Southampton to London Pipeline Project

Volume 6

Environmental Statement (Volume D)
Appendix 8.2: Detailed Trenchless and Targeted Open Cut Assessment

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Southampton to London Pipeline Project

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Appendix 8.2 Detailed Trenchless and Targeted Open Cut Assessments

1.1 Introduction

1.1.1 Esso Petroleum Company, Limited (Esso) is making an application for development consent to replace 90km (56 miles) of its existing 105km (65 miles) aviation fuel pipeline that runs from the Fawley Refinery near Southampton, to the Esso West London Terminal storage facility in Hounslow. The replacement pipeline is 97km (60 miles) long, and within this report is referred to as ‘the project’.

1.1.2 Open cut methods would be used for the majority of the route. For crossings of trunk roads and motorways (including the M25 and M3) and other heavily trafficked roads, railways (including main and branch lines) and some watercourses (including the River Thames), specialist trenchless techniques, such as auger bore or horizontal directional drilling (HDD), would be used. This appendix contains the detailed assessments that have been undertaken for the trenchless crossings.

1.1.3 The appendix also contains an assessment of targeted open cut sections where the open cut runs parallel to rivers. If groundwater is shallow at these locations then there is the potential that dewatering for installation of the pipeline could cause water to be drawn from the river, affecting river flows.

1.2 Scope of the Assessment

1.2.1 The full description of the project can be found in Chapter 3 Project Description. This section includes a summary of the key assumptions applicable to the assessments and why these are relevant. The full list of trenchless crossings can be found in Appendix 3.1 Table of Trenchless Crossings.

Dewatering

1.2.2 In some locations, groundwater levels may be high and dewatering would be required to aid pipeline installation. Dewatering could cause the local drawdown of groundwater levels. This can lead to effects on groundwater receptors, such as groundwater dependent terrestrial ecosystems (GWDTEs), groundwater abstractions or flows in rivers. It may also lead to settlement of the ground and subsequent subsidence of buildings and other structures.

1.2.3 This appendix estimates the extent to which impacts from dewatering could be expected. It also estimates the likely quantities of water that would be pumped from the abstractions which would then require disposal.

1.2.4 In locations where auger boring is proposed, dewatering would not be required for the actual boring. However, dewatering of access shafts would be required where the auger bore technique is used and there is shallow groundwater.

1.2.5 Once the pipeline has been installed using the auger bore technique, there is potential that the pipeline might connect two aquifers which are currently unconnected. This appendix therefore also assesses these impacts.

1.2.6 For HDD methods, dewatering is generally not required, except potentially at the launch and reception end, which require excavations to a depth equivalent to a trench. As such the effect of dewatering for HDD launch and reception has been grouped with trench sections and is not considered in this appendix. However, HDD method could still connect two aquifers. This is considered in this appendix. Due to the uncertainty of exact depths required for each HDD crossing, as well as considering the likely depth of the HDD crossing as presented in this appendix, the assessment also considered the potential for HDDs to connect two aquifers if the crossing reached a maximum depth of 16 metres below ground level (mbgl). Only two HDD crossings at that depth were considered to have the potential to connect two aquifers: TC 034 and TC035. For the assessment of these two crossings, it is therefore assumed the HDD would go to 16m.

1.2.7 Where the proposed pipeline runs alongside a major watercourse (that is those watercourses shown on 1:50,000 OS maps) and the groundwater is shallow, abstraction of groundwater from the open cut may lead to impacts on river flow. This appendix also assesses these impacts.

1.2.8 The assessment has also considered areas where the trench would need to be constructed deeper for short lengths, for example where it crosses under the existing Esso pipeline. This assessment considered whether the trench would reach groundwater if it were to go to 4mbgl at such points and identified that risks to all receptors would be small. This matter has not been considered further in this appendix or in Chapter 8 Water.

1.3 Data Sources

1.3.1 The assessment is based on information from project engineering drawings, in combination with available information pertaining to geological and hydrogeological conditions at each location. This information has been used to determine the likely groundwater conditions at each crossing location.

1.3.2 Where site-specific design drawings were not available for a crossing location, details regarding the dimensions associated with the relevant crossing method have been obtained from drawings showing typical details. For HDD methods, a maximum depth of 5mbgl has been assumed, while for auger bore methods, a maximum pit depth of 6mbgl has been assumed where there was no crossing-specific design drawing available.

1.3.3 The key data compiled in this appendix for each trenchless crossing, and for lengths of the pipeline which run parallel and nearby to a surface water receptor, comprise:

- local and regional geological conditions (both superficial coverage and bedrock) obtained from British Geological Survey (BGS) maps (BGS, 2018a) and shown in Figure A8.1.1 and Figure A8.1.2) and BGS borehole logs (BGS, 2018a; all BGS borehole logs referred to are taken from this reference). Water level data from these borehole logs has also been compiled;
- ground and groundwater information found on borehole logs and associated water level monitoring taken from the recent (2018) project ground investigation. This includes data from groundwater level data loggers which have been installed in the majority of the boreholes (see Appendix 8.1 Groundwater Baseline for

details). Data from the 2018 ground investigation boreholes up until February 2019 has been used in the assessment;

- aquifer designations (Department for Environment, Food and Rural Affairs (Defra), 2018);
- Environment Agency (EA) groundwater modelling outputs where the crossing is on the unconfined Chalk or Upper Greensand in Groundwater Study Area B (GWSA-B). No relevant groundwater level model results are available for the other study areas; and
- consideration of any other additional available groundwater level information including BGS groundwater flooding susceptibility mapping (BGS, 2017) and data from landfill monitoring.

1.3.4 Using these data and considering the proposed trenchless technique at each location (locations are shown on Figure 11.7), it is determined whether temporary dewatering may be required for the construction of the access shafts for crossings using the auger bore method. For each crossing (HDD and auger bore crossings) the assessment also considers where the pipeline is likely to sit in relation to the groundwater conditions at each location (i.e. whether the pipe is likely to be above or below the groundwater table).

1.4 Methodology for Dewatering Assessment

1.4.1 Where dewatering is expected, the Sichardt method (e.g. Preene et al., 2016) has been used to estimate the "radius of influence", R, which is the radius of the area within which the water table is lowered due to groundwater abstraction.

1.4.2 The Sichardt equation is as follows:

$$R = C.drawdown.K\text{^}0.5$$

Where C is a constant shape factor with a value of 3,000, and where K is the hydraulic conductivity (permeability), 'drawdown' is the required drawdown to dewater the pit. As a conservative approach, in the calculations it is assumed that dewatering and associated drawdown would take place at the time of maximum groundwater level. As data on maximum groundwater levels are not known for most locations due to limited datasets, estimated maximum rest water levels have been used. These are based on groundwater modelling results (where available in GWSA-B) or using measured levels that consider the time of year the measurement was made and likely range in groundwater levels over the year.

1.4.3 Once R is calculated, an additional Re component is then added to reflect the dimensions of the pit and the total radius of influence as follows:

$$Re = ((x * y)/\pi)\text{^}0.5,$$

where x and y are the lengths of the sides of the pit. Ro is the sum of R and Re.

1.4.4 Once Ro has been estimated, the rate of dewatering, Q, can be calculated using the Dupuit-Forcheimer equation for unconfined conditions, as outlined in 'Groundwater control: design and practice (C750)' (Preene et al., 2016) as follows:

$$Q = \frac{\pi K(H^2 - h_w^2)}{\ln[\frac{Ro}{r_e}]}$$

Where:

- K = hydraulic conductivity
- H = initial piezometric head
- hw = drawndown piezometric head
- Ro = total radius of influence
- Re = equivalent radius of system

1.4.5 A degree of uncertainty is associated with these methods. Hydraulic conductivity values have been calculated as part of ground investigation works at some locations, and these values have been used in the calculations rather than literature values. Where there are no site-specific hydraulic conductivity values, literature values have been used with 1E-4m/s taken for a sand and gravel aquifer, and 1E-10m/s taken for clay substratum. Using literature values adds a degree of uncertainty to the assessment.

1.4.6 These calculations are performed twice for each trenchless crossing using the auger bore technique (where dewatering is required) for the drive pit (where the auger boring would start) and the reception pit (where the auger ends up on the other side of the crossing). In general, the drive pit is larger than the reception pit and consequently requires a higher dewatering rate.

1.4.7 Assessments have also been completed for areas of the pipeline route which are proposed in parallel, and nearby, to surface waters. The lengths of the route where this assessment was required were determined following review of the Order Limits and determining where the Order Limits were running close to a watercourse for a substantial distance (lengths of river considered range from 420m to 3.9km)). A conservative approach is taken in the calculation as it is assumed that the full length of the open cut parallel to the watercourse would be dewatered. These lengths of the route may be more likely to see shallow groundwater conditions, dependent on the local geology, and shallow groundwaters may be found in continuity with any surface waters. Assessments for these locations are therefore necessary to determine the likely groundwater conditions, and the potential requirement and significance of any dewatering needed during excavation of the pipeline trench. Dewatering assessments have been completed according to methodologies outlined in 'Groundwater control: design and practice (C750)' (Preene et al., 2016) for partially penetrating slots (trenches) in unconfined conditions, as follows:

$$Q = \left[0.73 + 0.27\frac{P}{H}\right]\frac{Kx(H^2 - h_w^2)}{Lo}$$

1.4.8 Where:

- P = depth of penetration of the trench below the top of the water table
- H = piezometric level

- K = hydraulic conductivity
- x = linear length of the trench
- hw = drawndown piezometric head
- Lo = distance of influence (derived using the Sichardt formula, using a shape factor of 1750 as recommended in Preene et al. (2016))

1.4.9 The above equation assumes the trench is of infinite length and groundwater flows into the trench at right angles to the sides of the trench.

1.4.10 Additional receptors other than the respective surface water feature in each case have not been considered at this stage.

1.4.11 The assessment is based on the information available at the time of writing, such as BGS records, ground investigation data, groundwater level and groundwater strike information. As these data are not always available at the location of the crossing itself, extrapolation has been made where needed. For each crossing, the location of the nearest data point is stated and the further away the data point is the more uncertainty there is in relation to the crossing itself. Further data at the point of each crossing would allow further refinement. However, the information available at the time of writing is considered sufficiently robust to allow the assessments to be undertaken and determine which receptors may be impacted as a result of the project.

1.4.12 Where data have been supplied by third parties, these have been accepted at face value without further verification. Any inaccuracies in third-party data have the potential to reduce the accuracy of the assessment in Chapter 8 Water which relies on that data.

Trenchless Crossing (TC) Assessment

1.5 TC 001 – Ford Lake Stream

Feature(s) requiring trenchless crossing	Ford Lake Stream
Trenchless crossing technique and characteristics	HDD technique Following details derived from site-specific design drawing: • Reaches a maximum depth of about 2.9mAOD (metres Above Ordnance Datum) and maximum depth below ground of 12.2m • Drive length: approximately 253m
Groundwater study area	GWSA-A

Geological and Hydrogeological Conditions at TC 001

1.5.1 The BGS geological map (BGS, 2018b) indicates that the London Clay Formation is present to the north, east and west of the crossing. To the south, the Wittering Formation of clay, silt and sand is shown. The crossing is located within the Wittering Formation.

1.5.2 Superficial deposits in the area vary in their nature from south to north. River Terrace Deposits of sand and gravel are present to the north of the crossing, extending east and west. Deposits of Alluvium are encountered further south, with additional deposits of River Terrace Deposits to the south of the crossing. These too, extend east and west of the crossing. The crossing is located within both these deposit types.

1.5.3 The aquifer designation map (Defra, 2018) indicates that the crossing is located within an area of Secondary A bedrock aquifer and Secondary A superficial aquifer. The London Clay bedrock is defined as Unproductive strata.

1.5.4 The nearest available BGS record, located 23m to the west, SU51SW111, indicates the following ground conditions:

- 0 – 0.45mbgl: Topsoil;
- 0.45 – 3.26mbgl: Ballast (sand and gravel) with clay;
- 3.26 – 4.49mbgl: Clay; and
- standing water level at approximately 1.52mbgl (approximately 13.48mAOD).

1.5.5 A second borehole, located approximately 82m southeast of the crossing, SU51SW107, indicates the following ground conditions:

- 0 – 0.3mbgl: Topsoil;
- 0.3 – 1.83mbgl: Clay;
- 1.83 – 4.26mbgl: Ballast; and
- 4.26 – 6.1mbgl: Clay.

1.5.6 Both SU51SW111 and SU51SW107 are located at similar elevations to those seen over the crossing.

1.5.7 During the 2018 ground investigation works, Borehole (BH)126 was completed 95m west of the crossing in September 2018 (when groundwater conditions may be lower than the potential maximum level), and recorded the following:

- 0 – 5.50mbgl: Sand;
- 5.50 – 20.0mbgl: Clay; and
- no information is given regarding groundwater strike.

1.5.8 Groundwater levels have been measured manually on three separate occasions at location BH126, which is located at an elevation of 14.13mAOD and was completed to a depth of 20.22mbgl. These measurements indicate an average groundwater level of -0.42mbgl, or 14.55mAOD. Artesian groundwater conditions have therefore been encountered at this location.

1.5.9 The BGS groundwater flooding susceptibility map (BGS, 2017) indicates that the crossing is located within an area with two classifications. The northern portion of the crossing is found within an area with potential for groundwater flooding of property situated below ground level. The southern portion of the crossing is located within an area with a potential for groundwater flooding to occur at the surface.

1.5.10 As part of the EA groundwater level monitoring network, the Wintershill Chalk and Wintershill Tertiary monitoring point located approximately 4km north recorded a maximum groundwater level in the Chalk of 0mbgl (42mAOD), and a minimum water level of 8.13mbgl (33.87mAOD). The Tertiary record indicates a maximum water level of 0mbgl (42mAOD) and a minimum level of 1.31mbgl (40.69mAOD).

Crossing TC 001 Assessment

1.5.11 Historical ground investigation (BGS, 2018a) confirmed a shallow groundwater strike at 1.52mbgl, while groundwater monitoring records indicate that the maximum groundwater level in the region is 0mbgl. On a local level, manual groundwater monitoring shows the average groundwater level is -0.42mbgl, with artesian groundwater conditions. The data, combined with the BGS groundwater flooding susceptibility map (BGS, 2017) which shows there is potential for flooding to occur, indicates that shallow groundwater conditions should be expected at the crossing location. HDD methods do not require dewatering. However, it is likely that the water table would be intercepted, and that following installation, a large proportion of the pipeline would be installed below the water table at crossing TC 001.

1.5.12 The nature of superficial deposits is expected to change along the route of the crossing. Recent ground investigation records indicate that sands were encountered to a maximum depth of approximately 5.5mbgl. Underlying these, clay was recorded. These records suggest the presence of the London Clay, as mapped in this area. HDD, assuming a maximum drilling depth of 12.2m, therefore has the potential to encounter both the superficial deposits and the London Clay, which is defined as thick Unproductive strata. As a consequence, no hydraulic connection is expected to be created between aquifer units at this crossing. However, due to artesian groundwater conditions identified at this location, the installed pipeline could release pressure in the aquifer and potentially act as a conduit for groundwater to discharge to the surface at a point where there is currently no discharge.

1.6 TC 002 – Stakes Lane

Feature(s) requiring trenchless crossing	Stake's Lane
Trenchless crossing technique and characteristics	Auger bore technique Following details assumed from typical details drawings: • Assumes minimum depth of 2.0mbgl below any services • Drive pit depth: assumed as 6.0mbgl • Drive pit length: approximately 11m • Drive pit width: approximately 3m • Reception pit depth: assumed as 6.0mbgl • Reception pit length: approximately 3m • Reception pit width: approximately 3m • Drive length: approximately 35m
Groundwater study area	GWSA-B

Geological and Hydrogeological Conditions at TC 002

1.6.1 The BGS geological map (BGS, 2018c) indicates that the bedrock at the crossing comprises the Seaford Chalk Formation.

1.6.2 The geological map (BGS, 2018c) shows that no superficial deposits are expected at the crossing location. To the east and west, however, deposits of Head are shown to be present, although these are over 200m from the crossing. The presence of superficials in the area is thus shown to be variable.

1.6.3 The aquifer designation map (Defra, 2018) indicates that the crossing is located within an area designated as a Principal bedrock aquifer. The nearby areas of Head deposits are classed as a Secondary Undifferentiated superficial aquifer.

1.6.4 The nearest available BGS record, SU52SE37, is located approximately 850m north of the crossing. The record for this indicates the following ground conditions:

- 0 – 0.3mbgl: Topsoil;
- 0.3 – 27.4mbgl: Upper Chalk;
- 27.4 – 86.6mbgl: Upper Chalk with flint bands;
- 86.6 – 106.7mbgl: Middle Chalk; and
- water was struck at 70.1m below datum (approximately 49.9mbgl).

1.6.5 The ground level for the borehole in the BGS record is located at a similar elevation to the crossing.

1.6.6 During the 2018 ground investigation works, the nearest borehole completed to this crossing is BH122, approximately 2.8km southwest. The record for this indicates the following ground conditions:

- 0 – 0.08mbgl: Topsoil;
- 0.08 – 3.48mbgl: Slightly gravelly clay to gravelly clay;
- 3.48 – 20.45mbgl: Chalk; and

- no groundwater strikes were noted during drilling and well was dry on completion.

1.6.7 Groundwater levels have been measured manually on five separate occasions at location BH122, which is located at an elevation of 71.47mAOD and was completed to a depth of 20.45mbgl. These measurements show that the well was dry on three occasions. The data logger in BH122 has recorded the highest groundwater level as 18.97mbgl.

1.6.8 The EA East Hampshire and Chichester Chalk (EHCC) Chalk and Upper Greensand groundwater model (EA, 2007) indicates the crossing is located between contours with values of 65.0mAOD and 70.0mAOD. These are considered maximum simulated groundwater levels. Elevation at the crossing is indicated to be approximately 104mAOD. Thus, groundwater would be expected at between 39 and 34mbgl. Deep groundwater is supported by the BGS groundwater flooding susceptibility map (BGS, 2017), which shows that there is limited potential for groundwater flooding to occur at this location.

1.6.9 As part of the EA water level monitoring network, the Street End hydrometric monitoring point is located approximately 1.8km south of the crossing and monitors the Lewes Nodular Chalk Member. The monitoring record for this location indicates that the maximum groundwater level is 111.89mAOD. The elevation at this crossing is indicated as approximately 104mAOD. The groundwater monitoring data would therefore indicate that the maximum groundwater level is potentially above ground level at the crossing, but given the distance of the monitoring location from the crossing, these groundwater levels are unlikely to be representative of conditions at the crossing.

Crossing TC 002 Assessment

1.6.10 Historical ground investigation (BGS, 2018a) confirmed a groundwater strike at 49.9mbgl locally to the crossing location, which is further supported by the BGS groundwater flooding susceptibility map (BGS, 2017) which shows limited potential for flooding, thereby suggesting that deeper groundwater conditions would be encountered. EA groundwater models provide further evidence for deep groundwater levels. EA monitoring records, however, contrast this by suggesting groundwater levels close to or above the ground surface. But, given the distance of the EA record from the crossing location, it is assumed these values are not representative of the crossing location itself, and groundwater levels are assumed as being well below the ground surface.

1.6.11 The geological map (BGS, 2018c) shows that there are no superficial deposits expected at this location and this was confirmed by ground investigation records which encountered the Upper Chalk from depths as shallow as 0.3mbgl. Therefore, auger boring at an assumed depth of 6.0mbgl would likely only encounter the Chalk aquifer unit, and therefore no hydraulic connection between two aquifer units would be expected to be created by the pipeline installation.

1.6.12 Based on available information pertaining to the water level for this location, the water table is not expected to be intercepted during auger boring at a depth of 6.0mbgl, and therefore, dewatering is likely not required at this location due to the deep groundwater conditions expected. No dewatering assessment has therefore been completed for this location. Once installed, it is expected that the pipeline would sit above the water table.

1.7 TC 003 – Riversdown Road (suboption A2b only)

Feature(s) requiring trenchless crossing	Riversdown Road
Trenchless crossing technique and characteristics	Auger bore technique Following details assumed from typical details drawings: • Assumes minimum depth of 2.0mbgl below services • Drive pit depth: assumed as 6.0mbgl • Drive pit length: approximately 11m • Drive pit width: approximately 3m • Reception pit depth: assumed as 6.0mbgl • Reception pit length: approximately 3m • Reception pit width: approximately 3m • Drive length: approximately 52m
Groundwater study area	GWSA-B

Geological and Hydrogeological Conditions at TC 003

1.7.1 The BGS geological map (BGS, 2018d) indicates that the bedrock at the crossing and in the surrounding region comprises the Newhaven Chalk Formation.

1.7.2 The geological map (BGS, 2018d) indicates that superficial deposits at the crossing, and continuing to the east and west comprise deposits of Head. To the north and south, Clay-with-Flints are shown to be present.

1.7.3 The aquifer designation map (Defra, 2018) shows that the crossing is located within an area defined as a Principal bedrock aquifer. The deposits of Head are classed as a Secondary Undifferentiated superficial aquifer. The Clay-with-Flints are classed as Unproductive strata.

1.7.4 The nearest available BGS borehole record, SU62NW27, is located approximately 470m northeast of the crossing. The record for this indicates the following ground conditions:

- 0 – 0.6mbgl: Topsoil;
- 0.6 – 6.09mbgl: Clay;
- 6.09 – 32.30mbgl: Soft chalk;
- 32.30 – 106.68mbgl: Hard chalk; and
- the rest water level was 54.86mbgl (approximately 80.1mAOD).

1.7.5 The BGS record is located at a higher elevation (approximately 135mAOD) compared to the crossing (approximately 110mAOD).

1.7.6 During the 2018 ground investigation works, the nearest borehole completed to the crossing is BH119, approximately 1.3km north of the crossing. The log record shows that the borehole was completed in September 2018 (when groundwater conditions may be expected to be lower than their potential maximum), and indicates the following ground conditions:

- 0 – 1.10mbgl: Gravelly clayey silt;
- 1.10 – 1.60mbgl: Gravelly silty clay;
- 1.60 – 3.0mbgl: Silty very gravelly sand;
- 3.0 – 15.45mbgl: Chalk; and
- water strikes were masked by the addition of drilling water.

1.7.7 Groundwater levels have been measured manually on four separate occasions at location BH119, which is at an elevation of 88.95mAOD, and was completed to a depth of 15.65mbgl. These measurements indicate an average groundwater level of 9.87mbgl, or 79.08mAOD. The data logger in BH119 has recorded the highest groundwater level as 8.64mbgl.

1.7.8 The EA EHCC groundwater model for the Chalk and Upper Greensand (EA, 2007) maximum indicates that the crossing is located near to a groundwater level contour with a value of 90.0mAOD. These are considered as the maximum simulated groundwater levels. The crossing is located at an approximate elevation of 110mAOD. Therefore, the maximum modelled groundwater level is approximately 20.0mbgl. The BGS groundwater flooding susceptibility map (BGS, 2017) also indicates deep groundwater conditions by showing that there is limited potential for groundwater flooding to occur.

1.7.9 As part of the EA groundwater level monitoring network, the hydrometric monitoring location Parsonage Farm, Bramdean, is located approximately 2.2km northeast of the crossing. The monitoring record for this location details a maximum water level of 8.11mbgl (93.89mAOD), while the minimum water level is 25.93mbgl (76.07mAOD).

Crossing TC 003 Assessment

1.7.10 Historical ground investigation records held by the BGS (BGS, 2018a) encountered groundwater at 54.86mbgl (80.1mAOD). These records are assumed to best represent conditions at the crossing compared with the 2018 ground investigation records which are at a greater distance. In addition, groundwater monitoring completed during the 2018 ground investigation suggests an average groundwater level of 8.11mbgl (at a distance of approximately 1.3km from the crossing). Deep groundwater levels are also indicated by the BGS groundwater flooding susceptibility map (BGS, 2017) which shows there is limited potential for flooding to occur, by EA modelling which shows that maximum simulated groundwater levels are approximately 20.0mbgl, and by EA monitoring records. Based on available local data, groundwater at levels close to the ground surface is therefore not expected at this location.

1.7.11 Superficial deposits are expected to comprise Head at the crossing. This was confirmed by ground investigation records, which identified clays and gravels to a maximum depth of 6.09mbgl. Underlying these, Chalk was encountered, at 3.0mbgl at its shallowest. Therefore, with a drive depth of 6.0mbgl, auger boring is likely to intercept the Chalk bedrock and any overlying superficial deposits. The Chalk is a Principal aquifer, but groundwater levels are expected to be deep. The deposits of Head are classed as a Secondary Undifferentiated aquifer, and depending on the proportion of clays, there may be some hydraulic connection with the underlying Chalk. However, as there is a lack of evidence to support shallow groundwater at this location, this is not thought likely. In addition, there is a low likelihood of creating a new connection between the units during construction, as the deposits are likely to have a natural hydraulic connection owing to the absence of a significant low permeability horizon.

1.7.12 Based on available information pertaining to groundwater levels, the water table is not expected to be intercepted during construction at this location, and thus dewatering is not likely to be required at TC 003 because of the deeper groundwater conditions indicated. No dewatering assessment has thus been completed for TC 003. Based on currently available data, once installed, the pipeline is expected to sit above the water table.

1.8 TC 004 – A272

Feature(s) requiring trenchless crossing	A272
Trenchless crossing technique and characteristics	HDD technique Reaches a maximum depth of 78.87mAOD and maximum depth below ground of 8.13m Drive length: 121m
Groundwater study area	GWSA-B

Geological and Hydrogeological Conditions at TC 004

1.8.1 The BGS geological map (BGS, 2018d) indicates that the bedrock to the south of the crossing comprises the Newhaven Chalk. The bedrock underlying the crossing and to the north comprises the Seaford Chalk. Both lithologies extend east and west.

1.8.2 Superficial deposits are mapped as comprising Head deposits (BGS, 2018d). These deposits do not occur as continuous deposits; they are localised and roughly follow topographic contours and extend in east and west directions.

1.8.3 The aquifer designation map (Defra, 2018) shows the crossing is located within an area of Principal bedrock aquifer. The superficial deposits of Head are classed as a Secondary Undifferentiated superficial aquifer.

1.8.4 The nearest BGS record located 420m north of the crossing, SU62NW42, indicates the following ground conditions:

- 0 – 1.8mbgl: Drift deposits of gravel and clay;
- 1.8 – 36.3mbgl: Chalk; and
- groundwater is indicated at 78.9mAOD (approximately 23.1mbgl).

1.8.5 The BGS record is located at a topographically higher elevation than the elevation of the crossing which is approximately 88mAOD.

1.8.6 During the 2018 ground investigation works, BH119 was completed approximately 410m southeast of the crossing in September 2018 when groundwater conditions are expected to be lower than the maximum level seen during winter months. The log record for this borehole indicates the following:

- 0 – 1.10mbgl: Silt;
- 1.10 – 1.60mbgl: Clay;
- 1.60 – 3.00mbgl: Sand;
- 3.00 – 15.45mbgl: Chalk; and
- groundwater strikes were masked by the addition of drilling water.

1.8.7 Groundwater levels have been measured manually on four separate occasions at location BH119, which is at an elevation of 88.95mAOD and was completed to a depth of 15.65mbgl. These measurements indicate an average groundwater level of 9.87mbgl, or 79.08mAOD. The data logger in BH119 has recorded the highest groundwater level as 8.64mbgl.

1.8.8 The EA EHCC groundwater model for the Chalk and Upper Greensand (EA, 2007) indicates that the crossing is located near to groundwater level contours with a value of 90mAOD. These are considered maximum simulated groundwater levels. The elevation at the crossing is between approximately 87 and 89mAOD. Therefore, the EA model indicates that the maximum groundwater level is potentially above ground level at this location. This is supported by the BGS groundwater flooding susceptibility map (BGS, 2017) which indicates the crossing is located within an area which has two definitions. The central area of the pipeline has potential for groundwater flooding of property situated below ground level, while the rest of the crossing has limited potential for groundwater flooding to occur.

1.8.9 As part of the EA groundwater level monitoring network, the hydrometric monitoring location Parsonage Farm, Bramdean is located approximately 830m northeast of the crossing and has recorded a maximum water level of 8.11mbgl (93.89mAOD) while the minimum water level is 25.93mbgl (76.07mAOD).

Crossing TC 004 Assessment

1.8.10 BGS records (BGS, 2018a) indicate a groundwater strike at approximately 23.1mbgl. The minimum and maximum groundwater levels recorded by EA monitoring records agree with these ground investigation records. In addition, groundwater monitoring completed during the 2018 ground investigation suggest an average groundwater level of 9.87mbgl (from manual dips). The data, combined with the BGS groundwater flooding susceptibility definition, indicates that relatively shallow groundwater conditions may occur at this location at times of high groundwater levels. HDD would not require dewatering. Available data at this stage suggests that groundwater likely sits below the maximum anticipated drilling depth, and therefore it is likely that this portion of the pipeline may sit above the water table for much of the year. At times of very high groundwater level the pipe may be below the water table.

1.8.11 The thicknesses and depths of both superficial and bedrock deposits are expected to be variable, as shown by ground investigation records. Superficial deposits have been encountered with thicknesses varying between 1.8mbgl and 3.00mbgl. The Chalk was encountered underlying these deposits reaching depths greater than 15.45mbgl. HDD, to a maximum depth of 8.13mbgl, therefore has the potential to intercept both the superficial geology and the underlying Chalk bedrock. There is no significant low permeability layer indicated on ground investigation records that would hydraulically separate the two aquifer units, and the shallowest groundwater level is indicated as being below the maximum recorded superficial deposit depth. As such, it is unlikely that this crossing would create a connection of two aquifers during construction or operation.

1.9 TC 005 – Petersfield Road

Feature(s) requiring trenchless crossing	Petersfield Road
Trenchless crossing technique and characteristics	Auger bore technique Following details assumed from typical details drawings: • Assumes minimum depth of 2.0mbgl below services • Drive pit depth: assumed as 6.0mbgl • Drive pit length: approximately 11m • Drive pit width: approximately 3m • Reception pit depth: assumed as 6.0mbgl • Reception pit length: approximately 3m • Reception pit width: approximately 3m • Drive length: approximately 35m
Groundwater study area	GWSA-B

Geological and Hydrogeological Conditions at TC 005

1.9.1 The BGS geological map (BGS, 2018e) indicates that the bedrock at the crossing and in the surrounding area comprises the Newhaven Chalk Formation.

1.9.2 Superficial deposits are shown to be variable in their nature and their extent. Deposits at the crossing and to the north, east and south comprise Clay-with-Flints (Diamicton). To the east of the crossing, additional deposits of Head (Diamicton) are indicated on the geological map (BGS, 2018e).

1.9.3 The aquifer designation map (Defra, 2018) shows that the crossing is located within an area defined as a Principal bedrock aquifer. The Head deposits located to the east of the crossing are defined as a Secondary Undifferentiated superficial aquifer.

1.9.4 The nearest available BGS borehole record detailing groundwater is SU63SE13, which is located approximately 1.1km northwest of the crossing. The online record for this borehole indicates the following ground conditions:

- 0 – 0.3mbgl: Topsoil;
- 0.3 – 82.3mbgl: Very soft white chalk with flints;
- 82.3 – 88.4mbgl: Hard white chalk; and
- a water strike was encountered at 73.15m below the well top.

1.9.5 The BGS record is located at a considerably lower elevation (approximately 140mAOD) compared to the crossing (approximately 178mAOD).

1.9.6 During the 2018 ground investigation works, BH104 was completed approximately 2.4km northeast of the crossing. The log record for this shows the borehole was completed in August 2018, when groundwater conditions are expected to be lower than the winter maximum. The log indicates the following ground conditions:

- 0 – 0.95mbgl: Slightly gravelly sand;
- 0.95 – 2.30mbgl: Slightly gravelly clay;
- 2.30 – 3.90mbgl: Slightly sandy clay;
- 3.90 – 20.0mbgl: Chalk; and
- no groundwater strikes were noted during drilling, with the well dry on completion.

1.9.7 Groundwater levels have been measured manually on four separate occasions in BH104, which is at an elevation of 175.45mAOD. These measurements indicate that the borehole was dry on all four dates, to a depth of 20.0mbgl. The groundwater logger in the borehole also shows the borehole to have remained dry.

1.9.8 The EA EHCC groundwater model for the Chalk and Upper Greensand (EA, 2007) shows that the crossing is located close to a groundwater level contour with a value of 110.0mAOD. These are considered maximum simulated groundwater levels. The elevation at the crossing is approximately 178mAOD. Therefore, modelling indicates that shallow groundwater conditions are not expected at this location, with an approximate groundwater level at 68mbgl. This is further supported by the BGS groundwater flooding susceptibility map (BGS, 2017), which indicates that the crossing is located in an area with limited potential for groundwater flooding to occur.

1.9.9 As part of the EA groundwater level monitoring network, the hydrometric monitoring location Soames Place, Ropley, is located approximately 800m southwest of the crossing. The monitoring record for this location has recorded a maximum groundwater level of 39.82mbgl (98.18mAOD) and a minimum groundwater level of 61.9mbgl (76.1mAOD).

Crossing TC 005 Assessment

1.9.10 Historical ground investigation records local to the crossing (BGS, 2018a) indicate deep groundwater conditions, with a groundwater strike encountered at 73.15m below the well top. Additional evidence to support deep groundwater levels is derived from EA groundwater models which indicate an approximate maximum groundwater level of 68mbgl; by EA groundwater monitoring records which record a maximum groundwater level of 39.82mbgl; and the BGS groundwater flooding susceptibility map (BGS, 2017) which indicates flooding potential is limited. In addition, groundwater monitoring completed as part of the 2018 ground investigation works showed the borehole to be dry on all monitoring visits.

1.9.11 Based on available information, the water table is not expected to be intercepted during construction of the auger bore pits, and therefore, dewatering is not likely to be required. On this basis, no dewatering assessment has been completed. Based on currently available data, once installed, the pipeline is expected to sit above the water table.

1.9.12 Assuming a maximum auger bore pit depth of 6m and based on ground investigation records, it is likely that both superficial geological units (where present) and the underlying bedrock geology would be encountered together. Depending on the clay content of Head deposits, the Chalk and Head deposits may be expected to be in hydraulic continuity with one another, as no significant low permeability layer to separate them was indicated by ground investigation. Considering that there is a natural continuity between these two aquifers, it is unlikely that this crossing would create a connection of two aquifers during construction or operation.

1.10 TC 006 – A32

Feature(s) requiring trenchless crossing	A32
Trenchless crossing technique and characteristics	HDD technique Following details derived from site-specific design drawing: • Reaches a maximum depth of 108.9mAOD and maximum depth below ground of 6.1m • Drive length: approximately 162m
Groundwater study area	GWSA-B

Geological and Hydrogeological Conditions at TC 006

1.10.1 The BGS geological map (BGS, 2018f) indicates that the bedrock comprises the Zig Zag Chalk formation at the crossing and in its surrounding regions.

1.10.2 Superficial deposits are expected to be variable in their presence and extent in the area. Deposits of Head (clay, silt, sand and gravel) are indicated as present surrounding the route of the pipeline, but with greater coverage to the west than the east of the route (BGS, 2018f).

1.10.3 The aquifer designation map (Defra, 2018) shows the crossing is located within an area classed as a Principal bedrock aquifer. The Head deposits are classed as a Secondary Undifferentiated superficial aquifer.

1.10.4 The nearest BGS log record, SU73NW4, located approximately 280m to the northwest of the crossing, encountered drift and Lower Chalk together to a depth of 36.5mbgl, but no details are given regarding their respective thicknesses or groundwater information. Other logs in the area were not detailed or were drilled into different bedrock.

1.10.5 During the 2018 ground investigation works, BH128 was completed in August 2018, 170m to the north of the crossing. The groundwater levels observed in August are likely to be lower than the maximum level seen during winter months. The log record for this borehole indicates the following ground conditions:

- 0 – 1.40mbgl: Made ground;
- 1.40 – 2.05mbgl: Sand;
- 2.05 – 4.35mbgl: Clay;

- 4.35 – 10.46mbgl: Chalk; and
- No groundwater strikes were noted during drilling, and the well was dry on installation.

1.10.6 Groundwater levels have been measured manually on four separate occasions in BH128. These measurements indicate that the borehole was dry on two dates with levels of 8.51mbgl and 7.30mbgl recorded on the other two. The elevation of BH128 is 114.77mAOD, and it has been completed to a depth of 10.4mbgl. The data logger in BH128 has recorded the highest groundwater level as 7.29mbgl.

