLE
- ROTARY CORED BOREHOLE
- TRIAL PIT
- CONE PENETRATION TEST

- EXISTING GROUND LEVEL
- PROPOSED GROUND LEVEL
- GROUND WATER STRIKE

REV	DATE	REVISION NOTE	ORG	CHK'D	APP'D
P01	03/07/20	Review for comment	GW	EW	MS
P02	02/10/20	First Issue	CT	EWat	MSan
P03	16/10/20	For Review and Issue	CT	MSan	MSan
P04	26/11/20	Vertical scale bar added	CT	MSan	MSan

DESIGNER
SWECO

CONTRACTOR
GallifordTry

CLIENT
highways england

PROJECT TITLE
A47 WANSFORD TO SUTTON DUALLING

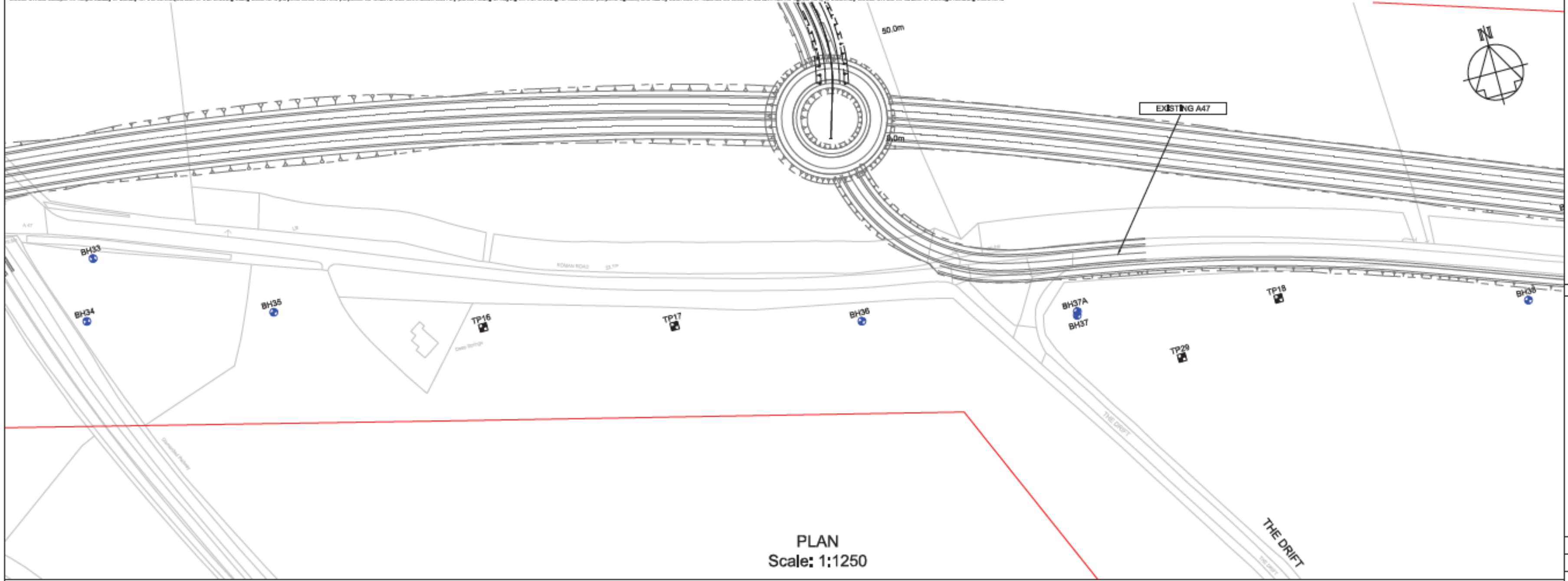
PROJECT STAGE
PCF STAGE 3

DRAWING TITLE
GEOLOGICAL LONGSECTIONS
PLANS & PROFILES
SHEET 2 OF 6

SUITABILITY
SUITABLE FOR REVIEW & COMMENT

SHEET SIZE	SCALE	STATUS	REVISION
A1	1:1250	S3	P04

DRAWING NUMBER
HE551494-GTY-HGT-000-DR-CE-30011



PLAN
Scale: 1:1250

NOTES

1: SIDESLOPES: 1:3 CUT, 1:2.5 FILL, 1:2 FILL AT SCHEDULED MONUMENT, SUBJECT TO GEOTECHNICAL INPUT

KEY TO SYMBOLS

- ● CABLE PERCUSSIVE BOREHOLE
- ● ROTARY CORED BOREHOLE
- ■ TRIAL PIT
- ⊙ CONE PENETRATION TEST

- – – EXISTING GROUND LEVEL
- —— PROPOSED GROUND LEVEL
- ▼ GROUND WATER STRIKE

REV	DATE	REVISION NOTE	ORG	CHK'D	APP'D
P01	09/07/20	Review for comment	GW	EW	MS
P02	02/10/20	First Issue	CT	EWat	MSan
P03	16/10/20	For Review and Issue	CT	MSan	MSan
P04	26/11/20	Vertical scale bar added	CT	MSan	MSan

- ▨ TOPSOIL
- ▩ MADE GROUND
- 🟪 HEAD
- 🟦 ALLUVIUM
- 🟧 RIVER TERRACE DEPOSITS
- ■ RUTLAND FORMATION
- 🟥 LINCOLNSHIRE LIMESTONE FORMATION
- 🟨 GRANTHAM FORMATION
- 🟩 LIAS GROUP
- ☐ ASSUMED ZONES OF CORE LOSS

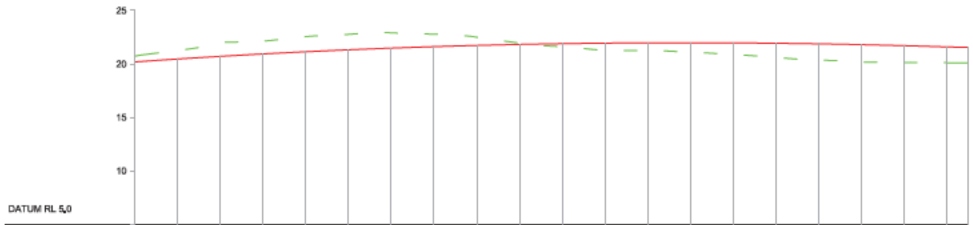
IMPORTANT

SAFETY, HEALTH & ENVIRONMENTAL INFORMATION

TO BE READ IN CONJUNCTION WITH HAZARD REGISTER DOC. REF: Requires updating.

HAZARD REF AND BRIEF DESCRIPTION OF HAZARD:-

HAZARD REF	BRIEF HAZARD DESCRIPTION
⚠	

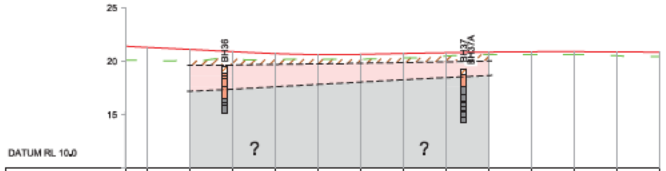


DATUM RL 5,0

CHAINAGE	1400	1420	1440	1460	1480	1500	1520	1540	1560	1580	1600	1620	1640	1660	1680	1700	1720	1740	1760	1780	1790
DESIGN LEVELS	20,169	20,459	20,708	20,934	21,139	21,322	21,482	21,621	21,737	21,832	21,905	21,955	21,984	21,991	21,976	21,938	21,879	21,798	21,699	21,599	21,549
EXISTING LEVELS	20,729	21,261	21,938	22,147	22,554	22,770	22,913	22,782	22,503	21,944	21,817	21,287	21,247	21,102	20,873	20,597	20,366	20,191	20,139	20,117	20,103

PROFILE
Scale: 1:1250 H, 1:250 V

1:1250 0 62,5m 125m



DATUM RL 10,0

CHAINAGE	1790	1800	1820	1840	1860	1880	1900	1920	1940	1960	1980	2000	2020	2040
DESIGN LEVELS	21,414	21,314	21,114	20,914	20,728	20,636	20,652	20,742	20,815	20,866	20,896	20,903	20,888	20,851
EXISTING LEVELS	20,103	20,060	20,056	20,282	20,168	20,196	20,200	20,312	20,492	20,637	20,684	20,692	20,522	20,451

PROFILE
Scale: 1:1250 H, 1:250 V

DESIGNER
SWECO

CONTRACTOR
GallifordTry

CLIENT
highways england

PROJECT TITLE
A47 WANSFORD TO SUTTON DUALLING

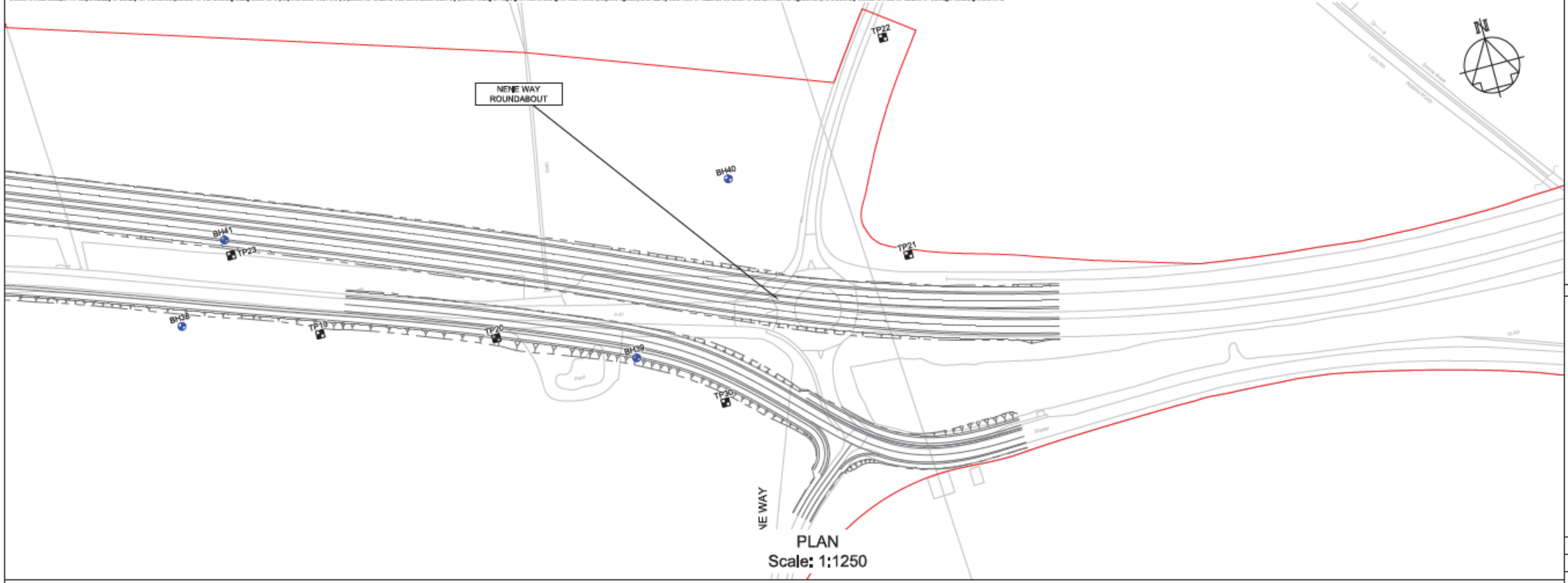
PROJECT STAGE
PCF STAGE 3

DRAWING TITLE
GEOLOGICAL LONGSECTIONS
PLANS & PROFILES
SHEET 3 OF 6

SUITABILITY
SUITABLE FOR REVIEW & COMMENT

SHEET SIZE	SCALE	STATUS	REVISION
A1	1:1250	S3	P04

DRAWING NUMBER
HE551494-GTY-HGT-000-DR-CE-30012



PLAN
Scale: 1:1250

NOTES

1: SIDESLOPES: 1:3 CUT, 1:2.5 FILL, 1:2 FILL AT SCHEDULED MONUMENT, SUBJECT TO GEOTECHNICAL INPUT

KEY TO SYMBOLS

- ● CABLE PERCUSSIVE BOREHOLE
- ● ROTARY CORED BOREHOLE
- ▪ TRIAL PIT
- ⊙ CONE PENETRATION TEST

- EXISTING GROUND LEVEL
- PROPOSED GROUND LEVEL
- GROUND WATER STRIKE

- ▨ TOPSOIL
- ▩ MADE GROUND
- 🟪 HEAD
- 🟦 ALLUVIUM
- 🟧 RIVER TERRACE DEPOSITS
- ⬛ RUTLAND FORMATION
- 🟥 LINCOLNSHIRE LIMESTONE FORMATION
- 🟨 GRANTHAM FORMATION
- 🟩 LIAS GROUP
- ☐ ASSUMED ZONES OF CORE LOSS

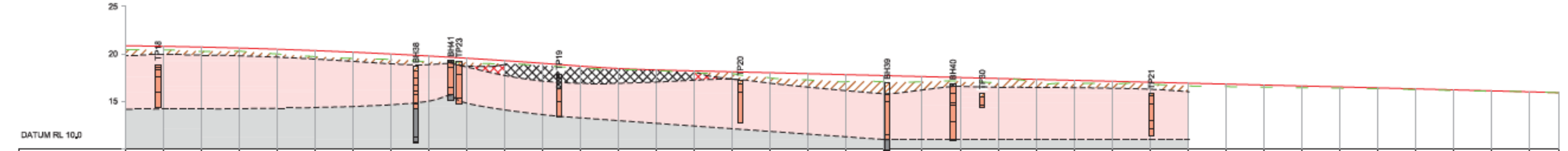
IMPORTANT

SAFETY, HEALTH & ENVIRONMENTAL INFORMATION

TO BE READ IN CONJUNCTION WITH HAZARD REGISTER
DOC. REF: Requires updating.