1.10.7 The EA Mole groundwater model for the Chalk and Upper Greensand (EA, 2011) show the crossing is located between groundwater level contours with values between 110.0mAOD and 115.0mAOD. The EHCC Chalk and Upper Greensand groundwater model (EA, 2007) shows that the crossing is located between contours with values between 115.0 and 120.0mAOD. Ground level at the site is approximately 115mAOD. The EA groundwater models thus indicate the maximum groundwater level is close to the ground level, or potentially above ground level depending on the model used. This is supported by the BGS groundwater flooding susceptibility map (BGS, 2017) which indicates the crossing is located within an area with potential for groundwater flooding to occur at the surface. A very small segment of the route cuts through an area defined as having potential for groundwater flooding of property situated below ground level.

1.10.8 As part of the EA groundwater monitoring network, the nearest groundwater monitoring locations are Woodside observation borehole (OBH) Chalk and Woodside OBH Greensand, both 490m northwest of the crossing. The maximum water level in the Chalk is 5.23mbgl (117.14mAOD) while the minimum is 23.25mbgl (99.12mAOD). The maximum water level in the Upper Greensand is 11.39mbgl (110.58mAOD), while the minimum is 23.85mbgl (98.12mAOD).

Crossing TC 006 Assessment

1.10.9 EA groundwater monitoring records close to the crossing record a maximum groundwater level of 5.23mbgl. The data, combined with EA groundwater modelling and the BGS groundwater flooding susceptibility map (BGS, 2017), which shows there is potential for flooding to occur at the surface, indicates that shallow groundwater conditions are likely to be encountered in this area. However, groundwater monitoring during the 2018 ground investigation found the well to be dry on two monitoring visits local to the crossing, with a maximum groundwater level recorded by the logger of 7.29mbgl. HDD would not require dewatering to take place. However, based on available data, with a drilling depth of 6.1m, the water table might be intercepted, and following installation, the pipeline could sit below the water table at TC 006, at least for part of the year or periods of high groundwater level.

1.10.10 Recent ground investigation identified made ground and superficial deposits to a maximum depth of 4.35mbgl. This value will locally be variable. The Chalk was found underlying these deposits reaching a depth greater 10.3mbgl. Therefore, with an HDD depth of 6.1mbgl, it is likely that both the superficial geology and the underlying Chalk bedrock would be encountered. Where these aquifer units are encountered together, it is likely there would be hydraulic continuity (dependent on the clay content of any superficial deposits) as there is no significant low permeability layer to separate the two horizons shown by ground investigation. As such, it is unlikely that this crossing would create a connection of two aquifers during construction or operation.

1.11 TC 007 – Caker Lane

Feature(s) requiring trenchless crossing	B3004 Caker Lane
Trenchless crossing technique and characteristics	Open cut or auger bore technique Following details derived from typical details drawing: • Assumes minimum depth of 2.0mbgl below services • Drive pit depth: assumed as 6.0mbgl • Drive pit length: approximately 11m • Drive pit width: approximately 3m • Reception pit depth: assumed as 6.0mbgl • Reception pit length: approximately 3m • Reception pit width: approximately 3m • Drive length: approximately 28m
Groundwater study area	GWSA-B

Geological and Hydrogeological Conditions at TC 007

1.11.1 The BGS online map (BGS, 2018f) indicates that the bedrock underlying the crossing comprises the Upper Greensand Formation of sandstone and siltstone.

1.11.2 No superficial deposits are mapped as present (BGS, 2018f), either at the crossing location or in the immediate surroundings.

1.11.3 The aquifer designation map (Defra, 2018) shows that the crossing is located within an area classed as a Principal bedrock aquifer.

1.11.4 The nearest BGS borehole record, SU73NW19, is located approximately 740m northeast of the crossing. The log record for this location indicates the following ground conditions:

- 0 – 55.47mbgl: Upper Greensand Formation;
- 55.47 – 60.96mbgl: Clay with sand; and
- water was struck at depths of 39.62mbgl (approximately 90.38mAOD).

1.11.5 During the 2018 ground investigation works, the nearest borehole is BH102 which is located approximately 1.1km north west of the crossing. The log record for this location indicates the borehole was completed in January 2019, when groundwater levels may be highest. The following ground conditions are indicated:

- 0 – 0.05mbgl: Topsoil
- 0.05 – 1.20mbgl: Sandy gravelly clay;
- 1.20 – 17.50mbgl: Chalk;

- 17.50 – 19.50mbgl: Sandstone; and
- no water strikes noted during drilling due to the addition of water flush.

1.11.6 No data relating to monitored groundwater levels is available for BH102. However, groundwater levels have been measured manually on five separate occasions at location BH101, located approximately 2.5km north of the crossing and at an elevation of 100.02mAOD. BH101 was completed to a depth of 20.16mbgl. These measurements indicate an average groundwater level of 9.05mbgl, or 90.97mAOD. The data logger in BH101 has recorded the highest groundwater level as 6.55mbgl.

1.11.7 The EA EHCC groundwater model for the Chalk and Upper Greensand (EA, 2007) shows that the crossing is located between contours with values of 120.0 and 125.0mAOD. The EA Mole groundwater model for the Upper Greensand (EA, 2011) agrees with this, showing contours with a value of 125.0mAOD close to the crossing location. These are considered maximum simulated groundwater levels. Elevation at the crossing is shown as between 124 and 125mAOD. Modelling therefore indicates that the maximum groundwater level is at or very close to the ground surface.

1.11.8 The BGS groundwater flooding susceptibility map (BGS, 2017) shows that the crossing is located within an area classed as having limited potential for groundwater flooding to occur, suggesting shallow groundwater conditions are not expected.

1.11.9 As part of the EA groundwater monitoring network, the nearest groundwater monitoring location is Alton Town OBH, approximately 2.5km to the northwest of the crossing. Monitoring records for this location indicate that the maximum groundwater level recorded here is -3.194mbgl (104.67mAOD) (i.e. artesian conditions) while the minimum groundwater level is 3.89mbgl (97.58mAOD).

Crossing TC 007 Assessment

1.11.10 Historical ground investigation records held by the BGS (BGS, 2018a) indicate a deep groundwater strike at 39.62mbgl, with deeper groundwater conditions supported conceptually by the BGS groundwater flooding susceptibility map (BGS, 2017) which shows limited potential for flooding. In addition, groundwater monitoring undertaken as part of the 2018 ground investigation works at BH101 indicate an average groundwater level of 9.05mbgl, with shallower groundwater also supported by EA groundwater modelling and EA groundwater monitoring. However, the EA groundwater monitoring and data from BH101 are likely to not be representative of the crossing location considering its distance from the monitoring points. No groundwater strike or monitoring information is available for the closest ground investigation location (BH102) as part of the 2018 investigation works.

1.11.11 Ground investigation records closest to the crossing location confirm an absence of superficial deposits in this area to any significant thickness, with the Chalk bedrock encountered at shallow depths and Upper Greensand Formation bedrock encountered below this. At a greater distance from the crossing, superficial deposits were encountered to a depth of 2.65mbgl, but this is not expected at the crossing location itself. Therefore, assuming a maximum auger bore excavation depth of

6mbgl, it is likely that only the Chalk would be encountered at TC 007 and no pathway between separate aquifer units would be created.

1.11.12 Based on available information pertaining to the groundwater levels at this location, the water table is not expected to be intercepted during construction of the auger bore pits, and thus dewatering is likely not required at this location because of the expected deeper groundwater conditions. Therefore, no dewatering assessment has been completed. Once installed, the pipeline is expected to sit above the water table at TC 007.

1.12 TC 008 – River Wey and Alton to Waterloo Railway Line

Feature(s) requiring trenchless crossing	River Wey and Alton to Waterloo railway line
Trenchless crossing technique and characteristics	HDD technique Following details derived from site-specific design drawing: • Reaches a maximum depth of about 79.8mAOD and maximum depth below ground of 12.2m • Drive length: approximately 209m
Groundwater study area	GWSA-B

Geological and Hydrogeological Conditions at TC 008

1.12.1 The BGS geological map (BGS, 2018f) indicates that the crossing is located within an area comprising both the Upper Greensand and the West Melbury Marly Chalk Formation. The Upper Greensand Formation of calcareous sandstone and siltstone is mapped to the south, east and west of the crossing. To the north, the West Melbury Marly Chalk Formation and the Zig Zag Chalk Formation are shown.

1.12.2 Superficial deposits to the south of the crossing are shown to comprise Alluvium along the course of the River Wey, with River Terrace Deposits of sand and gravel beyond (BGS, 2018f). To the north, further River Terrace Deposits of sand and gravel, and deposits of Head (clay, silt, sand and gravel) are shown. The crossing would likely intercept both the River Terrace Deposits and Alluvium.

1.12.3 The aquifer designation map (Defra, 2018) shows the crossing is located within an area of Principal bedrock aquifer and Secondary A superficial aquifer. Areas of Secondary Undifferentiated superficial aquifer are located in the immediate surroundings of the crossing but with limited extent.

1.12.4 The nearest available BGS record, SU74SW6, is located 250m to the southwest, the record for which indicates the following ground conditions:

- 0 – 0.9mbgl: Topsoil;
- 0.9 – 3.0mbgl: Gravel;
- 3.0 – 13.7mbgl: Green clay;
- 13.7 – 14.6mbgl: Rock;
- 14.6 – 17.7mbgl: Clay;
- 17.7 – 18.0mbgl: Rock;

- 18.0 – 20.7mbgl: Clay;
- 20.7 – 21.64mbgl: Rock;
- 21.64 – 24.4mbgl: Blue Clay; and
- the resting water level is indicated at 14.6mbgl (132.4mAOD).

1.12.5 A second borehole located 270m to the south, SU74SW28, shows the following data:

- 0 - 0.5mbgl: Topsoil/made ground;
- 0.5 – 3.0mbgl: Gravel/sand;
- 3.0 – 24.0mbgl: Clay/sandstone layer; and
- water was struck at 15mbgl. The ground level at this borehole is 162mAOD; thus, the water strike equates to approximately 147mAOD.

1.12.6 Both SU74SW6 and SU74SW28 are located on higher topographical ground compared to the crossing.

1.12.7 During the 2018 ground investigation works, BH98 was completed at the end of July 2018 when groundwater is expected to be relatively low. This borehole is immediately adjacent to the west of the crossing and recorded the following:

- 0 – 0.05mbgl: Topsoil;
- 0.05 – 4.55mbgl: Clay with varying properties with gravel;
- 4.55 – 6.80mbgl: Gravel with weak sandstone layers;
- 6.80 – 14.30mbgl: Sandstone, with layers of weathered clay and sandstones;
- 14.30 – 20.15mbgl: Mudstone with some small gravel layers; and
- water strike is recorded at 2.80mbgl (159.2mAOD).

1.12.8 Groundwater levels have been measured manually on five separate occasions at location BH98, which is located at an elevation of 91.42mAOD and was completed to a depth of 20.15mbgl. These measurements indicate an average groundwater level of 2.77mbgl, or 88.65mAOD. The data logger in BH98 has recorded the highest groundwater level as 2.46mbgl.

1.12.9 The EA Mole groundwater model output for both the Chalk and Upper Greensand (EA, 2011) indicates the crossing is located between contours with values of less than 90m in the south and 95m in the north, which are considered as maximum simulated groundwater levels. Topography at the crossing ranges between 91mAOD and 98mAOD. Therefore, the model data indicate that maximum groundwater level could be shallow at this location. This is also confirmed by the BGS groundwater flooding susceptibility map (BGS, 2017) indicating that the crossing is located within an area with potential for groundwater flooding to occur at the surface.

1.12.10 As part of the EA water level monitoring network, the Malms Farm Hydrometric monitoring point located approximately 400m southeast of the southern limit of the crossing recorded a maximum groundwater level of 12.36mbgl (94.12mAOD) while the minimum level was 16.6mbgl (89.88mAOD).

Crossing TC 008 Assessment

1.12.11 Recent investigations recorded a groundwater strike at 2.80mbgl adjacent to TC 008, while historical records held by the BGS (BGS, 2018a) indicate deeper groundwater levels ranging between 14.6mbgl and 15mbgl at further distances from the crossing. Groundwater monitoring completed as part of the 2018 investigation identified an average groundwater level of 2.77mbgl. Shallow groundwater conditions are further indicated by the EA groundwater model output, combined with the BGS groundwater flooding susceptibility map (BGS, 2017). Therefore, shallow groundwater should be expected at the location of TC 008. HDD would not require dewatering. However, based on a maximum pipeline depth of 12.2mbgl, it is expected that the water table would be encountered, and that following installation, a large proportion of the pipeline would sit below the water table along crossing TC 008.

1.12.12 The presence and extent of superficial deposits are uncertain. BGS boreholes and ground investigation records indicate that sands and gravels are found to a maximum depth of 3m (with potential to encounter gravel to 6mbgl), with clays and sandstone layers predominantly found underlying these. The Chalk bedrock was not recorded on any of these logs. The 2018 ground investigation record suggests a drift thickness of less than 7m, followed by sandstone underlying these. This information suggests the presence of the Upper Greensand Formation. HDD may therefore encounter the Upper Greensand Formation, which is expected to be in hydraulic connectivity with any overlying superficial sands and gravel aquifers in this location as there is no significant low permeability layer to separate them. As such, it is unlikely that this crossing would create a new connection of two aquifers during construction or operation.

1.13 TC 009 – A31 and Minor Access Road

Feature(s) requiring trenchless crossing	A31 and minor access road
Trenchless crossing technique and characteristics	HDD technique Following details derived from site-specific design drawing: • Reaches a maximum depth of about 95.3mAOD and maximum depth below ground of approximately 7.7m • Drive length: approximately 163m
Groundwater study area	GWSA-B

Geological and Hydrogeological Conditions at TC 009

1.13.1 The BGS geological map (BGS, 2018f) shows several lithological boundaries in this area. The Upper Greensand Formation of calcareous sandstone and siltstone is to be expected to the south, and also to encroach on the location of the crossing. The West Melbury Marly Chalk Formation is indicated at the crossing itself, while the Zig Zag Chalk Formation is indicated to the north of the crossing. The bedrock underlying the crossing is most likely to comprise the West Melbury Marly Chalk.

1.13.2 Superficial deposits comprise Alluvium of clay, silt, sand and gravel along the course of the River Wey, with River Terrace Deposits of sand and gravel indicated to the north and south (BGS, 2018f). Deposits of Head are mapped further south.

1.13.3 The aquifer designation map (Defra, 2018) show the crossing is located within an area designated as a Principal bedrock aquifer, with localised areas of Secondary A superficial aquifer associated with deposits of Alluvium and River Terrace Deposits.

1.13.4 The nearest BGS record located approximately 450m southwest of the crossing, SU74SW6, indicates the following ground conditions:

- 0 – 0.9mbgl: Topsoil;
- 0.9 – 3.0mbgl: Gravel;
- 3.0 – 13.7mbgl: Green clay;
- 13.7 – 14.6mbgl: Rock;
- 14.6 – 17.7mbgl: Clay;
- 17.7 – 18.0mbgl: Rock;
- 18.0 – 20.7mbgl: Clay;
- 20.7 – 21.64mbgl: Rock;
- 21.64 – 24.4mbgl: Blue clay; and
- the resting water level is indicated at 14.6mbgl (approximately 88.4mAOD).

1.13.5 BGS record SU74SW6 is located at a similar elevation to the crossing at approximately 102mAOD, compared to between 99mAOD and 103mAOD over the length of the crossing.

1.13.6 During the 2018 ground investigation works, BH69 was completed approximately 111m west of the crossing. This was completed in November 2018, when groundwater is likely to be higher. The record for BH69 indicates the following ground conditions:

- 0 – 0.1mbgl: Topsoil;
- 0.1 – 0.60mbgl: Sandy clay;
- 0.6 – 1.90mbgl: Sandy gravel;
- 1.90 – 6.10mbgl: Sandy clay;
- 6.10 – 7.05mbgl: Siltstone;
- 7.05 – 8.40mbgl: Sandstone and Siltstone;
- 8.40 – 17.20mbgl: Sandstone; and
- water strike at 1.60mbgl (approximately 97.2mAOD).

1.13.7 Groundwater levels have been measured manually on two separate occasions at location BH69, which is located at an elevation of 98.58mAOD and was completed to a depth of 17.20mbgl, with the monitoring installation at 7.20mbgl. These measurements indicate an average groundwater level of 2.67mbgl, or 95.91mAOD. The data logger in BH69 has recorded the highest groundwater level as 2.42mbgl.

1.13.8 EA Mole groundwater models for the Chalk (EA, 2011) indicate maximum groundwater levels between 95mAOD and 110mAOD. The Mole groundwater model for the Upper Greensand agrees and indicates levels between 95mAOD and 100mAOD over the length of the crossing. These are considered maximum simulated groundwater levels. Elevation at the crossing location is indicated as ranging from 99mAOD in the south and 103mAOD in the north, suggesting that groundwater levels are around 3mbgl in high water table conditions. This is also confirmed by the BGS groundwater flooding susceptibility map (BGS, 2017) placing the crossing in an area with potential for groundwater flooding to occur at the surface.

1.13.9 As part of the EA water level monitoring network, the Malms Farm hydrometric monitoring point is located approximately 750m southeast of the crossing recorded a maximum water level of 12.36mbgl (or 94.12mAOD) and a minimum water level of 16.6mbgl (or 89.88mAOD).

Crossing TC 009 Assessment

1.13.10 Recent ground investigation confirmed a groundwater strike at 1.60mbgl in proximity to TC 009, with subsequent groundwater monitoring at the same location providing an average groundwater level at around 2.6mbgl with the highest groundwater level recorded as 2.42mbgl. However, historical records held by the BGS (BGS, 2018a) show a deeper groundwater level at 14.60mbgl at a further distance from the crossing. Additional evidence of shallow groundwaters is shown by the EA groundwater model outputs and the BGS groundwater flooding susceptibility map (BGS, 2017), which shows there is potential for flooding to occur at the surface. Therefore, shallow groundwater conditions should be anticipated at this location. HDD would not require dewatering. However, assuming a maximum drill depth of 7.7mbgl, the water table would likely be intercepted, and following installation, a large proportion of the pipeline would be below the water table along crossing TC 009.

1.13.11 The nature of superficial deposits is expected to be variable in the vicinity of the crossing. BGS borehole and recent ground investigation records indicate that gravels are found to maximum depths of between 3mbgl and 6.10mbgl, with clay and sandstone layers identified below these. The Chalk bedrock was not identified on these log records, and the clay and sandstone layers are assumed to represent the Upper Greensand Formation. Therefore, based on a maximum HDD depth of 7.7m, there is potential that the Upper Greensand Formation would be encountered. This formation is expected to be in hydraulic connectivity with the overlying superficial gravel aquifer expected at this location, as there is no significant low permeability layer shown by ground investigation records to separate them. As such, it is unlikely that this crossing would create a new connection of two aquifers during construction or operation.

1.14 TC 010 – A287 Ewshot Hill

Feature(s) requiring trenchless crossing	A287 Ewshot Hill
Trenchless crossing technique and characteristics	HDD technique Following details assumed from typical details drawings: • Assumed a drilling depth of 5mbgl for this assessment • Drive length: approximately 185m
Groundwater study area	GWSA-C

Geological and Hydrogeological Conditions at TC 010

1.14.1 The BGS geological map (BGS, 2018g) indicates that the bedrock at the crossing and in the surrounding areas comprises the London Clay Formation of clay, silt and sand.

1.14.2 The geological map (BGS, 2018g) indicates that there are no superficial deposits mapped as present at the crossing location, or in the immediate surroundings of the crossing.

1.14.3 The aquifer designation map (Defra, 2018) shows that the crossing is not located within any important aquifer units. The bedrock is defined as Unproductive strata, while there is an absence of superficial deposits.

1.14.4 The nearest BGS borehole record, SU85SW26, is located approximately 850m northwest of the crossing. The record for this indicates the following ground conditions:

- 0 – 66.3mbgl: London Clay;
- 66.3 – 96.3mbgl: Reading Beds;
- 96.3 – 162.2mbgl: Upper Chalk; and
- no groundwater observations are recorded on this record.

1.14.5 An additional record, SU84NW28, is located approximately 1.1km southeast of the crossing. The log record shows the following ground and groundwater conditions:

- 0 – 6.09mbgl: Yellow clay;
- 6.09 – 18.28mbgl: Blue clay;
- the resting water level was identified at 12.19mbgl; and
- water was struck at 15.54mbgl.

1.14.6 BGS record SU85SW26 is located at a lower elevation to the crossing, while record SU84NW28 is located at a notably higher elevation than that of the crossing.

1.14.7 The nearest SLP ground investigation borehole is BH67, located approximately 2km southwest of the crossing. BH67 is shown to have been completed in early October 2018 when groundwater conditions are likely to be lower than the maximum. The log record for this borehole does not indicate the presence of London Clay and indicates the following ground conditions:

- 0 – 1.95mbgl: Gravelly sand;
- 1.95 – 20.65mbgl: Chalk recovered as gravel; and
- no groundwater strikes observed due to the addition of water flush.

1.14.8 Groundwater levels have been measured manually on five separate occasions at location BH67, which is located at an elevation of 101.91mAOD and was completed to a depth of 20.65mbgl. These measurements indicate an average groundwater level of 17.55mbgl, or 84.36mAOD. The data logger in BH67 has recorded the highest groundwater level as 15.62mbgl.

1.14.9 The BGS groundwater flooding susceptibility map (BGS, 2017) does not provide information for this location due to the location being on Unproductive strata.

1.14.10 As part of the EA water level monitoring network, the hydrometric monitoring point 6_Cottages_Clean is located approximately 1.75km southwest of the crossing. This location monitors groundwater levels in the Chalk and, as such, is not of relevance for the crossing location.

Crossing TC 010 Assessment

1.14.11 The nearest BGS record (BGS, 2018a) did not record groundwater to a depth of 162mbgl. However, recent manual groundwater monitoring at a location approximately 2km from the crossing recorded an average groundwater level of 17.55mbgl, while continuous data suggests the shallowest groundwater at 15.62mbgl. Therefore, based on data local to the crossing, it is assumed that groundwater levels would be relatively deep. HDD would not require dewatering during excavation, and based on a maximum drilling depth of 5m, it is unlikely that the water table would be intercepted, and following installation, it is likely that the pipeline would sit above the water table, should deeper groundwater levels be proved at TC 010.

1.14.12 There are no superficial deposits expected at this location according to the geological map (BGS, 2018g). This is confirmed by ground investigation records local to the crossing location, which encountered clay (the London Clay) from ground level to depth. HDD is therefore likely to only encounter the London Clay Formation. This formation is defined as Unproductive strata, and thus is not expected to be in hydraulic continuity with any other stratigraphic deposits, should any superficial deposits be encountered locally. As such, it is unlikely that this crossing would create a new connection of two aquifers during construction or operation.

1.15 TC 011 – Bourley and Long Valley SSSI

Feature(s) requiring trenchless crossing	Bourley and Long Valley Site of Special Scientific Interest (SSSI)
Trenchless crossing technique and characteristics	HDD technique Following details assumed from typical details drawings: • Assumed a maximum drilling depth of 5mbgl • Drive length: approximately 309m
Groundwater study area	GWSA-C

Geological and Hydrogeological Conditions at TC 011

1.15.1 The BGS online map (BGS, 2018g) indicates that the bedrock at the crossing and in the immediate surroundings comprises the Windlesham Formation of sand, silt and clay. Further to the west, south and northeast, the Camberley Sand Formation is mapped as being present.

1.15.2 The geological map (BGS, 2018g) shows that the crossing itself is absent of superficial coverage. Further to the north, and to the west, deposits of Head comprising sand and gravel are shown as being present.

1.15.3 The aquifer designation map (Defra, 2018) shows that the crossing is located within an area classed as a Secondary A bedrock aquifer. There are localised areas of Secondary A aquifer associated with Head deposits of sand and gravel in the immediate surroundings of the crossing.

1.15.4 The nearest BGS borehole, SU85SW6, is located approximately 515m northwest of the crossing. The online record for this indicates the following ground conditions:

- 0 – 1.7mbgl: Gravel;
- 1.7 – 6.2mbgl: Bracklesham Beds; and
- the water strike was encountered at 75.8mAOD and the surface level is given as 80.5mAOD; therefore, the groundwater strike was encountered at approximately 4.7mbgl.

1.15.5 For the 2018 ground investigation works, the nearest proposed borehole to the crossing is BH61, located approximately 1.3km northeast. However, no data was available for BH61 at the time of writing.

1.15.6 The BGS groundwater flooding susceptibility map (BGS, 2017) shows that the crossing is located within an area defined as having limited potential for groundwater flooding to occur, suggesting shallow groundwater conditions are not expected.

1.15.7 As part of the EA groundwater level monitoring network, the hydrometric monitoring point Bourley Lane OBH is located approximately 2km southeast of the crossing. The monitoring record for this location has recorded a maximum groundwater level of 49.38mbgl (50.61mAOD) and a minimum value of 53.17mbgl (46.83mAOD).

Crossing TC 011 Assessment

1.15.8 Historical ground investigation (BGS, 2018a) confirmed a groundwater strike at approximately 4.7mbgl. Limited additional data is available to substantiate the groundwater levels at this location. While historical records indicate a relatively shallow groundwater table, EA groundwater level monitoring records (albeit at a distance from the crossing) and the BGS groundwater flooding susceptibility map (BGS, 2017) suggest the contrary; that deeper groundwater is anticipated. Based on the limited data available for this location, and assuming a worst case scenario, it is assumed that groundwater is shallow at this location, and that the historical BGS records are representative. HDD does not require dewatering. However, based on an HDD depth of 5m, the water table might be intercepted, and that following installation, the pipeline could sit below the water table at this location.

1.15.9 Information relating to ground conditions at this location is limited. While the BGS geological map (BGS, 2018g) shows that the site is expected to be absent of superficial deposits, ground investigation records indicate gravel and gravelly sand to a depth of 1.95mbgl. The Bracklesham Beds (of which the Windlesham Formation and Camberley Sands are members of) were encountered at depths below 1.7mbgl in proximity to the crossing. Based on the assumed maximum depth of 5mbgl for HDD, it is therefore likely that the bedrock would be encountered, and should superficial deposits be present locally to depths of approximately 1.7m, these too would be intercepted. Should both superficial and bedrock aquifer units both be encountered together in succession at the crossing location, they would be expected to be in continuity with one another as there is no low permeability layer shown by ground investigation to separate them. Furthermore, based on evidence that the shallowest groundwater level recorded is below the maximum recorded depth of the superficial deposits, it is unlikely that there would be a hydraulic connection at this location. As such, it is unlikely that this crossing would create a new connection of two aquifers during construction or operation.

1.16 TC 012 – Bourley and Long Valley SSSI

Feature(s) requiring trenchless crossing	Bourley and Long Valley SSSI
Trenchless crossing technique and characteristics	HDD technique Following details assumed from typical details drawings: • Assumed a depth of maximum drilling depth of 5mbgl • Drive length: approximately 252m
Groundwater study area	GWSA-C

Geological and Hydrogeological Conditions at TC 012

1.16.1 The geological map (BGS, 2018g) indicates that the bedrock at the crossing and in the immediate surroundings comprises the Windlesham Formation of sand, silt and clay. Further east, the Camberley Sand Formation is indicated.

1.16.2 The geological map (BGS, 2018g) indicates that superficial deposits are expected to be variable in their presence and extent in the vicinity of the crossing. Deposits of Head comprising sand and gravel may be present over some of the crossing, while to the south, the area is largely absent of superficial coverage.

1.16.3 The aquifer designation map (Defra, 2018) indicates that the crossing is located within an area defined as a Secondary A bedrock aquifer. A small area of Secondary A superficial aquifer cuts across the crossing associated with the Head deposits. To the west are localised areas of Secondary Undifferentiated superficial aquifer.

1.16.4 The nearest BGS borehole, SU85SW6, is located approximately 540m west of the crossing. The online record for this indicates the following ground conditions:

- 0 – 1.7mbgl: Gravel;
- 1.7 – 6.2mbgl: Bracklesham Beds; and

- the water strike was encountered at 75.8mAOD and the surface level is given as 80.5mAOD; therefore, groundwater strike was encountered at approximately 4.7mbgl.

1.16.5 The BGS record detailed above is located at a similar elevation to that of the crossing.

1.16.6 For the 2018 ground investigation works, the nearest proposed borehole to the crossing is BH61. No data was available for BH61 at the time of writing. The next nearest ground investigation record is that of BH55, located approximately 4.9km northeast of the crossing. BH55 is shown to have been completed in August 2018 when groundwater conditions may be lower than the maximum. The log record for this indicates the following ground conditions:

- 0 – 1.0mbgl: Silty sand;
- 1.0 – 1.10mbgl: Clayey sand;
- 1.10 – 1.50mbgl: Slightly gravelly sand;
- 1.50 – 10.45mbgl: Slightly silty sand; and
- groundwater strike was encountered at 3.75mbgl (approximately 68.25mAOD).

1.16.7 Groundwater levels have been measured manually on five separate occasions at BH55, which is located at an elevation of 72.93mAOD and was completed to a depth of 10.45mbgl. These measurements indicate an average groundwater level of 8.58mbgl, or 64.35mAOD. The data logger in BH55 has recorded the highest groundwater level as 5.40mbgl.

1.16.8 The BGS groundwater flooding susceptibility map (BGS, 2017) shows that the crossing is located within an area defined as having limited potential for groundwater flooding to occur, suggesting shallow groundwater conditions are not expected.

1.16.9 As part of the EA water level monitoring network, the hydrometric monitoring point Bourley Land OBH is located approximately 2.19km southeast of the crossing. The monitoring record for this location has recorded a maximum groundwater level of 49.38mbgl (50.61mAOD) and a minimum value of 53.17mbgl (46.83mAOD).

Crossing TC 012 Assessment

1.16.10 Historical ground investigation by the BGS (BGS, 2018a) confirmed a groundwater strike at approximately 4.7mbgl. Recent ground investigation also identified a shallow groundwater strike at 3.75mbgl, while subsequent groundwater monitoring at the same location provides an average groundwater level of 8.58mbgl, although this investigation location is at a distance from the crossing and therefore may not be representative of the crossing itself. Both EA groundwater level monitoring and the BGS groundwater flooding susceptibility map (BGS, 2017) suggest that shallow groundwater is not expected. HDD methods do not require dewatering. However, with an HDD depth of 5.0mbgl, based on the available data, the water table might be intercepted, and following installation, the pipeline may sit below the water table at crossing TC 012. However, there is uncertainty in this.

1.16.11 The presence of superficial deposits at this location is expected to be variable, as indicated by the geological map (BGS, 2018g). Ground investigation records encountered gravels to a depth of 1.7mbgl. Underlying these, records show silty sands and the Bracklesham Beds, of which the Windlesham Formation is a member. With an assumed maximum HDD depth of 5mbgl, it is likely that the Bracklesham Beds would be encountered, and where they are present, superficial deposits would also be intercepted. Both deposits are classed as important aquifer units. Where both are encountered together in succession, they are likely to be in hydraulic continuity with one another as no significant low permeability layer is shown by ground investigation to separate them. Furthermore, the shallowest groundwater level recorded here falls below the maximum recorded depth of superficial deposits, and thus it is unlikely that there would be a hydraulic connection at this location. As such, it is unlikely that this crossing would create a new connection of two aquifers during construction or operation.

1.17 TC 013 –Basingstoke Canal and A323

Feature(s) requiring trenchless crossing	Basingstoke Canal SSSI and A323
Trenchless crossing technique and characteristics	HDD technique Following details derived from site-specific design drawings: • Depth: 6.1m below base of Basingstoke Canal • Maximum depth of approximately 68.86mAOD, and maximum depth below ground of 14.23m. • Drive length: approximately 198m
Groundwater study area	GWSA-C

Geological and Hydrogeological Conditions at TC 013

1.17.1 The BGS geological map (BGS, 2018g) indicates that the bedrock at and in the surrounding areas of the crossing is expected to comprise the Camberley Sand Formation, with the Windlesham Formation of sand, silt and clay shown to the west of the crossing.

1.17.2 Superficial deposits are shown on the map (BGS, 2018g) to be largely absent where most the crossing is proposed. Deposits of Head which comprise sand and gravel are mapped immediately south of the crossing and are shown as present over a small portion of the southern part of the route. Deposits of Head are also indicated further to the north. The immediate east and west are notably absent of superficial coverage, confirming that their extent is limited.

1.17.3 The aquifer designation map (Defra, 2018) indicates that the crossing is located within an area designated as a Secondary A bedrock aquifer. A small area of Secondary A superficial aquifer correlates with the superficial Head deposits at the crossing, with other nearby deposits of Head also classed the same. Localised areas of Secondary Undifferentiated superficial aquifer are indicated to the east.

1.17.4 The nearest available BGS record located approximately 185m to the northwest, SU85SW9, indicates the following ground conditions:

- 0 - 0.1mbgl: Topsoil (clayey);

- 0.1 – 2.7mbgl: Very clayey sandy gravel;
- 2.7 – 5.7mbgl: Sandy silt; and
- the log states that water was not struck at this location.

1.17.5 An additional BGS record, SU85SW6, located approximately 800m southwest of the crossing, was consulted to determine the water strike. The online record for this indicates the following ground conditions:

- 0 – 1.7mbgl: Downwash gravel of clayey pebbly sand, and sand and gravels;
- 1.7 – 6.2mbgl: Bracklesham Beds; and
- water was struck at 75.8mAOD, with the surface level indicated as 80.5mAOD; therefore, the water strike was encountered at approximately 4.7mbgl.

1.17.6 SU85SW9 is located topographically higher than the crossing, at 86mAOD compared to approximately 78mAOD at the crossing.

1.17.7 For the 2018 ground investigation works, the nearest proposed borehole to the crossing is BH61 approximately 545m to the northeast of the crossing. The log record for this was not available at the time of writing. The next nearest borehole location is BH59, located approximately 2.7km northeast of the crossing. The log record for BH59 indicates it was completed in January 2019, when seasonal groundwater levels are likely to be relatively high. The following ground conditions were encountered:

- 0 – 1.40mbgl: Made ground;
- 1.40 – 15.45mbgl: Silty sand; and
- groundwater strike was encountered at 1.65mbgl or 61.03mAOD.

1.17.8 As part of the EA water level monitoring network, the Bourley Lane OBH monitoring point, located approximately 2.7km south of the crossing, recorded a maximum groundwater level of 49.38mbgl (50.61mAOD) and a minimum value of 53.17mbgl (46.83mAOD).

1.17.9 Groundwater levels have been measured manually on two separate occasions at BH59, which is located at an elevation of 62.68mAOD and was completed to a depth of 15.0mbgl. These measurements indicate an average groundwater level of 0.95mbgl, or 61.73mAOD. The data logger in BH59 has recorded the highest groundwater level as 0.47mbgl.

1.17.10 The BGS groundwater flooding susceptibility map (BGS, 2017) indicates that the crossing is located within an area of limited potential for groundwater flooding to occur, suggesting that shallow groundwater conditions are not expected at this area.

Crossing TC 013 Assessment

1.17.11 There is limited groundwater level information available local to crossing TC 013, aside from a BGS record (BGS, 2018a) which encountered groundwater at 4.7mbgl, which would suggest relatively shallow groundwater conditions. However, the most local BGS record did not encounter groundwater up to 5.7mbgl, and the BGS groundwater flooding susceptibility map (BGS, 2017) shows there is limited potential for flooding, thereby suggesting that groundwater is not found close to the ground surface. In addition, EA monitoring records indicate that groundwater would not be expected to be shallow, although the relevance of EA monitoring data is uncertain based on its distance from the crossing location. Recent ground investigation at greater distances from the crossing identified a groundwater strike at 1.65mbgl with the highest rest water levels around 0.5mbgl, although these levels may not be representative given the distance. HDD would not require any dewatering. However, based on an HDD depth of 8.13m below the top of Basingstoke Canal, the water table might be intercepted, and following installation, the pipeline may sit below the water table along crossing TC 013. The exact position of the water table is, however, uncertain.