HAZARD REF AND BRIEF DESCRIPTION OF HAZARD:-

	HAZARD REF	BRIEF HAZARD DESCRIPTION
⚠		



CHAINAGE	2040	2060	2080	2100	2120	2140	2160	2180	2200	2220	2240	2260	2280	2300	2320	2340	2360	2380	2400
DESIGN LEVELS	20.851	20.792	20.712	20.609	20.484	20.337	20.169	19.978	19.765	19.531	19,274	18,996	18,698	18,442	18,294	18,194	18,094	17,994	17,894
EXISTING LEVELS	20.451	20.413	20.253	20.276	19.975	19.692	19.509	19.399	19.166	19.071	18,931	18,728	18,491	18,337	18,234	17,997	17,899	17,441	17,231

CHAINAGE	2420	2440	2460	2480	2500	2520	2540	2560	2580	2600	2620	2640	2660	2680	2700	2720	2740	2760	2780	2796
DESIGN LEVELS	17,794	17,694	17.594	17.494	17.394	17.294	17.194	17.094	16.994	16.894	16.794	16.694	16.594	16.494	16.394	16.294	16.194	16.094	15.981	15.885
EXISTING LEVELS	17,053	17,028	17.031	17.064	16.925	17.040	16.914	16.863	16.798	16.600	16.527	16.472	16.419	16.367	16.305	16.221	16.124	16.040	15.981	15.885

PROFILE
Scale: 1:1250 H, 1:250 V

1:1250 0 62.5m 125m

REV	DATE	REVISION NOTE	ORG	CHK'D	APP'D
P01	09/07/20	Review for comment	GW	EW	MS
P02	02/10/20	First Issue	CT	EWat	MSan
P03	16/10/20	For Review and Issue	CT	MSan	MSan
P04	26/11/20	Vertical scale bar added	CT	MSan	MSan

DESIGNER
SWECO

CONTRACTOR
GallifordTry

CLIENT
highways england

PROJECT TITLE
A47 WANSFORD TO SUTTON DUALLING

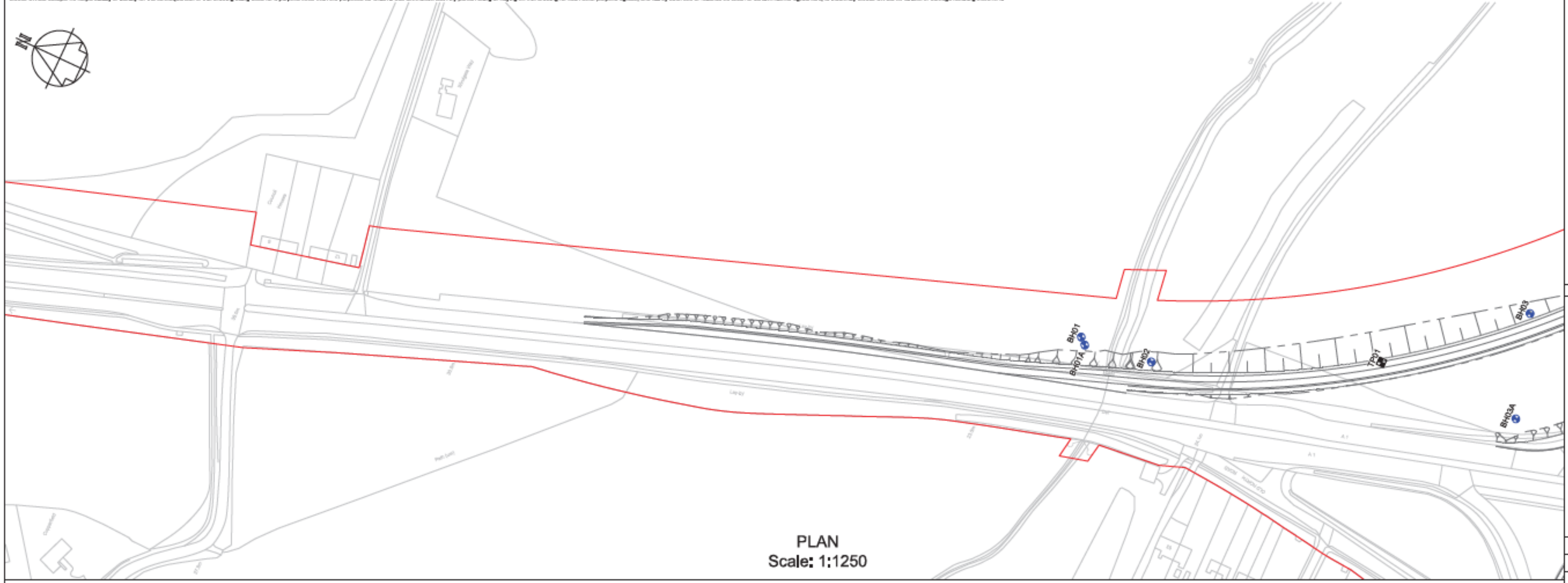
PROJECT STAGE
PCF STAGE 3

DRAWING TITLE
GEOLOGICAL LONGSECTIONS
PLANS & PROFILES
SHEET 4 OF 6

SUITABILITY
SUITABLE FOR REVIEW & COMMENT

SHEET SIZE	SCALE	STATUS	REVISION
A1	1:1250	S3	P04

DRAWING NUMBER
HE551494-GTY-HGT-000-DR-CE-30013



PLAN
Scale: 1:1250

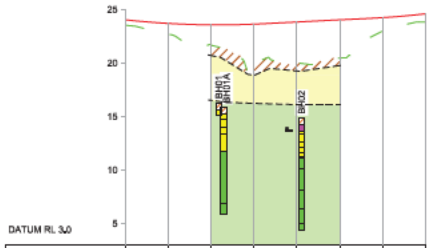
NOTES

1: SIDESLOPES: 1:3 CUT, 1:2.5 FILL, 1:2 FILL AT SCHEDULED MONUMENT, SUBJECT TO GEOTECHNICAL INPUT

KEY TO SYMBOLS

●	CABLE PERCUSSIVE BOREHOLE
●	ROTARY CORED BOREHOLE
■	TRIAL PIT
⊙	CONE PENETRATION TEST
– –	EXISTING GROUND LEVEL
—	PROPOSED GROUND LEVEL
▼	GROUND WATER STRIKE

▨	TOPSOIL
▩	MADE GROUND
🟪	HEAD
🟦	ALLUVIUM
🟧	RIVER TERRACE DEPOSITS
⬛	RUTLAND FORMATION
🟥	LINCOLNSHIRE LIMESTONE FORMATION
🟨	GRANTHAM FORMATION
🟩	LIAS GROUP
☐	ASSUMED ZONES OF CORE LOSS



DATUM RL 3.0

CHAINAGE	0	20	40	60	80	100	120	140
DESIGN LEVELS	24,021	23,695	23,563	23,631	23,828	24,028	24,234	24,582
EXISTING LEVELS	23,530	22,688	21,659	19,561	19,953	20,462	22,880	23,823

PROFILE
Scale: 1:1250 H, 1:250 V

IMPORTANT

SAFETY, HEALTH & ENVIRONMENTAL INFORMATION

TO BE READ IN CONJUNCTION WITH HAZARD REGISTER DOC. REF: Requires updating.

HAZARD REF AND BRIEF DESCRIPTION OF HAZARD:-

	HAZARD REF	BRIEF HAZARD DESCRIPTION
⚠		

REV	DATE	REVISION NOTE	ORG	CHK'D	APP'D
P01	09/07/20	Review for comment	GW	EW	MS
P02	02/10/20	First Issue	CT	EWat	MSan
P03	16/10/20	For Review and Issue	CT	MSan	MSan
P04	26/11/20	Vertical scale bar added	CT	MSan	MSan

DESIGNER
SWECO

CONTRACTOR
GallifordTry

CLIENT
highways england

PROJECT TITLE
A47 WANSFORD TO SUTTON DUALLING

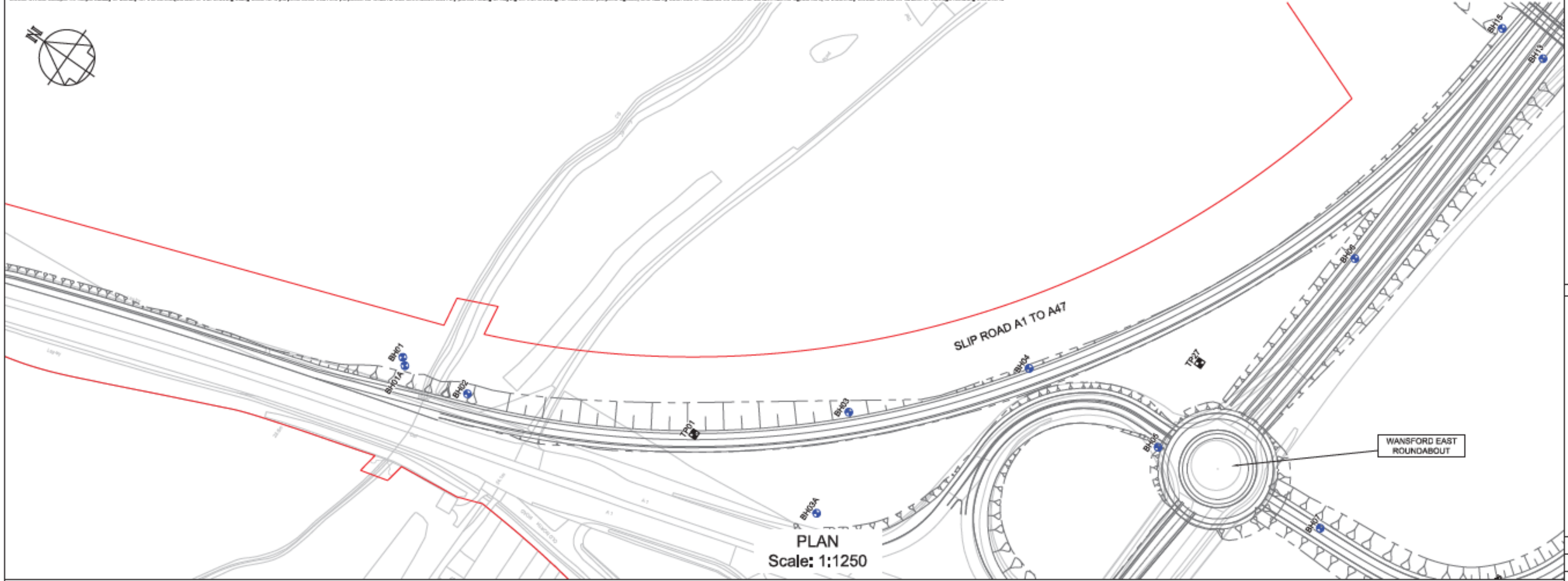
PROJECT STAGE
PCF STAGE 3

DRAWING TITLE
GEOLOGICAL LONGSECTIONS
PLANS & PROFILES
SHEET 5 OF 6

SUITABILITY
SUITABLE FOR REVIEW & COMMENT

SHEET SIZE	SCALE	STATUS	REVISION
A1	1:1250	S3	P04

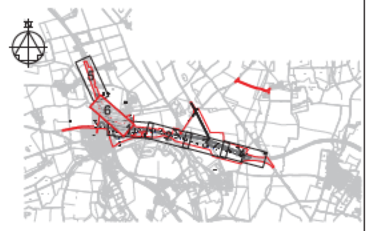
DRAWING NUMBER
HE551494-GTY-HGT-000-DR-CE-30014



PLAN
Scale: 1:1250

NOTES

1: SIDESLOPES: 1:3 CUT, 1:2.5 FILL, 1:2 FILL AT SCHEDULED MONUMENT, SUBJECT TO GEOTECHNICAL INPUT



KEY TO SYMBOLS

- ● CABLE PERCUSSIVE BOREHOLE
- ● ROTARY CORED BOREHOLE
- ■ TRIAL PIT
- ⊙ CONE PENETRATION TEST

- — — EXISTING GROUND LEVEL
- —— PROPOSED GROUND LEVEL
- ▼ GROUND WATER STRIKE

- ▨ TOPSOIL
- ▩ MADE GROUND
- 🟪 HEAD
- 🟦 ALLUVIUM
- 🟧 RIVER TERRACE DEPOSITS
- ⬛ RUTLAND FORMATION
- 🟥 LINCOLNSHIRE LIMESTONE FORMATION
- 🟨 GRANTHAM FORMATION
- 🟩 LIAS GROUP
- ☐ ASSUMED ZONES OF CORE LOSS

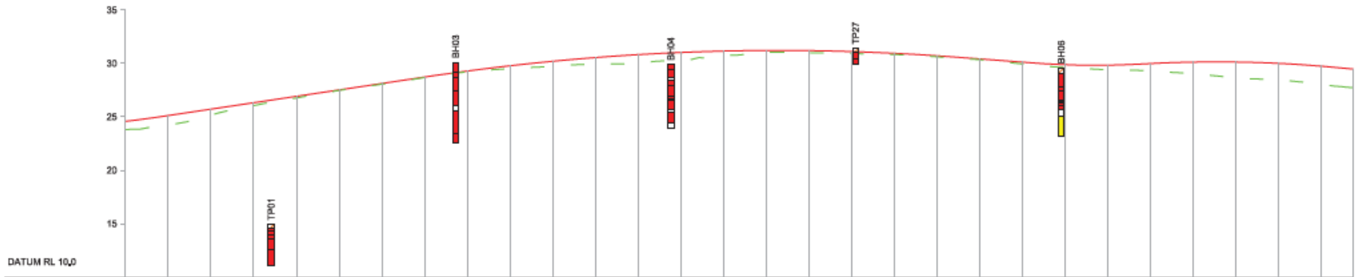
IMPORTANT

SAFETY, HEALTH & ENVIRONMENTAL INFORMATION

TO BE READ IN CONJUNCTION WITH HAZARD REGISTER DOC. REF: Requires updating.

HAZARD REF AND BRIEF DESCRIPTION OF HAZARD:-

HAZARD REF	BRIEF HAZARD DESCRIPTION
⚠	



CHAINAGE	DESIGN LEVELS	EXISTING LEVELS
140	24,582	23,823
160	25,125	24,229
180	25,725	25,165
200	26,325	26,056
220	26,925	26,766
240	27,525	27,480
260	28,125	28,058
280	28,725	28,682
300	29,291	29,206
320	29,784	29,517
340	30,205	29,726
360	30,553	29,939
380	30,828	30,047
400	31,030	30,279
420	31,180	30,596
440	31,217	31,007
460	31,201	31,004
480	31,113	30,943
500	30,952	30,832
520	30,718	30,620
540	30,424	30,358
560	30,124	29,954
580	29,886	29,623
600	29,843	29,398
620	29,992	29,291
640	30,130	29,019
660	30,136	28,682
680	30,009	28,432
700	29,748	28,042
715	29,470	27,725

PROFILE
Scale: 1:1250 H, 1:250 V

1:1250 0 62,5m 125m

REV	DATE	REVISION NOTE	ORG	CHK'D	APP'D
P01	09/07/20	Review for comment	GW	EW	MS
P02	02/10/20	First Issue	CT	EWat	MSan
P03	16/10/20	For Review and Issue	CT	MSan	MSan
P04	26/11/20	Vertical scale bar added	CT	MSan	MSan

DESIGNER
SWECO

CONTRACTOR
GallifordTry

CLIENT
highways england

PROJECT TITLE
A47 WANSFORD TO SUTTON DUALLING

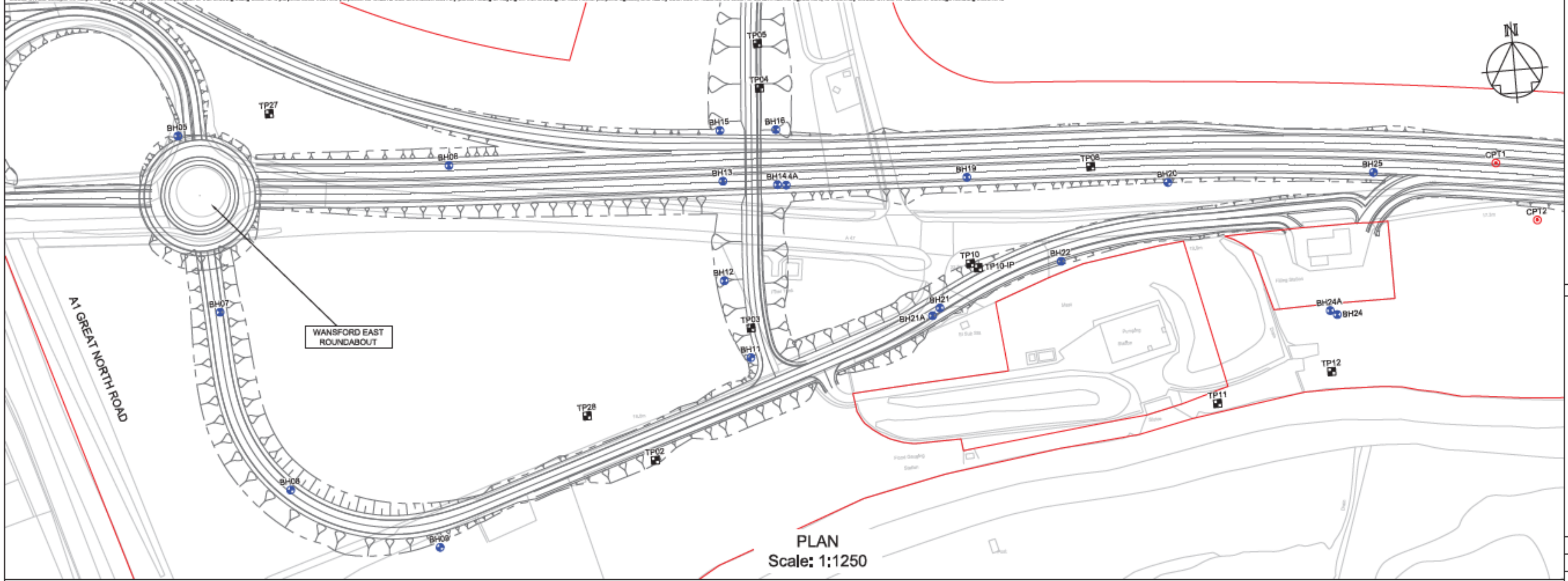
PROJECT STAGE
PCF STAGE 3

DRAWING TITLE
GEOLOGICAL LONGSECTIONS
PLANS & PROFILES
SHEET 6 OF 6

SUITABILITY
SUITABLE FOR REVIEW & COMMENT

SHEET SIZE	SCALE	STATUS	REVISION
A1	1:1250	S3	P04

DRAWING NUMBER
HE551494-GTY-HGT-000-DR-CE-30015



PLAN
Scale: 1:1250

IMPORTANT

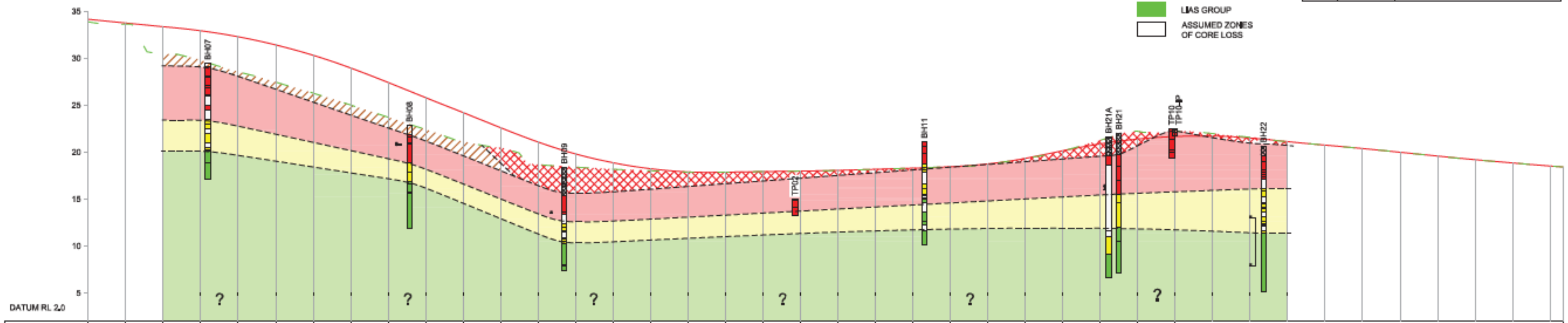
SAFETY, HEALTH & ENVIRONMENTAL INFORMATION

TO BE READ IN CONJUNCTION WITH HAZARD REGISTER DOC. REF: Requires updating.

HAZARD REF AND BRIEF DESCRIPTION OF HAZARD>

HAZARD REF	BRIEF HAZARD DESCRIPTION
⚠	

▨	TOPSOIL
▦	MADE GROUND
🟪	HEAD
🟦	ALLUVIUM
🟧	RIVER TERRACE DEPOSITS
⬛	RUTLAND FORMATION
🟥	LINCOLNSHIRE LIMESTONE FORMATION
🟨	GRANTHAM FORMATION
🟩	LIAS GROUP
☐	ASSUMED ZONES OF CORE LOSS



CHAINAGE	0	20	40	60	80	100	120	140	160	180	200	220	240	260	280	300	320	340	360	380
DESIGN LEVELS	34.148	33.748	33.348	32.919	32.284	31.413	30.307	28.966	27.408	25.808	24.208	22.608	21.068	19.813	18.867	18.227	17.896	17.863	17.921	17.978
EXISTING LEVELS	33.872	33.619	30.439	29.785	28.542	27.454	26.280	25.015	23.706	22.410	21.115	20.450	18.669	18.398	18.176	18.015	17.864	17.863	17.920	17.977

CHAINAGE	400	420	440	460	480	500	520	540	560	580	600	620	640	660	680	700	720	740	760	780	787
DESIGN LEVELS	18.051	18.167	18.298	18.438	18.736	19.341	20.138	20.876	21.387	21.663	21.704	21.510	21.102	20.737	20.373	19.986	19.573	19.192	18.841	18.520	18.415
EXISTING LEVELS	18.051	18.167	18.296	18.438	18.658	19.328	20.119	21.260	22.211	22.174	21.977	21.577	21.102	20.737	20.373	19.984	19.567	19.178	18.867	18.520	18.414

PROFILE
Scale: 1:1250 H, 1:250 V

1:1250 0 62.5m 125m

NOTES

1: SIDESLOPES: 1:3 CUT, 1:2.5 FILL, 1:2 FILL AT SCHEDULED MONUMENT, SUBJECT TO GEOTECHNICAL INPUT

KEY TO SYMBOLS

- CABLE PERCUSSIVE BOREHOLE
- ROTARY CORED BOREHOLE
- TRIAL PIT
- CONE PENETRATION TEST

- EXISTING GROUND LEVEL
- PROPOSED GROUND LEVEL
- GROUND WATER STRIKE

P01	09/07/20	Review for comment	GW	EW	MS
P02	02/10/20	First Issue	OT	EWat	MSan
P03	16/10/20	For Review and Issue	OT	MSan	MSan
P04	26/11/20	Vertical scale bar added	OT	MSan	MSan
REV	DATE	REVISION NOTE	ORG	CHK'D	APP'D