1.17.12 The presence, nature and extent of superficial deposits are expected to be variable at this location. BGS records indicate that sands and gravels were encountered to a maximum depth of 2.7mbgl at locations close to the crossing. Underlying these are sandy silt with thicknesses of greater than 3m. These are assumed to represent the Camberley Sand Formation. At this location, HDD is therefore likely to encounter both superficial deposits and the underlying Camberley Sand. Both geological units are classed as important aquifer units. Where they are found together in succession, they would be expected to be in continuity with one another as there is no significant low permeability layer shown by ground investigation to separate them. Furthermore, as the shallowest groundwater level falls below the maximum recorded depth of any superficial deposits, it is unlikely that there would be any hydraulic continuity. As such, it is unlikely that this crossing would create a new connection of two aquifers during construction or operation.

1.18 TC 014 – A327 Ively Road

Feature(s) requiring trenchless crossing	A327 Ively Road
Trenchless crossing technique and characteristics	Auger bore technique Following details assumed from typical details drawings: • Assumes minimum depth of 2.0mbgl below services • Drive pit depth: assumed as a maximum of 6.0mbgl • Drive pit length: approximately 11m • Drive pit width: approximately 3m • Reception pit depth: assumed as a maximum of 6.0mbgl • Reception pit length: approximately 3m • Reception pit width: approximately 3m • Drive length: approximately 32m
Groundwater study area	GWSA-C

Geological and Hydrogeological Conditions at TC 014

1.18.1 The BGS geological map (BGS, 2018g) indicates that the bedrock at the crossing and in its surroundings comprises the Windlesham Formation of sand, silt and clay.

1.18.2 Superficial deposits are mapped as being variable in their nature near the crossing (BGS, 2018g). To the south of the crossing, deposits of Head comprising clay, silt, sand and gravel are shown. To the north and along the crossing, deposits of Alluvium associated with a small watercourse are mapped.

1.18.3 The aquifer designation map (Defra, 2018) indicates that the crossing is located within an area classed as a Secondary A bedrock aquifer. The deposits of Alluvium are classed as a Secondary A superficial aquifer, while the Head deposits are classed as a Secondary Undifferentiated superficial aquifer.

1.18.4 The nearest BGS borehole record, SU85SE355, is located approximately 380m southeast of the crossing. The online record for this indicates the following ground conditions:

- 0 – 0.25mbgl: Topsoil;
- 0.25 – 1.22mbgl: Silty organic clay;
- 1.22 – 1.52mbgl: Organic clay;
- 1.52 - 1.74mbgl: Peat;
- 1.74 – 3.04mbgl: Clayey sand; and
- water was struck at 2.44mbgl (approximately 60.56mAOD).

1.18.5 An additional record, SU85SE16, located approximately 470m southeast of the crossing, indicates the following ground conditions:

- 0 – 0.2mbgl: Clayey, loamy soil;
- 0.2 – 0.7mbgl: Silty clay – Alluvium;
- 0.7 – 4.7mbgl: Clayey sand – Bracklesham Beds; and
- groundwater was encountered at 4.4mbgl (approximately 57.6mAOD).

1.18.6 During the 2018 ground investigation works, BH59 was completed immediately adjacent to the crossing. The log record for BH59 indicates it was completed in January 2019, when seasonal groundwater levels are likely to be high. The following ground conditions are expected:

- 0 – 1.40mbgl: Made ground;
- 1.40 – 15.45mbgl: Silty sand; and
- groundwater strike was encountered at 1.65mbgl or 61.03mAOD.

1.18.7 Groundwater levels have been measured manually on two separate occasions at BH59, which is located at an elevation of 62.68mAOD and was completed to a depth of 15.0mbgl. These measurements indicate an average groundwater level of 0.95mbgl, or 61.73mAOD. The data logger in BH59 has recorded the highest groundwater level as 0.47mbgl.

1.18.8 The BGS groundwater flooding susceptibility map (BGS, 2017) shows that the crossing is located within an area defined as having limited potential for groundwater flooding to occur, suggesting shallow groundwater conditions are not expected.

1.18.9 As part of the EA groundwater level monitoring network, the nearest hydrometric monitoring location is Bourley Lane OBH, approximately 4.65km southwest of the crossing. The monitoring record for this location has recorded a maximum groundwater level of 49.38mbgl (50.61mAOD) and a minimum value of 53.17mbgl (46.83mAOD).

Crossing TC 014 Assessment

1.18.10 Both historical (BGS, 2018a) and recent ground investigations completed at locations close to the crossing all confirm shallow groundwater strikes, ranging between 1.65mbgl and 4.4mbgl, while the highest groundwater level recorded during the 2018 ground investigation works is around 0.5mbgl. Based on the available data, shallow groundwater conditions are likely to be encountered at crossing TC 014.

1.18.11 Following installation, the pipeline is likely to sit below the water table at this location. Based on available information pertaining to the water level, the water table could be intercepted at this location, assuming the worst case scenario of installation at 6mbgl.

1.18.12 The nature of superficial deposits is variable within the vicinity of the crossing. At the crossing, deposits of Alluvium are expected, overlying bedrock of the Windlesham Formation of sand, silt and clay. Ground investigation records encountered Alluvium to a depth of 0.7mbgl and 1.50mbgl respectively. peat was also encountered to 1.74mbgl. Made Ground was encountered at the most local investigation point. Underlying these deposits, beds of silty sand and clayey sand were encountered. These beds are assumed to represent the Windlesham Formation bedrock, which were encountered to depths >10.45mbgl. The auger bore method of drilling has the potential to encounter both superficial deposits and the underlying Windlesham Formation, based on ground investigation records. Where these deposits are encountered together, they are expected to be in continuity as there is no significant low permeability layer shown by ground investigation records to separate them. Furthermore, as the shallowest recorded groundwater level is below the maximum recorded depth of any superficial deposits, it is unlikely that there would be hydraulic continuity between two aquifer units at this location. As such, it is unlikely that this crossing would create a new connection of two aquifers during construction or operation.

1.18.13 For the calculation of effects due to dewatering, hydraulic conductivity values are available for BH59, the average value for which is 2.97E-06m/s. This value has been used as a representative hydraulic conductivity value for this location for this assessment.

1.18.14 The expected maximum groundwater level has been estimated as 0.47mbgl, assuming that the highest groundwater level measured in BH59 represents the maximum groundwater level.

1.18.15 Table 8.2.1 presents the input and results of the radius of influence calculations. Additional input parameters and results used for the calculation of dewatering rates are given in Table 8.2.2. Potential receptors within the calculated radius of influence have been identified as detailed in Table 8.2.3.

Table 8.2.1: Input and Results for Calculating the Radius of Influence for TC 014

Parameter	Drive Pit Value	Reception Pit Value
Length (m)	11.0	3
Width (m)	3	3
Maximum pit depth (m)	6	6
Expected groundwater level (mbgl)	0.47	0.47
Hydraulic conductivity, K (m/s)	2.97E-6	2.97E-6
Calculated drawdown (m)	5.5	5.5
R (m)	28.6	28.6
Re (m)	3.2	1.7
Total radius of influence Ro (m)	32	30

Table 8.2.2: Input and Results for Estimating Dewatering Rate for TC 014

Parameter	Drive Pit Value	Reception Pit Value
H, saturated aquifer thickness (assumed as silty sand thicknesses derived from the ground investigation (GI) (m)	8.45	8.45
Q, dewatering rate	28.2m^3/day	22.3m^3/day
	0.33l/s	0.26l/s

Table 8.2.3: Potential Receptors Identified within the Radius of Influence for TC 014

Receptor	Distance from Drive Pit	Distance from Reception Pit	Comments
Groundwater abstractions			
None			
Buildings and Infrastructure			
None			
Surface waters			
Unnamed surface water flowing into Cove Brook	Within Order Limits; approximately 20m from the pit	Within Order Limits; approximately 20m from the pit	
GWDTEs			
Ively Road (Golf Course)	0m. Within Order Limits	0m. Within Order Limits	
Potentially contaminated land			
Southwood (former military land)	Within Order Limits; approximately 10m from pit	Beyond radius	
Scheduled monuments and listed buildings			
None			

1.19 TC 015 – South Western Main Railway Line

Feature(s) requiring trenchless crossing	Railway

Trenchless crossing technique and characteristics	Auger bore technique Following details taken from site-specific design drawing: • Reaches a maximum depth of about 59.4mAOD and maximum depth below ground of 8.6m (beneath the elevated ground comprising the railway). • Drive length: 36m • Drive pit depth: approximately 4.9mbgl • Drive pit length: approximately 4.0m • Drive pit width: approximately 8m • Reception pit depth: 4.9mbgl • Reception pit length: approximately 4m • Reception pit width: approximately 4m • Drive length: approximately 43m
Groundwater study area	GWSA-C

Geological and Hydrogeological Conditions at TC 015

1.19.1 The BGS geological map (BGS, 2018g) indicates that the bedrock at the crossing and in the surroundings comprises the Camberley Sand Formation. Further south, the Windlesham Formation of sand, silt and clay is indicated.

1.19.2 The geological map (BGS, 2018g) shows that Alluvium deposits are mapped at the crossing, associated with the watercourse. Superficial deposits are largely absent from the surrounding area aside from Alluvium following the path of Cove Brook.

1.19.3 The aquifer designation map (Defra, 2018) indicates that the crossing is located within an area classed as a Secondary A bedrock aquifer. The deposits of Alluvium are classed as a Secondary A superficial aquifer.

1.19.4 The nearest available BGS record, SU85NW172, is located approximately 870m northwest of the crossing. The online record for this indicates the following conditions:

- 0 – 0.35mbgl: Topsoil;
- 0.35 – 0.9mbgl: Fine sand;
- 0.9 – 2.0mbgl: Fine sand; and
- the water strike was encountered at 1.35mbgl (approximately 63.65mAOD).

1.19.5 A second borehole record was consulted to determine deeper conditions. Record SU85SE16 is located approximately 1.1km south of the crossing. The online record indicates the following ground conditions:

- 0 – 0.2mbgl: Clayey loamy soil;
- 0.2 – 0.7mbgl: Alluvium;
- 0.7 – 4.7mbgl: Bracklesham Beds; and
- the water strike was encountered at +57.8mAOD, with the ground level shown as 62.2mAOD, therefore the water strike was at approximately 4.4mbgl.

1.19.6 The boreholes for the BGS records detailed above are found at a similar elevation as the crossing (approximately 65mAOD).

1.19.7 During the 2018 ground investigation works, BH56 was completed approximately 107m northeast from the crossing. The log record shows this was completed in December 2018, when groundwater levels may be seasonally higher. The following ground conditions are expected:

- 0 – 0.38mbgl: Made ground;
- 0.38 – 1.32mbgl: Silty sand;
- 1.32 – 2.15mbgl: Sandy clay;
- 2.15 – 10.55mbgl: Slightly silty sand; and
- groundwater strike was encountered at 1.40mbgl (approximately 60.57mAOD).

1.19.8 Groundwater levels have been measured manually on three separate occasions at location BH56, which is located at an elevation of 61.97mAOD and was completed to a depth of 10.55mbgl. These measurements indicate an average groundwater level of 1.56mbgl, or 60.41mAOD. No groundwater level data from a data logger is currently available for this borehole.

1.19.9 The BGS groundwater flooding susceptibility map (BGS, 2017) shows that the crossing is located within an area defined as having limited potential for groundwater flooding to occur, suggesting shallow groundwater conditions are not expected.

1.19.10 No EA groundwater level monitoring boreholes are available in the vicinity of the crossing.

Crossing TC 015 Assessment

1.19.11 Ground investigation records, both recent and historical (BGS, 2018a), suggest that shallow groundwater conditions are expected at this location, with groundwater strikes measured at between 1.35mbgl and 4.4mbgl. In addition, the average groundwater level recorded from manual groundwater monitoring is 1.56mbgl. Contrary to this, the BGS groundwater flooding susceptibility map (BGS, 2017) indicates that shallow groundwater is not expected at this location. A worst case scenario is assumed for this crossing, and an assessment has been made based on there potentially being shallow groundwater conditions.

1.19.12 Based on available information pertaining to the water level, the water table is likely to be intercepted at this location, assuming that auger boring is completed at 8.6mbgl. Following installation, the pipeline may sit below the water table at TC 015.

1.19.13 Superficial deposits are expected to be variable in their extent at this location. Ground investigation records held by the BGS locally to this crossing recorded Alluvium and fine sand assumed to represent Alluvium to depths of 0.7 and 0.9mbgl respectively, while gravelly sand was encountered to a depth of 1.50mbgl in a recent investigation. Underlying these, the Bracklesham Beds are recorded, of which the Windlesham Formation is a member. Therefore, auger bore drilling is likely to encounter both superficial Alluvium and the underlying Windlesham Formation bedrock at TC 015. There is no significant low permeability layer separating superficial deposits from the bedrock shown by ground investigation, and the shallowest recorded groundwater level is located at depths equivalent to the gravelly sand bedrock. As such, it is unlikely that this crossing would create a new connection of two aquifers during construction or operation.

1.19.14 For the calculation of effects due to dewatering, hydraulic conductivity values are available for BH56, the average value for which is 5.93E-06m/s. This value has been used as a representative hydraulic conductivity value for this location for this assessment.

1.19.15 The expected maximum groundwater level has been estimated as 1.0mbgl, assuming that shallow groundwater encountered at approximately 1.35mbgl may show variability over the course of a year.

1.19.16 Table 8.2.4 presents the input and results of the radius of influence calculations. Additional input parameters and results used for the calculation of dewatering rates are given in Table 8.2.5. Potential receptors within the calculated radius of influence have been identified as detailed in Table 8.2.6.

Table 8.2.4: Input and Results for Calculating the Radius of Influence for TC 015

Parameter	Drive Pit Value	Reception Pit Value
Length (m)	4	4
Width (m)	8	4
Maximum pit depth (m)	4.9	4.9
Expected groundwater level (mbgl)	1.0	1.0
Hydraulic conductivity, K (m/s)	5.93E-06	5.93E-06
Calculated drawdown (m)	3.9	3.9
R (m)	28.5	28.5
Re (m)	3.2	2.3
Total radius of influence Ro (m)	32	31

Table 8.2.5: Input and Results for Estimating Dewatering Rate for TC 015

Parameter	Drive Pit Value	Reception Pit Value
H, saturated aquifer thickness (assumed as silty thicknesses derived in GI) (m)	9.45	9.45
Q, dewatering rate	41.0m^3/day	36.1m^3/day
	0.47l/s	0.42l/s

Table 8.2.6: Potential Receptors Identified within the Radius of Influence for TC 015

Receptor	Distance from Drive Pit	Distance from Reception Pit	Comments
Groundwater abstractions			
None			
Buildings and Infrastructure			

Receptor	Distance from Drive Pit	Distance from Reception Pit	Comments
Residential properties along Nash Close and West Heath Lane	Drive Pit located near West Heath Lane. Nearest properties approximately 20m from the pit	Reception pit located on Nash Close. Nearest properties approximately 8.5m from the pit	Properties at edge of radius of influence would be affected less by dewatering
Railway line	Approximately 15m from pit	Approximately 20m from pit	
Surface waters			
None			
GWDTEs			
None			
Potentially contaminated land			
None			
Scheduled monuments and listed buildings			
None			

1.20 TC 016 – Cove Brook

Feature(s) requiring trenchless crossing	Railway
Trenchless crossing technique and characteristics	HDD technique Following details derived from site-specific design drawing: • Reaches a maximum depth of about 58.5mAOD and maximum depth below ground of 4.5m. • Shown on design drawings as 2m below the base of Cove Brook • Drive length: approximately 85m
Groundwater study area	GWSA-C

Geological and Hydrogeological Conditions at TC 016

1.20.1 The BGS geological map (BGS, 2018g) indicates that the bedrock at the crossing and in the surrounding area comprises the Camberley Sand Formation. Approximately 250m south is the boundary with the Windlesham Formation of sand, silt and clay.

1.20.2 Superficial deposits are expected to be variable in their nature. Much of the area is shown on the geological map (BGS, 2018g) to be absent of superficial coverage. However, Alluvium of clay, silt, sand and gravel is shown at the crossing associated with Cove Brook.

1.20.3 The aquifer designation map (Defra, 2018) indicates that the crossing is located within an area defined as a Secondary A bedrock aquifer. The Alluvium deposits are defined as a Secondary A superficial aquifer.

1.20.4 The nearest available BGS record, SU85NW172, is located approximately 970m northwest of the crossing. The record for this indicates the following conditions:

- 0 – 0.35mbgl: Topsoil;

- 0.35 – 0.9mbgl: Fine sand;
- 0.9 – 2.0mbgl: Fine sand; and
- the water strike was encountered at 1.35mbgl (approximately 63.65mAOD).

1.20.5 A second record was consulted to determine deeper conditions. Record SU85SE16 is located approximately 1.15km south of the crossing. The online record indicates the following ground conditions:

- 0 – 0.2mbgl: Clayey loamy soil;
- 0.2 – 0.7mbgl: Alluvium;
- 0.7 – 4.7mbgl: Bracklesham Beds; and
- the water strike was encountered at 57.8mAOD, with the ground level shown as 62.2mAOD, therefore the water strike was found at approximately 4.4mbgl.

1.20.6 During the 2018 ground investigation works, BH56 is shown as having been completed approximately 75m north of the crossing. The log record shows this was completed in December 2018, when groundwater levels may be seasonally higher. The following ground conditions are expected:

- 0 – 0.38mbgl: Made ground;
- 0.38 – 1.32mbgl: Silty sand;
- 1.32 – 2.15mbgl: Sandy clay;
- 2.15 – 10.55mbgl: Slightly silty sand; and
- groundwater strike was encountered at 1.40mbgl (approximately 60.57mAOD).

1.20.7 Groundwater levels have been measured manually on three separate occasions at location BH56, which is located at an elevation of 61.97mAOD and was completed to a depth of 10.55mbgl. These measurements indicate an average groundwater level of 1.56mbgl, or 60.41mAOD. No groundwater level data from a data logger is currently available for this borehole.

1.20.8 The BGS groundwater flooding susceptibility map (BGS, 2017) shows that the crossing is located within an area defined as having limited potential for groundwater flooding to occur, suggesting shallow groundwater conditions are not expected.

1.20.9 No EA groundwater level monitoring boreholes are available in the vicinity of the crossing.

Crossing TC 016 Assessment

1.20.10 Ground investigation, both historical (BGS, 2018a) and recent, confirmed groundwater strike at shallow levels ranging between 1.35mbgl and 4.4mbgl at locations local to the crossing. In addition, manual groundwater monitoring completed during the 2018 ground investigation shows an average groundwater level of 1.56mbgl. However, the BGS groundwater flooding susceptibility map (BGS, 2017) indicates that groundwater is not expected to be shallow. Based on available data, and allowing for a worst case scenario, groundwater is assumed to be shallow at this location. HDD methods do not require dewatering. However, it is likely that the water table would be intercepted, and that once installed, based on the pipeline's maximum depth of 4.5mbgl, it is expected that the pipeline over much of the length of crossing TC 016 would sit below the water table.

1.20.11 Ground investigation records encountered both bedrock and superficial deposits. Alluvium and superficial sands and gravels were encountered to depths of 0.7mbgl and 1.50mbgl. At locations closest to the crossing, Made Ground was encountered to a depth of 0.38mbgl. Underlying these, the Bracklesham Beds (of which the Camberley Sand Formation is a member) were encountered. Therefore, HDD has the potential to encounter deposits of Alluvium and the underlying Camberley sand bedrock. Where encountered together in succession, they are expected to be in hydraulic continuity with one another as there is an absence of any significant low permeability layer to separate them shown by ground investigation. As such, it is unlikely that this crossing would create a new connection of two aquifers during construction or operation.

1.21 TC 017 – North Side of Railway Embankment

Feature(s) requiring trenchless crossing	Railway Embankment
Trenchless crossing technique and characteristics	HDD technique Following details derived from site-specific design drawing: • A maximum depth below ground of HDD is 4.4m, and the maximum depth is 57.6mAOD. • Drive length: approximately 294m
Groundwater study area	GWSA-C

Geological and Hydrogeological Conditions at TC 017

1.21.1 The BGS geological map (BGS, 2018g) indicates that the bedrock at the crossing and in the surrounding area comprises the Camberley Sand Formation.

1.21.2 Superficial deposits are expected to be variable in their extent. Much of the area is shown on the geological map (BGS, 2018g) to be absent of superficial coverage. However, Alluvium of clay, silt, sand and gravel is shown to possibly encroach at the western end of the crossing, associated with Cove Brook.

1.21.3 The aquifer designation map (Defra, 2018) indicates that the crossing is located within an area defined as a Secondary A bedrock aquifer. The deposits of Alluvium are defined as a Secondary A superficial aquifer.

1.21.4 The nearest available BGS record, SU85NW172, is located approximately 980m northwest of the crossing. The online record for this indicates the following conditions:

- 0 – 0.35mbgl: Topsoil;
- 0.35 – 0.9mbgl: Fine sand;
- 0.9 – 2.0mbgl: Fine sand; and
- the water strike was encountered at 1.35mbgl (approximately 63.65mAOD).

1.21.5 A second record was consulted to determine deeper conditions. Record SU85SE16 is located approximately 1.18km south of the crossing. The online record indicates the following ground conditions:

- 0 – 0.2mbgl: Clayey loamy soil;
- 0.2 – 0.7mbgl: Alluvium;
- 0.7 – 4.7mbgl: Bracklesham Beds; and
- the water strike was encountered at 57.8mAOD, with the ground level shown as 62.2mAOD, therefore the water strike was found at approximately 4.4mbgl.

1.21.6 The BGS records detailed above are located at a similar elevation to that of the crossing.

1.21.7 During the 2018 ground investigation works, BH56 is shown as having been completed approximately 80m northwest of the crossing. The log record shows this was completed in December 2018, when groundwater levels may be seasonally higher. The following ground conditions are expected:

- 0 – 0.38mbgl: Made ground;
- 0.38 – 1.32mbgl: Silty sand;
- 1.32 – 2.15mbgl: Sandy clay;
- 2.15 – 10.55mbgl: Slightly silty sand; and
- groundwater strike was encountered at 1.40mbgl (approximately 60.57mAOD).

1.21.8 Groundwater levels have been measured manually on three separate occasions at location BH56, which is located at an elevation of 61.97mAOD and was completed to a depth of 10.55mbgl. These measurements indicate an average groundwater level of 1.56mbgl, or 60.41mAOD. No groundwater level data from a data logger is currently available for this borehole.

1.21.9 The BGS groundwater flooding susceptibility map (BGS, 2017) shows that the crossing is located within an area defined as having limited potential for groundwater flooding to occur, suggesting shallow groundwater conditions are not expected.

1.21.10 No EA groundwater level monitoring boreholes are available in the vicinity of the crossing.

Crossing TC 017 Assessment

1.21.11 Ground investigations, both recent and historical (BGS, 2018a), confirmed a groundwater strike at shallow levels ranging between 1.34 and 4.4mbgl, thereby suggesting shallow groundwater conditions at this location. In addition, manual groundwater monitoring completed as part of the 2018 ground investigation works indicates an average groundwater level of 1.56mbgl. Other evidence from the BGS groundwater flooding susceptibility map (BGS, 2017) does not support this, and instead suggests deeper groundwater. Due to the limited data specific to the location, and assuming a worst-case scenario, groundwater is assumed to be shallow at this location. HDD methods do not require dewatering to take place during construction. However, assuming a maximum pipeline depth of 4.4mbgl, much of the pipeline length for this crossing might sit below the water table following installation.

1.21.12 The geological map (BGS, 2018g) indicates that the crossing is largely absent of superficial deposits. However, ground investigation records in the surrounding areas of the crossing encountered Alluvium and deposits of gravelly sand to a depth of 1.5mbgl. Made Ground was encountered to a depth of 0.38m locally to the crossing. Elsewhere, fine sand, assumed to be the Camberley Sand, was encountered from 0.35mbgl. Underlying superficial deposits, silty sands and the Bracklesham Beds (of which the Camberley Sand is a member) were recorded. Assuming a maximum crossing depth of 4.4m, HDD therefore has the potential to encounter and intercept both superficial deposits and the Camberley Sand bedrock. Where these units are encountered together in succession, they are expected to be in hydraulic continuity with one another as there is an absence of any significant low permeability layer shown by ground investigation. Furthermore, the groundwater strikes recorded are shown at depths below the maximum recorded depths of any superficial deposits. As such, it is unlikely that this crossing would create a new connection of two aquifers during construction or operation.

1.22 TC 018 – Parallel to West Heath Adjacent Railway Embankment Northside

Feature(s) requiring trenchless crossing	Railway Embankment
Trenchless crossing technique and characteristics	HDD technique Following details assumed from typical details drawings: • Assumed a drilling depth of 5mbgl for this assessment • Drive length: approximately 443m
Groundwater study area	GWSA-C

Geological and Hydrogeological Conditions at TC 018

1.22.1 The BGS geological map (BGS, 2018g) indicates that the bedrock at the crossing and in the surrounding area comprises the Camberley Sand Formation.

1.22.2 Superficial deposits are expected to be variable in their nature and extent. Much of the area is shown on the geological map (BGS, 2018g) to be absent of superficial coverage. However, Alluvium of clay, silt, sand and gravel is shown to possibly encroach at the western end of the crossing, associated with Cove Brook.

1.22.3 The aquifer designation map (Defra, 2018) indicates that the crossing is located within an area defined as a Secondary A bedrock aquifer. The deposits of Alluvium are defined as a Secondary A superficial aquifer.

1.22.4 The nearest available BGS record, SU85NW339, is located approximately 500m north of the crossing. The online record for this indicates the following conditions:

- 0 – 0.20mbgl: Topsoil;
- 0.20 – 0.60mbgl: Sandy clay with some gravel;
- 0.6 – 2.0mbgl: Gravelly sandy silt;

- 2.0 – 5.0mbgl: Clayey silty sand; and
- the water strike is not indicated, but it is noted that the ground was very wet below 2.0m.

1.22.5 A second borehole record was consulted to determine deeper conditions. Record SU85SE171 is located approximately 760m southeast of the crossing. The online record indicates the following ground conditions:

- 0 – 0.6mbgl: Gravel and flint hardcore fill;
- 0.6 – 1.22mbgl: Silty sandy clay;
- 1.22 – 9.15mbgl: Fine-grained sand with traces of silt; and
- a water strike was encountered at 3.0mbgl (approximately 62mAOD).

1.22.6 The BGS records detailed above are located at a similar elevation to that of the crossing.

1.22.7 During the 2018 ground investigation works, BH56 is indicated as having been completed approximately 350m north-west of the crossing. The log record shows this was completed in December 2018, when groundwater levels may be seasonally higher. The following ground conditions are expected:

- 0 – 0.38mbgl: Made ground;
- 0.38 – 1.32mbgl: Silty sand;
- 1.32 – 2.15mbgl: Sandy clay;
- 2.15 – 10.55mbgl: Slightly silty sand
- groundwater strike was encountered at 1.40mbgl (approximately 60.57mAOD).

1.22.8 Groundwater levels have been measured manually on three separate occasions at location BH56, which is located at an elevation of 61.97mAOD and was completed to a depth of 10.55mbgl. These measurements indicate an average groundwater level of 1.56mbgl, or 60.41mAOD. No groundwater level data from a data logger is currently available for this borehole.

1.22.9 The BGS groundwater flooding susceptibility map (BGS, 2017) shows that the crossing is located within an area defined as having limited potential for groundwater flooding to occur, suggesting shallow groundwater conditions are not expected.

1.22.10 No EA groundwater level monitoring boreholes are available in the vicinity of the crossing.

Crossing TC 018 Assessment

1.22.11 Ground investigations, both recent and historical (BGS, 2018a), confirmed groundwater strikes at shallow levels ranging between 1.40 and 3.75mbgl. In addition, manual groundwater monitoring completed as part of the 2018 works indicates an average groundwater level of 1.56mbgl. However, other evidence does not support shallow groundwater conditions, including the BGS groundwater flooding susceptibility map (BGS, 2017). Due to limited additional data, and assuming a worst case scenario, it is assumed that shallow groundwater conditions may occur at this location. HDD does not require dewatering during construction. However, assuming a final pipeline depth of approximately 5mbgl, much of the pipeline length at this crossing may sit below the water table.

The geological map (BGS, 2018g) shows that much of the crossing is expected to be absent of superficial deposits. However, ground investigation records encountered sandy clays and gravelly sands to a maximum depth of 1.50mbgl. Made Ground has also been encountered locally. Underlying these, silty sands and fine sands were recorded. These deposits are assumed to represent the Camberley Sand Formation bedrock. HDD at a depth of approximately 5m therefore has the potential to encounter both superficial deposits (where present) and the Camberley Sand Formation bedrock. Where these units are found together, they would be expected to be in hydraulic continuity with one another as there is no significant low permeability layer to separate them shown by ground investigation. Furthermore, the shallowest recorded groundwater level is below the maximum recorded depth of any superficial deposits. As such, it is unlikely that this crossing would create a new connection of two aquifers during construction or operation.

1.23 TC 019 – A325 Farnborough Road

Feature(s) requiring trenchless crossing	A325
Trenchless crossing technique and characteristics	Auger bore technique Following details assumed from typical details drawings: • Assumes minimum depth of 2.0mbgl below services • Drive pit depth: assumed as 6.0mbgl • Drive pit length: approximately 11m • Drive pit width: approximately 3m • Reception pit depth: assumed as 6.0mbgl • Reception pit length: approximately 3m • Reception pit width: approximately 3m • Drive length: approximately 51m
Groundwater study area	GWSA-C

Geological and Hydrogeological Conditions at TC 019

1.23.1 The BGS geological map (BGS, 2018g) indicates that the bedrock at the crossing and in the surrounding area comprises the Camberley Sand Formation.

1.23.2 The geological map (BGS, 2018g) shows that the extent of superficial deposits is variable in this area. Superficial deposits are absent from the location of the crossing. However, approximately 220m northeast are localised deposits of River Terrace Deposits comprising sand and gravel.

1.23.3 The aquifer designation map (Defra, 2018) indicates that the crossing is located within an area defined as a Secondary A bedrock aquifer. The localised River Terrace Deposits to the east of the crossing are defined as Secondary A superficial aquifers, but the crossing does not intercept these.

1.23.4 The nearest available BGS investigation record, SU85NE167 (a trial pit), is located approximately 325m south of the crossing. The record for this indicates the following ground conditions:

- 0 – 0.3mbgl: Topsoil;
- 0.3 – 0.6mbgl: Silty fine sand;
- 0.6 – 2.2mbgl: Silty fine sand; and
- no groundwater observations are recorded.

1.23.5 An additional record, SU85NE165, was consulted to establish groundwater conditions. SU85NE165 is located approximately 440m south of the crossing. The online record indicates the following conditions:

- 0 – 0.35mbgl: Topsoil (made ground);
- 0.35 – 0.95mbgl: Clayey sand and gravel;
- 0.95 – 15.0mbgl: Clayey sand; and
- groundwater was encountered at 7.10mbgl and rose to 6.10mbgl after 20 minutes (strike at approximately 62.9mAOD).

1.23.6 The two BGS records detailed above are located at a slightly lower elevation to that of the crossing.

1.23.7 During the 2018 ground investigation works, the nearest available ground investigation record is that of BH55. BH55 is shown immediately east of the crossing and is shown to have been completed in mid-August 2018, when groundwater conditions are likely to be lower than the winter maximum. The record for this borehole indicates the following conditions:

- 0 – 1.0mbgl: Silty sand;
- 1.0 – 1.10mbgl: Clayey sand;
- 1.10 – 1.50mbgl: Slightly gravelly sand;
- 1.50 – 10.45mbgl: Slightly silty sand; and
- groundwater strike was encountered at 3.75mbgl (approximately 68.25mAOD).

1.23.8 Groundwater levels have been measured manually on five separate occasions at BH55, which is located at an elevation of 72.93mAOD and was completed to a depth of 10.45mbgl. These measurements indicate an average groundwater level of 8.58mbgl, or 64.35mAOD. The data logger in BH55 has recorded the highest groundwater level as 5.40mbgl although this level only occurred for a short time with the level being above 6.0mbgl for two days. Typically groundwater levels were recorded at around 9mAOD.

1.23.9 The BGS groundwater flooding susceptibility map (BGS, 2017) shows that the crossing is located within an area defined as having limited potential for groundwater flooding to occur, suggesting shallow groundwater conditions are not expected.

1.23.10 No EA groundwater level monitoring boreholes are available in the vicinity of the crossing.

Crossing TC 019 Assessment

1.23.11 Ground investigations, both recent and historical (BGS, 2018a), identified groundwater strikes at reasonably shallow depths ranging between 3.75mbgl and 7.10mbgl (although the latter was at a distance from the crossing). However, manual groundwater monitoring completed as part of the 2018 ground investigation works shows an average groundwater level of 8.58mbgl at the crossing and the continuous logger record shows the highest recorded groundwater level of 5.40mbgl, although such high levels only occurred for a short time. Other evidence from the BGS groundwater flooding susceptibility map (BGS, 2017) indicates that shallow groundwater is not expected. Assuming that the recent monitoring data is most representative, and groundwater levels do not rise substantially above 6.0mbgl for prolonged periods at wetter times of the year, groundwater is not expected at depths close to the ground surface. Dewatering for the driving and reception pits for auger bores is therefore not likely to be required.

1.23.12 Following installation, based on a maximum depth of 6mbgl of auger boring, the groundwater table may be intercepted for short periods with the highest groundwater levels, although much of the length of the pipeline is likely to sit above the water table for much of the year.

1.23.13 Superficial deposits in this area are expected to be variable in nature and extent, with the geological map (BGS, 2018g) showing an absence of coverage over the crossing itself. Despite this, sand and gravel deposits were recorded on ground investigation records local to the crossing to a maximum depth of 1.50mbgl. Underlying these, silty sands and clayey sands are found to depths of greater than 15.0mbgl. These are assumed to represent the Camberley Sand Formation bedrock. Therefore, assuming a maximum depth for the pipeline of 6m, auger boring has the potential to encounter both superficial deposits and the underlying bedrock. There is no significant low permeability layer shown to separate these units, and thus where encountered together there is potential for hydraulic continuity. Furthermore, no groundwater has been encountered at shallow depths within the superficial aquifer units. As such, it is unlikely that this crossing would create a new connection of two aquifers during construction or operation.

1.23.14 As the auger bore pits are unlikely to intercept the groundwater table, and any groundwater dewatering required would be minimal if the highest groundwater level were encountered, a dewatering assessment has not been undertaken.

1.24 TC 020 – Blackwater Valley

Feature(s) requiring trenchless crossing	The North Downs rail line, the Ascot to Guildford rail line, A331 and River Blackwater
Trenchless crossing technique and characteristics	The crossing at Blackwater Valley has been divided into four sections; three of these sections would be completed using auger bore methods, while one would use open cut techniques. It is proposed that sections 1, 2 and 4 would be auger bore using a total of five pits, while section 3 is open cut. The following presents the dimensions of the five pits required over the sections. **1. Pit No. 1 details:**

	Drive pit for section 1 Length: 18m Width: 5m Depth: 4mbgl **2. Pit No. 2 details:** Reception pit for section 1 and section 2 Length: 5m Width: 5m Depth: 4mbgl **3. Pit No. 3 details:** Drive pit for section 2 Length: 18m Width: 5m Depth: 6mbgl **4. Pit No. 4 details:** Reception pit for section 4 Length: 5m Width: 5m Depth: 4m **5. Pit No. 5 details:** Drive pit for section 4 Length: 18m Width: 5m Depth: 4mbgl Total drive length: approximately 433m
Groundwater study area	GWSA-C

Geological and Hydrogeological Conditions at TC 020

1.24.2 The following conditions are relevant for all four of the sections of the total crossing. Distances to certain points have therefore been estimated from the overall crossing length.

1.24.3 The BGS geological map (BGS, 2018g) indicates that the bedrock at the crossing and in the surrounding areas comprises the Camberley Sand Formation.

1.24.4 Superficial deposits are expected to be variable in their nature (BGS, 2018g). Deposits of Alluvium, comprising clay, silt, sand and gravel, and River Terrace Deposits, comprising sand and gravel, are expected along the course of River Blackwater. Deposits of Head comprising sand and gravel are expected in localised areas to the west and east.

1.24.5 The aquifer designation map (Defra, 2018) shows that the crossing is located within an area classed as a Secondary A bedrock aquifer. All of the superficial deposits are shown to be classed as a Secondary A superficial aquifer.

1.24.6 The nearest available BGS borehole record located approximately 360m northeast of the crossing, SU85NE99, indicates the following ground conditions:

- 0.0 – 0.3mbgl: Clayey, loamy soil;

- 0.3 – 4.9mbgl: Sandy gravel (River Terrace Deposits);
- 4.9 – 6.5mbgl: Clayey sand (Bracklesham Beds); and
- water was struck at 62.6mAOD, and the surface level is given as 65.1mAOD. This equates to approximately 2.5mbgl.

1.24.7 The BGS record is at a slightly higher topographical elevation than the crossing, at 65mAOD compared to 62mAOD at the crossing.

1.24.8 During the 2018 ground investigation works, BH151 and BH152 were completed in proximity to the immediate eastern and western ends of the trenchless crossing respectively. BH151 was completed at the end of August 2018. The groundwater levels observed in August are likely to be lower than the maximum level seen during winter months. The log record indicates the following ground conditions were encountered:

- 0 – 1.0mbgl: Made ground;
- 1.00 – 1.30mbgl: Clay;
- 1.3 – 3.50mbgl: Sand;
- 3.5 – 3.9mbgl: Clay;
- 3.9 – 8.4mbgl: Gravel;
- 8.4 – 20.028mbgl: Sand; and
- water was encountered at 1.40mbgl and 3.18mbgl (61.6mAOD and 59.82mAOD).

BH152 is located immediately adjacent to the western end of the crossing. The preliminary log record for this location indicates this was completed in December 2018, when groundwater levels may be seasonally high. The following ground conditions were recorded:

- 0 – 1.48mbgl: Made Ground;
- 1.48 – 1.95mbgl: Silty clay;
- 1.95 – 3.94mbgl: Gravelly sand;
- 3.94 – 5.18mbgl: Sand;
- 5.18 – 17.20mbgl: Silty sand; and
- No water strikes are noted due to the addition of a water flush.

1.24.9 Groundwater levels have been measured manually on five separate occasions at location BH151, which is located at an elevation of 63.55mAOD and was completed to a depth of 20.28mbgl. These measurements indicate an average groundwater level of 1.69mbgl, or 61.86mAOD. No reliable groundwater level data is currently available for the groundwater level logger installed in BH151. No groundwater level data is available for BH152.

1.24.10 No EA groundwater level monitoring boreholes are available in the vicinity of the crossing. Groundwater flooding susceptibility mapping (BGS, 2017) indicates that the crossing is located within an area with limited potential for groundwater flooding to occur.

Crossing TC 020 Assessment

1.24.11 Ground investigation, both recent and historical (BGS, 2018a), confirmed shallow groundwater strikes ranging between 1.4 and 3.18mbgl adjacent to the crossing. In addition, groundwater monitoring completed as part of the 2018 ground investigation works indicate an average groundwater level of 1.69mbgl at a location close to the crossing. Shallow groundwater conditions are likely for this location. Assuming a maximum HDD depth of 8.1mbgl, it is expected that the water table would be intercepted, and following installation, a large proportion of the pipeline would sit below the water table along crossing TC 020.

1.24.12 Following installation, based on the assumption of a maximum depth of 6mbgl of auger boring, the groundwater table is likely to be intercepted, and much of the length of the pipeline would sit below the water table.

1.24.13 The nature of superficial deposits is expected to be variable. BGS boreholes and ground investigation records indicate superficial deposits to maximum depths of between 8.4 and 4.9mbgl, with sands and clays found underlying these. This information suggests the presence of the Bracklesham Group. Both the HDD and the auger bore methods have the potential to encounter both superficial deposits and the Bracklesham Group. These aquifer units are expected to be in hydraulic continuity with each other as no significant low permeability layer to separate them is shown by ground investigation. As such, it is unlikely that this crossing would create a new connection of two aquifers during construction or operation.

1.24.14 For the calculation of effects due to dewatering, calculated values of hydraulic conductivity have been used, which were completed as part of ground investigation works at BH151. The average hydraulic conductivity value derived from these and used in subsequent calculations is 1.77E-04m/s.

1.24.15 The expected maximum groundwater level has been estimated as 1.0mbgl, assuming that shallow groundwater encountered at approximately 1.4mbgl may show variability over the course of a year.

1.24.16 Dewatering calculations have been completed for the three sections of the crossing which are proposed as trenchless auger bore techniques.

Section 1

1.24.17 Table 8.2.7 presents the input and results of the radius of influence calculations for section 1 of the Blackwater Valley crossing. Additional input parameters and results used for the calculation of dewatering rates are given in Table 8.2.8. Potential receptors within the calculated radius of influence have been identified as detailed in Table 8.2.9.

Table 8.2.7: Input and Results for Calculating the Radius of Influence for TC 020 Section 1

Parameter	Drive Pit Value (Pit 1)	Reception Pit Value (Pit 2)
Length (m)	18	5

Parameter	Drive Pit Value (Pit 1)	Reception Pit Value (Pit 2)
Width (m)	5	5
Maximum pit depth (m)	4	4
Expected groundwater level (mbgl)	1.0	1.0
Calculated drawdown (m)	3.0	3.0
Hydraulic conductivity, K (m/s)	1.77E-04	1.77E-04
R (m)	119.7	119.7
Re (m)	5.4	2.8
Total radius of influence Ro (m)	125	123

Table 8.2.8: Input and Results for Estimating Dewatering Rate for TC 020 Section 1

Parameter	Drive Pit Value (Pit 1)	Reception Pit Value (Pit 2)
H, saturated aquifer thickness (assumed as gravelly sand and underlying sand thicknesses derived in GI) (m)	19.28	19.28
Q, dewatering rate	1,626m^3/day	1,359m^3/day
	18.8l/s	15.7l/s

Table 8.2.9: Potential Receptors Identified within the Radius of Influence for TC 020 Section 1

Receptor	Distance from Drive Pit (Pit 1)	Distance from Reception Pit (Pit 2)	Comments
Groundwater abstractions			
None			
Buildings and Infrastructure			
Ship Lane Cemetery	Approximately 40m southwest of the pit	Approximately 100m southwest of the pit,	Would be less affected by dewatering from the reception pit
Residential properties	Immediately adjacent to Order Limits. Nearest property approximately 30m.	Unlikely to impact residential properties; unlabelled building adjacent to cemetery approximately 60m southwest.	
Retail park	Approximately 40m northwest of the pit	Approximately 70mnorthwest of the pit	
Surface waters			
River Blackwater	Flows through Order Limits; approximately 110m northeast of the pit	Approximately 65m north of the pit	
GWDTEs			
Blackwater Valley Frimley Hatches	Within Order Limits; approximately 55m from the pit	Reception pit location within GWDTE	
Potentially contaminated land			
Farnborough (north) (former railway sidings)	Within Order Limits and approximately 12m west of the pit	Approximately 80m west of the pit	

Receptor	Distance from Drive Pit (Pit 1)	Distance from Reception Pit (Pit 2)	Comments
South of Frimley Station (former landfill)	Beyond radius	Within Order Limits and approximately 115m east of the pit	
Scheduled monuments and listed buildings			
None			

Section 2

1.24.18 Table 8.2.10 presents the input and results of the radius of influence calculations for section 2 of the Blackwater Valley crossing. Additional input parameters and results used for the calculation of dewatering rates are given in Table 8.2.11. Potential receptors within the calculated radius of influence have been identified as detailed in Table 8.2.12.

Table 8.2.10: Input and Results for Calculating the Radius of Influence for TC 020 Section 2

Parameter	Drive Pit Value (Pit 3)	Reception Pit Value (Pit 2)
Length (m)	18	5
Width (m)	5	5
Maximum pit depth (m)	6	4
Expected groundwater level (mbgl)	1.0	1.0
Calculated drawdown (m)	5.0	3.0
Hydraulic conductivity, K (m/s)	1.77E-04	1.77E-04
R (m)	199.6	119.7
Re (m)	5.4	2.8
Total radius of influence Ro (m)	205	123

Table 8.2.11: Input and Results for Estimating Dewatering Rate for Section 2

Parameter	Drive Pit Value (Pit 3)	Reception Pit Value (Pit 2)
H, saturated aquifer thickness (assumed as gravelly sand and underlying sand thicknesses derived in GI) (m)	19.28	19.28
Q, dewatering rate	2,212m^3/day	1,359m^3/day
	25.6l/s	15.7l/s

Table 8.2.12: Potential Receptors Identified within the Radius of Influence for TC 020 Section 2

Receptor	Distance from Drive Pit (Pit 3)	Distance from Reception Pit (Pit 2)	Comments
Groundwater abstractions			
None			
Buildings and Infrastructure			
Ship Lane Cemetery	Beyond radius	Approximately 100m southwest	
Residential properties	Unlikely to impact residential properties	Unlikely to impact residential properties;	

Receptor	Distance from Drive Pit (Pit 3)	Distance from Reception Pit (Pit 2)	Comments
		unlabelled building adjacent to cemetery approximately 60m southwest.	
Retail park	Beyond radius	Approximately 70m northwest of the pit	
Surface waters			
River Blackwater	Approximately 5m to 10m of the pit	Approximately 65m north of the pit	
Unnamed standing water body	Approximately 50m of the pit		
GWDTEs			
Blackwater Valley, Frimley Hatches	Within Order Limits; approximately 135m from the pit	Reception pit location within GWDTE	
Potentially contaminated land			
Farnborough (north) (former railway sidings)	Beyond radius	Approximately 80m west of the pit	
South of Frimley Station (former landfill)	Within Order Limits and approximately 25m east of the pit	Within Order Limits and approximately 115m east of the pit	
Scheduled monuments and listed buildings			
None			

Section 4

1.24.19 Table 8.2.13 presents the input and results of the radius of influence calculations for section 4 of the Blackwater Valley crossing. Additional input parameters and results used for the calculation of dewatering rates are given in Table 8.2.14. Potential receptors within the calculated radius of influence have been identified as detailed in Table 8.2.15.

Table 8.2.13: Input and Results for Calculating the Radius of Influence for TC 020 Section 4

Parameter	Drive pit value (Pit 5)	Reception pit value (Pit 4)
Length (m)	18	5
Width (m)	5	5
Maximum pit depth (m)	4	4
Expected groundwater level (mbgl)	1.0	1.0
Calculated drawdown (m)	3.0	3.0
Hydraulic conductivity, K (m/s)	1.77E-04	1.77E-04
R (m)	119.7	119.7
Re (m)	5.4	2.8
Total radius of influence Ro (m)	125	123

Table 8.2.14: Input and Results for Estimating Dewatering Rate for TC 020 Section 4

Parameter	Drive Pit Value (Pit 5)	Reception Pit Value (Pit 4)
H, saturated aquifer thickness (assumed as gravelly sand and underlying sand thicknesses derived in GI) (m)	19.28	19.28
Q, dewatering rate	1,626m^3/day	1,359m^3/day
	18.8l/s	15.7l/s

Table 8.2.15: Potential Receptors Identified within the Radius of Influence for TC 020 Section 4

Receptor	Distance from Drive Pit (Pit 5)	Distance from Reception Pit (Pit 4)	Comments
Groundwater abstractions			
None			
Buildings and Infrastructure			
Factory (SC Johnson)	Nearest buildings associated with site approximately 90m northeast of the pit	Nearest buildings associated with site approximately 135m northeast of the pit.	
Surface waters			
Drain	Approximately 20m west of the pit	Approximately 20m east of the pit	
Drain	Approximately 60m southeast of the pit	Approximately 70m southeast of the pit	
Unnamed standing water body	Approximately 45m west of the pit	Approximately 5m west of the pit	
GWDTEs			
Blackwater Valley, Frimley Hatches	Just outside of radius	Approximately 110m south of the pit	
Potentially contaminated land			
Frimley Station (former railway sidings)	Approximately 55m northwest of the pit	Approximately 40m north of the pit	
South of Frimley Station (former landfill)	Approximately 40m west of the pit	Pit located within designated area	
Johnson Wax Ltd, Frimley (Former COMAH site)	Approximately 75m northeast of the pit	Approximately 105m northeast of the pit	
Scheduled monuments and listed buildings			
None			

1.25 TC 021 – A322 Lightwater Bypass

Feature(s) requiring trenchless crossing	A322 Lightwater Bypass
Trenchless crossing technique and characteristics	Auger bore technique Following details derived from site-specific design drawing: • Drive pit depth: approximately 7.2mbgl • Drive pit length: approximately 5.8m • Drive pit width: approximately 2m

	• Reception pit depth: approximately 5.8mbgl • Reception pit width: approximately 3m • Reception pit length: approximately 4m • Drive length: approximately 58m
Groundwater study area	GWSA-C

Geological and Hydrogeological Conditions at TC 021

1.25.1 The BGS geological map (BGS, 2018h) indicates that bedrock is variable in the region. To the north and underlying the crossing, the Windlesham Formation is mapped. Bedrock to the south of the crossing is expected to comprise the Camberley Sand Formation. Both of these are continuous to the east and west.

1.25.2 The geological map (BGS, 2018h) shows a notable absence of superficial deposits in this area, both at the crossing and its surroundings.

1.25.3 The aquifer designation map (Defra, 2018) shows the crossing is located within an area classed as a Secondary A bedrock aquifer.

1.25.4 The nearest BGS borehole record which recorded groundwater is located 1.9km northeast of the crossing, SU96SE34, and indicates the following ground conditions:

- 0 – 0.75mbgl: Topsoil;
- 0.75 – 1.65mbgl: Peat;
- 1.65 – 1.87mbgl: Gravel;
- 1.87 – 2.74mbgl: Fine sand; and
- groundwater was first encountered at 1.65mbgl.

1.25.5 It is worth noting that the BGS record is at a considerably lower topographical elevation than that of the crossing.

1.25.6 During the 2018 ground investigation, BH39 was completed in September 2018, 62m southeast of the crossing. The groundwater level observed in September is likely to be lower than the maximum level seen during winter months. The log record of this indicates the following ground conditions:

- 0 – 0.3mbgl: Sandy topsoil;
- 0.3 – 15.40mbgl: Alternating layers of sand and clay; and
- no groundwater strikes were observed during drilling due to the addition of water flush.

1.25.7 Groundwater levels have been measured manually on four separate occasions at location BH39, which is located at an elevation of 51.49mAOD and was completed to a depth of 15.72mbgl. These measurements indicate an average groundwater level of 3.81mbgl, or 47.68mAOD. No reliable data are currently available from the groundwater level logger installed in BH39.

1.25.8 The BGS groundwater flooding susceptibility map (BGS, 2017) indicates the crossing is located within an area with limited potential for groundwater flooding to occur.

1.25.9 As part of the EA groundwater monitoring network, the Brock Cottage OBH hydrometric monitoring location, approximately 440m northeast of the crossing, recorded a maximum water level of 7.75mbgl (41.9mAOD) and a minimum water level of 9.10mbgl (37.6mAOD).

Crossing TC 021 Assessment

1.25.10 The nearest BGS ground investigation record (BGS, 2018a) is located almost 2km away. The local ground investigation did not record any groundwater up to a depth of 15mbgl and the EA monitoring records indicate that maximum groundwater levels are at 7.75mbgl. The absence of shallow groundwater conditions is reinforced by the BGS groundwater flooding susceptibility map (BGS, 2017), which indicate groundwater flooding potential is limited. However, groundwater monitoring completed as part of the 2018 ground investigation indicated an average groundwater level of 3.81mbgl locally to the crossing with the highest value measured as 3.12mbgl.

1.25.11 The auger bore approach requires the excavation of two pits of around 7m and 6m deep. Based on the information available at the time of writing, it is uncertain whether these pits would intercept the water table. Considering a worst case scenario and assuming groundwater would be encountered at approximately 3.8mbgl, it is assumed that the water table would be intercepted and therefore require dewatering.

1.25.12 There are no superficial deposits indicated as present at the site. However, BGS records did encounter gravel to a depth of 1.87mbgl and a thickness of approximately 20cm. Auger bore methods are likely to encounter the Camberley Sand, as alternating sand and clay layers were encountered in a recent investigation commencing at 0.3mbgl. Where localised deposits of superficials may be present, both these and the bedrock are expected to be encountered, thereby forming a potential pathway between two aquifer units. However, as the superficial deposits appear to be of limited thickness, it is unlikely these will have a water table associated with them, and thus no hydraulic continuity is expected. As such, it is unlikely that this crossing would create a new connection of two aquifers during construction or operation.

1.25.13 For the calculation of effects due to dewatering, calculated values of hydraulic conductivity have been used, completed as part of the 2018 ground investigation works. The average hydraulic conductivity value from these calculations is 7.57E-07m/s.

1.25.14 The expected maximum groundwater level has been estimated as 3.0mbgl, assuming that shallow groundwater measured at approximately 3.12mbgl may show variability over the course of a year.

1.25.15 Table 8.2.16 presents the input and results of the radius of influence calculations. Additional input parameters and results used for the calculation of dewatering rates are given in Table 8.2.17. Potential receptors within the calculated radius of influence have been identified as detailed in Table 8.2.18.

Table 8.2.16: Input and Results for Calculating the Radius of Influence for TC 021

Parameter	Drive Pit Value	Reception Pit Value
Length (m)	5.8	4
Width (m)	2	3
Maximum pit depth (m)	7.2	5.8
Expected groundwater level (mbgl)	3.0	3.0
Calculated drawdown (m)	3.2	1.8
Hydraulic conductivity, K (m/s)	7.57E-07	7.57E-07
R (m)	11	7.3
Re (m)	1.9	2.0
Total radius of influence Ro (m)	13	9

Table 8.2.17: Input and Results for Estimating Dewatering Rate for TC 021

Parameter	Drive Pit Value	Reception Pit Value
H, saturated aquifer thickness (assumed as interbedded sands derived in GI) (m)	11.4	11.4
Q, dewatering rate	9.3m^3/day	8.1m^3/day
	0.11l/s	0.09l/s

Table 8.2.18: Potential Receptors Identified within the Radius of Influence for TC 021

Receptor	Distance from Drive Pit	Distance from Reception Pit	Comments
Groundwater abstractions			
None			
Buildings and Infrastructure			
None			
Surface waters			
None			
GWDTEs			
None			
Potentially contaminated land			
None			
Scheduled monuments and listed buildings			
None			

1.26 TC 022 – Hale Bourne

Feature(s) requiring trenchless crossing	Two watercourses – Windle Brook and Mill Bourne
Trenchless crossing technique and characteristics	HDD technique Following details assumed from typical details drawings:

	• Assumed a maximum drilling depth of 5mbgl for this assessment • Drive length: approximately 33m
Groundwater study area	GWSA-C

Geological and Hydrogeological Conditions at TC 022

1.26.1 The BGS geological map (BGS, 2018h) indicates that the bedrock underlying the crossing comprises the Windlesham Formation of sand. Approximately 50m to the east of the crossing, the Bagshot Formation of sand is shown to be present.

1.26.2 Superficial deposits are expected to be variable in their extent. The geological map (BGS, 2018h) shows that Alluvium comprising sand, silt and clay is expected at the crossing and its immediate surroundings.

1.26.3 The aquifer designation map (Defra, 2018) indicates that the crossing is located within an area classed as a Secondary A bedrock aquifer, while the deposits of Alluvium are classed as a Secondary A superficial aquifer.

1.26.4 The nearest BGS borehole record, SU96SW105, is located approximately 110m southwest of the crossing. The online record for this indicates the following ground conditions:

- 0 – 0.3mbgl: Topsoil;
- 0.3 – 1.05mbgl: Sand and gravel;
- 1.05 – 4.57mbgl: Fine sand; and
- no groundwater was encountered.

1.26.5 An additional record, SU96SW159, is located approximately 500m west of the crossing and was consulted to determine deeper geological conditions and groundwater observations. The online record indicates the following conditions:

- 0 – 1.0mbgl: Made ground;
- 1.0 – 3.80mbgl: Silty clay;
- 3.80 – 6.80mbgl: Clayey silty sand;
- 6.80 – 7.80mbgl: Silty sand;
- 7.8 – 12.00mbgl: Silty clay and silty sand; and
- groundwater was first encountered at 7.3mbgl, with a rest water level the following day at 3.5mbgl (approximately 32.7 and 36.5mAOD respectively).

1.26.6 The two BGS records detailed above are shown at approximately similar elevations to that of the crossing itself.

1.26.7 During the 2018 ground investigation works, no boreholes were completed locally to the proposed crossing. The nearest ground investigation record is that of BH39, located approximately 610m southwest of the crossing. BH39 was completed in September 2018. The groundwater levels observed at this time may be lower than the maximum level seen during winter months. The log record for this location indicates the following ground conditions:

- 0 – 0.3mbgl: Sandy topsoil;
- 0.3 – 15.4mbgl: Alternating layers of sand and clay; and
- no groundwater strikes were observed during drilling due to the addition of water flush.

1.26.8 8.25.7 Groundwater levels have been measured manually on four separate occasions at location BH39, which is located at an elevation of 51.49mAOD and was completed to a depth of 15.72mbgl. These measurements indicate an average groundwater level of 3.81mbgl, or 47.68mAOD. No reliable data are currently available from the groundwater level logger installed in BH39.

1.26.9 The BGS groundwater flooding susceptibility map (BGS, 2017) indicates that the crossing is located within an area with limited potential for groundwater flooding to occur.

1.26.10 As part of the EA groundwater level monitoring network, the nearest hydrometric monitoring point is Brock Cottage OBH, located approximately 2.43km northeast of this area of the route. Monitoring data indicates the maximum groundwater level here is 4.75mbgl (41.98mAOD), while the minimum water level is 9.11mbgl (37.62mAOD).

Crossing TC 022 Assessment

1.26.11 During historical ground investigations (BGS, 2018a), groundwater was first encountered at a depth of 7.3m, which rose to 3.5m. The most recent ground investigation did not record any groundwater strikes, although subsequent manual groundwater monitoring at the same location identified an average groundwater level of 3.81mbgl. EA monitoring records for a location approximately 2.5km away also suggest relatively shallow groundwater levels ranging between 4.8mbgl and 9.1mbgl. However, BGS data (BGS, 2017) shows that the potential for groundwater flooding is limited, therefore indicating groundwater levels that are not close to the ground surface. Assuming an HDD depth of 5mbgl, based on currently available data and a worst case scenario, it is likely that the groundwater table would be encountered (according to the average recorded depths from recent monitoring). HDD does not require dewatering, but following installation, the pipeline would likely sit below the water table, at least for part of the year.

1.26.12 Superficial coverage is expected to be variable. This is confirmed by the ground investigation records, not all of which encountered superficial deposits. Where encountered, sand and gravels assumed to represent the Alluvium were found to a depth of 1.05mbgl. Underlying these were fine sands and equivalent deposits of interbedded clays and sands, and silty sands. These are assumed to represent the Windlesham Formation, which was encountered at 0.3mbgl at its shallowest. HDD therefore has the potential to encounter superficial deposits (where present) and the underlying Windlesham Formation bedrock. Where found together, these aquifer units would be expected to be continuous as there is no significant low permeability layer shown to separate them by ground investigation records. Furthermore, the shallowest recorded groundwater level is below the maximum recorded depth of any superficial deposits. As such, it is unlikely that this crossing would create a new connection of two aquifers during construction or operation.

1.27 TC 023 – Windlesham Road

Feature(s) requiring trenchless crossing	Windlesham Road
Trenchless crossing technique and characteristics	HDD/auger bore/open cut There are no site-specific details available. The following details are taken from typical details and assumptions. Following details assumed from HDD typical details drawings: • Assumed a depth of 5mbgl for this assessment • Drive length: unknown at this stage Following details assumed from auger bore typical details drawings: • Assumes minimum depth of 2.0mbgl below services • Drive pit depth: assumed as 6.0mbgl • Drive pit length: approximately 11m • Drive pit width: approximately 3m • Reception pit depth: assumed as 6.0mbgl • Reception pit length: approximately 3m • Reception pit width: approximately 3m • Drive length: approximately 67m
Groundwater study area	GWSA-C

Geological and Hydrogeological Conditions at TC 023

1.27.1 The BGS geological map (BGS, 2018i) indicates that the crossing is located in an area where the underlying bedrock comprises the Bagshot Formation of sand. Approximately 100m to the north of the crossing, the bedrock is shown to comprise the Windlesham Formation, also of sand.

1.27.2 Superficial deposits are mapped as being variable in their presence and nature. The geological map (BGS, 2018i) shows there are no deposits at the crossing itself. However, 20m to the west, there are River Terrace Deposits of sand and gravel, and Alluvium is shown further west associated with Clappers Brook watercourse.

1.27.3 The aquifer designation map (Defra, 2018) shows that the crossing is located within an area classed as a Secondary A bedrock aquifer. The superficial deposits to the west of the crossing are classed as Secondary A superficial aquifers.

1.27.4 The nearest available BGS record, SU96SE63, is located approximately 270m west of the crossing. The log record for this indicates the following ground conditions:

- 0 – 0.3mbgl: Topsoil;
- 0.3 – 0.8mbgl: Alluvial gravels;
- 0.8 – 12.0mbgl: Bagshot Beds; and
- rest water level was encountered at 1.70mbgl (approximately 35.30mAOD).

1.27.5 The BGS record detailed above is located at a similar elevation to the crossing.

1.27.6 During the 2018 ground investigation works, BH37 was completed adjacent to the east of the crossing, at the end of July 2018. Groundwater levels at this time would be expected to be lower than their potential winter maximum. The log record for this location indicates the following ground conditions:

- 0 – 1.95mbgl: Gravelly sand;
- 1.95 – 2.90mbgl: Sandy clay;
- 2.90 – 10.30mbgl: Medium sand;
- 10.30 – 13.50mbgl: Sandy clay;
- 13.50 – 14.50mbgl: Silty clay;
- 14.50 – 16.50mbgl: Sand;
- 16.50 – 19.0mbgl: Sandy clay;
- 19.0 – 20.5mbgl: Silty sand;
- 20.5 – 22.0mbgl: Sandy clay;
- 22.0 – 25.0mbgl: Clayey sand; and
- groundwater strike was encountered at 3.70mbgl with the level falling to 3.75mbgl (approximately 35.25mAOD).

1.27.7 Groundwater levels have been measured manually on four separate occasions at BH37, which is located at an elevation of 38.87mAOD and was completed to a depth of 25.0mbgl. These measurements indicate an average groundwater level of 2.44mbgl, or 36.43mAOD. The data logger in BH37 has recorded the highest groundwater level as 2.60mbgl which is noted as being lower than the manual dip measurements so there is currently some uncertainty over the logger data.

1.27.8 The BGS groundwater flooding susceptibility map (BGS, 2017) indicates that the crossing is located within an area defined as having the potential for groundwater flooding of property situated below ground level.

1.27.9 As part of the EA groundwater level monitoring network, the nearest hydrometric monitoring point is Brock Cottage OBH, located approximately 400m northeast of this crossing. Monitoring data indicates the maximum groundwater level here is 4.75mbgl (41.98mAOD), while the minimum water level is 9.11mbgl (37.62mAOD).

Crossing TC 023 Assessment

1.27.10 Ground investigations, both recent and historical (BGS, 2018a), encountered groundwater at shallow levels ranging between 1.70mbgl and 3.70mbgl. In addition, manual groundwater monitoring completed as part of the 2018 ground investigation works indicates an average groundwater level of 2.44mbgl. Shallow groundwater conditions are confirmed by the BGS groundwater flooding susceptibility map (BGS, 2017), which shows there is potential for flooding, and by EA groundwater monitoring records, which indicate groundwater levels ranging between 4.75mbgl and 9.1mbgl at locations close to the crossing location. Based on available data, shallow groundwater is expected at this location. HDD methods do not require dewatering. However, assuming a depth of 5mbgl, it is likely that the groundwater table would be encountered, and that the pipeline would likely sit below the water table following installation if HDD methods are used.

1.27.11 Following installation, based on the assumption of a maximum depth of 6mbgl of auger boring, the groundwater table is likely to be intercepted, and much of the length of the pipeline is expected to sit below the water table following installation if auger boring is used.

1.27.12 Superficial deposits are expected to be variable in their nature and their extent. Ground investigations recorded Alluvial gravels, and gravelly sands to a maximum depth of 1.95mbgl. Below these, interbedded clays and sands which are assumed to represent the Bagshot Formation were identified. At their shallowest, these are found at depths of 0.8mbgl. Therefore, both HDD and auger bore methods are likely to intercept both superficial and bedrock units based on their maximum depths of installation. Data suggests the superficial deposits are not saturated, and there is no low permeability horizon identified separating superficial and bedrock deposits. As such, it is unlikely that this crossing would create a new connection of two aquifers during construction or operation.

1.27.13 For the calculation of effects due to dewatering, published values of hydraulic conductivity have been used. Given the mixed typology ranging from gravels to clay, an average hydraulic conductivity of 1.0E-04m/s has been selected for this assessment.

1.27.14 The expected maximum groundwater level has been estimated as 1.5mbgl, assuming that shallow groundwater encountered at approximately 1.7mbgl may show variability over the course of a year.

1.27.15 Table 8.2.19 presents the input and results of the radius of influence calculations. Additional input parameters and results used for the calculation of dewatering rates are given in Table 8.2.20. Potential receptors within the calculated radius of influence have been identified as detailed in Table 8.2.21.

Table 8.2.19: Input and Results for Calculating the Radius of Influence for TC 023

Parameter	Drive Pit Value	Reception Pit Value
Length (m)	11	3
Width (m)	3	3
Maximum pit depth (m)	6	6
Expected groundwater level (mbgl)	1.5	1.5
Calculated drawdown (m)	4.50	4.50
Hydraulic conductivity, K (m/s)	1.00E-04	1.00E-04
R (m)	135	135
Re (m)	3.2	1.7
Total radius of influence Ro (m)	138	137

Table 8.2.20: Input and Results for Estimating Dewatering Rate for TC 023

Parameter	Drive Pit Value	Reception Pit Value
H, saturated aquifer thickness (assumed as interbedded sands plus the gravel aquifer thickness derived in GI) (m)	23.5	23.5

Parameter	Drive Pit Value	Reception Pit Value
Q, dewatering rate	1,383m^3/day	1,182m^3/day
	16.0l/s	13.7l/s

Table 8.2.21: Potential Receptors Identified within the Radius of Influence for TC 023

Receptor	Distance from Drive Pit	Distance from Reception Pit	Comments
Groundwater abstractions			
None			
Buildings and Infrastructure			
Residential and farm properties, with residential access roads	Roads within Order Limits. Nearest property approximately 15m west of the pit	Roads within Order Limits. Nearest property approximately 25m east of the pit	
Surface waters			
None			
GWDTEs			
None			
Potentially contaminated land			
None			
Scheduled monuments and listed buildings			
Listed building – Steep Acre Farm, Grade II, listed on 28/02/1995	Approximately 112m of the pit	Approximately 65m from the pit	Would be less affected by dewatering at drive pit

1.28 TC 024 – Chobham Common

Feature(s) requiring trenchless crossing	Chobham Common
Trenchless crossing technique and characteristics	HDD Following details assumed from HDD typical details drawings: • Assumed a maximum drilling depth of 5mbgl for this assessment • Drive length: approximately 237m
Groundwater study area	GWSA-C

Geological and Hydrogeological Conditions at TC 024

1.28.1 The BGS geological map (BGS, 2018i) indicates that the bedrock at the crossing comprises the Windlesham Formation of sand and the Bagshot Formation of sand. The Bagshot Formation encroaches midway along the crossing, while the Windlesham Formation is present elsewhere.

1.28.2 Superficial deposits are shown to be variable in both their nature and their extent. Over the crossing, deposits of peat are mapped as variably present (BGS, 2018i). Approximately 20m to the southeast of the crossing, localised areas of River Terrace Deposits (undifferentiated) of sand and gravel are indicated. The wider area comprises these deposits and areas absent of superficial deposits.

1.28.3 The aquifer designation map (Defra, 2018) indicates that the crossing is located within an area defined as a Secondary A bedrock aquifer. The localised deposits of River Terrace Deposits are classed as Secondary A superficial aquifer. Peat is defined as Unproductive superficial strata.

1.28.4 The nearest available BGS record, SU96SE47, is located approximately 90m northwest of the crossing. The online record for this indicates the following ground conditions:

- 0 – 0.35mbgl: Clayey topsoil;
- 0.35 – 0.75mbgl: Clay;
- 0.75 – 1.83mbgl: Clay with traces of gravel;
- 1.83 – 6.1mbgl: Fine sand, clayey in parts; and
- groundwater was first encountered at 0.6mbgl (approximately 37.4mAOD).

1.28.5 The BGS record detailed above is located at a similar observation to that of the crossing.

1.28.6 During the 2018 ground investigation works, BH35 was completed immediately adjacent to the crossing at the west. This borehole was completed in October 2018 when groundwater levels would be expected to be below their potential maximum. The log record for this location indicates the following ground conditions:

- 0 – 0.2mbgl: Topsoil;
- 0.2 – 2.20mbgl: Slightly clayey sand;
- 2.2 – 2.50mbgl: Slightly sandy clay;
- 2.50 – 9.60mbgl: Slightly silty sand;
- 9.60 – 10.0mbgl: Clay;
- 10.0 – 10.45mbgl: Slightly silty sand; and
- no groundwater strike observations are on the log record due to the water flush used in drilling.

1.28.7 Groundwater levels have been measured manually on six separate occasions at BH35, which is located at an elevation of 38.74mAOD and was completed to a depth of 10.0mbgl. These measurements indicate an average groundwater level of 1.27mbgl, or 37.47mAOD. The data logger in BH35 has recorded the highest groundwater level as 1.08mbgl,

1.28.8 The BGS groundwater flooding susceptibility map (BGS, 2017) has a variable coverage at this location. The map shows that much of the crossing is located within an area with potential for groundwater flooding to occur at the surface. The remainder of the crossing is not mapped.

1.28.9 As part of the EA groundwater level monitoring network, the nearest hydrometric monitoring point is Brock Cottage OBH, located approximately 1.5km southwest of this crossing. Monitoring data indicates the maximum groundwater level here is 4.75mbgl (41.98mAOD), while the minimum water level is 9.11mbgl (37.62mAOD).

Crossing TC 024 Assessment

1.28.10 Historical ground investigation records held by the BGS (BGS, 2018a) indicate that groundwater was encountered at 0.6mbgl, at a location approximately 90m from the crossing. Recent groundwater monitoring completed immediately adjacent to the crossing showed the highest groundwater at a depth of 1.08mbgl. The BGS groundwater flooding susceptibility map (BGS, 2017) shows that there is potential for flooding to occur, also indicating potentially shallow groundwater levels. As such, shallow groundwater conditions are expected at this location. Dewatering is not required as part of HDD. However, the groundwater table is likely to be intercepted, and it is likely that following installation, the pipeline would sit below the water table.

1.28.11 Superficial geology is expected to be variable, both by nature and in its extent. Where present, deposits of gravelly clay were encountered to a depth of 1.83mbgl. Underlying these, fine sand with clay was identified. This correlates with recent ground investigation records which recorded interbedded sands and clays – these are assumed to represent the bedrock of the Windlesham Formation and the Bagshot Formation. Therefore, assuming a maximum drilling depth of 5mbgl, both superficial and bedrock units are expected to be encountered. There is no significant low permeability layer separating these shown by ground investigation. As such, it is unlikely that this crossing would create a new connection of two aquifers during construction or operation.

1.29 TC 025 – Chobham Common

Feature(s) requiring trenchless crossing	Chobham Common
Trenchless crossing technique and characteristics	HDD technique Following details assumed from HDD typical details drawings: • Assumed a maximum drilling depth of 5mbgl for this assessment • Drive length: approximately 232m
Groundwater study area	GWSA-C

Geological and Hydrogeological Conditions at TC 025

1.29.1 The BGS geological map (BGS, 2018i) indicates that the crossing is located within an area where the underlying bedrock comprises the Windlesham Formation of sand. Approximately 120m to the east of the crossing, the Bagshot Formation of sand is shown to be present and dominates to the south of the crossing.

1.29.2 Superficial deposits are mapped as being variable in both their nature and their extent (BGS, 2018i). A localised area of peat is shown to overly the central area of the crossing only. To the south and east, localised deposits of River Terrace Deposits (undifferentiated) of sand and gravel are shown. Much of the surrounding area and the remainder of the crossing length is shown to be absent of superficial coverage.

1.29.3 The aquifer designation map (Defra, 2018) indicates that the crossing is located within an area classed as a Secondary A bedrock aquifer. The River Terrace Deposits are classed as a Secondary A superficial aquifer, while the peat superficial deposits are defined as Unproductive strata.