DESIGNER
SWECO

CONTRACTOR
GallifordTry

CLIENT
highways england

PROJECT TITLE
A47 WANSFORD TO SUTTON DUALLING

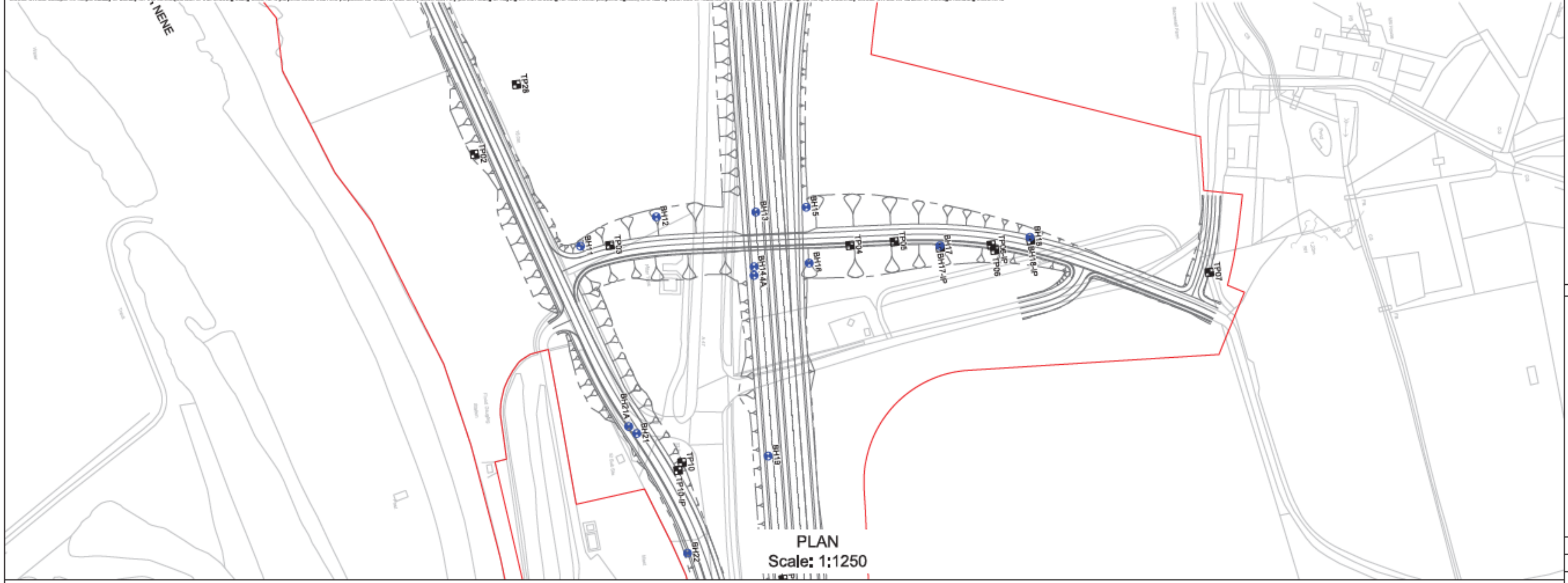
PROJECT STAGE
PCF STAGE 3

DRAWING TITLE
GEOLOGICAL LONGSECTIONS
SIDEROADS PLANS & PROFILES
SHEET 1 OF 4

SUITABILITY
SUITABLE FOR REVIEW & COMMENT

SHEET SIZE	SCALE	STATUS	REVISION
A1	1:1250	S3	P04

DRAWING NUMBER
HE551494-GTY-HGT-000-DR-CE-30016



PLAN
Scale: 1:1250

NOTES

1: SIDESLOPES: 1:3 CUT, 1:2.5 FILL, 1:2 FILL AT SCHEDULED MONUMENT, SUBJECT TO GEOTECHNICAL INPUT

KEY TO SYMBOLS

- CABLE PERCUSSIVE BOREHOLE
- ROTARY CORED BOREHOLE
- TRIAL PIT
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- EXISTING GROUND LEVEL
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REV	DATE	REVISION NOTE	ORG	CHK'D	APP'D
P01	03/07/20	Review for comment	GW	EW	MS
P02	02/10/20	First Issue	CT	EWat	MSan
P03	16/10/20	For Review and Issue	CT	MSan	MSan
P04	26/11/20	Vertical scale bar added	CT	MSan	MSan

DESIGNER
SWECO

CONTRACTOR
GallifordTry

CLIENT
highways england

PROJECT TITLE
A47 WANSFORD TO SUTTON DUALLING

PROJECT STAGE
PCF STAGE 3

DRAWING TITLE
GEOLOGICAL LONGSECTIONS
SIDEROADS PLANS & PROFILES
SHEET 2 OF 4

SUITABILITY
SUITABLE FOR REVIEW & COMMENT

SHEET SIZE	SCALE	STATUS	REVISION
A1	1:1250	S3	P04

DRAWING NUMBER
HE551494-GTY-HGT-000-DR-CE-30017

IMPORTANT

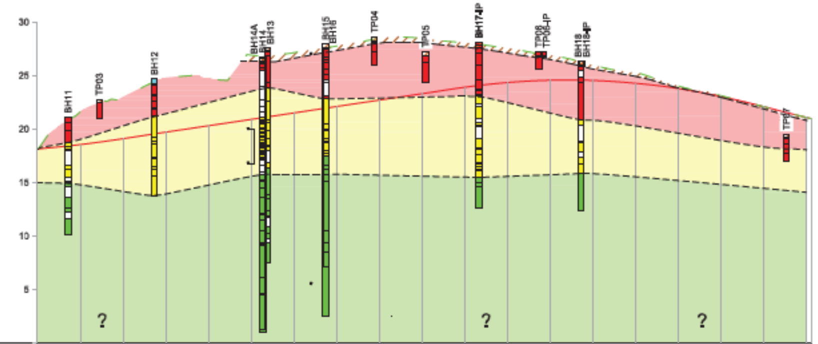
SAFETY, HEALTH & ENVIRONMENTAL INFORMATION

TO BE READ IN CONJUNCTION WITH HAZARD REGISTER DOC. REF: Requires updating.

HAZARD REF AND BRIEF DESCRIPTION OF HAZARD:-

HAZARD REF	BRIEF HAZARD DESCRIPTION
⚠	

▨	TOPSOIL
▩	MADE GROUND
🟪	HEAD
🟦	ALLUVIUM
🟧	RIVER TERRACE DEPOSITS
⬜	RUTLAND FORMATION
🟥	LINCOLNSHIRE LIMESTONE FORMATION
🟨	GRANTHAM FORMATION
🟩	LIAS GROUP
☐	ASSUMED ZONES OF CORE LOSS

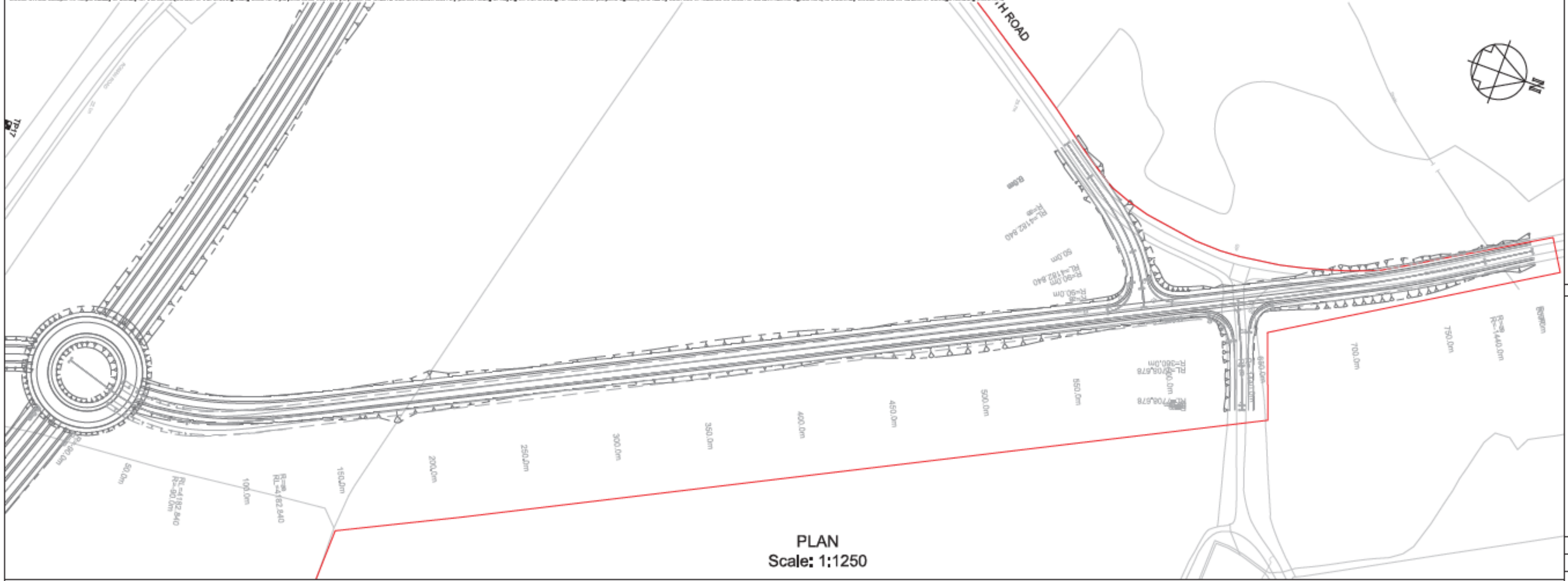


DATUM RL 0.0

CHAINAGE	0	20	40	60	80	100	120	140	160	180	200	220	240	260	280	300	320	340	360 362
DESIGN LEVELS	18.320	18.725	19.293	19.893	20.493	21.093	21.693	22.293	22.893	23.493	24.090	24.537	24.749	24.725	24.466	23.972	23.242	22.277	21.264 21.131
EXISTING LEVELS	18.350	21.808	23.171	24.971	24.885	27.099	27.324	27.941	28.642	28.669	28.242	27.747	27.078	26.163	25.425	24.212	23.313	22.277	21.264 21.131

PROFILE
Scale: 1:1250 H, 1:250 V

1:1250 0 62.5m 125m



PLAN
Scale: 1:1250

NOTES

1: SIDESLOPES: 1:3 CUT, 1:2.5 FILL, 1:2 FILL AT SCHEDULED MONUMENT, SUBJECT TO GEOTECHNICAL INPUT

KEY TO SYMBOLS

◕	CABLE PERCUSSIVE BOREHOLE
◒	ROTARY CORED BOREHOLE
◩	TRIAL PIT
⊙	CONE PENETRATION TEST

– –	EXISTING GROUND LEVEL
—	PROPOSED GROUND LEVEL
▼	GROUND WATER STRIKE

P01	09/07/20	Review for comment	GW	EW	MS
P02	02/10/20	First Issue	CT	EWat	MSan
P03	16/10/20	For Review and Issue	CT	MSan	MSan
P04	26/11/20	Vertical scale bar added	CT	MSan	MSan
REV	DATE	REVISION NOTE	ORG	CHK'D	APP'D

▨	TOPSOIL
▩	MADE GROUND
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☐	ASSUMED ZONES OF CORE LOSS

IMPORTANT

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TO BE READ IN CONJUNCTION WITH HAZARD REGISTER
DOC. REF: Requires updating.