1.29.4 The nearest available BGS record, SU96SE44, is located approximately 125m northwest of the crossing. The online record for this indicates the following conditions:

- 0 – 0.45mbgl: Sandy topsoil;
- 0.45 – 1.22mbgl: Fine sand;
- 1.22 – 6.09mbgl: Fine sand; and
- no groundwater observations are recorded.

1.29.5 A second record was consulted to determine groundwater conditions. The nearest available record with groundwater details, SU96SE47, is located approximately 230m northwest of the crossing. The online record for this indicates the following ground conditions:

- 0 – 0.35mbgl: Clayey topsoil;
- 0.35 – 0.75mbgl: Clay;
- 0.75 – 1.83mbgl: Clay with traces of gravel;
- 1.83 – 6.1mbgl: Fine sand, clayey in parts; and
- groundwater was first encountered at 0.8mbgl (approximately 37.4mAOD).

1.29.6 The BGS records detailed above show the boreholes are situated at a similar elevation to that of the crossing.

1.29.7 During the 2018 ground investigation works, BH138 is shown to have been completed along the proposed length of the crossing. Records show that BH138 was completed in October 2018, when groundwater conditions would be expected to be lower than the potential winter maximum. The log record for this location indicates the following ground conditions:

- 0 – 0.20mbgl: Slightly silty sand;
- 0.20 – 1.65mbgl: Slightly clayey sand;
- 1.65 – 5.65mbgl: Fine to medium sand; and
- groundwater strike was encountered at 0.80mbgl (approximately 38.29mAOD).

1.29.8 Groundwater levels have been measured manually on three separate occasions at BH138, which is located at an elevation of 39.09mAOD and was completed to a depth of 5.65mbgl. These measurements indicate an average groundwater level of 0.27mbgl, or 38.81mAOD. The data logger in BH138 has recorded the highest groundwater level as 0.60mbgl which is noted as being lower than the manual dip measurements so there is currently some uncertainty over the logger data.

1.29.9 The BGS groundwater flooding susceptibility map (BGS, 2017) indicates that the crossing is located within an area classed as having the potential for groundwater flooding to occur at the surface.

1.29.10 As part of the EA groundwater level monitoring network, the nearest hydrometric monitoring point is Brock Cottage OBH, located approximately 1.7km southwest of this crossing. Monitoring data indicates the maximum groundwater level here is 4.75mbgl (41.98mAOD), while the minimum water level is 9.11mbgl (37.62mAOD).

Crossing TC 025 Assessment

1.29.11 During ground investigation, both recent and historical (BGS, 2018a), groundwater was encountered at shallow depths of 0.8mbgl. Recent manual groundwater monitoring confirmed an average groundwater level of 0.27mbgl. Shallow groundwater conditions are further supported by the BGS groundwater flooding susceptibility map (BGS, 2017) which shows there is potential for flooding at the surface to occur in this area. Based on available data, shallow groundwater conditions are expected at the location of crossing TC 025. HDD does not require dewatering. However, based on an HDD depth of 5mbgl, it is likely that the water table would be encountered, and following installation, the pipeline would sit below the water table.

1.29.12 Superficial geology is expected to be variable in both its nature and extent. This is confirmed by the ground investigation records above. Where present, deposits of clay with gravel are encountered to a depth of 1.83mbgl. Underlying these, fine sand with clay is present. At its shallowest, clayey sand was encountered at a depth of 0.2mbgl. Therefore, based on available data, HDD has the potential to encounter both superficial and bedrock geology at this location. Where these are found together in succession, they would be expected to be in hydraulic continuity with one another as there is no significant low permeability layer shown by ground investigation to separate them. As such, it is unlikely that this crossing would create a new connection of two aquifers during construction or operation.

1.30 TC 026 – Chobham Common

Feature(s) requiring trenchless crossing	Chobham Common
Trenchless crossing technique and characteristics	HDD technique Following details assumed from HDD typical details drawings: • Assumed a maximum drilling depth of 5mbgl for this assessment • Drive length: approximately 271m
Groundwater study area	GWSA-C

Geological and Hydrogeological Conditions at TC 026

1.30.1 The BGS geological map (BGS, 2018i) indicates that the crossing is located within an area where the underlying bedrock likely comprises the Bagshot Formation of sand. Approximately 210m to the west and approximately 240m to the east, the Windlesham Formation of sand is shown as present.

1.30.2 Superficial geology is mapped as being variable in its nature and extent (BGS, 2018i). Deposits of peat are shown across some parts of the crossing with the rest of the crossing being absent of superficial coverage. Approximately 30m to the east and approximately 140m northwest of the crossing, sporadic local deposits of River Terrace Deposits (undifferentiated) of sand and gravel are shown as present. Much of the surrounding area is shown as absent of superficial geology.

1.30.3 The aquifer designation map (Defra, 2018) indicates that the crossing is located within an area classed as a Secondary A bedrock aquifer. The localised River Terrace Deposits immediately surrounding the crossing are classed as a Secondary A superficial aquifer, while the superficial peat is defined as Unproductive strata.

1.30.4 The nearest available BGS record, SU96SE16, is located approximately 70m south of the crossing. The record for this indicates the following ground conditions:

- 0 – 0.15mbgl: Peaty topsoil;
- 0.15 – 1.52mbgl: Fine sand; and
- no groundwater was encountered.

1.30.5 A second BGS record was consulted to determine groundwater conditions. Record SU96SE11 is located approximately 580m southeast of the crossing. The online record for this indicates the following ground conditions:

- 0 – 0.3mbgl: peaty Topsoil;
- 0.3 – 0.9mbgl: Clayey fine sand;
- 0.9 – 1.22mbgl: Clay;
- 1.22 – 1.52mbgl: Clayey fine sand with a small amount of gravel;
- 1.52 – 1.97mbgl: Fine sand; and
- groundwater was first encountered at 1.22mbgl (approximately 32.78mAOD).

1.30.6 The two BGS records detailed above show the boreholes are located at similar elevations to that of the crossing.

1.30.7 During the 2018 ground investigation works, BH34 is shown to have been completed approximately 180m west of the crossing. The record for this shows that the borehole was completed in October 2018, when groundwater levels are likely to be lower than the expected winter maximum. The log record for this location indicates the following ground conditions:

- 0 – 0.15mbgl: Slightly silty sand;
- 0.15 – 2.20mbgl: Slightly clayey sand;
- 2.20 – 3.37mbgl: Fine to medium sand;
- 3.37 – 4.60mbgl: Fine to medium clayey sand;
- 4.60 – 8.51mbgl: Medium silty sand;
- 8.51 – 9.15mbgl: Clay;
- 9.15 – 10.15mbgl: Fine to medium sand; and
- no groundwater observations are recorded on the log record due to the water flush used when drilling.

1.30.8 Groundwater levels have been measured manually on five separate occasions at BH34, which is located at an elevation of 40.19mAOD and was completed to a depth of 10.0mbgl. These measurements indicate an average groundwater level of

2.87mbgl, or 37.32mAOD. The data logger in BH34 has recorded the highest groundwater level as 2.44mbgl.

1.30.9 The BGS groundwater flooding susceptibility map (BGS, 2017) indicates that the crossing is located within an area with two classifications. The west of the crossing is classed as having the potential for groundwater flooding of property situated below ground level, while the east of the crossing is classed as having limited potential for groundwater flooding to occur, suggesting shallow groundwater conditions are not expected here. Immediately south of the crossing are areas with the potential for groundwater flooding to occur at the surface.

1.30.10 As part of the EA groundwater level monitoring network, the nearest hydrometric monitoring point is Brock Cottage OBH, located approximately 2.6km southwest of this crossing. Monitoring data indicates the maximum groundwater level here is 4.75mbgl (41.98mAOD), while the minimum water level is 9.11mbgl (37.62mAOD).

Crossing TC 026 Assessment

1.30.11 During historical ground investigations (BGS, 2018a), groundwater was only encountered at one location, at a shallow depth of 1.22mbgl at a location close to the crossing. The most recent ground investigation identified groundwater levels at around 2.5mbgl some 180m from the crossing. Further to this, the BGS groundwater flooding susceptibility map (BGS, 2017) offers a conflicting definition, with areas where there is potential for flooding located immediately adjacent to areas where flooding is unlikely. Based on currently available data, and assuming a worst-case scenario, shallow groundwater conditions are to be expected at TC 026. Assuming an HDD depth of 5mbgl, it is likely that the water table would be encountered. HDD does not require any dewatering, although it is likely that following installation, the pipeline would sit below the water table.

1.30.12 Superficial geology is expected to be variable at the crossing and in the immediate surroundings in both its nature and extent; much of the crossing is shown to be absent of superficial deposit coverage. This is confirmed by ground investigation records, which record fine sands and clayey sands to depths as shallow as 0.15mbgl which are assumed to represent the Bagshot Formation bedrock. Peaty topsoil was recorded at one location to a depth of 0.3mbgl. With a depth of 5m, HDD methods therefore have the potential to encounter the Bagshot Formation bedrock. In the surrounding areas are River Terrace Deposits, although according to the geological map (BGS, 2018i), these are not expected at the crossing itself. Where peat and Bagshot Formation deposits are found together, they are expected to be in continuity with one another, but the degree of hydraulic connection is unlikely to be significant. Should localised deposits of River Terrace Deposits be encountered, these will likely be in hydraulic continuity, as no significant low permeability layer to separate them is expected. As such, it is unlikely that this crossing would create a new connection of two aquifers during construction or operation.

1.31 TC 027 – Accommodation Road

Feature(s) requiring trenchless crossing	Accommodation Road

Trenchless crossing technique and characteristics	HDD technique Following details assumed from HDD typical details drawings: • Assumed a maximum drilling depth of 5mbgl for this assessment • Drive length: approximately 168m
Groundwater study area	GWSA-C

Geological and Hydrogeological Conditions at TC 027

1.31.1 The BGS geological maps (BGS, 2018j, BGS 2018k) indicate that the crossing is located within an area where the underlying bedrock comprises the Windlesham Formation of sand at the west of the crossing, which continues west and south. Over the eastern portion of the crossing, the Bagshot Formation of sand is mapped as present, continuing northwards.

1.31.2 The geological maps (BGS, 2018j, BGS 2018k) show that at the crossing and its immediate surroundings, there are no superficial deposits present. The surrounding area is also largely absent of superficial geology.

1.31.3 The aquifer designation map (Defra, 2018) shows that the crossing is located within an area classed as a Secondary A bedrock aquifer.

1.31.4 The nearest available BGS record, TQ06NW295, is located approximately 110m south of the crossing. The record for this location indicates the following ground conditions:

- 0 – 0.61mbgl: Sandy topsoil with gravel;
- 0.61 – 1.52mbgl: Sandy clay;
- 1.52 – 4.57mbgl: Clayey fine sand; and
- no groundwater conditions are given.

1.31.5 A second BGS record was reviewed to determine local groundwater conditions. The nearest record detailing groundwater, SU96SE5, is located approximately 255m south of the crossing, and indicates the following ground conditions:

- 0 – 0.3mbgl: Topsoil;
- 0.3 – 6.03mbgl: Bracklesham Beds;
- 6.03 – 18.43mbgl: Bracklesham Beds and clayey Bagshot Beds; and
- the rest level of water is indicated at 0.75mbgl (approximately 49.25mAOD).

1.31.6 It is worth noting that the BGS records detailed above show the boreholes are at a slightly higher elevation than that of the crossing.

1.31.7 During the 2018 ground investigation works, there are no locations in the immediate vicinity of the crossing. The nearest investigation location is BH34, located approximately 1.5km southwest of the crossing. The record for this shows that BH34 was completed in October 2018, when groundwater levels are expected to be lower than the winter maximum. The log record for this location indicates the following ground conditions:

- 0 – 0.15mbgl: Slightly silty sand;
- 0.15 – 2.20mbgl: Slightly clayey sand;
- 2.20 – 3.37mbgl: Fine to medium sand;
- 3.37 – 4.60mbgl: Fine to medium clayey sand;
- 4.60 – 8.51mbgl: Medium silty sand;
- 8.51 – 9.15mbgl: Clay;
- 9.15 – 10.15mbgl: Fine to medium sand; and
- no groundwater observations are recorded on the log record due to the water flush used when drilling.

1.31.8 Groundwater levels have been measured manually on five separate occasions at BH34, which is located at an elevation of 40.19mAOD and was completed to a depth of 10.0mbgl. These measurements indicate an average groundwater level of 2.87mbgl, or 37.32mAOD. The data logger in BH34 has recorded the highest groundwater level as 2.44mbgl.

1.31.9 The BGS groundwater flooding susceptibility map (BGS, 2017) shows that the crossing is located within an area with different classifications. The very west and east of the crossing is classed as having the potential for groundwater flooding of property situated below ground level, while the central area of the crossing is indicated as having limited potential for groundwater flooding to occur, suggesting shallow groundwater conditions are not expected. There are areas immediately south of the crossing which have the potential for groundwater flooding to occur at the surface.

1.31.10 There are no EA groundwater level monitoring locations local to the crossing.

Crossing TC 027 Assessment

1.31.11 Groundwater levels were only encountered on one historical ground investigation record, at a shallow depth of 0.75mbgl (BGS, 2018a). Shallow groundwater conditions are supported in part by the BGS groundwater flooding susceptibility map (BGS, 2017) which indicates that there is potential for groundwater flooding of below ground property to occur over some parts of the crossing, although there are classifications immediately adjacent where there is limited potential for flooding to occur. Based on a lack of additional data, and assuming a worst-case scenario, groundwater conditions are expected to be relatively shallow at this location. HDD does not require dewatering. However, it is likely that with a maximum depth of drilling of 5m, the water table would be encountered, and that following installation, the pipeline would sit below the water table.

1.31.12 No superficial deposits are expected at the location of TC 027. This is largely confirmed by ground investigation records, aside from one historical record approximately 100m from the crossing which recorded gravels to a depth of 0.61mbgl. Otherwise, sands, clayey sands and silty sands were encountered either underlying these gravels, or at depths as shallow as 0.15mbgl. These are likely to represent the Windlesham Formation and the Bagshot Formation bedrock, both of which are members of the Bracklesham Group. Therefore, HDD is likely to encounter the bedrock at this location. As no superficial deposits are expected, it is not thought likely that the bedrock will be in hydraulic continuity with any other aquifer unit, and it is unlikely that this crossing would create a new connection of two aquifers during construction or operation.

1.32 TC 028 – Holloway Hill Woods

Feature(s) requiring trenchless crossing	Foxhills Golf course to Holloway Hill Woods, B386 Longcross Road
Trenchless crossing technique and characteristics	HDD technique Following details assumed from HDD typical details drawings: • Assumed a maximum drilling depth of 5mbgl for this assessment • Drive length: approximately 464m
Groundwater study area	GWSA-D

Geological and Hydrogeological Conditions at TC 028

1.32.1 The BGS geological map (BGS, 2018k) shows that the crossing is located within an area where the underlying bedrock comprises the Bagshot Formation of sand, which is continuous in the surrounding areas.

1.32.2 The geological map (BGS, 2018k) shows that superficial deposits are expected to be variable in their extent. No superficial coverage is indicated over the route of the crossing. However immediately north, the Lynch Hill Gravel Member of sand and gravel is shown as present.

1.32.3 The aquifer designation map (Defra, 2018) shows that the crossing is located within an area defined as a Secondary A bedrock aquifer. The deposits of the Lynch Hill Gravel Member adjacent to the crossing are shown to be classed as a Secondary A superficial aquifer.

1.32.4 The nearest available BGS record, TQ06NW289, is located approximately 650m northwest of the crossing. The log for this indicates the following groundwater conditions:

- 0 – 0.3mbgl: Topsoil;
- 0.3 – 0.6mbgl: Silty clay;
- 0.6 – 2.13mbgl: Silty fine sand with a small amount of fine gravel;
- 2.13 – 4.87mbgl: Silty clay; and
- groundwater was first encountered at a depth of 2.58mbgl (approximately 32.42mAOD).

1.32.5 The borehole for the BGS record above is located at a similar elevation to much of the crossing.

1.32.6 During the 2018 ground investigation works, no boreholes have been completed local to the crossing itself. The nearest investigation point is that of BH32, located approximately 1.3km northeast of the crossing. Records show that BH32 was completed in January 2019, when the groundwater levels observed are likely to be seasonally high. The log record for this indicates the following ground conditions:

- 0 – 0.8mbgl: Made ground;
- 0.8 – 1.13mbgl: Gravelly silty sand;
- 1.13 – 8.70mbgl: Clayey sand with thin bands of sandy clay;
- 8.70 – 10.20mbgl: Fine to medium sand;
- 10.20 – 15.30mbgl: Silty sand; and
- Groundwater strike was recorded at 1.40mbgl.

1.32.7 One manual measurement of the groundwater level in BH32 from February 2019 is available. This shows a groundwater level of 5.71mbgl, or 16.53mAOD. No groundwater level data from a logger is currently available for this borehole.

1.32.8 The BGS groundwater flooding susceptibility map (BGS, 2017) shows that the crossing is located within an area defined as having limited potential for groundwater flooding to occur, suggesting shallow groundwater conditions are not expected. However, immediately south and east of the crossing are localised areas defined as having the potential for groundwater flooding of property situated below ground level.

1.32.9 There are no EA groundwater monitoring locations located locally to this crossing location.

Crossing TC 028 Assessment

1.32.10 During ground investigations, both recent and historical (BGS, 2018a), groundwater strikes were confirmed at shallow depths ranging between 1.4 and 2.58mbgl. One manual measurement of groundwater level in BH32 shows a deeper level at 5.71mbgl, although this is some distance from the crossing. The BGS groundwater flooding susceptibility map in some way confirms that shallow groundwater may be present in the surrounding areas as they suggest the potential for flooding in areas south and east of the crossing, although at the crossing location itself the map shows limited potential for flooding. Due to a lack of available data, and assuming a worst-case scenario, shallow groundwater conditions may be encountered at crossing TC 028. HDD does not require dewatering, although it is assumed that with a maximum drilling depth of 5m, the water table is likely to be encountered, and following installation, the pipeline would likely sit below the water table.

1.32.11 There are no superficial deposits mapped as present over the crossing itself (BGS, 2018k), but there are gravel deposits indicated to the immediate north. The ground investigation records reviewed confirm that gravels may be found to a maximum depth of 3.20mbgl. Underlying these, interbedded layers of sand, silt and clay are shown which are assumed to represent the Bagshot Formation of sand. Therefore, with a maximum depth of 5m, HDD is likely to encounter the Bagshot Formation bedrock at this location, in addition to superficial gravel deposits should they be present at the crossing location. If found together, these deposits are expected to be in continuity with each other as no significant low permeability layer is shown by ground investigation to separate them. As such, it is unlikely that this crossing would create a new connection of two aquifers during construction or operation.

1.33 TC 029 – Hardwick Lane

Feature(s) requiring trenchless crossing	Hardwick Lane, Chertsey
Trenchless crossing technique and characteristics	HDD technique Following details assumed from HDD typical details drawings: • Assumed a maximum drilling depth of 5mbgl for this assessment • Drive length: approximately 177m
Groundwater study area	GWSA-D

Geological and Hydrogeological Conditions at TC 029

1.33.1 The BGS geological map (BGS, 2018k) indicates that the crossing and surrounding area is located within an area where the underlying bedrock comprises the Bagshot Formation of sand.

1.33.2 Superficial deposits are mapped as being variable in their nature over the length of the crossing and in the surrounding areas. The geological map (BGS, 2018k) shows that, from west to east across the crossing, deposits comprise the Kempton Park Gravel Formation, Alluvium (silt) and Head (Diamicton).

1.33.3 The aquifer designation map (Defra, 2018) shows that portions of the crossing are located within areas defined as a Principal superficial aquifer, Secondary A superficial aquifer and Secondary Undifferentiated superficial aquifer. The entire crossing is located within an area defined as a Secondary A bedrock aquifer.

1.33.4 The nearest available BGS record, TQ06NW583, is located approximately 370m east of the crossing. The record for this indicates the following ground conditions:

- 0 – 0.15mbgl: Topsoil;
- 0.15 – 1.0mbgl: Silty fine sand with occasional fine gravel;
- 1.0 – 2.0mbgl: Silty fine sand;
- 2.0 – 6.50mbgl: Fine to medium sand;
- 6.50 – 10.0mbgl: Sandy silt with fine sand; and
- groundwater was encountered at 2.20mbgl (approximately 15.30mAOD).

1.33.5 During the 2018 ground investigation works, no boreholes were completed locally to the crossing itself. The nearest location is indicated as BH32, located approximately 590m southeast of the crossing. Records show that BH32 was completed in January 2019, when the groundwater levels observed are likely to be seasonally high. The log record for this indicates the following ground conditions:

- 0 – 0.8mbgl: Made ground;
- 0.8 – 1.13mbgl: Gravelly silty sand;
- 1.13 – 8.70mbgl: Clayey sand with thin bands of sandy clay;

- 8.70 – 10.20mbgl: Fine to medium sand;
- 10.20 – 15.30mbgl: Silty sand; and
- Groundwater strike was recorded at 1.40mbgl.

1.33.6 One manual measurement of the groundwater level in BH32 from February 2019 is available. This shows a groundwater level of 5.71mbgl, or 16.53mAOD. No groundwater level data from a logger is currently available for this borehole.

1.33.7 The BGS groundwater flooding susceptibility map (BGS, 2017) shows that the crossing is located within an area with limited potential for groundwater flooding to occur suggesting shallow groundwater conditions are not expected. However, immediately south of the crossing are areas defined as having the potential for groundwater flooding of property situated below ground level.

1.33.8 There are no EA groundwater monitoring locations locally to the crossing.

Crossing TC 029 Assessment

1.33.9 Ground investigations, both recent and historical (BGS, 2018a), recorded shallow groundwater strikes at locations in proximity to the crossing, ranging between 1.4mbgl and 2.20mbgl. One manual measurement of groundwater level in BH32 shows a deeper level at 5.71mbgl, although this is some distance from the crossing. The groundwater flooding susceptibility map (BGS, 2017) does not support shallow groundwater levels at this crossing, showing that there is limited potential for groundwater flooding to occur at this location. However, based on available information, and assuming a worst-case scenario, groundwater levels might be shallow at crossing TC 029. HDD would not require dewatering. However, with a maximum drilling depth of 5m, the groundwater table might be encountered and following installation, it is possible that the pipeline would sit below the water table.

1.33.10 Superficial deposits are expected to be variable in their nature at the crossing location, with Alluvium, Head and the Kempton Park Gravel suggested on the geological map (BGS, 2018k). The ground investigation records detail gravel deposits to a maximum depth of 3.20mbgl. Underlying these, interbedded layers of silt, sand and clay are identified. These are assumed to represent the Bagshot Formation bedrock. Therefore, with an assumed maximum HDD depth of 5mbgl, both the bedrock and the superficial deposits are likely to be encountered by the drilling. Where they are encountered together at the crossing location, they are expected to be in hydraulic continuity with one another as there is no significant low permeability layer shown to separate them. As such, it is unlikely that this crossing would create a new connection of two aquifers during construction or operation.

1.34 TC 030 – A320 Guildford Road, Salesian School Grounds and M25

Feature(s) requiring trenchless crossing	Guildford Road and M25
Trenchless crossing technique and characteristics	HDD technique Following details assumed from HDD typical details drawings: • Assumed a maximum depth of 5mbgl for this assessment • Drive length: approximately 317m

Groundwater study area	GWSA-D

Geological and Hydrogeological Conditions at TC 030

1.34.1 The BGS geological map (BGS, 2018k) indicates that the crossing is located within an area where the underlying bedrock at the crossing and in the surrounding area comprises the Bagshot Formation of sand.

1.34.2 Superficial deposits are mapped as being variable in their nature and their extent, as indicated by the geological map (BGS, 2018k). The western portion of the crossing is shown to underlie deposits of the Lynch Hill Gravel Member of sand and gravel, and deposits of Head (Diamicton). The central and eastern portion of the crossing is mapped as being absent of superficial coverage. Approximately 130m to the south of the crossing, deposits of the Kempton Park Gravel Formation of sand and gravel are indicated, while to the north, Alluvium comprising silt is mapped.

1.34.3 The aquifer designation map (Defra, 2018) shows that the very west of the crossing is within an area defined as a Principal superficial aquifer associated with the Lynch Hill Gravel Member. The eastern area also crosses through an area classed as a Secondary Undifferentiated superficial aquifer, associated with the Head deposits. The entire crossing is located within an area defined as a Secondary A bedrock aquifer.

1.34.4 The nearest available BGS record detailing groundwater conditions, TQ06NW583, is located approximately 100m north of the crossing. The online record for this location indicates the following ground conditions:

- 0 – 0.15mbgl: Topsoil;
- 0.15 – 1.0mbgl: Silty fine sand with occasional fine gravel;
- 1.0 – 2.0mbgl: Silty fine sand;
- 2.0 – 6.50mbgl: Fine to medium sand;
- 6.50 – 10.0mbgl: Sandy silt with fine sand; and
- groundwater was encountered at 2.20mbgl (approximately 15.30mAOD).

1.34.5 The BGS record described above indicates the borehole is located at a similar elevation to that of the crossing.

1.34.6 During the 2018 ground investigation, BH32 is shown as present immediately east of the crossing. Records show that BH32 was completed in January 2019, when the groundwater levels observed are likely to be seasonally high. The log record for this indicates the following ground conditions:

- 0 – 0.8mbgl: Made ground;
- 0.8 – 1.13mbgl: Gravelly silty sand;
- 1.13 – 8.70mbgl: Clayey sand with thin bands of sandy clay;
- 8.70 – 10.20mbgl: Fine to medium sand;
- 10.20 – 15.30mbgl: Silty sand; and

- Groundwater strike was recorded at 1.40mbgl.

1.34.7 One manual measurement of the groundwater level in BH32 from February 2019 is available. This shows a groundwater level of 5.71mbgl, or 16.53mAOD. No groundwater level data from a logger is currently available for this borehole.

1.34.8 The BGS groundwater flooding susceptibility map (BGS, 2017) indicates that the crossing is located within an area where there is limited potential for groundwater flooding to occur suggesting shallow groundwater conditions are not expected.

1.34.9 There are no EA groundwater monitoring locations found locally to the crossing.

Crossing TC 030 Assessment

1.34.10 Ground investigations, both historical (BGS, 2018a) and recent, identified shallow groundwater strikes at locations close to the crossing location. Values ranged between 1.4mbgl and 2.20mbgl. One manual measurement of groundwater level in BH32 shows a deeper level at 5.71mbgl, and the BGS groundwater flooding susceptibility map (BGS, 2017) shows there is limited potential for groundwater flooding to occur which would suggest that shallow groundwater is not expected. Based on currently available data, and assuming a worst-case scenario, shallow groundwater conditions may occur at crossing TC 030, although there is uncertainty in this. HDD does not require dewatering. However, assuming a maximum drilling depth of 5m, the water table may be encountered, and following installation, the pipeline may sit below the water table.

1.34.11 Superficial deposits are expected to be variable in their extent and nature, with much of the crossing expected to be absent of superficial deposits. Previous ground investigation records show that gravel deposits were found to a maximum depth of 3.20mbgl. Underlying these, interbedded layers of sand, silt and clays were identified, which likely represent the Bagshot Formation bedrock which is expected at this location. Assuming HDD occurs at a depth of 5m, it is likely therefore that both superficial and bedrock units would be encountered. Where superficial gravels and underlying bedrock are found together in succession, they are expected to be in hydraulic continuity with one another as no significant low permeability layer is shown to separate them. As such, it is unlikely that this crossing would create a new connection of two aquifers during construction or operation.

1.35 TC 031 – Chertsey Branch Railway Line

Feature(s) requiring trenchless crossing	Railway (Near Canford Drive)
Trenchless crossing technique and characteristics	Auger bore technique Following details taken from site-specific design drawing: • Reaches a maximum depth of about 9.5mAOD and maximum depth below ground of 5m. • Drive pit depth: approximately 4.9mbgl • Drive pit length: approximately 11m • Drive pit width: approximately 3.5m • Reception pit depth: approximately 4mbgl • Reception pit length: approximately 4m

	• Reception pit width: approximately 4m • Drive length: approximately 71m
Groundwater study area	GWSA-D

Geological and Hydrogeological Conditions at TC 031

1.35.1 The BGS geological map (BGS, 2018k) shows that the crossing is located within an area where the underlying bedrock at the crossing and in the surrounding area comprises the Bagshot Formation of sand.

1.35.2 Superficial deposits are mapped as being variable in their nature as indicated by the geological map (BGS, 2018k). Over much of the length of the crossing, deposits of Alluvium comprising silt are mapped as present, continuing southwards. Over the very north of the crossing, deposits of the Kempton Park Gravel Formation are mapped as present and continue to the north.

1.35.3 The aquifer designation map (Defra, 2018) indicates that the whole length of the crossing is located within an area defined as a Secondary A bedrock aquifer. The Kempton Park Gravel Formation over the north of the crossing is classed as a principal superficial aquifer. The Alluvium deposits which cover much of the crossing route are classed as a Secondary A superficial aquifer.

1.35.4 The nearest available BGS borehole record, TQ06NW157, is located approximately 170m west of the crossing. The online record for this indicates the following ground conditions:

- 0 – 0.40mbgl: Topsoil;
- 0.40 – 1.20mbgl: Sandy clay;
- 1.20 – 1.65mbgl: Sandy silty clay;
- 1.65 – 3.00mbgl: Very sandy gravel;
- 3.00 – 4.00mbgl: Gravel;
- 4.00 – 6.65mbgl: Silty fine sand (Bagshot Beds); and
- water was struck at 1.2mbgl (approximately 11.8mAOD).

1.35.5 The BGS record described above indicates the borehole is located at a similar elevation to that of the crossing.

1.35.6 During the 2018 ground investigation works, BH30 is shown as located along the crossing. Records show that this was completed in December 2018, when groundwater levels observed may be seasonally higher. The log record shows the following ground conditions:

- 0.0 – 1.24mbgl: Made ground;
- 1.24 – 1.50mbgl: Slightly gravelly to slightly sandy clay;
- 1.50 – 2.20mbgl: Clayey gravelly sand;
- 2.20 – 3.60mbgl: Sandy gravel;
- 3.60 – 7.90mbgl: Silty sandy clay;

- 7.90 – 15.10mbgl: Clayey silty sand; and
- groundwater was struck at 1.40mbgl (11.84mAOD) and 2.00mbgl (11.24mAOD).

1.35.7 Groundwater levels have been measured manually on two separate occasions at location BH30, which is located at an elevation of 13.24mAOD and was completed to a depth of 15.10mbgl. These measurements indicate an average groundwater level of 0.92mbgl, or 12.32mAOD. The data logger in BH30 has recorded the highest groundwater level as 0.32mbgl.

1.35.8 The BGS groundwater flooding susceptibility map (BGS, 2017) indicates that the crossing is located within an area defined as having limited potential for groundwater flooding to occur, suggesting shallow groundwater conditions are not expected.

1.35.9 There are no EA monitoring locations found locally to this crossing location.

Crossing TC 031 Assessment

1.35.10 During ground investigations, both recent and historical (BGS, 2018a), groundwater strikes were confirmed at shallow depths ranging between 1.2mbgl and 1.93mbgl. In addition, groundwater monitoring completed as part of the 2018 ground investigation works indicates an average groundwater level of 0.92mbgl, although the logger shows a higher water level at 0.32mbgl. There is limited additional data available for this location regarding groundwater levels, although the BGS groundwater flooding susceptibility map (BGS, 2017) indicates that there is limited potential for flooding to occur, suggesting that groundwater levels close to the surface would not be expected. Based on the available data, and assuming a worst-case scenario, shallow groundwater conditions may be encountered at this location. The auger bore method here is indicated to a maximum depth of 5m. Therefore, it is likely that the groundwater table would be intercepted at this location.

1.35.11 Following pipeline installation, based on a maximum depth of 5mbgl of auger boring, the groundwater table would potentially be intercepted, and much of the length of the pipeline may sit below the water table following installation.

1.35.12 Superficial deposits are expected to be variable in their nature. This is suggested by ground investigation records. Deposits of gravels, sands and clays were encountered to a maximum depth of 4.0mbgl. Underlying these, interbedded layers of clay, sands and silts were encountered. These represent the Bagshot Formation bedrock. The minimum depth that the bedrock was encountered is 3.20mbgl. It is therefore likely that, during auger boring methods, both the superficial deposits and the underlying bedrock may be encountered, with an auger bore depth of 5m. Both are classed as important aquifer units. Where they are found together, they are expected to be in hydraulic continuity with one another as no significant low permeability layer is shown to separate them. As such, it is unlikely that this crossing would create a new connection of two aquifers during construction or operation.

1.35.13 For the calculation of effects due to dewatering, calculated hydraulic conductivity values from BH30 have been used, completed as part of ground investigation works. The average hydraulic conductivity value used for this assessment is 9.7E-05m/s.

1.35.14 The expected maximum groundwater level has been estimated as 0.5mbgl based on the shallow groundwater measured in the manual dips at approximately 0.9mbgl and typical levels of 0.5mbgl being recorded in the logger data.

1.35.15 Table 8.2.22 presents the input and results of the radius of influence calculations. Additional input parameters and results used for the calculation of dewatering rates are given in Table 8.2.23. Potential receptors within the calculated radius of influence have been identified as detailed in Table 8.2.24.

Table 8.2.22: Input and Results for Calculating the Radius of Influence for TC 031

Parameter	Drive Pit Value	Reception Pit Value
Length (m)	11.0	4.0
Width (m)	3.5	4.0
Maximum pit depth (m)	4.9	4.0
Expected groundwater level (mbgl)	0.5	0.5
Calculated drawdown (m)	3.9	3.0
Hydraulic conductivity, K (m/s)	9.7E-05	9.7E-05
R (m)	130	103
Re (m)	3.5	2.3
Total radius of influence Ro (m)	134	106

Table 8.2.23: Input and Results for Estimating Dewatering Rate for TC 031

Parameter	Drive Pit Value	Reception Pit Value
H, saturated aquifer thickness (assumed as Bagshot Formation thickness, plus saturated superficial thickness derived in GI) (m)	14.3	14.3
Q, dewatering rate	802m^3/day	625m^3/day
	9.28l/s	7.24/s

Table 8.2.24: Potential Receptors Identified within the Radius of Influence for TC 031

Receptor	Distance from Drive Pit	Distance from Reception Pit	Comments
Groundwater abstractions			
None			
Buildings and Infrastructure			
Residential properties	Nearest property approximately 59m northeast of the pit	Nearest property approximately 5m northeast of the pit	
Surface waters			
Three drains	Within Order Limits Approximately 24m west, 50m northeast and 17m east. of the pit	Within Order Limits. Approximately 17m west, 35m west and 95m west of the pit	
Small unnamed surface water body	Approximately 106m of the pit	Beyond radius	

Receptor	Distance from Drive Pit	Distance from Reception Pit	Comments
GWDTEs			
None			
Potentially contaminated land			
Abbey Moor Golf Club (former landfill)	Drive pit located within the area	Approximately 55m southwest of the pit	
Scheduled monuments and listed buildings			
None			

1.36 TC 032 – A317 Chertsey Road

Feature(s) requiring trenchless crossing	A317 Chertsey Road
Trenchless crossing technique and characteristics	HDD or auger bore technique **1. Auger bore method** Following details taken from site-specific design drawing: • Reaches a maximum depth of about 8mAOD and maximum depth below ground of 5m. • Drive pit depth: approximately 6.3mbgl • Drive pit length: approximately 7.5m • Drive pit width: approximately 7.5m • Reception pit depth: approximately 5.8mbgl • Reception pit length: approximately 4m • Reception pit width: approximately 4m • Drive length: approximately 89m **2. HDD technique** Following details taken from site-specific design drawing: • Assumed a depth of 5mbgl for this assessment • Drive length: approximately 89m
Groundwater study area	GWSA-D

Geological and Hydrogeological Conditions at TC 032

1.36.2 The BGS geological map (BGS, 2018k) indicates that the crossing is located within an area where the bedrock underlying the crossing and in the surrounding area is likely to comprise the Bagshot Formation of sand.

1.36.3 The superficial deposits at the crossing and in the surrounding areas are indicated on the geological map (BGS, 2018k) to comprise the Kempton Park Gravel Formation of sand and gravel. Approximately 130m to the south of the crossing, deposits of Alluvium (silt) are mapped as present.