HAZARD REF AND BRIEF DESCRIPTION OF HAZARDS-

	HAZARD REF	BRIEF HAZARD DESCRIPTION
⚠		

DATUM RL 12.0

PROFILE NOT DESIGNED AS YET FOR THIS ALIGNMENT & NO BOREHOLES ALONG THE PROPOSED ROUTE YET EITHER

CHAINAGE	0	20	40												
DESIGN LEVELS	21.415	21.615	21.815	22.01	22.31	22.71	23.1	23.5	23.7	23.9	24.1	24.1	24.1	24.0	23.9
EXISTING LEVELS	20.103	20.263	20.657	21.127	21.797	22.610	23.285	23.915	-999,000	24.543	24.364	24.049	23.659	23.383	23.119

CHAINAGE												520	540	560	580	600
DESIGN LEVELS	23.8	23.7	23.8	23.5	23.4	23.2	23.0	22.71	22.3	21.8	21.3	20.744	20.144	19.618	19.290	19.163
EXISTING LEVELS	23.057	23.093	23.164	23.277	23.414	23.412	23.303	23.289	22.898	22.220	21.561	20.670	20.082	19.579	19.229	18.272

PROFILE
Scale: 1:1250 H, 1:250 V

1:1250 0 62.5m 125m

DESIGNER
SWECO

CONTRACTOR
GallifordTry

CLIENT
highways england

PROJECT TITLE
A47 WANSFORD TO SUTTON DUALLING

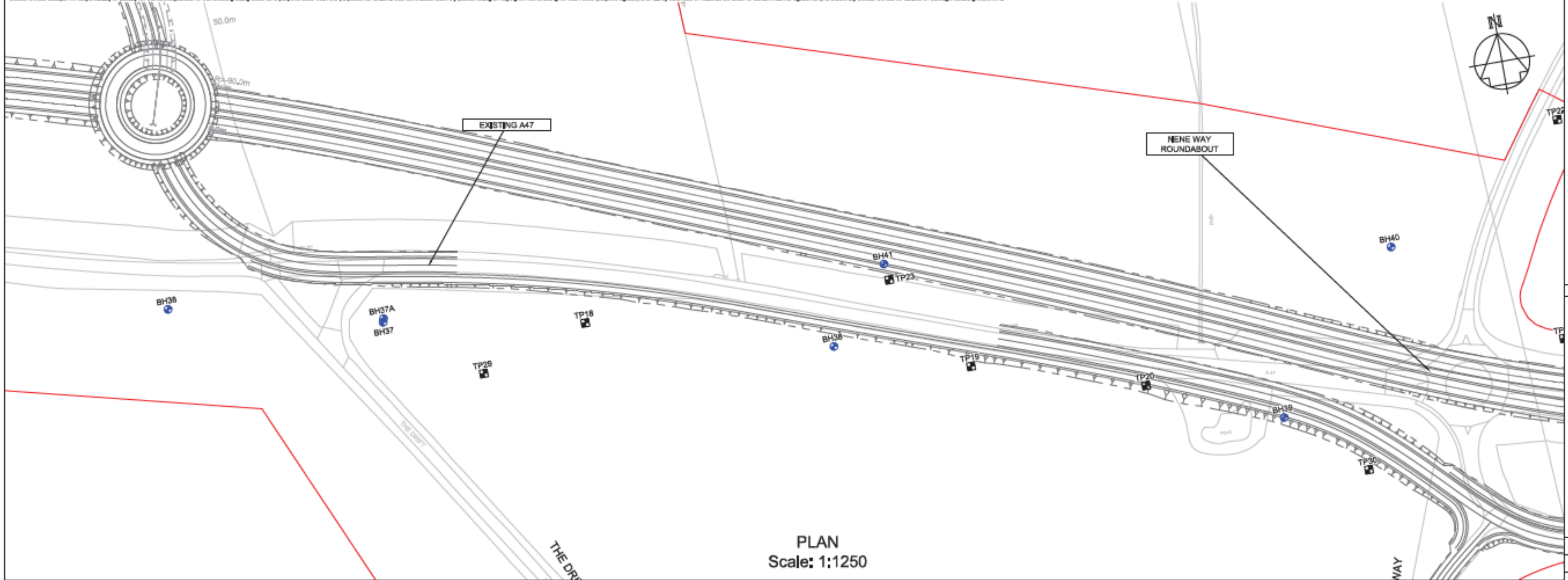
PROJECT STAGE
PCF STAGE 3

DRAWING TITLE
GEOLOGICAL LONGSECTIONS
SIDEROADS PLANS & PROFILES
SHEET 3 OF 4

SUITABILITY
SUITABLE FOR REVIEW & COMMENT

SHEET SIZE	SCALE	STATUS	REVISION
A1	1:1250	S3	P04

DRAWING NUMBER
HE551494-GTY-HGT-000-DR-CE-30018



PLAN
Scale: 1:1250

NOTES

1: SIDESLOPES: 1:3 CUT, 1:2.5 FILL, 1:2 FILL AT SCHEDULED MONUMENT, SUBJECT TO GEOTECHNICAL INPUT

KEY TO SYMBOLS

- ● CABLE PERCUSSIVE BOREHOLE
- ● ROTARY CORED BOREHOLE
- ▣ TRIAL PIT
- ⊙ CONE PENETRATION TEST

- — — EXISTING GROUND LEVEL
- —— PROPOSED GROUND LEVEL
- ▼ GROUND WATER STRIKE

- ▨ TOPSOIL
- ▩ MADE GROUND
- ■ HEAD
- ■ ALLUVIUM
- ■ RIVER TERRACE DEPOSITS
- ■ RUTLAND FORMATION
- ■ LINCOLNSHIRE LIMESTONE FORMATION
- ■ GRANTHAM FORMATION
- ■ LIAS GROUP
- ☐ ASSUMED ZONES OF CORE LOSS

IMPORTANT

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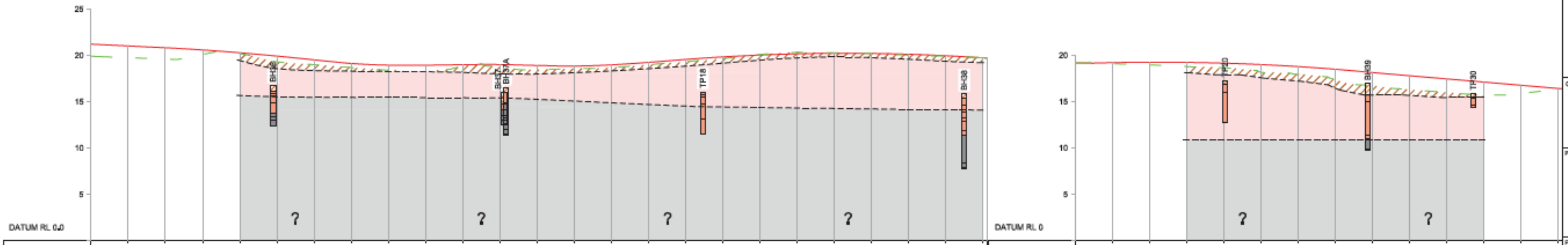
HAZARD REF AND BRIEF DESCRIPTION OF HAZARD:-

HAZARD REF	BRIEF HAZARD DESCRIPTION
⚠	



CHAINAGE	0	20	40	60	80	100	120	140	160	180	200	220	240	260	280	300	320	340	360	390	400	420	440	460	[illegible]
DESIGN LEVELS	21.415	21.215	21.015	20.787	20.487	20.115	19.715	19.340	19.140	19.140	19.204	19.196	19.115	19.061	19.171	19.456	19.756	20.030	20.233	20.364	20.421	20.406	20.318	20.157	[illegible]
EXISTING LEVELS	20.103	19.941	19.798	20.306	20.410	19.501	19.194	18.884	18.593	18.495	19.027	18.964	18.663	18.753	18.886	19.158	19.494	19.852	20.294	20.528	20.471	20.393	20.233	20.116	[illegible]

CHAINAGE	0	20	40	60	80	100	120	140	160	180	200	220	240	260
DESIGN LEVELS	19.182	19.180	19.244	19.236	19.155	19.001	18.775	18.476	18.133	17.790	17.447	17.103	16.760	16.417
EXISTING LEVELS	19.182	19.097	18.959	18.777	18.644	18.155	17.922	17.318	16.719	16.288	15.982	15.743	15.848	16.336

PROFILE
Scale: 1:1250 H, 1:250 V

1:1250 0 62.5m 125m

P01	09/07/20	Review for comment	GW	EW	MS
P02	02/10/20	First Issue	OT	EWat	MSan
P03	16/10/20	For Review and Issue	OT	MSan	MSan
P04	26/11/20	Vertical scale bar added	OT	MSan	MSan
REV	DATE	REVISION NOTE	ORG	CHK'D	APP'D

DESIGNER
SWECO

CONTRACTOR
GallifordTry

CLIENT
highways england

PROJECT TITLE
A47 WANSFORD TO SUTTON DUALLING

PROJECT STAGE
PCF STAGE 3

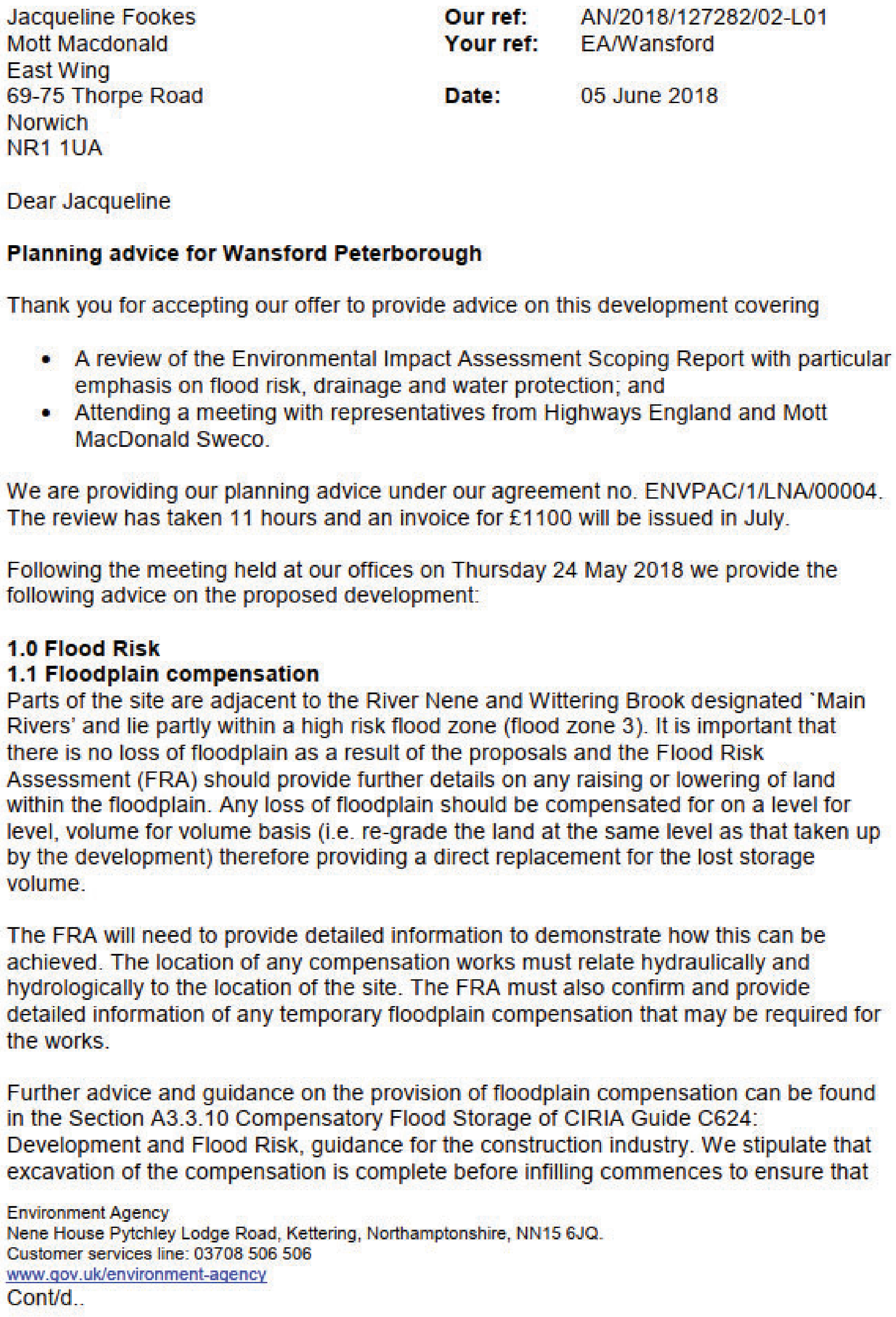
DRAWING TITLE
GEOLOGICAL LONGSECTIONS
SIDEROADS PLANS & PROFILES
SHEET 4 OF 4

SUITABILITY
SUITABLE FOR REVIEW & COMMENT

SHEET SIZE	SCALE	STATUS	REVISION
A1	1:1250	S3	P04

DRAWING NUMBER
HE551494-GTY-HGT-000-DR-CE-30019

Annex C. Environment Agency hydrogeological conceptualisation



Jacqueline Fookes
Mott Macdonald
East Wing
69-75 Thorpe Road
Norwich
NR1 1UA

Our ref: AN/2018/127282/02-L01
Your ref: EA/Wansford

Date: 05 June 2018

Dear Jacqueline

Planning advice for Wansford Peterborough

Thank you for accepting our offer to provide advice on this development covering

- A review of the Environmental Impact Assessment Scoping Report with particular emphasis on flood risk, drainage and water protection; and
- Attending a meeting with representatives from Highways England and Mott MacDonald Sweco.

We are providing our planning advice under our agreement no. ENVPAC/1/LNA/00004. The review has taken 11 hours and an invoice for £1100 will be issued in July.