1.36.4 The aquifer designation map (Defra, 2018) indicates that the crossing is located within an area defined as a Principal superficial aquifer, associated with deposits of the Kempton Park Gravel Formation. The Alluvium deposits to the south of the crossing are defined as a Secondary A superficial aquifer. The bedrock is defined as a Secondary A bedrock aquifer.

1.36.5 The nearest BGS record, TQ06NW127, is located approximately 155m southeast of the crossing. The online record for this location indicates the following ground conditions:

- 0 – 0.30mbgl: Topsoil (Alluvium);
- 0.30 – 1.40mbgl: Silty and sandy clays with variable gravel (Alluvium);
- 1.40 – 4.6mbgl: Gravel with variable sand content, into gravel with very sandy clay (Terrace Gravels);
- 4.6 – 10.05mbgl: Clayey and sandy silt with lenses of clay and fine sand (Bagshot Beds); and
- water was encountered at 1.4mbgl and 1.9mbgl (approximately 13.6mAOD and 13.1mAOD respectively).

1.36.6 The borehole relating to the BGS record described above is located at a similar elevation to that of the crossing.

1.36.7 During the 2018 ground investigation works, BH29 was indicated to be installed near the crossing. Records show that this was completed in November 2018, when observed groundwater levels may be seasonally higher. The log record for this borehole indicates the following ground conditions:

- 0 – 0.08mbgl: Topsoil;
- 0.08 – 1.30mbgl: Possible made ground;
- 1.30m – 1.70mbgl: Sandy clay;
- 1.70 – 4.10mbgl: Slightly clayey gravelly sand;
- 4.10 – 8.65mbgl: Sandy silty clay;
- 8.65 – 11.90mbgl: Silty sand;
- 11.90 – 15.45mbgl: Sandy clay; and
- no groundwater strikes were observed due to the addition of flush.

1.36.8 Groundwater levels have been measured manually on three separate occasions in BH29, which is located at an elevation of 10.90AOD and was completed to a depth of 15.45mbgl. These measurements indicate an average groundwater level of 1.51mbgl, or 9.39mAOD. The data logger in BH29 has recorded the highest groundwater level as 1.09mbgl.

1.36.9 The BGS groundwater flooding susceptibility map (BGS, 2017) indicates that the crossing is located within an area with limited potential for groundwater flooding to occur.

1.36.10 There are no EA monitoring locations pertinent to the location of this crossing.

Crossing TC 032 Assessment

1.36.11 During ground investigations, both recent and historical (BGS, 2018a), groundwater strikes were encountered at shallow depths ranging between 1.4 and 1.93mbgl. In addition, groundwater monitoring completed as part of the 2018 ground investigation works suggests an average groundwater level of 1.51mbgl with the logger recording a highest level of 1.09mbgl. There is limited additional data available for this location regarding groundwater levels, although the BGS groundwater flooding susceptibility map (BGS, 2017) indicates that there is limited potential for flooding to occur, suggesting that groundwater levels would not be expected to be close to the surface. Based on the available data, and assuming a worst-case scenario, shallow groundwater conditions may be encountered at this location. HDD methods do not require dewatering. However, based on the assumption that drilling would occur to a depth of 5m, the groundwater table might be intercepted, and following installation, much of the length of the pipeline may sit below the water table at TC 032.

1.36.12 Following pipeline installation, based on the auger bore pit depths and dimensions indicated, the groundwater table is likely to be intercepted, and following installation, much of the length of the pipeline is expected to sit below the water table at TC 032 if the auger bore method was used.

1.36.13 The superficial deposits at the crossing are expected to comprise gravel deposits. Ground investigation records confirm this, with a maximum recorded depth of gravels to 4.6mbgl. Underlying these deposits, interbedded layers of clays, sand and silts were encountered. These are likely to represent the Bagshot Formation bedrock. The bedrock was encountered at a minimum depth of 3.20mbgl. Therefore, both auger bore and HDD methods are likely to encounter both superficial and bedrock geology at this location. Both units are classed as important aquifer units. Where they are identified together, they are expected to be in hydraulic continuity with one another as there is no significant low permeability layer shown to separate them. As such, it is unlikely that this crossing would create a new connection of two aquifers during construction or operation.

1.36.14 For the calculation of effects due to dewatering, calculated values of hydraulic conductivity completed during ground investigation works at BH29 have been used. The average hydraulic conductivity derived for this location is 1.73E-05m/s.

1.36.15 The expected maximum groundwater level has been estimated as 1.0mbgl, assuming that shallow groundwater measured at approximately 1.1mbgl may show variability over the course of a year.

1.36.16 Table 8.2.25 presents the input and results of the radius of influence calculations. Additional input parameters and results used for the calculation of dewatering rates are given in Table 8.2.26. Potential receptors within the calculated radius of influence have been identified as detailed in Table 8.2.27.

Table 8.2.25: Input and Results for Calculating the Radius of Influence for TC 032

Parameter	Drive Pit Value	Reception Pit Value
Length (m)	7.5	4
Width (m)	7.5	4
Maximum pit depth (m)	6.3	5.8
Expected groundwater level (mbgl)	1.0	1.0
Calculated drawdown (m)	5.3	4.8
Hydraulic conductivity, K (m/s)	1.53E-04	1.53E-04

Parameter	Drive Pit Value	Reception Pit Value
R (m)	66	60
Re (m)	4.2	2.3
Total radius of influence Ro (m)	70	62

Table 8.2.26: Input and Results for Estimating Dewatering Rate for TC 032

Parameter	Drive Pit Value	Reception Pit Value
H, saturated aquifer thickness (assumed as interbedded sand and superficial gravel thicknesses derived in GI) (m)	14.1	14.1
Q, dewatering rate	206m^3/day	162m^3/day
	2.39l/s	1.87l/s

Table 8.2.27: Potential Receptors Identified within the Radius of Influence for TC 032

Receptor	Distance from Drive Pit	Distance from Reception Pit	Comments
Groundwater abstractions			
None			
Buildings and Infrastructure			
Chertsey High School buildings	Nearest building approximately 54m from the pit	Beyond radius	
Jubilee Church	Approximately 15m from the pit	Beyond radius	
Residential properties and residential roads	Nearest property approximately 10m south.	Roads located within Order Limits. Nearest property approximately 15m from the pit	
Surface waters			
None			
GWDTEs			
None			
Potentially contaminated land			
None			
Scheduled monuments and listed buildings			
None			

1.37 TC 033 – Chertsey Bourne

Feature(s) requiring trenchless crossing	The Bourne watercourse, copse
Trenchless crossing technique and characteristics	HDD technique Following details assumed from HDD typical details drawings: • Assumed a maximum depth of 5mbgl for this assessment • Drive length: approximately 62m
Groundwater study area	GWSA-D

Geological and Hydrogeological Conditions at TC 033

1.37.1 The BGS geological map (BGS, 2018l) indicates that the bedrock underlying the crossing and in the surrounding areas comprises the Bagshot Formation of sand.

1.37.2 Superficial deposits are mapped as being variable in their nature, as indicated by the geological map (BGS, 2018l). The southern portion of the crossing and continuing south and west comprises the Kempton Park Gravel Formation of sand and gravel. The northern portion of the crossing, and continuing north and east, comprises deposits of Alluvium (silt).

1.37.3 The aquifer designation map (Defra, 2018) shows that the southern portion of the crossing, associated with the Kempton Park Gravel Formation, is classed as a Principal superficial aquifer. The northern portion of the crossing, associated with the deposits of Alluvium, is defined as a Secondary A superficial aquifer. The entire length of the crossing is located within an area defined as a Secondary A bedrock aquifer.

1.37.4 The nearest available BGS record, TQ06NE184, is located approximately 285m southeast of the crossing. The online record for this indicates the following ground conditions:

- 0 – 0.91mbgl: clayey Topsoil;
- 0.91 – 2.44mbgl: Peaty clay;
- 2.44 – 2.74mbgl: Sandy clay; and
- groundwater was encountered at 1.37mbgl (approximately 11.63mAOD).

1.37.5 An additional BGS record was consulted to determine deeper ground conditions. The nearest available deeper record, TQ06NE17, is located approximately 350m southeast of the crossing. The online record for this indicates the following ground conditions:

- 0 – 0.45mbgl: Made ground;
- 0.45 – 0.65mbgl: Sandy loam;
- 0.65 – 1.50mbgl: Sandy clay;
- 1.50 – 2.40mbgl: Silty fine to medium sand;
- 2.40 – 4.30mbgl: Sandy gravel;
- 4.30 – 9.05mbgl: Bagshot Beds; and
- groundwater was encountered at a depth of 2.4mbgl (approximately 10.6mAOD).

1.37.6 During the 2018 ground investigation works, BH139 was completed immediately north of the crossing. Records show that BH139 was completed in September 2018, when the groundwater levels observed are likely to be lower than the maximum level seen during winter. The log record for this borehole indicates the following ground conditions:

- 0 – 0.15mbgl: Topsoil;

- 0.15 – 1.50mbgl: Clay;
- 1.50m – 3.20mbgl: Gravel;
- 3.20 – 5.20mbgl: Silt;
- 5.20 – 8.80mbgl: Sand of varying properties;
- 8.80 – 9.50mbgl: Clay;
- 9.50 – 15.30mbgl: Sand of varying properties; and
- groundwater was struck at 1.93mbgl (10.07mAOD).

1.37.7 Groundwater levels have been measured manually on six separate occasions at location BH139, which is located at an elevation of 12.24mAOD and was completed to a depth of 15.30mbgl. These measurements indicate an average groundwater level of 1.73mbgl, or 10.51mAOD. The data logger in BH139 has recorded the highest groundwater level as 0.84mbgl.

1.37.8 The BGS groundwater flooding susceptibility map (BGS, 2017) indicates that the crossing is located within an area with limited potential for groundwater flooding to occur. Approximately 40m east of the crossing is an area defined as having the potential for groundwater flooding of property situated below ground level.

1.37.9 There are no EA groundwater level monitoring locations local to this crossing.

Crossing TC 033 Assessment

1.37.10 During ground investigations, both recent and historical, groundwater strikes were encountered at shallow depths ranging between 1.93mbgl and 2.40mbgl. Groundwater monitoring completed as part of the 2018 ground investigation works show an average groundwater level of 1.73mbgl, although the BGS groundwater flooding susceptibility map (BGS, 2017) indicates that there is limited potential for flooding to occur. Based on the available information and assuming a worst-case scenario, shallow groundwater conditions are likely to be expected at this location.

1.37.11 HDD methods do not require dewatering. However assuming a drilling depth of 5mbgl, it is likely that the water table would be intercepted, and following installation, much of the length of the pipeline would sit below the water table at this location.

1.37.12 The thicknesses and nature of superficial deposits are expected to be variable. Ground investigation records confirm this, with gravels recorded to a maximum depth of 4.30mbgl. Underlying these deposits, interbedded sands and clays (the Bagshot Formation) were encountered. Therefore, HDD would likely encounter both superficial geology and bedrock units. Where these are encountered together, there is likely to be hydraulic continuity as there is no significant low permeability layer shown to separate them. As such, it is unlikely that this crossing would create a new connection of two aquifers during construction or operation.

1.38 TC 034 – River Thames and B375 Chertsey Bridge Road

Feature(s) requiring trenchless crossing	River Thames and Chertsey Road (B375)

Trenchless crossing technique and characteristics	HDD technique Following details taken from site-specific design drawing: • Reaches a maximum depth of -3.2mAOD and maximum depth below ground of 16m • Drive length: approximately 350m
Groundwater study area	GWSA-D

Geological and Hydrogeological Conditions at TC 034

1.38.1 The BGS geological map (BGS, 2018l) indicates that the bedrock at the crossing and in the surrounding areas comprises the Bagshot Formation of sand.

1.38.2 Superficial deposits along the north, northeast and west of the crossing comprise the Shepperton Gravel Member. Along the southern portion of the crossing and to the southwest and southeast, Alluvium deposits are mapped (BGS, 2018l).

1.38.3 The aquifer designation map (Defra, 2018) shows the crossing is located within an area classed as a principal superficial aquifer, associated with the Shepperton Gravel Member. Deposits of Alluvium in the south of the crossing are classed as a Secondary A superficial aquifer. The entire crossing is located within an area defined as a Secondary A bedrock aquifer.

1.38.4 The nearest available BGS borehole record, located 90m west of the crossing, TQ06NE84, indicates the following ground conditions:

- 0 – 1.8mbgl: Clay;
- 1.8 – 2.7mbgl: Gravel;
- 2.7 – 4.5mbgl: Laminated clayey silt; and
- groundwater was encountered at approximately 3mbgl (8mAOD).

1.38.5 A second record located 130m east of the crossing, TQ06NE180, indicates the following ground conditions:

- 0 – 0.3mbgl: Topsoil;
- 0.3 – 1.35mbgl: Clay;
- 1.35 – 2.85mbgl: Sand;
- 2.85 – 7.9mbgl: Gravel;
- 7.9 – 9.1mbgl: Clayey silt with traces of fine sand; and
- groundwater strike was encountered at 0.6mbgl (10.4mAOD).

1.38.6 These BGS borehole records are located at similar elevations to that of the crossing.

1.38.7 During the 2018 ground investigation works, BH26 is shown adjacent to the south of the crossing. Records show that BH26 was completed in mid-November 2018 (when groundwater conditions may not reflect the maximum level). The log record for this location indicates the following ground conditions:

- 0 – 0.32mbgl: Made ground;

- 0.32 – 1.26mbgl: Sandy clay;
- 1.26 – 1.68mbgl: Clayey sand;
- 1.68 – 1.88mbgl: Gravel;
- 1.88 – 3.30mbgl: Gravelly sand;
- 3.30 – 5.98mbgl: Gravel;
- 5.98 – 10.20mbgl: Silty sandy clay;
- 10.20 – 12.70mbgl: Slightly silty sand;
- 12.70 – 16.15mbgl: Clay; and
- groundwater was encountered at 1.26mbgl (approximately 10.74mAOD).

1.38.8 Groundwater levels have been measured manually on four separate occasions at location BH26, which is located at an elevation of 11.45mAOD and was completed to a depth of 16.15mbgl. These measurements indicate an average groundwater level of 1.00mbgl, or 10.45mAOD. The data logger in BH26 has recorded the highest groundwater level as 0.88mbgl.

1.38.9 BGS groundwater flooding susceptibility mapping (BGS, 2017) indicates that the vast majority of the crossing is located within an area with potential for groundwater flooding of below ground property to occur. The extreme south of the crossing is defined as having limited potential for groundwater flooding to occur.

1.38.10 As part of landfill groundwater level monitoring, a number of landfill groundwater level locations are present close to the crossing. The nearest of these is located on Littleton Lane, approximately 175m north of the crossing, with borehole reference GGW51. The average groundwater level recorded at this location is 10.2mAOD (approximately 1.8mbgl).

Crossing TC 034 Assessment

1.38.11 Ground investigation records, both recent and historical (BGS, 2018a), encountered groundwater strike at shallow levels ranging between 0.6 and 3.0mbgl. Recent groundwater monitoring indicates an average groundwater level of 1.00mbgl with the highest level recorded by the data logger as 0.88mbgl. In addition, EA landfill monitoring records to the north of the crossing indicate an average groundwater level of approximately 1.8mbgl. The BGS groundwater flooding susceptibility map (BGS, 2017) also supports shallow groundwater conditions by indicating that there is potential for flooding of below ground property in this area. HDD would not require any dewatering. However, it is expected that, during drilling, the water table would be intercepted, and the pipeline would sit below the water table at TC 034 following installation.

1.38.12 The nature of superficial deposits is expected to be variable at the crossing location. Gravel deposits were encountered during previous ground investigation by the BGS and also confirmed during recent 2018 ground investigation. Gravels were found to a maximum depth of 7.9mbgl. Underlying these deposits, laminated clayey silt deposits and interbedded layers of clay, silt and sand were encountered. These likely represent the Bagshot Formation bedrock expected at the crossing. Therefore, based on a maximum HDD depth of 9.2mbgl, it is likely that both the superficial gravels and underlying Bagshot Formation bedrock would be intercepted, depending on the local thicknesses of superficial deposits. Both the superficial and bedrock geology are classed as important aquifer units. Based on the recent site investigation data, the pipeline may penetrate the silty sandy clay horizon from 5.98mbgl to 10.2mbgl (an aquiclude) and reach the slightly silty sand horizon below. As such, it is possible that this crossing may create a new connection of two aquifers during construction or operation.

1.39 TC 035 – M3

Feature(s) requiring trenchless crossing	M3
Trenchless crossing technique and characteristics	HDD technique Following details taken from site-specific design drawing: • Reaches a maximum depth of -2.0mAOD and maximum depth below ground of 16m • Drive length: approximately 122m
Groundwater study area	GWSA-D

Geological and Hydrogeological Conditions at TC 035

1.39.1 The BGS geological map (BGS, 2018l) indicates that the bedrock underlying the crossing and the surrounding area comprises the Bagshot Formation of sand.

1.39.2 The geological map (BGS, 2018l) indicates that the superficial deposits at the crossing and in the surrounding area comprise the Shepperton Gravel Member of sand and gravel.

1.39.3 The aquifer designation map (Defra, 2018) shows that the crossing is located within an area defined as a Principal superficial aquifer associated with the Shepperton Gravel Member. The underlying bedrock is classed as a Secondary A bedrock aquifer.

1.39.4 The nearest BGS record detailing both groundwater and deeper ground conditions is TQ06NE76, located approximately 80m east of the crossing. The record for this borehole indicates the following ground conditions:

- 0 – 1.22mbgl: Silty gravel;
- 1.22 – 7.62mbgl: Sand and gravel;
- 7.62 – 8.22mbgl: Silty sand and gravel;
- 8.22 – 8.84mbgl: Clayey silt;
- 8.84 – 12.5mbgl: Clayey sandy silt with occasional gravel;
- 12.5 – 15.24mbgl: Clayey silt; and
- standing water level was recorded at 3.35mbgl when drilled (approximately 10.65mAOD).

1.39.5 The BGS record detailed above indicates the borehole is located at a similar elevation to that of the crossing.

1.39.6 During the 2018 ground investigation works, the nearest available investigation location is BH25, located approximately 290m south of the crossing. Records show that this was completed in August 2018, when observed groundwater levels may not reflect the potential maximum. The log record for this borehole indicates the following ground conditions:

- 0 – 0.70mbgl: Clay;
- 0.70 – 1.20mbgl: Slightly sandy clay;
- 1.20m – 1.80mbgl: Clay;
- 1.80 – 7.60mbgl: Sandy gravel;
- 7.60 – 8.10mbgl: Sand;
- 8.10 – 8.50mbgl: Clay;
- 8.50 – 10.40mbgl: Clayey sand;
- 10.40 – 13.50mbgl: Clay;
- 13.50 – 14.60mbgl: Sand;
- 14.60 – 20.41mbgl: Sandy clay; and
- no groundwater strike noted due to the addition of water flush. Potential strikes within the sands and gravels (from 1.8m) and potential strike at 13.5m.

1.39.7 Groundwater levels have been measured manually on five separate occasions in BH25, which is located at an elevation of 11.43mAOD and was completed to a depth of 20.41mbgl. These measurements indicate an average groundwater level of 1.09mbgl, or 10.34mAOD. The data logger in BH25 has recorded the highest groundwater level as 0.55mbgl.

1.39.8 The BGS groundwater flooding susceptibility map (BGS, 2017) indicates that the crossing is located within an area with the potential for groundwater flooding of property situated below ground level.

1.39.9 There are no EA groundwater monitoring locations pertinent to the location of this crossing. There are, however, records from monitoring of groundwater levels at landfill locations. One such monitoring location, approximately 50m west of the crossing, records an average groundwater level of 10.20mAOD (approximately 1.8mbgl).

Crossing TC 035 Assessment

1.39.10 Historical ground investigations (BGS, 2018a), encountered groundwater strikes at shallow depths of 3.35mbgl. In addition, groundwater monitoring completed as part of the 2018 ground investigation works show an average groundwater level at 1.09mbgl, while landfill monitoring records indicate an average groundwater level of approximately 1.8mbgl. This data, in combination with the BGS groundwater flooding susceptibility map (BGS, 2017) which shows there is potential for flooding of below ground property, indicates that shallow groundwater conditions are expected at the location of TC 035. HDD methods do not require dewatering. However, based on a maximum drilling depth of 6.1mbgl, it is likely that the water table would be intercepted, and following installation, much of the pipeline length is expected to sit below the water table.

1.39.11 Superficial deposits are expected to comprise the Shepperton Gravel at the crossing. Ground investigation records confirm the presence of gravels, which are recorded to a maximum depth of 8.22mbgl at locations close to the crossing. Recent ground investigation only encountered gravel to a depth of 7.60mbgl. Underlying the gravels, interbedded layers of sand, silt and clay were encountered which represent the Bagshot Formation bedrock which is expected at this location. Both these units are classed as important aquifer units. Based on available data, and a maximum HDD depth of 16mbgl, it is possible that the gravel and sand deposit down to 8.1mbgl in BH25 may be connected to the thin sand horizon from 14.5 to 15.6mbgl by the pipeline (a similar sand horizon was not identified in the BGS borehole TQ06NE76). As such, this crossing may create a new connection of two aquifer horizons during construction or operation with the horizons being separated by a clayey silt (as identified in BGS borehole TQ06NE76) or a clay and clayey sand (as identified in BH25).

1.40 TC 036 – B376 Shepperton Road

Feature(s) requiring trenchless crossing	B376 Shepperton Road
Trenchless crossing technique and characteristics	Auger bore technique Following details assumed from auger bore typical details drawings: • Assumes minimum depth of 2.0mbgl below services • Drive pit depth: assumed as 6.0mbgl • Drive pit length: approximately 11m • Drive pit width: approximately 3m • Reception pit depth: assumed as 6.0mbgl • Reception pit length: approximately 3m • Reception pit width: approximately 3m • Drive length: approximately 54m
Groundwater study area	GWSA-D

Geological and Hydrogeological Conditions at TC 036

1.40.1 The BGS geological map (BGS, 2018l) indicates that the bedrock underlying the crossing and in the surrounding area comprises the Claygate Member of sand.

1.40.2 The geological map (BGS, 2018l) shows that superficial deposits at the crossing over the path of the crossing comprise the Kempton Park Gravel Formation of sand and gravel. Approximately 90m to the south, the Shepperton Gravel Member of sand and gravel is mapped as present. Approximately 130m to the north of the crossing, the Langley Silt Member is mapped.

1.40.3 The aquifer designation map (Defra, 2018) shows that the crossing is located within an area classed as a Secondary A bedrock aquifer and a Principal superficial aquifer. The superficial deposits to the north of the crossing are defined as Unproductive strata.

1.40.4 Many of the nearest BGS records are confidential or lack data. The nearest record of use is TQ06NW352, located approximately 815m southwest of the crossing. The record for this location indicates the following ground conditions:

- 0 – 0.3mbgl: Topsoil;
- 0.3 – 0.9mbgl: Subsoil and stone;
- 0.9 – 8.5mbgl: Ballast;
- 8.5 – 9.1mbgl: Blue clay; and
- groundwater was encountered at 1.8mbgl (approximately 13.2mAOD).

1.40.5 The borehole elevation for the BGS record detailed above is at a slightly higher elevation than that of the crossing.

1.40.6 During the 2018 ground investigation works, BH17 was proposed immediately adjacent to the east of the crossing. However, this location has not been drilled. The nearest location which has been investigated is BH25, located approximately 1.6km south of the crossing. Records show that BH25 was completed in August 2018, when groundwater levels are likely to be lower than their maximum. The log record for this location indicates the following conditions:

- 0.70 – 1.20mbgl: Slightly sandy clay;
- 1.20m – 1.80mbgl: Clay;
- 1.80 – 7.60mbgl: Sandy gravel;
- 7.60 – 8.10mbgl: Sand;
- 8.10 – 8.50mbgl: Clay;
- 8.50 – 10.40mbgl: Clayey sand;
- 10.40 – 13.50mbgl: Clay;
- 13.50 – 14.60mbgl: Sand;
- 14.60 – 20.41mbgl: Sandy clay; and
- no groundwater strike noted due to the addition of water flush. Potential strikes within the sands and gravels (from 1.8m) and potential strike at 13.5m.

1.40.7 Groundwater levels have been measured manually on five separate occasions in BH25, which is located at an elevation of 11.43mAOD and was completed to a depth of 20.41mbgl. These measurements indicate an average groundwater level of 1.09mbgl, or 10.34mAOD. The data logger in BH25 has recorded the highest groundwater level as 0.55mbgl.

1.40.8 The BGS groundwater flooding susceptibility map (BGS, 2017) shows that the crossing is located within an area with two classifications. The majority of the crossing is located within an area classed as having the potential for groundwater flooding to occur at the surface. The south of the crossing is located in an area with the potential for groundwater flooding of property situated below ground level.

1.40.9 There are no EA groundwater level monitoring locations local to this crossing. However, groundwater level monitoring of landfills has been carried out close to the crossing. The nearest monitoring location, approximately 130m west of the crossing, recorded a maximum groundwater level of 12.0mAOD and an average groundwater level of 11.0mAOD (approximately 3mbgl and 4mbgl respectively).

Crossing TC 036 Assessment

1.40.10 During ground investigations, groundwater strikes were encountered at various levels. At locations closest to the crossing, the strike was identified at 1.8mbgl (BGS, 2018a). During the 2018 ground investigation, manual groundwater monitoring at a location approximately 1.6km from the crossing indicated an average groundwater level of 1.09mbgl, while continuous monitoring recorded the highest groundwater level at 0.55mbgl. Landfill monitoring data collected near to the crossing indicates groundwater levels between 3 and 4mbgl. In addition, the BGS groundwater flooding susceptibility map (BGS, 2017) shows that there is potential for flooding to occur at the surface. Based on available data, groundwater conditions at the crossing location are considered to be shallow. Assuming a maximum auger boring depth of 6mbgl, it is therefore likely that the water table would be intercepted.

1.40.11 Following installation, based on a maximum auger boring depth of 6mbgl, much of the length of the pipeline is expected to sit below the water table at TC 036.

1.40.12 Superficial deposits at the crossing are expected to comprise the Kempton Park Gravel Formation. Recent ground investigation records confirm the presence of gravel to a maximum depth of 7.60mbgl, although this location is 1.6km from the crossing. Underlying these gravel deposits, interbedded layers of clays and sand were encountered, and these likely represent the Claygate Member bedrock which is expected at this location. Based on available data, and assuming an auger bore depth of 6m, it is likely that the gravel deposits would be intercepted and unlikely that the underlying bedrock would be intercepted. However, this would depend on the local thicknesses of superficial deposits at the crossing itself. Both superficial and bedrock geology are classed as aquifer units. Should they be encountered together, they would be expected to be in hydraulic continuity with one another as there is no significant low permeability layer shown to separate them. As such, it is unlikely that this crossing would create a new connection of two aquifers during construction or operation.

1.40.13 For the calculation of effects due to dewatering, due to no local borehole, published values of hydraulic conductivity have been used. Given the mixed typology ranging from gravels to clay, an average hydraulic conductivity of 1.00E-04m/s has been selected to reflect the sands and gravels for this assessment. Calculated hydraulic conductivity values were available for BH25 but were not viewed as local enough to be representative of the crossing location (the average value from BH25 was 3.2E-04).

1.40.14 The expected maximum groundwater level has been estimated as 1.5mbgl, assuming that shallow groundwater encountered in the BGS borehole 800m from the crossing at approximately 1.8mbgl may show variability over the course of a year.

1.40.15 Table 8.2.28 presents the input and results of the radius of influence calculations. Additional input parameters and results used for the calculation of dewatering rates are given in Table 8.2.29. Potential receptors within the calculated radius of influence have been identified as detailed in Table 8.2.30.

Table 8.2.28: Input and Results for Calculating the Radius of Influence for TC 036

Parameter	Drive Pit Value	Reception Pit Value
Length (m)	11	3
Width (m)	3	3
Maximum pit depth (m)	6	6
Expected groundwater level (mbgl)	1.5	1.5
Calculated drawdown (m)	4.50	4.50
Hydraulic conductivity, K (m/s)	1.00E-04	1.00E-04
R (m)	135	135
Re (m)	3.2	1.7
Total radius of influence Ro (m)	138	137

Table 8.2.29: Input and Results for Estimating Dewatering Rate for TC 036

Parameter	Drive Pit Value	Reception Pit Value
H, saturated aquifer thickness (assumed as interbedded sands and clays thicknesses derived in GI) (m)	18.91	18.91
Q, dewatering rate	1,084m^3/day	927m^3/day
	12.6l/s	10.7l/s

Table 8.2.30: Potential Receptors Identified within the Radius of Influence for TC 036

Receptor	Distance from Drive Pit	Distance from Reception Pit	Comments
Groundwater abstractions			
None			
Buildings and Infrastructure			
Unlabelled buildings	Nearest building approximately 14m from the pit. Roads fall within Order Limits.	Nearest building approximately 60m from the pit. Roads fall within Order Limits.	
Surface waters			
Drain	Approximately 15m	Approximately 74m from the pit	
Unnamed surface water body	Approximately 103m from the pit	Approximately 47m from the pit	
GWDTEs			
None			
Potentially contaminated land			

Receptor	Distance from Drive Pit	Distance from Reception Pit	Comments
Laleham Landfill	Drive pit located within the area	Approximately 51m from the pit	
Home Farm Landfill	Approximately 37m from the pit	Reception pit located within the area	
Scheduled monuments and listed buildings			
None			

1.41 TC 037 – Queen Mary Reservoir Intake Canal

Feature(s) requiring trenchless crossing	Intake canal for reservoir
Trenchless crossing technique and characteristics	Auger bore technique Following details taken from site-specific design drawing and assuming a relatively deep crossing is needed: • Reaches an assumed maximum depth of about -3mAOD and maximum depth below ground of approximately 16m. • Drive pit depth: approximately 16mbgl • Drive pit length: approximately 11.5m • Drive pit width: approximately 3.5m • Reception pit depth: approximately 16mbgl • Reception pit length: approximately 4m • Reception pit width: approximately 4m • Drive length: approximately 44m
Groundwater study area	GWSA-D

Geological and Hydrogeological Conditions at TC 037

1.41.1 The BGS geological map (BGS, 2018l) shows that the bedrock underlying the crossing and much of the surrounding area comprises the Claygate Member of sand. Approximately 40m to the north of the crossing, the boundary with the London Clay Formation is shown.

1.41.2 Superficial deposits are mapped as being variable in their nature according to the geological map (BGS, 2018l). The crossing itself is shown to be located within an area of the Langley Silt Member. Approximately 20m to the north of the crossing, however, the Kempton Gravel Formation is shown to be present.

1.41.3 The aquifer designation map (Defra, 2018) shows that the crossing is located within an area classed as a Secondary A bedrock aquifer. The Langley Silt Member is classed as Unproductive strata, while the Kempton Park Gravel Formation to the north of the crossing is classed as a Principal superficial aquifer.

1.41.4 The nearest available BGS record, TQ06NE544, is located approximately 140m northeast of the crossing. The record for this location indicates the following ground conditions:

- 0 – 0.61mbgl: Topsoil;
- 0.61 – 1.22mbgl: Dirty ballast;

- 1.22 – 7.0mbgl: Sandy ballast;
- 7.0 – 9.75mbgl: Blue running sand;
- 9.75 – 12.80mbgl: London Clay (sandy); and
- water was encountered at 1.22mbgl (approximately 12.78mAOD).

1.41.5 The BGS record detailed above is located at a similar elevation to that of the crossing.

1.41.6 During the 2018 ground investigation works, the nearest proposed borehole is BH13 immediately west of the crossing. No data was available for this location at the time of writing. The nearest available ground investigation record is that of BH10, located approximately 1.45km northeast of the crossing. Records show that BH10 was completed at the end of September 2018, when the groundwater levels observed are likely to be lower than the potential maximum level. The borehole log record for this location indicates the following ground conditions:

- 0 – 0.15mbgl: Made ground;
- 0.15 – 1.10mbgl: Gravelly clay;
- 1.10 – 2.35mbgl: Gravelly sand;
- 2.35 – 3.70mbgl: Sand and gravel;
- 3.70 – 5.20mbgl: Clay; and
- a water strike was encountered at 0.83mbgl (12.17mAOD) within gravelly clay deposits.

1.41.7 Groundwater levels have been measured manually on five separate occasions at location BH10, which is located at an elevation of 12.80mAOD and was completed to a depth of 5.20m. These measurements indicate an average groundwater level of 0.52mbgl, or 12.28mAOD. The data logger in BH10 has recorded the highest groundwater level as 0.13mbgl.

1.41.8 There is no mapped data available regarding the groundwater flooding susceptibility rating at the location of the crossing due to the Langley Silt Member being classed as Unproductive strata (BGS, 2017). However, immediately north are areas classed as having the potential for groundwater flooding to occur at the surface.

1.41.9 There are no EA groundwater level monitoring locations local to this crossing. However, monitoring of groundwater levels has been completed at landfill locations in this region. The nearest EA landfill monitoring location is located approximately 60m east of the crossing. Records for this location indicate a maximum groundwater level of 12.20mAOD and an average groundwater level of 11.40mAOD (approximately 0.80mbgl and 1.60mbgl respectively).

Crossing TC 037 Assessment

1.41.10 During ground investigations, groundwater strikes were encountered at shallow depths ranging between 0.83 and 1.22mbgl (BGS, 2018a) at locations close to the crossing. In addition, landfill monitoring records provide an average groundwater level of 1.60mbgl and a maximum groundwater level of 0.8mbgl. During the 2018 ground investigation works, a groundwater level logger was installed into BH10, which recorded groundwater at 0.13mbgl at its shallowest, while manual groundwater monitoring confirmed an average groundwater level of 0.52mbgl. This borehole though is some distance from the crossing. Based on available data, groundwater levels are expected to be shallow at this location, and based on an auger boring depth of 7m, it is likely that the water table would be intercepted at this location.

1.41.11 Following pipeline installation, based on the auger boring depths, much of the length of the pipeline is expected to sit below the water table following installation at TC 037.

1.41.12 Superficial deposits at the crossing are expected to comprise the Langley Silt Member, although the Kempton Park Gravels are mapped immediately north (BGS, 2018l). Ground investigation records for this location are limited in displaying the thickness of superficial geology. The recent ground investigation, completed approximately 1.4km from the crossing, encountered sands and gravels to a depth of 3.70mbgl, while the BGS record located nearer to the crossing encountered ballast to a depth of 7.0mbgl. Underlying these, clay and sand was encountered. This is assumed to represent the Claygate Member bedrock expected at this location, while the BGS record indicates that the London Clay underlies deposits of sand at a depth of 9.75mbgl.

1.41.13 Due to the crossings' location in proximity to geological boundaries, in both the bedrock and the superficial deposits, the likely depths at which each would be encountered is uncertain based on currently available data. Based on an auger bore depth of 7mbgl, it is likely that both the superficial deposits, and potentially deposits of clay and sand, would be intercepted. The hydraulic continuity of these deposits is uncertain owing to their different aquifer classifications and their expected variability. Should the London Clay be encountered, no hydraulic connection would be expected. However, should the Claygate Member be encountered, hydraulic continuity with any overlying deposits of the Kempton Park Gravel would be expected, but would not be expected where the Langley Silt Member (Unproductive strata) is found to overly the bedrock. In the case where the Claygate Member is encountered beneath the Kempton Park Gravel, it is unlikely that a new pathway to connect two aquifers would be created as the two deposits would already be in hydraulic connection.

1.41.14 For the calculation of effects due to dewatering, hydraulic conductivity values have been calculated for BH10 at this location, the average of which is 2.96E-05m/s. This value, although from some distance from the crossing, has been used to represent hydraulic conductivity for this dewatering assessment. The maximum groundwater level of 0.13mbgl recorded at BH10 has been used for the rest water level, although this is some distance from the crossing.

1.41.15 Table 8.2.31 presents the input and results of the radius of influence calculations. Additional input parameters and results used for the calculation of dewatering rates are given in Table 8.2.32. Potential receptors within the calculated radius of influence have been identified as detailed in Table 8.2.33.