Following the meeting held at our offices on Thursday 24 May 2018 we provide the following advice on the proposed development:

1.0 Flood Risk

1.1 Floodplain compensation

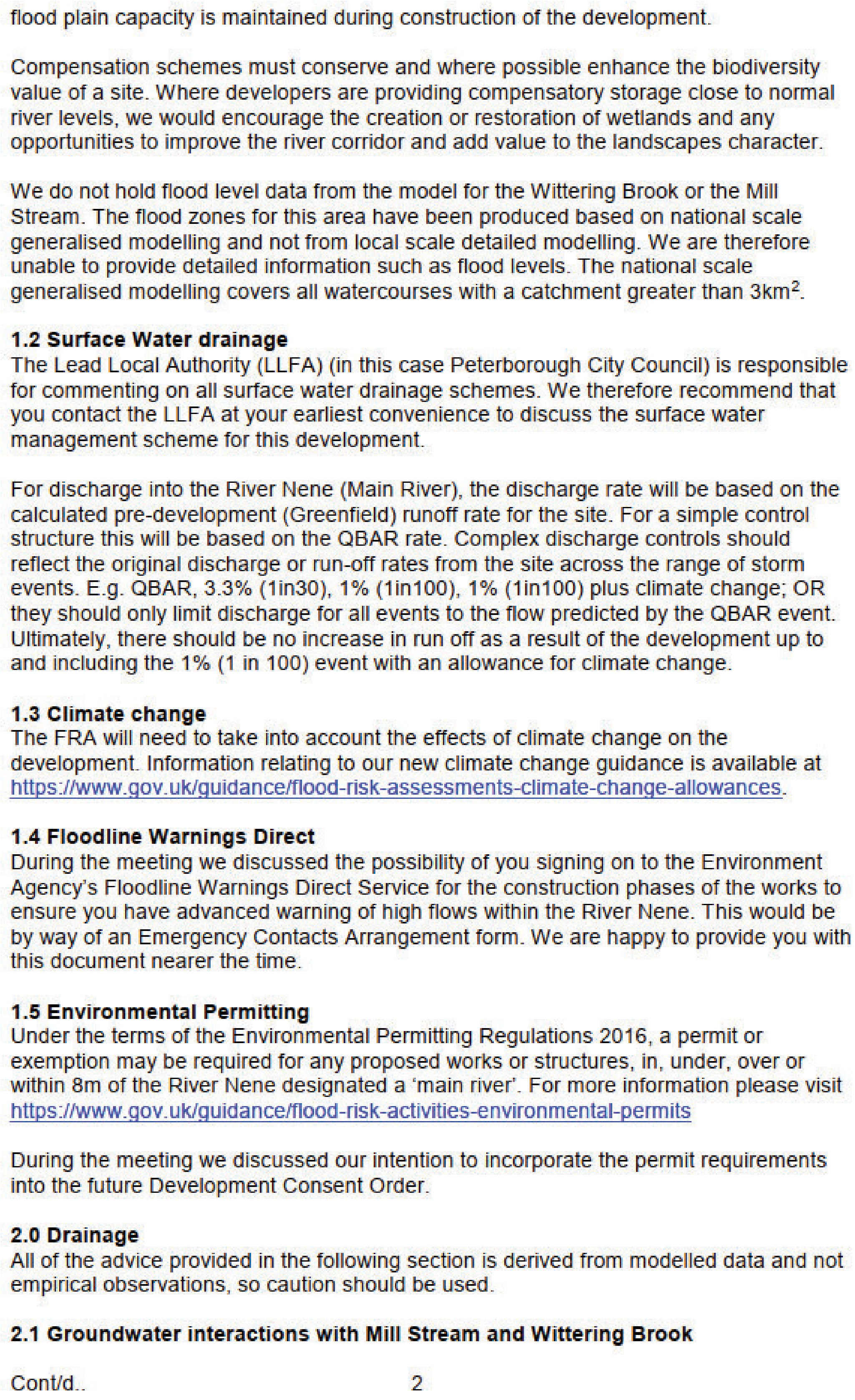
Parts of the site are adjacent to the River Nene and Wittering Brook designated `Main Rivers' and lie partly within a high risk flood zone (flood zone 3). It is important that there is no loss of floodplain as a result of the proposals and the Flood Risk Assessment (FRA) should provide further details on any raising or lowering of land within the floodplain. Any loss of floodplain should be compensated for on a level for level, volume for volume basis (i.e. re-grade the land at the same level as that taken up by the development) therefore providing a direct replacement for the lost storage volume.

The FRA will need to provide detailed information to demonstrate how this can be achieved. The location of any compensation works must relate hydraulically and hydrologically to the location of the site. The FRA must also confirm and provide detailed information of any temporary floodplain compensation that may be required for the works.

Further advice and guidance on the provision of floodplain compensation can be found in the Section A3.3.10 Compensatory Flood Storage of CIRIA Guide C624: Development and Flood Risk, guidance for the construction industry. We stipulate that excavation of the compensation is complete before infilling commences to ensure that

Environment Agency
Nene House Pytchley Lodge Road, Kettering, Northamptonshire, NN15 6JQ.
Customer services line: 03708 506 506
www.gov.uk/environment-agency

Cont/d..



flood plain capacity is maintained during construction of the development.

Compensation schemes must conserve and where possible enhance the biodiversity value of a site. Where developers are providing compensatory storage close to normal river levels, we would encourage the creation or restoration of wetlands and any opportunities to improve the river corridor and add value to the landscapes character.

We do not hold flood level data from the model for the Wittering Brook or the Mill Stream. The flood zones for this area have been produced based on national scale generalised modelling and not from local scale detailed modelling. We are therefore unable to provide detailed information such as flood levels. The national scale generalised modelling covers all watercourses with a catchment greater than $3km^2$.

1.2 Surface Water drainage

The Lead Local Authority (LLFA) (in this case Peterborough City Council) is responsible for commenting on all surface water drainage schemes. We therefore recommend that you contact the LLFA at your earliest convenience to discuss the surface water management scheme for this development.

For discharge into the River Nene (Main River), the discharge rate will be based on the calculated pre-development (Greenfield) runoff rate for the site. For a simple control structure this will be based on the QBAR rate. Complex discharge controls should reflect the original discharge or run-off rates from the site across the range of storm events. E.g. QBAR, 3.3% (1in30), 1% (1in100), 1% (1in100) plus climate change; OR they should only limit discharge for all events to the flow predicted by the QBAR event. Ultimately, there should be no increase in run off as a result of the development up to and including the 1% (1 in 100) event with an allowance for climate change.

1.3 Climate change

The FRA will need to take into account the effects of climate change on the development. Information relating to our new climate change guidance is available at https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances.

1.4 Floodline Warnings Direct

During the meeting we discussed the possibility of you signing on to the Environment Agency's Floodline Warnings Direct Service for the construction phases of the works to ensure you have advanced warning of high flows within the River Nene. This would be by way of an Emergency Contacts Arrangement form. We are happy to provide you with this document nearer the time.

1.5 Environmental Permitting

Under the terms of the Environmental Permitting Regulations 2016, a permit or exemption may be required for any proposed works or structures, in, under, over or within 8m of the River Nene designated a 'main river'. For more information please visit https://www.gov.uk/guidance/flood-risk-activities-environmental-permits

During the meeting we discussed our intention to incorporate the permit requirements into the future Development Consent Order.

2.0 Drainage

All of the advice provided in the following section is derived from modelled data and not empirical observations, so caution should be used.

2.1 Groundwater interactions with Mill Stream and Wittering Brook

Cont/d.. 2

We have a groundwater model which gives expected indicative interactions between groundwater and surface water, under different scenarios (wet, average and dry recharge conditions).

The model indicates the following:
Dry periods of rainfall:

- Stream flow in Mill Stream is around 0.5-5 Ml/d, with a very small baseflow contribution from groundwater of around <0.1 Ml/d.
- Stream flow in Wittering Brook is higher, >5 Ml/d, but again the baseflow contribution is very small, <0.1 Ml/d.

Average periods of rainfall:

- Stream flow in Mill Stream is around 5-50 Ml/d, with a small baseflow contribution from groundwater of around <0.5 Ml/d.
- Stream flow in Wittering Brook is higher, >50 Ml/d, but again the baseflow contribution is small, <0.5 Ml/d.

Wet periods of rainfall:

- Stream flow in Mill Stream is around >50 Ml/d, with a more baseflow contribution from groundwater, up to 1 Ml/d.
- Stream flow in Wittering Brook is also >50 Ml/d, but again the baseflow contribution is small, <0.5 Ml/d.

There doesn't seem to be any condition where we would expect the watercourses to loose water to ground. Vertical flow volumes under all recharge scenarios supports this data, showing a small amount of upward leakage from both the superficial deposits (where present) and also from the bedrock into the superficial deposits along the watercourse routes. The model confirms that groundwater level should be close to the ground level, as expected and stated in the Environmental Impact Assessment Scoping Report.

2.2 Hydrogeological requirements of Sutton Heath Bog
The Bog appears to sit directly on Lincolnshire Limestone outcrop, with no drift deposits. The limestone outcrop gives way to the underlying Grantham Formation and Whitby Mudstone to the western boundary of the Bog. Our groundwater model doesn't give any indication of vertical leakage from the Limestone to the bog, but stream leakage indicates that the direction of water flow is likely to be downward, i.e. infiltrating into the Limestone. Under wet conditions, up to 1 Ml/d may infiltrate into the limestone in the area of the Bog. The infiltration volumes become negligible in dry scenarios, because they are entirely dependent on effective rainfall (i.e. the rainfall which infiltrates, so total rainfall minus evapotranspiration and other losses such as runoff). Limestone is quite permeable so is likely to allow rapid infiltration.

The Bog sites on sloping ground, with several springs emerging within it from the base of the limestone outcrop where it meets the less permeable Grantham Formation/Whitby Mudstone. This is further evidence of the higher permeability of the limestone – rainfall appears to infiltrate at higher elevations to the east and emerge again downslope within the bog, heading westwards. These springs or seepages, which feed into Wittering Brook, are likely to be important features within the Bog.

There are three groundwater monitoring points within Sutton Heath Bog. It is our understanding that you already hold this data. This data will help in interpreting groundwater/surface water interactions. We are unable to provide a definitive response on the hydrogeological requirements of the Bog, but would surmise that it appears to be

Cont/d..

entirely rainfall-dependent. Rainfall will rapidly infiltrate and re-emerge downslope with little residence time.

2.3 HAWRAT Assessment (Q95 flow)
Natural Q95 flow data for the area is contained in the CAMS Ledger and is as follows:

- Wansford at grid ref 508124, 299560 – 111.5Ml/d (Natural flow)
- Orton Lock at grid ref 516603, 297215 – 120.6 Ml/d (Natural flow)

Unfortunately we don't have Q95 values for the Mill Stream or Wittering Brook.

There is some information on the National River Flow Archive that may be useful http://nrfa.ceh.ac.uk/data/station/info/32020.

2.4 Gauging station
To ensure that the development does not impact on the existing gauging station measurements, we advise that an unaltered channel is protected all the way up to the A1 road bridge (approximately 450 meters upstream of the gauge).

Please note, this response is based on the information you have made available at this time. It is based on current national planning policy, associated legislation and environmental data/information.

3.0 Water Framework Directive
The effects of the proposed development on Water Framework Directive (WFD) water bodies will need to be considered. In particular, the impacts on the River Nene and Wittering Brook. The development must not result in a deterioration of a water body or failure to meet WFD objectives.

We have some reservations that road drainage from the existing carriageway is not to be upgraded during the development and that surface water will enter the River Nene without passing through interceptors. Justification will need to be provided as to why this is not considered a pollution risk.

Investigation into improving fish, eel and otter passage through the existing A47 culvert should also be carried out. This work would ties into the improved culvert design that is to be installed under the new carriageway.

We are investigating potential WFD related mitigation and environmental enhancement opportunities within the area and will provide this to you when we have more information.

Should you require any additional information, or wish to discuss these matters further, please do not hesitate to contact me on the number below.

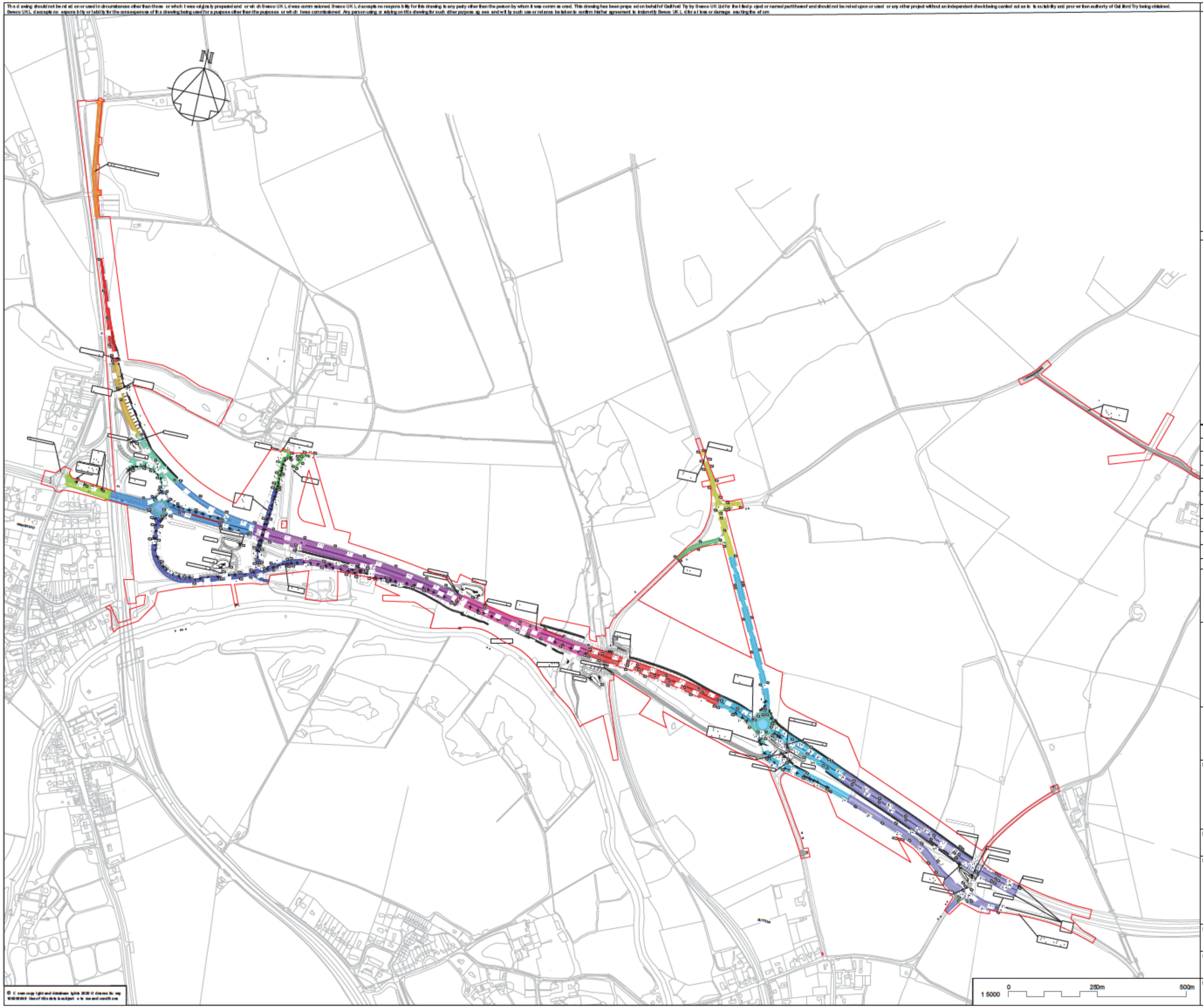
Yours faithfully

Jennifer Moffatt
Sustainable Places Planning Adviser

Direct dial [redacted]
Direct e-mail [redacted]@environment-agency.gov.uk

End 4

Annex D. LA 113 Groundwater quality and runoff assessment results



NOTES

1. THIS DRAWING SHALL BE USED FOR THE PURPOSE SHOWN IN THE TITLE BOX ONLY.
2. ALL DIMENSIONS ARE IN METRES UNLESS STATED OTHERWISE.
3. ALL LEVELS ARE ABOVE ORDNANCE DATUM.
4. DO NOT SCALE FROM THIS DRAWING.

KEY TO SYMBOLS

CATCHMENT A	🟥	CATCHMENT K	🟩
CATCHMENT B	🟨	CATCHMENT L	🟦
CATCHMENT D	🟩	CATCHMENT M	🟨
CATCHMENT E	🟩	CATCHMENT N	🟩
CATCHMENT F	🟦	CATCHMENT P	🟪
CATCHMENT G	🟦	CATCHMENT Q	🟧
CATCHMENT H	🟪		
CATCHMENT I	🟪		
CATCHMENT J	🟥		

P01	25/05/21	SGAR 3 ISSUE	CDye	AWoo	SCM
C01	25/05/21	SGAR 3 ISSUE	CDye	AWoo	SCM
REV	DATE	REVISION NOTE	ORG	CHK'D	APP'D

DESIGNER

SWECO

CONTRACTOR

GallifordTry

CLIENT

highways england

PROJECT TITLE

A47 WANSFORD TO SUTTON DUALLING

PROJECT STAGE

PCF STAGE 3

DRAWING TITLE

DRAINAGE CATCHMENT
LAYOUT PLAN

SUITABILITY

AUTHORISED AS STAGE 3 COMPLETED

SHEET SIZE	SCALE	STATUS	REVISION
A1	1:5000	A3	C01

DRAWING NUMBER

HE551494-GTY-HDG-000-DR-CD-30008

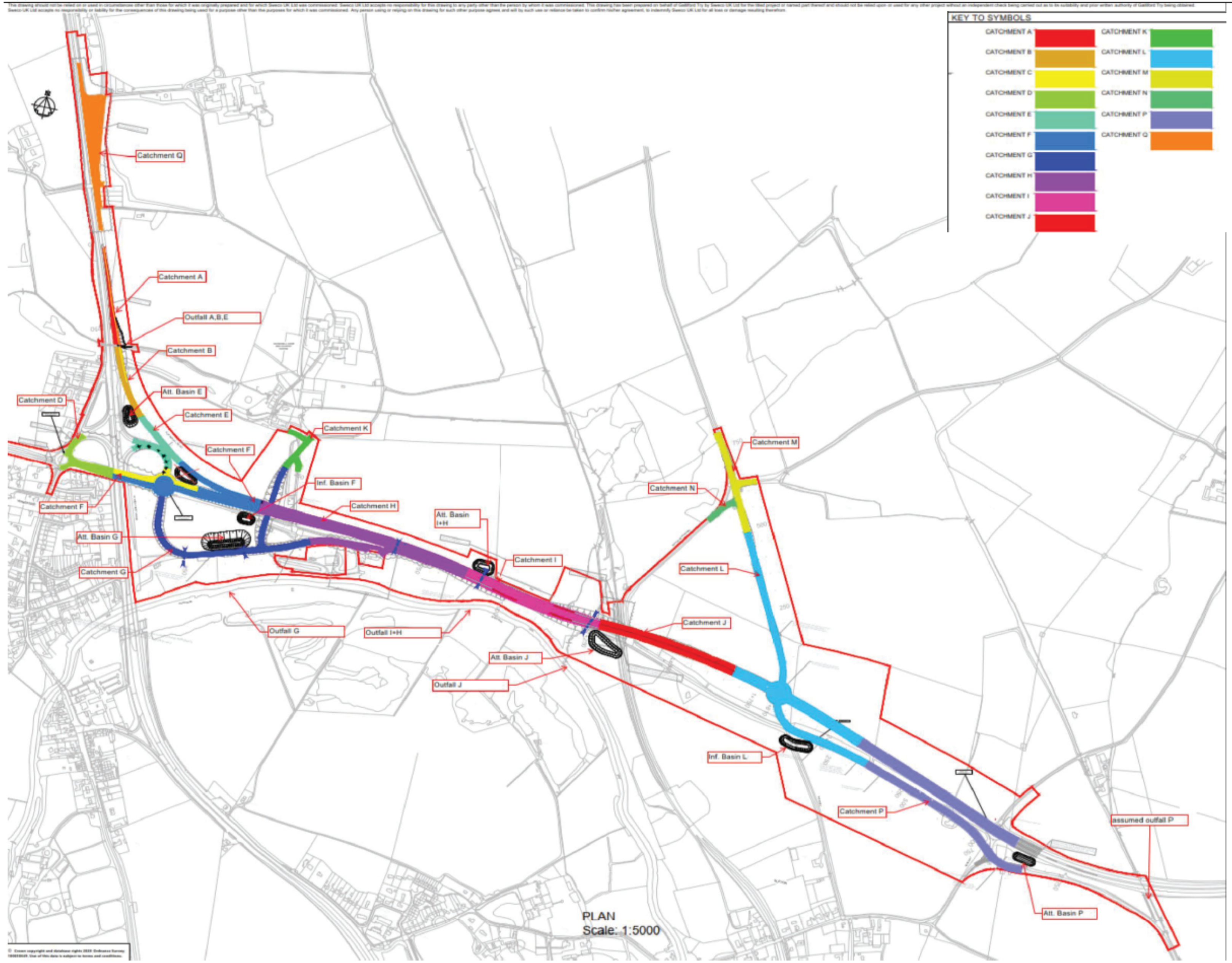


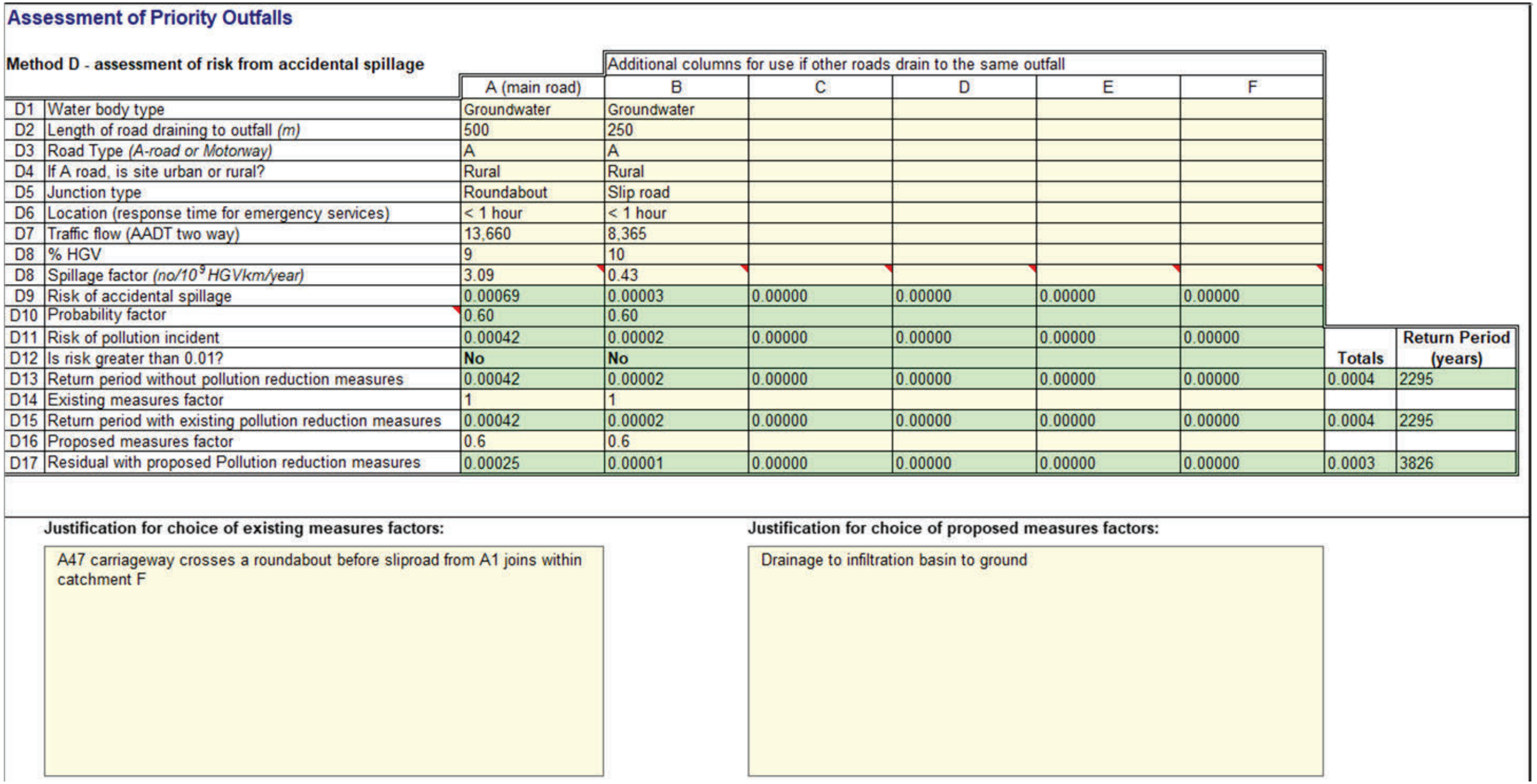
Figure D.1 Proposed drainage catchment layout plan