Table 8.2.31: Input and Results for Calculating the Radius of Influence for TC 037

Parameter	Drive Pit Value	Reception Pit Value
Length (m)	11.5	4
Width (m)	3.5	4
Maximum pit depth (m)	16	16
Expected groundwater level (mbgl)	0.13	0.13
Calculated drawdown (m)	3.57 (assumed as the maximum thickness of the gravel aquifer that would require dewatering)	3.57 (assumed as the maximum thickness of the gravel aquifer that would require dewatering)
Hydraulic conductivity, K (m/s)	2.96E-05	2.96E-05
R (m)	58	58
Re (m)	3.6	2.3
Total radius of influence Ro (m)	62	61

Table 8.2.32: Input and Results for Estimating Dewatering Rate for TC 037

Parameter	Drive Pit Value	Reception Pit Value
H, saturated aquifer thickness (assumed as sand and gravel thicknesses derived in GI) (m)	3.57	3.57
Q, dewatering rate	35.1m^3/day	30.4m^3/day
	0.41l/s	0.35l/s

Table 8.2.33: Potential Receptors Identified within the Radius of Influence for TC 037

Receptor	Distance from Drive Pit	Distance from Reception Pit	Comments
Groundwater abstractions			
None			
Buildings and Infrastructure			
Unlabelled buildings	Just beyond radius	Approximately 35m west of the pit	
Surface waters			
Intake Channel	Within Order Limits Approximately 24m from the pit	Within Order Limits Approximately 8m from the pit	
Unnamed surface water body	Within Order Limits Approximately 27m from the pit	Approximately 55m from the pit	Would be less affected by dewatering from reception pit
GWDTEs			
None			
Potentially contaminated land			
Queen Mary Quarry	Within Order Limits Approximately 60m from the pit	Within Order Limits Approximately 10m from the pit	
South of Queen Mary Reservoir Landfill	Approximately 12m from the pit	Approximately 57m from the pit	

Receptor	Distance from Drive Pit	Distance from Reception Pit	Comments
Scheduled monuments and listed buildings			
None			

1.42 TC 038 – Staines Reservoir Aqueduct and B377 Ashford Road

Feature(s) requiring trenchless crossing	Outlet canal and B377 Ashford Road
Trenchless crossing technique and characteristics	HDD technique Following details assumed from HDD typical details drawings: • Assumed a maximum drilling depth of 5mbgl for this assessment • Drive length: approximately 137m
Groundwater study area	GWSA-D

Geological and Hydrogeological Conditions at TC 038

1.42.1 The BGS geological map (BGS, 2018m) indicates that the bedrock underlying the crossing and in the surrounding areas comprises the London Clay Formation.

1.42.2 The geological map (BGS, 2018m) indicates that the superficial deposits at the crossing comprise the Kempton Park Gravel Formation of sand and gravel. Approximately 90m to the east, deposits of silty Alluvium are mapped.

1.42.3 The aquifer designation map (Defra, 2018) shows that the crossing is located within an area defined as a Principal superficial aquifer. The Alluvium deposits to the east of the crossing are classed as a Secondary A superficial aquifer. The bedrock at this crossing is classed as Unproductive strata.

1.42.4 The nearest available BGS record, TQ07SE401, is located approximately 125m southeast of the crossing. The log record for this borehole indicates the following ground conditions:

- 0 – 0.3mbgl: Soil;
- 0.3 – 1.52mbgl: Loam;
- 1.52 – 7.32mbgl: Thames Ballast;
- 7.32 – 13.72mbgl: Hard blue sand;
- 13.72 – 18.43mbgl: Blue running sand;
- 18.43 – 21.48mbgl: London Clay (sandy); and
- water was encountered at 0.91mbgl (approximately 12.09mAOD).

1.42.5 During the 2018 ground investigation works, BH10 was completed approximately 150m east of the crossing. Records show that BH10 was completed in September 2018, when the groundwater levels observed are likely to be lower than the potential maximum level. The log record for this location indicates the following ground conditions:

- 0 – 0.15mbgl: Made ground;

- 0.15 – 1.10mbgl: Gravelly clay;
- 1.10 – 2.35mbgl: Gravelly sand;
- 2.35 – 3.70mbgl: Sand and gravel;
- 3.70 – 5.20mbgl: Clay; and
- a water strike was encountered at 0.83mbgl (12.17mAOD) within gravelly clay deposits.

1.42.6 Groundwater levels have been measured manually on five separate occasions at location BH10, which is located at an elevation of 12.80mAOD and was completed to a depth of 5.20m. These measurements indicate an average groundwater level of 0.52mbgl, or 12.28mAOD. The data logger in BH10 has recorded the highest groundwater level as 0.13mbgl.

1.42.7 The BGS groundwater flooding susceptibility map (BGS, 2017) shows that the crossing is located within an area with potential for groundwater flooding to occur at the surface (superficial deposits flooding).

1.42.8 There are no EA groundwater monitoring locations pertinent to the location of this crossing. However, groundwater level monitoring at landfill locations in this region has been undertaken. The nearest landfill monitoring location, W14A, is located approximately 30m south of the crossing. Data for this location shows an average groundwater level of 12.20mAOD (approximately 1.80mbgl)

Crossing TC 038 Assessment

1.42.9 Groundwater strike was confirmed at shallow depths ranging between 0.83 and 0.91mbgl during both recent and historical (BGS, 2018a) ground investigations. In addition, landfill monitoring records indicate an average groundwater level of approximately 1.80mbgl. The BGS groundwater flooding susceptibility map shows that there is potential for flooding to occur at the surface, indicating groundwater levels are likely to be found at shallow depths. In addition, groundwater has been monitored continuously using a groundwater level logger in BH10, which recorded groundwater at 0.13mbgl at its shallowest, while manual measurements indicate an average groundwater level of 0.52mbgl. Based on available data, groundwater at TC 038 is therefore expected to be shallow. HDD methods do not require dewatering. However, assuming a maximum drilling depth of 5mbgl, it is likely that the water table would be intercepted during drilling, and following installation, much of the length of the pipeline would likely sit below the water table at TC 038 if HDD methods are used.

1.42.10 Superficial deposits at the crossing are expected to comprise the Kempton Park Gravel Formation. Ground investigation records adjacent to the crossing confirm the presence of gravels, to a maximum depth of 3.70mbgl. Underlying these gravels, clay was identified. This is assumed to represent the London Clay bedrock which is mapped at this location (BGS, 2018m). Therefore, assuming an HDD depth of 5m, it is likely that both the superficial and bedrock geological units would be intercepted during drilling. The London Clay is classed as Unproductive strata, and therefore it is unlikely that there would be any hydraulic connection between the bedrock and superficial gravel aquifer. As such, it is unlikely that this crossing would create a new connection of two aquifers during construction or operation.

1.43 TC 039 – Staines Bypass A308, River Ash and Woodthorpe Road

Feature(s) requiring trenchless crossing	A308 Staines Bypass, Woodthorpe Road, River Ash
Trenchless crossing technique and characteristics	HDD technique Following details assumed from HDD typical details drawings: • Assumed a maximum drilling depth of 5mbgl for this assessment • Drive length: approximately 204m
Groundwater study area	GWSA-D

Geological and Hydrogeological Conditions at TC 039

1.43.1 The BGS geological map (BGS, 2018m). shows that the bedrock geology underlying the crossing and in the surrounding area comprises the London Clay Formation.

1.43.2 Superficial deposits are expected to be variable in their nature according to geological map (BGS, 2018m). The southern portion of the crossing is shown to be located within deposits of the Kempton Park Gravel Formation of sand and gravel. The northern portion of the crossing is shown to be located within deposits of Alluvium (silt), which follows the route of the River Ash. To the north of the Alluvium deposits, the Kempton Park Gravel Formation is indicated to continue.

1.43.3 The aquifer designation map (Defra, 2018) indicates that the southern portion of the crossing, and further north, is classed as a Principal superficial aquifer. The Alluvium deposits that cover the crossing are classed as a Secondary A superficial aquifer. The bedrock in this region is classed as Unproductive strata.

1.43.4 The nearest BGS borehole record, TQ07SE13, is located approximately 320m northwest of the crossing. The online record for this borehole indicates the following ground conditions:

- 0 – 0.50mbgl: Topsoil;
- 0.5 – 1.20mbgl: Slightly sandy clay;
- 1.20 – 4.50mbgl: Gravel with varying amounts of sand, and bound in sandy clay;
- 4.50 – 6.50mbgl: Silty clay, with frequent partings of silty sand; and
- groundwater was encountered at 1.80mbgl (approximately 12.20mAOD).

1.43.5 The borehole for the BGS record detailed above is located at a similar elevation to that of the crossing.

1.43.6 During the 2018 ground investigation works, BH09 was completed immediately south of the crossing. BH09 was completed in September 2018, when groundwater levels are likely to be lower than their potential winter maximum. The log record for this location shows the following ground conditions:

- 0 – 0.42mbgl: Made ground;
- 0.42 – 1.38mbgl: Gravelly clay to sandy gravelly clay;

- 1.38 – 2.15mbgl: Clayey gravelly sand;
- 2.15 – 4.57mbgl: Sandy gravel;
- 4.57 – 5.10mbgl: Gravelly sand;
- 5.10 – 10.20mbgl: Silty clay; and
- a water strike of 1.7mbgl is recorded on the borehole log.

1.43.7 In addition, BH08 was completed immediately north of the crossing. Records show that this was completed in September 2018, when observed groundwater levels are likely lower than their potential maximum. The log record for this borehole shows the following ground conditions:

- 0 – 1.05mbgl: Made ground;
- 1.05 – 1.50mbgl: Gravelly sandy clay;
- 1.50 – 1.65mbgl: Clayey, slightly gravelly sand;
- 1.65 – 4.20mbgl: Gravelly sand;
- 4.20 – 10.65mbgl: Silty clay; and
- groundwater strike at 1.70mbgl is recorded on the borehole log.

1.43.8 Groundwater levels have been measured manually on five separate occasions at location BH09, which is located at an elevation of 13.41mAOD and was completed to a depth of 10.65mbgl. These measurements indicate an average groundwater level of 1.40mbgl, or 12.01mAOD. The data logger in BH09 has recorded the highest groundwater level as 0.62mbgl.

1.43.9 Groundwater levels have also been measured manually on five separate occasions at BH08, which is located at an elevation of 13.66mAOD and was completed to a depth of 10.65mbgl. These measurements indicate an average groundwater level of 1.32mbgl, or 12.34mAOD. The data logger in BH08 has recorded the highest groundwater level as 0.83mbgl.

1.43.10 The BGS groundwater flooding susceptibility map (BGS, 2017) shows that the crossing is located within an area with the potential for groundwater flooding to occur at the surface (superficial deposits flooding).

1.43.11 There are no EA groundwater level monitoring locations local to this crossing location. However, groundwater level monitoring at landfill locations has been undertaken in this region. The nearest EA landfill monitoring location, borehole W14A, is located approximately 550m southeast of the crossing and records an average groundwater level of 12.2mAOD (approximately 1.8mbgl).

Crossing TC 039 Assessment

1.43.12 Ground investigations record shallow groundwater levels. Historical records (BGS, 2018a) located approximately 320m from the crossing encountered a shallow groundwater strike at 1.80mbgl and ground investigation in 2018 recorded groundwater at a depth of 1.7mbgl immediately south and north of the crossing. Groundwater monitoring was completed at the same locations as part of the 2018 ground investigation which recorded average groundwater levels of 1.40mbgl and 1.32mbgl. The shallowest recorded groundwater levels from continuous groundwater monitoring is 0.83mbgl. EA landfill monitoring records in this region also show shallow groundwater levels of approximately 1.8mbgl. This data, in combination with the BGS groundwater flooding susceptibility map (BGS, 2017), which indicates there is potential for flooding to occur, indicates that groundwater conditions at this location are expected to be shallow. HDD does not require dewatering, but assuming a drilling depth of 5m, it is likely that the water table would be intercepted at this location. Following installation, based on available data, the pipeline would likely sit below the water table at TC 039.

1.43.13 Superficial deposits are expected to be variable in their nature and may comprise Kempton Park Gravel deposits or possibly Alluvium. Ground investigation records confirm the presence of gravels to a maximum depth of between 4.50 and 5.10mbgl. Underlying these deposits, silty clay with silty sand was recorded. This is assumed to represent the London Clay bedrock. Based on an HDD depth of 5m, it is therefore likely that the superficial gravel aquifer would be intercepted, and there is potential that the London Clay may be intercepted, depending on local thicknesses of gravels at the crossing. The London Clay is classed as Unproductive strata, and therefore no hydraulic connection is expected between the bedrock and the superficial gravels. As such, it is unlikely that this crossing would create a new connection of two aquifers during construction or operation.

1.44 TC 040 – B378 Church Road

Feature(s) requiring trenchless crossing	B378 Church Road
Trenchless crossing technique and characteristics	Auger bore technique Following details taken from site-specific design drawing: • Reaches a maximum depth of about 6mAOD and maximum depth below ground of approximately 7m • Drive pit depth: approximately 7.9mbgl • Drive pit length: approximately 11.5m • Drive pit width: approximately 3.5m • Reception pit depth: approximately 8.3mbgl • Reception pit length: approximately 4m • Reception pit width: approximately 4m • Drive length: approximately 41m
Groundwater study area	GWSA-D

Geological and Hydrogeological Conditions at TC 040

1.44.1 The BGS geological map (BGS, 2018m) indicates that the bedrock underlying the crossing and in the surrounding area comprises the London Clay Formation.

1.44.2 Superficial deposits comprise the Kempton Park Gravel Formation at the crossing and in the surrounding area (BGS, 2018m).

1.44.3 The aquifer designation map (Defra, 2018) shows the crossing is located in an area of Principal superficial aquifer associated with the Kempton Park Gravel Formation. The bedrock is classed as Unproductive strata.

1.44.4 The nearest BGS borehole record, located approximately 150m west of the crossing, TQ07SE68, indicates the following ground conditions:

- 0 – 3.50mbgl: Made ground;
- 3.50 – 3.90mbgl: Gravel;
- 3.90 – 7.00mbgl: Silty clay; and
- groundwater strike is indicated at 2.70mbgl (12.3mAOD).

1.44.5 The BGS record listed above is located at a similar elevation to the crossing. The presence of clay from 3.9m is potentially the start of the London Clay.

1.44.6 During the 2018 ground investigation works, BH06 was completed in early September 2018, approximately 150m to the north of the crossing. The groundwater levels observed in September are likely to be lower than the maximum level seen during winter months. The log record indicates the following ground conditions:

- 0 – 0.3mbgl: Topsoil;
- 0.3 – 1.60mbgl: Made ground;
- 1.60 – 2.48mbgl: Clay, possible made ground;
- 2.48 – 5.10mbgl: Gravelly sand;
- 5.10 – 15.45mbgl: Silty clay; and
- no water observations are recorded on the log record due to the use of water flush for drilling.

1.44.7 Groundwater levels have been measured manually on six separate occasions at location BH06, which is located at an elevation of 15.39mAOD and was completed to a depth of 5.0mbgl. These measurements indicate an average groundwater level of 2.26mbgl, or 13.13mAOD. The data logger in BH06 has recorded the highest groundwater level as 1.83mbgl.

1.44.8 As part of the local landfill monitoring network, a number of locations close to the crossing were monitored. The average groundwater levels recorded at locations closest to the crossing (about 120m away) is 12.26mAOD. This equates to approximately 2.8mbgl.

1.44.9 The BGS groundwater flooding susceptibility map (BGS, 2017) indicates the crossing is located within an area with potential for groundwater flooding to occur at the surface, indicating potential shallow groundwater conditions.

Crossing TC 040 Assessment

1.44.10 BGS ground investigation records (BGS, 2018a) indicate a groundwater strike at 2.70mbgl in a borehole approximately 150m from the crossing. Groundwater monitoring has been completed as part of the 2018 ground investigation at the crossing, records for which indicate an average groundwater level of 2.26mbgl. Continuous groundwater monitoring recorded 1.83mbgl as the shallowest groundwater level. Shallow groundwater conditions are further supported by landfill monitoring records, which provide an average groundwater level of 2.8mbgl. This data, combined with the BGS groundwater flooding susceptibility definition, indicates that shallow groundwater conditions are expected in this area. The boring phase of the construction would not require any dewatering to take place, although once installed, the pipeline is expected to sit below the water table.

1.44.11 Ground investigation records indicate the presence of made ground, which impacts the thickness of superficial deposits seen on these records. From these records, gravels were encountered at 3.50mbgl and 2.48mbgl with thicknesses between 0.4m and 2.62m. Silty Clay was found underlying these and is assumed to represent the London Clay Formation. This has a thickness of greater than 3.1m. The auger boring therefore has the potential to encounter the London Clay Formation, but as this is Unproductive strata, it is not expected to be in hydraulic connection with any overlying superficial aquifer unit. As such, it is unlikely that this crossing would create a new connection of two aquifers during construction or operation.

1.44.12 For the calculation of effects due to dewatering, hydraulic conductivity values have been calculated from ground investigation at BH6. The average of these hydraulic conductivity values, 9.83E-06m/s, has been used to represent hydraulic conductivity (K) for this assessment.

1.44.13 The expected maximum groundwater level has been estimated as 1.5mbgl, assuming that shallow groundwater encountered at approximately 1.83mbgl may show variability over the course of a year.

1.44.14 Table 8.2.34 presents the input and results of the radius of influence calculations. Additional input parameters and results used for the calculation of dewatering rates are given in Table 8.2.35. Potential receptors within the calculated radius of influence have been identified as detailed in Table 8.2.36.

Table 8.2.34: Input and Results for Calculating the Radius of Influence for TC 040

Parameter	Drive Pit Value	Reception Pit Value
Length (m)	11.5	4
Width (m)	3.5	4
Maximum pit depth (m)	7.9	8.3
Expected groundwater level (mbgl)	1.5	1.5
Calculated drawdown (m)	3.6 (Assumed as saturated aquifer thickness rather than calculated value)	3.6 (Assumed as saturated aquifer thickness rather than calculated drawdown)
Hydraulic conductivity, K (m/s)	9.83E-06	9.83E-06
R (m)	34	34
Re (m)	3.6	2.3
Total radius of influence Ro (m)	37	36

Table 8.2.35: Input and Results for Estimating Dewatering Rate for TC 040

Parameter	Drive Pit Value	Reception Pit Value
H, saturated aquifer thickness (assumed as gravel thicknesses	3.6	3.6

Parameter	Drive Pit Value	Reception Pit Value
derived from the most conservative value out of ground investigation and nearby BGS record) (m)		
Q, dewatering rate	14.7m^3/day	12.5m^3/day
	0.17l/s	0.14l/s

Table 8.2.36: Potential Receptors Identified within the Radius of Influence for TC 040

Receptor	Distance from Drive Pit	Distance from Reception Pit	Comments
Groundwater abstractions			
None			
Buildings and Infrastructure			
Educational facilities and buildings	Nearest school buildings located approximately 30m from the pit	Beyond radius	Located at edge of drive pit radius and so would likely not be greatly impacted by dewatering.
Commercial properties	Just beyond radius	Less than 10m	
Residential roads and properties	Just beyond radius	Nearest properties located approximately 20m from the pit	
Railway	Approximately 27m from the pit	Approximately 20m from the pit	At Ashford station
Surface waters			
None			
GWDTEs			
None			
Potentially contaminated land			
Hitchcock & King (former railway sidings)	Approximately 33m from the pit (at edge of radius)	Small portion within Order Limits Approximately 6m from the pit	Would not be greatly impacted by dewatering from drive pit
Scheduled monuments and listed buildings			
None			

1.45 TC 041 – Waterloo to Reading Railway Line

Feature(s) requiring trenchless crossing	South Western Railway
Trenchless crossing technique and characteristics	Auger bore technique Following details taken from site-specific design drawing: • Reaches a maximum depth of about 8.9mAOD and maximum depth below ground of approximately 6.1m • Drive pit depth: approximately 7.5mbgl • Drive pit length: approximately 11m • Drive pit width: approximately 4m • Reception pit depth: approximately 7mbgl

	• Reception pit length: approximately 4m • Reception pit width: approximately 3.5m • Drive length: approximately 75m
Groundwater study area	GWSA-D

Geological and Hydrogeological Conditions at TC 041

1.45.1 The BGS geological map (BGS, 2018m) indicates that the crossing is located within an area where bedrock comprises the London Clay Formation, which continues in the surrounding area.

1.45.2 Superficial deposits are mapped as comprising the Kempton Park Gravel, which is continuous in the surrounding areas (BGS, 2018m).

1.45.3 The aquifer designation map (Defra, 2018) shows the crossing is located in an area of Principal superficial aquifer associated with the Kempton Park Gravel Formation. The London Clay is classed as Unproductive strata.

1.45.4 The nearest available BGS record located approximately 195m west of the crossing, TQ07SE68, indicates the following ground conditions:

- 0 – 3.50mbgl: Made ground;
- 3.50 – 3.90mbgl: Gravel;
- 3.90 – 7.00mbgl: Silty clay; and
- groundwater strike is indicated at 2.70mbgl (12.3mAOD).

1.45.5 The borehole for the BGS record detailed above is at a similar elevation to that of the crossing itself.

1.45.6 During the 2018 ground investigation works, BH06 was completed approximately 120m to the northwest, in September 2018. The groundwater levels observed in September are likely to be lower than the maximum level seen during winter months. The log record indicates the following ground conditions:

- 0 – 0.3mbgl: Topsoil;
- 0.3 – 1.60mbgl: Made ground;
- 1.60 – 2.48mbgl: Clay, possible made ground;
- 2.48 – 5.10mbgl: Gravelly sand;
- 5.10 – 15.45mbgl: Silty clay; and
- no water observations are recorded on the log record due to the use of water flush for drilling.

1.45.7 Groundwater levels have been measured manually on six separate occasions at location BH06, which is located at an elevation of 15.39mAOD and was completed to a depth of 5.0mbgl. These measurements indicate an average groundwater level of 2.26mbgl, or 13.13mAOD. The data logger in BH06 has recorded the highest groundwater level as 1.83mbgl.

1.45.8 As part of the local landfill monitoring network, monitoring records from around 120m away from the crossing provide an average groundwater level of 12.2mAOD. This equates to a groundwater strike at approximately 2.8mbgl.

1.45.9 The BGS groundwater flooding susceptibility map (BGS, 2017) indicates the crossing is located in an area with potential for groundwater flooding to occur at the surface, indicating potential shallow groundwater conditions within this area.

Crossing TC 041 Assessment

1.45.10 Ground investigation records held by the BGS (BGS, 2018a) confirmed a groundwater strike at 2.7mbgl. In addition, groundwater monitoring completed as part of the 2018 ground investigation works shows an average groundwater level of 2.26mbgl, while continuous groundwater monitoring recorded groundwater at 1.83mbgl at its shallowest. Shallow groundwater is further supported by landfill records indicating similar average groundwater levels of 2.8mbgl and the BGS groundwater flooding susceptibility map classification. Available data suggests that groundwater conditions are expected to be shallow in this area. The boring phase of the construction would not require any dewatering to take place, although once installed, the pipeline is expected to sit below the water table.

1.45.11 Ground investigation records indicate that the depths and thicknesses of superficial strata are expected to be variable. Made ground was encountered in these records, so superficial deposits of sand and gravel were encountered with thicknesses of 0.4 and 2.60m. Made ground may vary significantly over a short distance, thereby causing variability in superficial thicknesses. The London Clay was encountered underlying these superficial deposits at depths of 3.9mbgl and 5.1mbgl. The depth to the London Clay will be dependent on local superficial thicknesses. Auger bore methods have the potential to encounter the London Clay, but as the clay is Unproductive strata, it is unlikely that this crossing would create a new connection of two aquifers during construction or operation.

1.45.12 For the calculation of effects due to dewatering, hydraulic conductivity values have been calculated from ground investigation at BH06. The average of these, 9.83E-06m/s has been used to represent hydraulic conductivity (K) for this assessment.

1.45.13 The expected maximum groundwater level has been estimated as 1.5mbgl, assuming that shallow groundwater encountered at approximately 1.83mbgl may show variability over the course of a year.

1.45.14 Table 8.2.37 presents the input and results of the radius of influence calculations. Additional input parameters and results used for the calculation of dewatering rates are given in Table 8.2.38. Potential receptors within the calculated radius of influence have been identified as detailed in Table 8.2.39.

Table 8.2.37: Input and Results for Calculating the Radius of Influence for TC 041

Parameter	Drive Pit Value	Reception Pit Value
Length (m)	11.0	4.0
Width (m)	4.0	3.5

Parameter	Drive Pit Value	Reception Pit Value
Maximum pit depth (m)	7.50	7.0
Expected groundwater level (mbgl)	1.5	1.5
Calculated drawdown (m)	3.6 (Assumed as saturated gravel aquifer thickness)	3.6 (Assumed as saturated gravel aquifer thickness)
Hydraulic conductivity, K (m/s)	9.83E-06	9.83E-06
R (m)	34	34
Re (m)	3.70	2.1
Total radius of influence Ro (m)	38	36

Table 8.2.38: Input and Results for Estimating Dewatering Rate for TC 041

Parameter	Drive Pit Value	Reception Pit Value
H, Saturated aquifer thickness (assumed as gravel thicknesses derived in GI) (m)	3.6	3.6
Q, dewatering rate	15.0m^3/day	12.2m^3/day
	0.17l/s	0.14l/s

Table 8.2.39: Potential Receptors Identified within the Radius of Influence for TC 041

Receptor	Distance from Drive Pit	Distance from Reception Pit	Comments
Groundwater abstractions			
None			
Buildings and Infrastructure			
Railway	Beyond radius	Within Order Limits approximately 12m from pit	At Ashford station
Surface waters			
Two unnamed surface water bodies	Within Order Limits Located approximately 21m and 19.5m from the pit	Just beyond radius	
GWDTEs			
None			
Potentially contaminated land			
Hitchcock and King (former railway sidings)	Beyond radius	Approximately 36m (on edge of radius)	Unlikely to be impacted by dewatering given the distances
St David's School (former landfill)	Within Order Limits Approximately 2m from the pit	Located approximately 32m from the pit (at edge of radius)	
Scheduled monuments and listed buildings			
None			

1.46 TC 042 –Staines Road A30

Feature(s) requiring trenchless crossing	South Western Railway
Trenchless crossing technique and characteristics	Auger bore or HDD technique **1. Auger bore technique** Following details assumed from auger bore typical details drawings: • Assumes minimum depth of 2.0mbgl below services • Drive pit depth: assumed as 6.0mbgl • Drive pit length: approximately 11m • Drive pit width: approximately 3m • Reception pit depth: assumed as 6.0mbgl • Reception pit length: approximately 3m • Reception pit width: approximately 3m • Drive length: not known at this stage **2. HDD technique** Following details assumed from HDD typical details drawings: • Assumed a maximum drilling depth of 5mbgl for this assessment • Drive length: approximately 66m
Groundwater study area	GWSA-D

Geological and Hydrogeological Conditions at TC 042

1.46.1 The BGS geological map (BGS, 2018m) shows that the bedrock underlying the crossing and the surrounding area comprises the London Clay Formation.

1.46.2 Superficial deposits both at the crossing and in the surrounding areas are shown on the geological map (BGS, 2018m) to comprise the Kempton Park Gravel Formation of sand and gravel.

1.46.3 The aquifer designation map (Defra, 2018) shows that the crossing is located within an area classed as a Principal superficial aquifer, associated with the Kempton Park Gravel Formation. The bedrock at this location is classed as Unproductive strata.

1.46.4 The nearest available BGS borehole record, located approximately 245m west of the crossing, TQ07SE486, indicates the following ground conditions:

- 0 – 0.20mbgl: Topsoil;
- 0.20 – 1.40mbgl: Gravelly silt;
- 1.40 – 1.80mbgl: Gravelly sand;
- 1.80 – 2.30mbgl: Sand; and
- no groundwater observations are given.

1.46.5 A second BGS borehole log was reviewed to determine the depths and thicknesses of deeper geology. The nearest deeper borehole located approximately 1.15km north of the crossing, TQ07SE4, indicates the following ground conditions:

- 0 – 3.5mbgl: Drift;
- 3.5 – 70.7mbgl: London Clay;

- 70.7 – 96.62mbgl – Reading Beds;
- 96.62 – 318.8mbgl – Chalk;
- 318.8 – 393.1mbgl – Gault; and
- Lower Greensand was touched beneath this.

1.46.6 The first BGS record detailed above is located at a similar elevation to that of the crossing, while the second record is located at a slightly higher elevation than the crossing.

1.46.7 During the 2018 ground investigation works, the nearest borehole to the crossing was BH03, located approximately 350m south of the crossing location. Records show that BH03 was completed at the end of May 2018, when groundwater levels may be slightly lower than their potential winter maximum. The log record for this borehole indicates the following ground conditions:

- 0 – 5.45mbgl: Made ground; and
- groundwater strike was encountered at 3.0mbgl with the water level rising to 2.10mbgl (approximately 13.90mAOD).

1.46.8 Groundwater levels have been measured manually on five separate occasions at location BH03, which is located at an elevation of 15.59mAOD and was completed to a depth of 5.0mbgl. This indicates an average groundwater level of 2.59mbgl, or 13.00mAOD. The data logger in BH03 has recorded the highest groundwater level as 2.14mbgl.

1.46.9 The BGS groundwater flooding susceptibility map (BGS, 2017) shows that the crossing is located within an area classed as having the potential for groundwater flooding to occur at the surface (superficial deposits flooding). Immediately south of the crossing are areas classed as having the potential for groundwater flooding of property situated below ground level (superficial deposits flooding).

1.46.10 There are no EA groundwater level monitoring locations local to the crossing. However, groundwater level monitoring at landfill locations in this region has been carried out. The nearest landfill monitoring location is located approximately 960m southwest of the crossing and records an average groundwater level of 12.26mAOD (approximately 2.7mbgl).

Crossing TC 042 Assessment

1.46.11 During the 2018 ground investigation works, a groundwater strike was encountered at a shallow depth of 2.10mbgl within deposits of made ground. Subsequent manual groundwater monitoring at the same location indicates an average groundwater level of 2.59mbgl, while continuous monitoring showed that the shallowest groundwater level recorded was 2.14mbgl. Historical ground investigation records (BGS, 2018a) did not record groundwater observations. However, landfill monitoring records provide an average groundwater level of approximately 2.7mbgl, less than 1km from the crossing. In addition, the BGS groundwater flooding susceptibility map (BGS, 2017) shows that there is potential for flooding to occur at the surface, which suggests that groundwater conditions are shallow. Therefore, at TC 042, groundwater is expected to be shallow. HDD methods do not require dewatering. However, assuming an HDD depth of 5m, the groundwater table is likely to be encountered during the drilling process. Following installation, much of the length of the pipeline is expected to sit below the water table.

1.46.12 If the auger bore method is used, once installed, assuming maximum pit depths of 6mbgl, much of the length of the pipeline is expected to sit below the water table.

1.46.13 Superficial deposits are expected to comprise sands and gravels of the Kempton Park Gravel Formation. Ground investigation records confirm gravels and drift deposits to a maximum depth of 3.50mbgl. Underlying this, the London Clay was encountered. Based on a maximum HDD depth of 5mbgl, and a maximum auger boring depth of 6mbgl, both methods are likely to encounter both the superficial deposits and the underlying London Clay bedrock. Only the superficial deposits comprise a viable aquifer unit, as the clay bedrock is classed as Unproductive strata. As such, it is unlikely that this crossing would create a new connection of two aquifers during construction or operation.

1.46.14 For the calculation of effects due to dewatering, published values of hydraulic conductivity have been used (no permeability tests were undertaken in BH03). Given the mixed typology ranging from gravels to clay, although likely to be dominated by gravels for dewatering purposes, a hydraulic conductivity of 1.00E-04m/s has been selected for this assessment.

1.46.15 The expected maximum groundwater level has been estimated as 1.8mbgl, assuming that shallow groundwater encountered at approximately 2.1mbgl may show variability over the course of a year.

1.46.16 Table 8.2.40 presents the input and results of the radius of influence calculations. Additional input parameters and results used for the calculation of dewatering rates are given in Table 8.2.41. Potential receptors within the calculated radius of influence have been identified as detailed in Table 8.2.42.

Table 8.2.40: Input and Results for Calculating the Radius of Influence for TC 042

Parameter	Drive Pit Value	Reception Pit Value
Length (m)	11	3
Width (m)	3	3
Maximum pit depth (m)	6	6
Expected groundwater level (mbgl)	1.8	1.8
Calculated drawdown (m)	1.7 (Assumed as saturated gravel aquifer thickness)	1.7 (Assumed as saturated gravel aquifer thickness)
Hydraulic conductivity, K (m/s)	1.00E-04	1.00E-04
R (m)	51	51
Re (m)	3.2	1.7
Total radius of influence Ro (m)	54	53

Table 8.2.41: Input and Results for Estimating Dewatering Rate for TC 042

Parameter	Drive Pit Value	Reception Pit Value
H, saturated aquifer thickness (assumed as drift sand thicknesses derived in GI) (m)	1.7	1.7
Q, dewatering rate	27.8m^3/day	22.8m^3/day
	0.32l/s	0.26l/s

Table 8.2.42: Potential Receptors Identified within the Radius of Influence for TC 042

Receptor	Distance from Drive Pit	Distance from Reception Pit	Comments
Groundwater abstractions			
None			
Buildings and Infrastructure			
Residential properties and roads	Nearest property located approximately 10m from the pit Road cuts through Order Limits and crossing.	Nearest property located approximately 57m from the pit (beyond radius). Road cuts through Order Limits and crossing.	Properties unlikely to be impacted by dewatering from reception pit
Surface waters			
None			
GWDTEs			
None			
Potentially contaminated land			
St David's School (former landfill)	Drive pit located within this area	Approximately 40m from the pit	
Scheduled monuments and listed buildings			
None			

1.47 Summary of Assessment

1.47.1 Table 8.2.43 summarises the potential for impact for each of the trenchless crossings. A tick indicates that there is a feature within the estimated radius of influence of the crossing (either the drive pit or reception pit or both) and a cross signifies that that feature is not within the estimated radius of influence.