Table D.1 HEWRAT assessment results for road drainage to groundwater

Catchment	A	B	E	F	H	I	J	K	L	M	N	P
Traffic flow	<50,000	<50,000	<50,000	>50,000 & <100,000	<50,000	<50,000	<50,000	<50,000	>50,000 & <100,000	<50,000	<50,000	<50,000
Rainfall depth	<740mm (nearest rainfall site: Huntingdon)											
Drainage ratio	<50											
Infiltration method	Continuous	Continuous	Continuous	Region	Continuous	Continuous	Continuous	Continuous	Region	Continuous	Continuous	Continuous
Unsaturated zone	<5	>5	>5	>5	<5	<5	>5	<5	<5	<5	<5	<5
Monitoring borehole	BH01A	3A	3A	13	26	29	33	No data	36, 37A	No data	No data	39
Flow Type	Flow dominated by fractures/fissures	Flow dominated by fractures/fissures	Flow dominated by fractures/fissures	Flow dominated by fractures/fissures	Flow dominated by fractures/fissures	Mixed fracture and intergranular flow	Mixed fracture and intergranular flow	Flow dominated by fractures/fissures	Mixed fracture and intergranular flow	Dominantly intergranular flow	Dominantly intergranular flow	Mixed fracture and intergranular flow
Geological description	Lincolnshire Limestone Formation	Lincolnshire Limestone Formation	Lincolnshire Limestone Formation	Lincolnshire Limestone Formation	Lincolnshire Limestone Formation	River terrace deposits overlying Lincolnshire Limestone Formation / Grantham Formation	River terrace deposits overlying Rutland Formation / Lincolnshire Limestone Formation	Lincolnshire Limestone Formation	River terrace deposits overlying Rutland Formation	Rutland Formation	Rutland Formation	River terrace deposits overlying Rutland Formation
Unsaturated zone clay content	<1%	<1%	<1%	<15%	<1%	<15%	<15%	<1%	<1%	<1%	<1%	<15%
Justification	Very low % clay in Lincolnshire Limestone Formation samples	Very low % clay in Lincolnshire Limestone Formation samples	Very low % clay in Lincolnshire Limestone Formation samples	9 - 15% clay in samples taken from BH11, BH12 & BH15	Very low % clay in Lincolnshire Limestone Formation samples	0 - 58% clay in samples taken from river terrace deposits - lower range selected as conservative approach	0 - 58% clay in samples taken from river terrace deposits - lower range (>1% - <15%) selected as conservative approach	Very low % clay in Lincolnshire Limestone Formation samples	No data available for Rutland Formation - lowest range selected as conservative approach.	No data available for Rutland Formation - lowest range selected as conservative approach.	No data available for Rutland Formation - lowest range selected as conservative approach.	0 - 58% clay in samples taken from river terrace deposits - lower range (>1% - <15%) selected as conservative approach
Organic Carbon	<1%	<1%	<1%	<1%	<1%	>1%	>1%	<1%	<1%	<1%	<1%	>1%
Justification	GI results range between 0.2 and 2.5% SOM for all samples - conservative approach adopted by selecting <1% for discharges to bedrock and >1% and <15% for discharges to river terrace deposits											
pH	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8
Justification	GI results pH <=8 for majority of samples from unsaturated zone.											
Risk score	200 **Medium**	185 **Medium**	185 **Medium**	205 **Medium**	180 **Medium**	175 **Medium**	175 **Medium**	180 **Medium**	210 **Medium**	165 **Medium**	165 **Medium**	175 **Medium**

Annex E. LA 113 Spillage assessment results

INF F



Assessment of Priority Outfalls

Method D - assessment of risk from accidental spillage

			Additional columns for use if other roads drain to the same outfall						
		A (main road)	B	C	D	E	F	**Totals**	**Return Period (years)**
D1	Water body type	Groundwater	Groundwater						
D2	Length of road draining to outfall *(m)*	500	250						
D3	Road Type *(A-road or Motorway)*	A	A						
D4	If A road, is site urban or rural?	Rural	Rural						
D5	Junction type	Roundabout	Slip road						
D6	Location (response time for emergency services)	< 1 hour	< 1 hour						
D7	Traffic flow (AADT two way)	13,660	8,365						
D8	% HGV	9	10						
D8	Spillage factor *(no/10^9 HGVkm/year)*	3.09	0.43						
D9	Risk of accidental spillage	0.00069	0.00003	0.00000	0.00000	0.00000	0.00000		
D10	Probability factor	0.60	0.60						
D11	Risk of pollution incident	0.00042	0.00002	0.00000	0.00000	0.00000	0.00000		
D12	Is risk greater than 0.01?	**No**	**No**						
D13	Return period without pollution reduction measures	0.00042	0.00002	0.00000	0.00000	0.00000	0.00000	0.0004	2295
D14	Existing measures factor	1	1						
D15	Return period with existing pollution reduction measures	0.00042	0.00002	0.00000	0.00000	0.00000	0.00000	0.0004	2295
D16	Proposed measures factor	0.6	0.6						
D17	Residual with proposed Pollution reduction measures	0.00025	0.00001	0.00000	0.00000	0.00000	0.00000	0.0003	3826

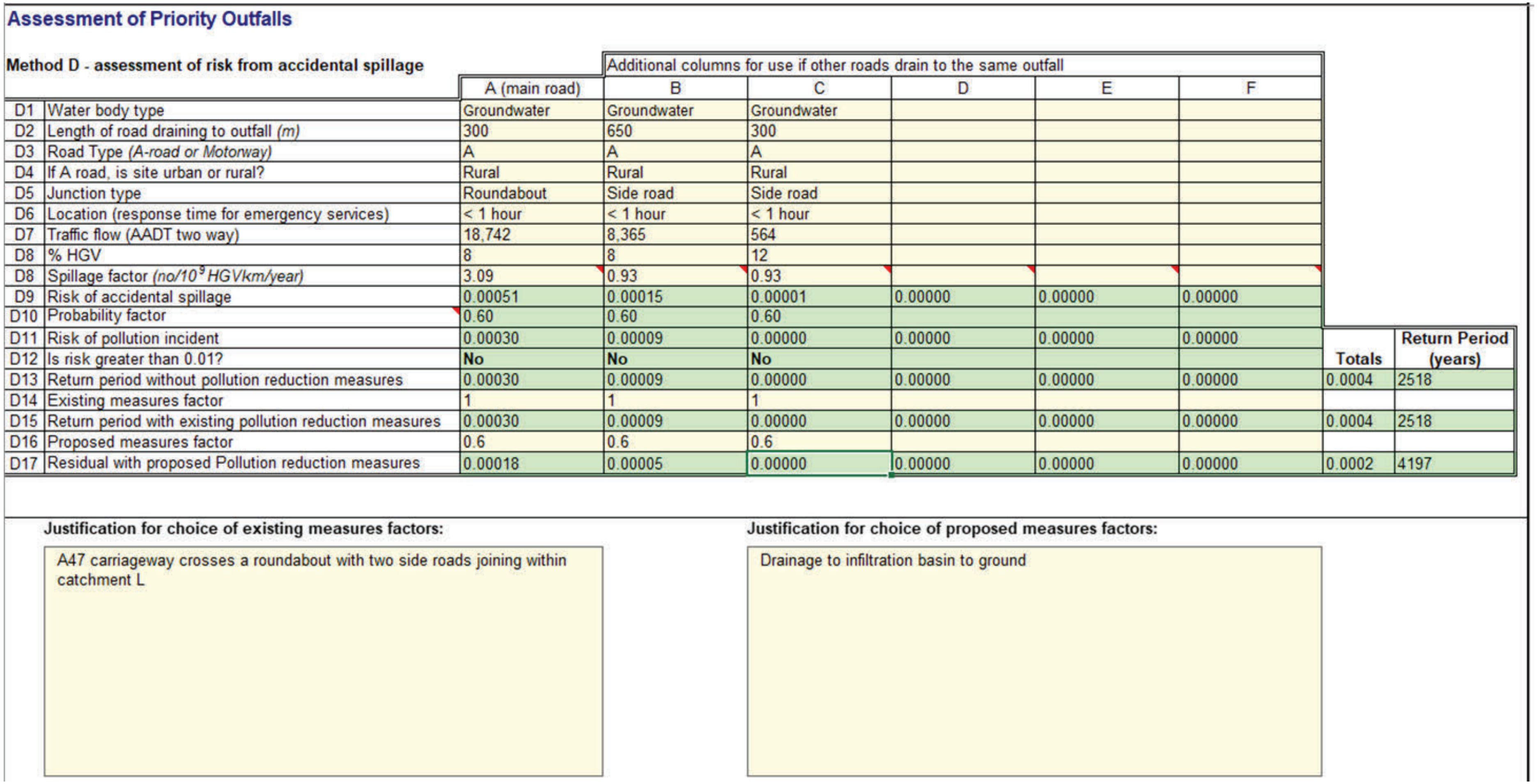
Justification for choice of existing measures factors:

A47 carriageway crosses a roundabout before sliproad from A1 joins within catchment F

Justification for choice of proposed measures factors:

Drainage to infiltration basin to ground

INF L



Assessment of Priority Outfalls

Method D - assessment of risk from accidental spillage

			Additional columns for use if other roads drain to the same outfall						
		A (main road)	B	C	D	E	F	**Totals**	**Return Period (years)**
D1	Water body type	Groundwater	Groundwater	Groundwater					
D2	Length of road draining to outfall *(m)*	300	650	300					
D3	Road Type *(A-road or Motorway)*	A	A	A					
D4	If A road, is site urban or rural?	Rural	Rural	Rural					
D5	Junction type	Roundabout	Side road	Side road					
D6	Location (response time for emergency services)	< 1 hour	< 1 hour	< 1 hour					
D7	Traffic flow (AADT two way)	18,742	8,365	564					
D8	% HGV	8	8	12					
D8	Spillage factor *(no/10^9 HGVkm/year)*	3.09	0.93	0.93					
D9	Risk of accidental spillage	0.00051	0.00015	0.00001	0.00000	0.00000	0.00000		
D10	Probability factor	0.60	0.60	0.60					
D11	Risk of pollution incident	0.00030	0.00009	0.00000	0.00000	0.00000	0.00000		
D12	Is risk greater than 0.01?	**No**	**No**	**No**					
D13	Return period without pollution reduction measures	0.00030	0.00009	0.00000	0.00000	0.00000	0.00000	0.0004	2518
D14	Existing measures factor	1	1	1					
D15	Return period with existing pollution reduction measures	0.00030	0.00009	0.00000	0.00000	0.00000	0.00000	0.0004	2518
D16	Proposed measures factor	0.6	0.6	0.6					
D17	Residual with proposed Pollution reduction measures	0.00018	0.00005	0.00000	0.00000	0.00000	0.00000	0.0002	4197

Justification for choice of existing measures factors:

A47 carriageway crosses a roundabout with two side roads joining within catchment L

Justification for choice of proposed measures factors:

Drainage to infiltration basin to ground

Annex F Radius of Influence (Sichardt) assessment

6.1.1. The empirical Sichardt formula presented in both CIRIA (2016) and EA (2007) is a very commonly used method for estimating the radius of influence (R_0) under steady state conditions and assuming radial flow:

- $R_0 = C (H_0 – h_w) \sqrt{K}$
    - where:
        - H_0 = water level above the base of the aquifer prior to dewatering (i.e. at R_0)
        - h_w = water level at the equivalent radius (r_e) of the excavation (i.e. the water level required to dewater the excavation)
        - Therefore $H_0 – h_w$ = target drawdown
        - K = hydraulic conductivity of the aquifer
        - C = an empirical calibration factor.

6.1.2. Table 13 details the parameters used and the result for radius of influence for the Sacrewell Farm underbridge (S05) and Wansford NMU underpass (S02).

Table 13 Radius of influence formula parameters

Structure	Minimum Design Level (maOD)	Borehole	Maximum recorded groundwater level (mAOD)	C	$H_0 – h_w$ (m)	K (m/s)	R_0 (m)
Sacrewell Farm underbridge (S05)	19.5	BH16	21.26	2000*	1.8	$5.8x10^{-4}$	86.70
Wansford NMU underpass (S02)	11	BH31	11.09 (groundwater strike)	2000*	1	$5.8x10^{-4}$	72.25

*higher C calibration factor selected as a worst case for linear excavations