Table 8.2.43: Summary of Trenchless Crossings Assessment: Receptors Identified within the Radius of Influence, Potential for Connection of Two Aquifers and Locations where Artesian Water has been Identified

Trenchless Crossing Number	Crossing Method	Receptors Identified within the Radius of Influence of Dewatering						Potential for Connection of Two Aquifers	Artesian Groundwater Identified
		Groundwater Abstractions	Buildings and Infrastructure	Surface Waters	GWDTEs	Potentially Contaminated Land	Scheduled Monuments and Listed Buildings		
TC 001	HDD	✗	✗	✗	✗	✗	✗	✗	✓
TC 002	Auger bore	✗	✗	✗	✗	✗	✗	✗	✗
TC 003	Auger bore	✗	✗	✗	✗	✗	✗	✗	✗
TC 004	HDD	✗	✗	✗	✗	✗	✗	✗	✗
TC 005	Auger bore	✗	✗	✗	✗	✗	✗	✗	✗
TC 006	HDD	✗	✗	✗	✗	✗	✗	✗	✗
TC 007	Open cut or auger bore	✗	✗	✗	✗	✗	✗	✗	✗
TC 008	HDD	✗	✗	✗	✗	✗	✗	✗	✗
TC 009	HDD	✗	✗	✗	✗	✗	✗	✗	✗
TC 010	HDD	✗	✗	✗	✗	✗	✗	✗	✗
TC 011	HDD	✗	✗	✗	✗	✗	✗	✗	✗
TC 012	HDD	✗	✗	✗	✗	✗	✗	✗	✗
TC 013	HDD	✗	✗	✗	✗	✗	✗	✗	✗
TC 014	Auger bore	✗	✗	✓	✓	✓	✗	✗	✗
TC 015	Auger bore	✗	✓	✗	✗	✗	✗	✗	✗
TC 016	HDD	✗	✗	✗	✗	✗	✗	✗	✗

Trenchless Crossing Number	Crossing Method	Receptors Identified within the Radius of Influence of Dewatering						Potential for Connection of Two Aquifers	Artesian Groundwater Identified
		Groundwater Abstractions	Buildings and Infrastructure	Surface Waters	GWDTEs	Potentially Contaminated Land	Scheduled Monuments and Listed Buildings		
TC 017	HDD	✗	✗	✗	✗	✗	✗	✗	✗
TC 018	HDD	✗	✗	✗	✗	✗	✗	✗	✗
TC 019	Auger bore	✗	✗	✗	✗	✗	✗	✗	✗
TC 020	HDD, open cut and auger bore	✗	✓	✓	✓	✓	✗	✗	✗
TC 021	Auger bore	✗	✗	✗	✗	✗	✗	✗	✗
TC 022	HDD	✗	✗	✗	✗	✗	✗	✗	✗
TC 023	HDD, open cut or auger bore	✗	✓	✗	✗	✗	✓	✗	✗
TC 024	HDD	✗	✗	✗	✗	✗	✗	✗	✗
TC 025	HDD	✗	✗	✗	✗	✗	✗	✗	✗
TC 026	HDD	✗	✗	✗	✗	✗	✗	✗	✗
TC 027	HDD	✗	✗	✗	✗	✗	✗	✗	✗
TC 028	HDD	✗	✗	✗	✗	✗	✗	✗	✗
TC 029	HDD	✗	✗	✗	✗	✗	✗	✗	✗
TC 030	HDD	✗	✗	✗	✗	✗	✗	✗	✗
TC 031	Auger bore	✗	✓	✓	✗	✓	✗	✗	✗
TC 032	HDD or auger bore	✗	✓	✗	✗	✗	✗	✗	✗

Trenchless Crossing Number	Crossing Method	Receptors Identified within the Radius of Influence of Dewatering						Potential for Connection of Two Aquifers	Artesian Groundwater Identified
		Groundwater Abstractions	Buildings and Infrastructure	Surface Waters	GWDTEs	Potentially Contaminated Land	Scheduled Monuments and Listed Buildings		
TC 033	HDD	✗	✗	✗	✗	✗	✗	✗	✗
TC 034	HDD	✗	✗	✗	✗	✗	✗	✗	✗
TC 035	HDD	✗	✗	✗	✗	✗	✗	✗	✗
TC 036	Auger bore	✗	✓	✓	✗	✓	✗	✗	✗
TC 037	Auger bore	✗	✓	✓	✗	✓	✗	✗	✗
TC 038	HDD	✗	✗	✗	✗	✗	✗	✗	✗
TC 039	HDD	✗	✗	✗	✗	✗	✗	✗	✗
TC 040	Auger bore	✗	✓	✗	✗	✓	✗	✗	✗
TC 041	Auger bore	✗	✓	✓	✗	✓	✗	✗	✗
TC 042	HDD or auger bore	✗	✓	✗	✗	✓	✗	✗	✗

✓ - Receptor identified within the radius of influence or potential to connect two aquifers or location where artesian water has been identified

✗ - Receptor not identified within the radius of influence or unlikely to connect two aquifers or location where artesian water has not been identified

1.48 River Wey

Area of parallel open cut	Alton
Watercourse	River Wey
Groundwater study area	GWSA-B
Approximate grid reference	474274, 140973

1.48.1 At this location, the Order Limits run roughly parallel to the River Wey for an approximate length of 3.6km (although crossing the river in the middle of this length). It is assumed that the length of the parallel route would follow typical design and excavation methods, with a maximum open cut depth of 2m. Excluding the section of pipeline that crosses the river, the Order Limits are located between approximately 230m and 560m from the banks of the River Wey where the route runs parallel.

Geological and Hydrogeological Conditions for this Area

1.48.2 The BGS geological map (BGS, 2018f) indicates that the bedrock at this part of the route is expected to be variable. To the south, the Upper Greensand Formation of calcareous sandstone and siltstone is expected, while the West Melbury Marly Chalk Formation and the Zig Zag Chalk Formation dominate to the north.

1.48.3 Superficial deposits are also mapped as being variable in their extent and nature (BGS, 2018f). Deposits of Alluvium are focused along the course of the River Wey. With distance from the river, River Terrace Deposits of sand and gravel are encountered, with local deposits of Head within the surrounding areas.

1.48.4 The route is located within an area classed as a Principal bedrock aquifer (Defra, 2018). The Alluvium deposits are defined as a Secondary A superficial aquifer, while the Head deposits are classed as Unproductive strata.

1.48.5 A BGS record is located approximately 130m north of the Order Limits. Record SU74SW6 indicates the following ground conditions:

- 0 – 0.9mbgl: Topsoil;
- 0.9 – 3.0mbgl: Gravel (superficial deposits);
- 3.0 – 24.4mbgl: Chalk and Upper Greensand (described as green clay and rock); and
- the resting water level is indicated at 14.6mbgl (approximately 88.4mAOD).

1.48.6 During the 2018 ground investigation works, BH98 was completed in this area. Records show that BH98 was completed at the end of July 2018 (when groundwater levels are likely to be lower than in the winter). The borehole log record for BH98 indicates the following ground conditions:

- 0 – 0.05mbgl: Topsoil;
- 0.05 – 4.55mbgl: Clay with gravel;
- 4.55 – 6.80mbgl: Gravel with weak sandstone layers;
- 6.80 – 14.30mbgl: Sandstone, with layers of weathered clay and sandstones;

- 14.30 – 20.05mbgl: Mudstone with some small gravel layers; and
- the water strike is recorded at 2.80mbgl (approximately 97.2mAOD).

1.48.7 Groundwater levels have been measured manually on five separate occasions at location BH98, which is located at an elevation of 91.42mAOD and was completed to a depth of 20.15mbgl. These measurements indicate an average groundwater level of 2.77mbgl, or 88.65mAOD. The data logger in BH98 has recorded the highest groundwater level as 2.46mbgl.

1.48.8 EA groundwater models for the Chalk indicate maximum groundwater levels between 95.0mAOD and 110.0mAOD. Upper Greensand maximum groundwater level contours indicate levels between 95.0mAOD and 100.0mAOD over the length of the crossing. These are considered maximum simulated groundwater levels. Ground elevation in this area is indicated as ranging from 99mAOD in the south to 103mAOD in the north, suggesting that groundwater levels are around 3mbgl in high water table conditions. The BGS groundwater flooding susceptibility map (BGS, 2017) shows potential for groundwater flooding to occur at the surface over most of the pipeline route in this area.

1.48.9 As part of the EA water level monitoring network, the Malms Farm hydrometric monitoring point is located approximately 280m east of the Order Limits and recorded a maximum water level of 12.36mbgl (or 94.12mAOD) and a minimum water level of 16.6mbgl (or 89.88mAOD).

Assessment of Route Parallel to the River Wey

1.48.10 Ground investigation records local to the crossing show a groundwater strike at 2.80mbgl (BGS, 2018a). Groundwater monitoring completed as part of the 2018 ground investigation works show an average groundwater level of 2.8mbgl with the logger recording a high groundwater level of 2.46mbgl. However, EA groundwater monitoring levels relevant to this location show that groundwater levels are deeper in this region at a maximum depth of 12.36mbgl. Based on available data, groundwater is unlikely to be encountered in the trench where it runs parallel to the river, although it is possible that, at times of extreme high groundwater levels, the water table may encroach the base of the open cut. As it is likely the open cut would remain dry at this location, no assessment for dewatering has been made. Further, at this location, the open cut runs around 230m to 560m from the river, and if dewatering from the open cut were required, due to the distance from the river, it is very unlikely that drawdown of groundwater alongside the open cut would have a direct impact on flows in the River Wey.

1.49 Farnborough – Cove Brook

Area of parallel open cut	Farnborough
Watercourse	Cove Brook
Groundwater study area	GWSA-C
Approximate grid reference	485537, 155419

1.49.1 At this location, the open cut runs parallel to Cove Brook. It is assumed that the length of the parallel route, which is approximately 1km, would follow typical design and excavation methods. The Order Limits are located between approximately 0m and 160m from Cove Brook, with the brook itself located at the edge of the Order Limits at one location.

Geological and Hydrogeological Conditions for this Area

1.49.2 The BGS geological map (BGS, 2018g) indicates that, at this location, most of the open cut would be in bedrock comprising the Windlesham Formation, although in the north where the Order Limits are adjacent to Cove Brook, the Camberley Sand Formation is shown to be present.

1.49.3 Superficial deposits are mapped as being variable in their extent and coverage (BGS, 2018g); much of the urban area is absent of coverage. Alluvium is present along the course of Cove Brook, while there are some localised areas of Head deposits comprising clay, silt, sand and gravel located in the south of the Order Limits.

1.49.4 The area is classed as a Secondary A bedrock aquifer with a Secondary A aquifer associated with the Alluvium (Defra, 2018). The area comprising deposits of Head is defined as a Secondary Undifferentiated superficial aquifer.

1.49.5 The nearest available BGS record, SU85SE355, is located approximately 320m southeast from the southern part of this area of the Order Limits and indicates the following ground conditions:

- 0 – 0.2mbgl: Topsoil;
- 0.2 – 1.2mbgl: Silty organic clay;
- 1.2 – 1.7mbgl: Organic clay and peat;
- 1.7 – 3.0mbgl: Clayey sand (Bracklesham Beds); and
- water was struck at 2.4mbgl with a maximum water level of 1.4mbgl recorded.

1.49.6 A second BGS record, SU85SE16, is located approximately 400m southeast from the southern part of this area of the Order Limits and indicates the following ground conditions:

- 0 – 0.2mbgl: Topsoil;
- 0.2 – 0.7mbgl: Silty clay – Alluvium;
- 0.7 – 4.7mbgl: Clayey sand – Bracklesham Beds; and
- water was struck at 4.4mbgl (58.6mAOD).

1.49.7 During 2018 ground investigation work, BH56 was completed at the north of the area and BH59 has been completed in the south. The log record shows this was completed in December 2018, when groundwater levels may be seasonally higher. The following ground conditions are expected:

- 0 – 0.38mbgl: Made ground;
- 0.38 – 1.32mbgl: Silty sand;
- 1.32 – 2.15mbgl: Sandy clay;
- 2.15 – 10.55mbgl: Slightly silty sand

- groundwater strike was encountered at 1.40mbgl (approximately 60.57mAOD).

The log record for BH59 indicates it was completed in January 2019, when seasonal groundwater levels are likely to be higher. The following ground conditions are expected:

- 0 – 1.40mbgl: Made Ground;
- 1.40 – 15.45mbgl: Silty sand; and
- groundwater strike was encountered at 1.65mbgl (no elevation is provided to determine this value in mAOD).

1.49.8 Groundwater levels have been measured manually on three separate occasions at location BH56, which is located at an elevation of 61.97mAOD and was completed to a depth of 10.55mbgl. These measurements indicate an average groundwater level of 1.56mbgl, or 60.41mAOD. No groundwater level data from a data logger is currently available for this borehole.

1.49.9 Groundwater levels have been measured manually on two separate occasions at BH59, which is located at an elevation of 62.68mAOD and was completed to a depth of 15.0mbgl. These measurements indicate an average groundwater level of 0.95mbgl, or 61.73mAOD. The data logger in BH59 has recorded the highest groundwater level as 0.47mbgl.

1.49.10 The BGS groundwater flooding susceptibility map (BGS, 2017) indicates the length of Order Limits in the area under consideration is located within an area with limited potential for groundwater flooding to occur and, as such, would indicate relatively deep groundwater.

Assessment of Route Parallel to Cove Brook

1.49.11 Available ground investigation records (BGS, 2018a) show that groundwater strike was encountered at shallow levels ranging between 1.4 and 4.4mbgl. The borehole log for a BGS borehole 320m from the Order Limits shows a groundwater level of 1.4mbgl. Groundwater monitoring completed as part of the 2018 ground investigation works in this area at BH56 indicate an average groundwater level of around 1.6mbgl. The BGS groundwater flooding susceptibility map (BGS, 2017) shows that there is limited potential for flooding, which suggests that groundwater levels are not close to the surface. However, based on available data local to the crossing, and assuming a worst-case scenario, the groundwater is expected to be shallow. Following installation, the pipeline is likely to sit below the water table, assuming a maximum open cut depth of 2mbgl.

1.49.12 Superficial sand and gravel, and Alluvium deposits are recorded on ground investigation records to a maximum depth of 0.70mbgl. Underlying these, the Bracklesham Beds bedrock (of which the Camberley Sand is a member) was identified at a minimum depth of 0.7mbgl. During construction and excavation of the open cut, both superficial deposits and bedrock may therefore be encountered and intercepted.

1.49.13 For the calculation of effects due to dewatering, hydraulic conductivity values have been calculated from ground investigation at BH55. The average of these hydraulic conductivity values, 7.53E-07m/s, has been used to represent hydraulic conductivity (K) for this assessment.

1.49.14 The expected maximum groundwater level has been estimated as 0.5mbgl, assuming that shallow groundwater encountered at approximately 0.5mbgl in BH59 is representative of the shallowest groundwater conditions.

1.49.15 Table 8.2.44 presents the input and results of the radius of influence calculations. Additional input parameters and results used for the calculation of dewatering rates are given in Table 8.2.45. The assessment indicates that the length where drawdown occurs adjacent to the open cut is 2.3m. As such, and assuming the open cut is more than 1.5m from the edge of the Order Limits, dewatering of the open cut is unlikely to impact directly on water flows within the river if it were in continuity with the surrounding aquifer.

Table 8.2.44: Input and Output Parameters of the Sichardt Equation

Parameter	Value
Hydraulic conductivity, K (m/s)	7.53E-07
Drawdown (m)	1.5
Distance of influence, Lo (m)	2.3

Table 8.2.45: Input and Output Parameters for Estimating Magnitude of Flow

Parameter	Value
Length of route parallel to watercourse, x (m)	1,000
Height of initial water level in the aquifer, H (m)	9.45
Height of drawndown water level in the aquifer, h_w (m)	7.95
Depth of penetration of the open cut below the original water table, P (m)	1.5
Q	576m^3/day
	6.7l/s

1.50 Frimley

Area of parallel open cut	Frimley
Watercourse	Unnamed watercourse
Groundwater study area	GWSA-C
Approximate grid reference	488635, 157707

1.50.1 At this location, the open cut runs parallel to an unnamed watercourse over a distance of approximately 1.2km. It is assumed that the length of the parallel route would follow typical design and excavation methods, with a maximum excavation depth of 2m. The Order Limits are located between approximately 2m and 40m from the watercourse.

Geological and Hydrogeological Conditions for this Area

1.50.2 The BGS geological map (BGS, 2018g) indicates that the area is located within bedrock comprising the Camberley Sand Formation.

1.50.3 Superficial deposits are mapped as being variable in their nature (BGS, 2018g). The BGS map shows deposits of Head follow the line of the watercourse, with River Terrace Deposits and Alluvium also indicated as present to the west.

1.50.4 The Head deposits are classified as a Secondary Undifferentiated superficial aquifer while the nearby areas of River Terrace Deposits are classed as a Secondary A superficial aquifer (Defra, 2018). The area is classified as a Secondary A bedrock aquifer.

1.50.5 The nearest available BGS borehole record, located approximately 30m south of the Order Limits, SU85NE99, indicates the following ground conditions:

- 0 – 0.3mbgl: Topsoil;
- 0.3 – 4.9mbgl: Sandy gravel – River Terrace Deposits;
- 4.9 – 6.5mbgl: Clayey sand – Bracklesham Beds; and
- water was encountered at 2.5mbgl (62.5mAOD).

1.50.6 The BGS record is located at a similar elevation to the crossing.

1.50.7 During the 2018 ground investigation works, BH151 is indicated as having been completed approximately 14m to the north of the Order Limits along the southern area of this part of the route. Records show that BH151 was completed at the end of August 2018. The groundwater levels observed in August are likely to be lower than the maximum level seen during winter months. The log record for this borehole indicates the following ground conditions:

- 0 – 1.0mbgl: Made ground;
- 1.0 – 1.3mbgl: Sandy clay;
- 1.3 – 3.50mbgl: Gravelly sand;
- 3.5 – 3.90mbgl: Clay;
- 3.9 – 8.4mbgl: Sandy gravel;
- 8.4 – 20.28mbgl: Clayey sand; and
- groundwater was struck at 1.40mbgl and 3.18mbgl (61.6mAOD and 59.82mAOD).

1.50.8 Groundwater levels have been measured manually on five separate occasions at location BH151, which is located at an elevation of 63.55mAOD and was completed to a depth of 20.28mbgl. These measurements indicate an average groundwater level of 1.69mbgl, or 61.86mAOD. No reliable groundwater level data is currently available for the groundwater level logger installed in BH151.

1.50.9 The BGS groundwater flooding susceptibility map (BGS, 2017) indicates that this part of the route is located within an area with limited potential for groundwater flooding to occur.

Assessment of Route Parallel to the Unnamed Watercourse

1.50.10 Recent ground investigation recorded a groundwater strike at 1.4 and 3.8mbgl, while BGS historical records encountered groundwater at 2.5mbgl (BGS, 2018a). Groundwater monitoring completed as part of the 2018 ground investigation works suggest an average groundwater level of 1.69mbgl. Based on available data, shallow groundwater conditions are therefore expected in the area, despite the BGS groundwater flooding susceptibility classification.

1.50.11 Superficial gravel deposits were encountered to a maximum depth of 8.4mbgl during the 2018 ground investigation. Underlying these, the Bracklesham Beds were identified. Assuming the open cut is excavated to a depth of 2m, it is likely that the pipeline would only encounter superficial gravel deposits, which are shown to be saturated. Following installation, the pipeline would likely sit below the water table. Given that shallow groundwater is likely, it is also expected that the watercourse is hydraulically connected with underlying groundwater.

1.50.12 For the calculation of effects due to dewatering, hydraulic conductivity values have been calculated from ground investigation at BH151. The average of these, 1.77E-4m/s, has been used to represent hydraulic conductivity (K) for this assessment.

1.50.13 The expected maximum groundwater level has been estimated as 1.0mbgl, assuming that shallow groundwater encountered at approximately 1.4mbgl may show variability over the course of a year with highest levels being in the winter.

1.50.14 Table 8.2.46 presents the input and results of the radius of influence calculations. Additional input parameters and results used for the calculation of dewatering rates are given in Table 8.2.47. The assessment indicates that the length where drawdown occurs adjacent to the open cut is 23m. As such, dewatering of the open cut may impact directly on water flows within the river if it is in continuity with the surrounding aquifer, pulling water from the river into the excavation.

Table 8.2.46: Input and Output Parameters of the Sichardt Equation

Parameter	Value
Hydraulic conductivity, K (m/s)	1.77E-04
Drawdown (m)	1.0
Distance of influence, Lo (m)	23.3

Table 8.2.47: Input and Output Parameters for Estimating Magnitude of flow

Parameter	Value
Length of route parallel to watercourse, x (m)	1,200
Height of initial water level in the aquifer, H (m)	7.4
Height of drawndown water level in the aquifer, hw (m)	6.4
Depth of penetration of the open cut below the original water table, P (m)	1.0
Q	8,337m^3/day
	96.5l/s

1.52 West End

Area of parallel open cut	West End
Watercourse	Halebourne (north of the Order Limits)
Groundwater study area	GWSA-C
Approximate grid reference	494456, 161989

1.52.1 At this location, the open cut runs parallel to Halebourne watercourse. It is assumed that the length of the parallel route would follow typical design and excavation methods, with a maximum open cut depth of 2m. The Order Limits cut across the watercourse via a trenchless crossing, with the route proceeding to the north of the river for approximately 420m running roughly parallel to the watercourse. Where the route runs parallel to the watercourse, the Order Limits are located between approximately 10m and 70m from the Halebourne.

Geological and Hydrogeological Conditions for this Area

1.52.2 The BGS geological map (BGS, 2018h) indicates that the bedrock largely comprises the Windlesham Formation of sand along this part of the route. To the east and south, the bedrock comprises the Bagshot Formation of sand. The Order Limits along this part of the route correlate with the geological boundary.

1.52.3 Superficial deposits of Alluvium are shown to be present in the vicinity of the Halebourne comprising sand, silt and clay (BGS, 2018h). The extent and presence of superficial deposits is expected to be variable within the surrounding area. With increasing distance from the watercourse, they are notably absent.

1.52.4 The area is classed as a Secondary A bedrock aquifer and within an area of Secondary A superficial aquifer associated with the Alluvium (Defra, 2018).

1.52.5 The nearest BGS record where groundwater was observed is located within the Order Limits along this length of the route. Record SU96SW106 indicates the following ground conditions:

- 0 – 0.52mbgl: Topsoil;
- 0.52 – 1.12mbgl: Peat;
- 1.12 – 3.0mbgl: gravel; and
- groundwater was encountered at 0.13mbgl (38.87mAOD).

1.52.6 A second record was consulted to determine deeper ground conditions. The BGS record SU96SW105 is located 130m south of the Order Limits, the record for which indicates the following ground conditions:

- 0 – 0.3mbgl: Topsoil;
- 0.3 – 1.05mbgl: Fine sand and gravel;
- 1.05 – 4.57mbgl: Fine sand; and
- groundwater was not encountered.

1.52.7 The boreholes identified in the BGS records are located at similar elevations to the area running parallel to Halebourne.

1.52.8 During 2018 ground investigation works, the nearest investigation point, BH39, was completed approximately 630m to the southwest of this area of the route in September 2018. The groundwater levels observed in September are likely to be lower than the maximum level seen during winter months. The log record for this indicates the following ground conditions:

- 0 – 0.3mbgl: Topsoil;
- 0.3 – 1.6mbgl: Sand (with gravel);
- 1.6 – 15.7mbgl: Layers of sand and clay; and
- no groundwater strike was observed due to the addition of water flush.

1.52.9 Groundwater levels have been measured manually on four separate occasions at location BH39, which is located at an elevation of 51.49mAOD and was completed to a depth of 15.72mbgl. These measurements indicate an average groundwater level of 3.81mbgl, or 47.68mAOD. No reliable data are currently available from the groundwater level logger installed in BH39.

1.52.10 From east to west, the Order Limits cut through areas classed as having limited potential for groundwater flooding to occur, into small areas classed as having potential for groundwater flooding of property situated below ground level, into an area with potential for groundwater flooding to occur at the surface.

1.52.11 As part of the EA groundwater level monitoring network, the nearest hydrometric monitoring point is Brock Cottage OBH, located approximately 2.22km northeast of this area of the route. Monitoring data indicates the maximum groundwater level here is 5.68mbgl, while the minimum water level is 6.48mbgl.

Assessment of Route Parallel to Halebourne

1.52.12 BGS ground investigation records (BGS, 2018a) show a groundwater strike at 0.13mbgl. Groundwater monitoring completed as part of the 2018 ground investigation works suggests an average groundwater level of 3.81mbgl. EA monitoring records also indicate that shallow groundwater levels are expected in the area, which is further supported by the BGS groundwater flooding susceptibility map (BGS, 2017).

1.52.13 The thickness of superficial deposits is expected to be variable, with deposits having been encountered to a maximum depth of 3.0mbgl. Bedrock was encountered underlying these deposits, recorded at a minimum depth of 1.6mbgl at its shallowest. Therefore, based on an excavation depth of 2m, both superficial and bedrock geology might be encountered.

1.52.14 Given an open cut excavation depth of 2m, based on available data it is likely that the water table would be encountered, and following installation, it is also likely that the pipeline would sit below the water table. In addition, it is likely that Halebourne watercourse would be in hydraulic connection with these underlying shallow groundwaters.

1.52.15 For the calculation of effects due to dewatering, hydraulic conductivity values have been calculated from ground investigation at BH39. The average of these, 7.57E-07m/s, has been used to represent hydraulic conductivity (K) for this assessment. A rest water level of 0.13mbgl has been used as identified in the BGS borehole SU96SW106.

1.52.16 Table 8.2.48 presents the input and results of the radius of influence calculations. Additional input parameters and results used for the calculation of dewatering rates are given in Table 8.2.49. The assessment indicates that the length where drawdown occurs adjacent to the open cut is 2.8m. As such, dewatering of the open cut would not impact directly on water flows within the river if it were in continuity with the surrounding aquifer.

Table 8.2.48: Input and Output Parameters of the Sichardt Equation

Parameter	Value
Hydraulic conductivity, K (m/s)	7.57E-07
Drawdown (m)	1.87
Distance of influence, Lo (m)	2.8

Table 8.2.49: Input and Output Parameters for Estimating Magnitude of Flow

Parameter	Value
Length of route parallel to watercourse, x (m)	420
Height of initial water level in the aquifer, H (m)	14.37
Height of drawndown water level in the aquifer, hw (m)	12.50
Depth of penetration of the open cut below the original water table, P (m)	1.87
Q	370m^3/day
	4.3l/s

1.53 Chertsey – River Thames

Area of parallel open cut	Chertsey
Watercourse	River Thames
Groundwater study area	GWSA-D
Approximate grid reference	505912, 166483

1.53.1 At this location, the open cut would run parallel to the River Thames for a length of approximately 450m, before cutting across the River Thames via a trenchless crossing. It is assumed that the length of the parallel route would follow typical design and excavation methods, with a maximum depth of 2m. The Order Limits are located between approximately 15m and 220m from the bank of the River Thames where the route runs parallel to the river. However, for most of the length of the open cut, the river is over 100m from the Order Limits.

Geological and Hydrogeological Conditions for this Area

1.53.2 The BGS geological map (BGS, 2018l) indicates that bedrock in this area of the route comprises the Bagshot Formation of sand.

1.53.3 The nature and extent of superficial deposits is expected to be variable. The BGS map (BGS, 2018l) shows deposits are expected to comprise Alluvium of silt. In some areas to the north and west, deposits of the Shepperton Gravel Member are expected.

1.53.4 This part of the route is located within an area of Secondary A bedrock aquifer and Secondary A superficial aquifer (Defra, 2018).

1.53.5 The nearest BGS borehole record is located within the Order Limits, TQ06NE181, and indicates the following ground conditions:

- 0 – 0.6mbgl: Topsoil;
- 0.6 – 1.67mbgl: Clay with a small amount of fine gravel;
- 1.67 – 4.57mbgl – Gravel;
- 4.57 – 6.09mbgl: Sand and gravel; and
- groundwater was encountered at 0.75mbgl (10.25mAOD).

1.53.6 A second record was consulted to determine whether shallow groundwater conditions are typical in this area. Record TQ06NE182 is located approximately 75m south of the area running parallel to the River Thames and shows the following ground conditions:

- 0 – 1.21mbgl: Topsoil;
- 1.21 – 6.0mbgl: Coarse sand and fine to medium gravel; and
- groundwater was first encountered at 1.36mbgl (approximately 10.64mAOD).

1.53.7 During the 2018 ground investigation works, BH150 and BH26 are indicated as having been completed along this section of the pipeline route. Records show that BH150 was completed in November 2018, when observed groundwater levels are likely to be lower than their maximum. The log record for BH150 location indicates the following conditions:

- 0 – 0.42mbgl: Made ground;
- 0.42 – 1.48mbgl: Slightly gravelly clay;
- 1.48 – 2.28mbgl: Slightly gravelly silt;
- 2.28 – 3.45mbgl: Slightly sandy gravel;
- 3.45 – 4.52mbgl: Gravelly sand;
- 4.52 – 5.01mbgl: Sand;
- 5.01 – 8.39mbgl: Slightly sandy gravel;
- 8.39 – 14.90mbgl: Slightly silty sand;
- 14.90 – 18.15mbgl: Slightly silty clay; and
- groundwater strike was encountered at 1.50mbgl (approximately 2.5mBOD (Below Ordnance Datum)).

1.53.8 Records show that BH26 was completed in mid-November 2018 (when groundwater conditions may not reflect the maximum level). The log record for this location indicates the following ground conditions:

- 0 – 0.32mbgl: Made ground;
- 0.32 – 1.26mbgl: Sandy clay;
- 1.26 – 1.68mbgl: Clayey sand;
- 1.68 – 1.88mbgl: Gravel;
- 1.88 – 3.30mbgl: Gravelly sand;
- 3.30 – 5.98mbgl: Gravel;
- 5.98 – 10.20mbgl: Silty sandy clay;
- 10.20 – 12.70mbgl: Slightly silty sand;
- 12.70 – 16.15mbgl: Clay; and
- groundwater was encountered at 1.26mbgl (approximately 10.74mAOD).

1.53.9 Groundwater levels have been measured manually on four separate occasions at location BH26, which is located at an elevation of 11.45mAOD and was completed to a depth of 16.15mbgl. These measurements indicate an average groundwater level of 1.00mbgl, or 10.45mAOD. The data logger in BH26 has recorded the highest groundwater level as 0.88mbgl.

1.53.10 Groundwater levels have also been manually measured on four separate occasions at BH150, which is located at an elevation of 11.30mAOD and was completed to a depth of 18.15mbgl. These measurements indicate an average groundwater level of 0.87mbgl, or 10.42mAOD. The data logger in BH150 has recorded the highest groundwater level as 0.09mbgl.

1.53.11 This area of the route is classed as having limited potential for groundwater flooding to occur, suggesting shallow groundwater conditions are not expected. Immediately adjacent, however, the course of the River Thames is classed as having potential for groundwater flooding of property situated below ground level.

Assessment of Route Parallel to the River Thames

1.53.12 BGS ground investigation records (BGS, 2018a) confirm a groundwater strike at 0.75mbgl, with the recent ground investigation also encountering groundwater at depths of 1.50mbgl and 1.26mbgl. Subsequent groundwater monitoring at the same locations shows average groundwater levels of 1.00mbgl and 0.87mbgl. The BGS groundwater flooding susceptibility map (BGS, 2017) further supports that groundwater is likely to be shallow.

1.53.13 This information suggests that shallow groundwater conditions are expected in this area. During excavation of the open cut, it is likely that the water table would be encountered, and that following installation, the pipeline would sit below the water table.

1.53.14 Superficial deposits were identified to a maximum depth of 7.60mbgl during ground investigations. Based on a maximum open cut excavation depth of 2m, it is therefore unlikely that bedrock would be encountered, and only superficial aquifers would thus be intercepted.

1.53.15 For the calculation of effects due to dewatering, hydraulic conductivity values have been calculated from ground investigation at BH25. The average of these, 3.17E-04m/s has been used to represent hydraulic conductivity (K) for this assessment.

1.53.16 The expected maximum groundwater level has been estimated as 0.09mbgl, assuming that shallow groundwater measured at 0.09mbgl represents the highest groundwater level.

1.53.17 Table 8.2.50 presents the input and results of the radius of influence calculations. Additional input parameters and results used for the calculation of dewatering rates are given in Table 8.2.51. The assessment indicates that the length where drawdown occurs adjacent to the open cut is 59.5m. As such, dewatering of the section of the open cut closest to the river may directly impact on water flows within the river if it is in continuity with the surrounding aquifer.

Table 8.2.50: Input and Output Parameters of the Sichardt Equation

Parameter	Value
Hydraulic conductivity, K (m/s)	3.17E-4
Drawdown (m)	1.91
Distance of influence, Lo (m)	59.5

Table 8.2.51: Input and Output Parameters for Estimating Magnitude of Flow

Parameter	Value
Length of route parallel to watercourse, x (m)	450
Height of initial water level in the aquifer, H (m)	8.1
Height of drawndown water level in the aquifer, hw (m)	6.8
Depth of penetration of the open cut below the original water table, P (m)	1.3
Q	4,486m^3/day
	51.9l/s

1.54 Laleham – River Ash

Area of parallel open cut	Laleham
Watercourse	River Ash
Groundwater study area	GWSA-D
Approximate grid reference	506150, 170110

1.54.1 At this location, the pipeline route runs roughly parallel to the River Ash for an approximate length of 3.9km. It is assumed that the length of the parallel route would follow typical design and excavation methods, with a maximum open cut depth of 2m. The Order Limits are located between approximately 3m and 350m from the banks of the River Ash where the route runs parallel. However, for most of the length of the open cut, the river is over 100m from the Order Limits.

Geological and Hydrogeological Conditions for this Area

1.54.2 The BGS geological maps (BGS, 2018l, BGS2018m) indicate that the bedrock at this part of the route is expected to be variable. The southern part of the route is located within bedrock comprising the Claygate Member of sand, with a small area of silt (also the Claygate Member). The London Clay Formation is shown to be present in the northern area of this part of the Order Limits.

1.54.3 Superficial deposits are mapped as being variable in their extent and nature (BGS, 2018l, BGS2018m). Much of the area running parallel to the River Ash comprises the Kempton Park Gravel Formation. To the north and south, deposits of Alluvium, and localised coverage of the Langley Silt Member are indicated. The Langley Silt Member is present to a greater extent to the south.

1.54.4 The route is located within an area classed as a Principal superficial aquifer, associated with the Kempton Park Gravel Formation, while the localised Alluvium deposits are defined as a Secondary A superficial aquifer (Defra, 2018). The Claygate Member is defined as a Secondary A bedrock aquifer, and the London Clay is classed as Unproductive strata.

1.54.5 The nearest BGS borehole record located approximately 335m west of the Order Limits, TQ07SE443, indicates the following ground conditions:

- 0 – 0.6mbgl: Loam;
- 0.6 – 5.79mbgl: Ballast;
- 5.79 – 7.32mbgl: Running sand;
- 7.32 – 10.36mbgl: London Clay; and
- water was encountered at 0.9mbgl (approximately 15.1mAOD).

1.54.6 During the 2018 ground investigation works, BH12, BH11 and BH136 were indicated as having been proposed along this part of the pipeline route. No records for these were available at the time of writing. BH10 is the nearest record, located just north of the area running parallel to the River Ash. Records show that BH10 was completed at the end of September 2018, when the groundwater levels observed are likely to be lower than the potential maximum level. The log record for this location indicates the following ground conditions:

- 0 – 0.15mbgl: Made ground;
- 0.15 – 1.10mbgl: Gravelly clay;
- 1.10 – 2.35mbgl: Gravelly sand;
- 2.35 – 3.70mbgl: Sand and gravel;
- 3.70 – 5.20mbgl: Clay; and
- water strike was encountered at 0.83mbgl (12.17mAOD) within gravelly clay deposits.

1.54.7 Groundwater levels have been measured manually on five separate occasions at location BH10, which is located at an elevation of 12.80mAOD and was completed to a depth of 5.20m. These measurements indicate an average groundwater level of 0.52mbgl, or 12.28mAOD. The data logger in BH10 has recorded the highest groundwater level as 0.13mbgl.

1.54.8 The BGS groundwater flooding susceptibility map (BGS, 2017) indicates that this part of the route is located within an area with potential for groundwater flooding to occur at the surface.

1.54.9 As part of the local landfill monitoring network, nearby monitoring locations indicate that the average groundwater level is 12.2mAOD (1.8mbgl).

Assessment of Route Parallel to the River Ash

1.54.10 BGS ground investigation records (BGS, 2018a) indicate a groundwater strike at 0.9mbgl, which is supported by the average groundwater levels, 1.8mbgl, recorded by the landfill monitoring network. In addition, continuous groundwater monitoring completed during the 2018 ground investigation works recorded a groundwater level of 0.13mbgl at its shallowest. These records indicate that shallow groundwater conditions are expected in this area, and that the River Ash is likely to be in hydraulic connection with these shallow groundwaters. With an open cut excavation depth of 2m, it is therefore likely that the groundwater table would be encountered, and the pipeline would sit below the water table following installation.

1.54.11 Ground investigation records suggest the presence of superficial gravels to a maximum depth of 3.7mbgl. Assuming an open cut excavation depth of 2m, it is therefore unlikely that bedrock would be encountered during installation.

1.54.12 For the calculation of effects due to dewatering, hydraulic conductivity values have been calculated from ground investigation at BH10. The average of these, 2.97E-05m/s, has been used to represent hydraulic conductivity (K) for this assessment.

1.54.13 The expected maximum groundwater level has been estimated as 0.13mbgl, assuming that shallow groundwater measured at 0.13mbgl represents the highest groundwater level.

1.54.14 Table 8.2.52 presents the input and results of the radius of influence calculations. Additional input parameters and results used for the calculation of dewatering rates are given in Table 8.2.53. The assessment indicates that the length where drawdown occurs adjacent to the open cut is 17.4m. The vast majority of the open cut is over 100m from the river. As such, dewatering of the open cut is unlikely to significantly impact directly on water flow within the river if it is in continuity with the surrounding aquifer.

Table 8.2.52: Input and Output Parameters of the Sichardt Equation

Parameter	Value
Hydraulic conductivity, K (m/s)	2.97E-05
Drawdown (m)	1.87
Distance of influence, Lo (m)	17.8

Table 8.2.53: Input and Output Parameters for Estimating Magnitude of Flow

Parameter	Value
Length of route parallel to watercourse, x (m)	3,900

Parameter	Value
Height of initial water level in the aquifer, H (m)	3.53
Height of drawndown water level in the aquifer, hw (m)	1.70
Depth of penetration of the open cut below the original water table, P (m)	1.83
Q	4,751m^3/day
	55.0l/s

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