M42 Junction 6 Improvement

Scheme Number TR010027

Volume 6

6.3 Environmental Statement

Appendix 14.2 Bickenhill Meadows SSSI – Preliminary Hydrological Investigation Technical Note

Regulation 5(2)(a)

Planning Act 2008

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

January 2019

Infrastructure Planning

Planning Act 2008

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

M42 Junction 6 Improvement

Development Consent Order 201[-]

6.3 Environmental Statement
Appendix 14.2 Bickenhill Meadows SSSI – Preliminary Hydrological Investigation Technical Note

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M42 JUNCTION 6 IMPROVEMENT

BICKENHILL MEADOWS SITE OF SPECIAL SCIENTIFIC INTEREST – HYDROLOGICAL INVESTIGATION TECHNICAL NOTE (V7)

Prepared for: HIGHWAYS ENGLAND

Prepared by: AECOM

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Quality information

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1. Introduction

1.1 The M42 Junction 6 Improvement (the Scheme) provides connections between the national motorway network and the A45 Coventry Road, which provides strategic access to Birmingham to the west and Coventry to the east. Current congestion and journey reliability issues on the M42 and at Junction 6 are causing severe delays on parts of the strategic road network, as the junction does not have sufficient capacity to accommodate the predicted growth in traffic associated with future planned development in the area.

1.2 The Scheme has been developed by Highways England to provide a solution to improve junction capacity, support economic growth, improve access, and ensure the safe and reliable operation of the network.

1.3 The Scheme is currently being subject to a process of Environmental Impact Assessment (EIA), the design of which includes the following key components and works.

- A new junction approximately 1.8km south of the existing Junction 6 off the M42 (referred to as M42 Junction 5A).
- A new 2.4km long dual carriageway link road between M42 Junction 5A and Clock Interchange, with a free flow slip road to the A45 Coventry Road.
- Capacity and junction improvements at Clock Interchange.
- New free flow links between the A45 and M42 motorway at M42 Junction 6.
- The realignment and modification of the B4438 Catherine-de-Barnes Lane, Clock Lane and St. Peters Lane west of the M42 motorway, and of East Way and the Middle Bickenhill Loop north east of M42 Junction 6.
- Modifications to the location and spacing of emergency refuge areas, overhead gantries and message signing along the M42 motorway.
- Modifications to the Warwickshire Gaelic Athletic Association (Páirc nah Éireann) sports facility.

1.4 A Ground Investigation has been undertaken to establish the existing ground conditions that would underlie key areas of the Scheme, and to obtain data for use in the Environmental Impact Assessment.

1.5 The proposed mainline link road is positioned below the flight path control zones of Birmingham Airport, and much of the dual carriageway is in cutting (up to 10m depth) in order to lower the road and thereby provide visual screening and noise attenuation benefits; however, construction of these earthworks has the potential to disrupt groundwater flows in the area.

1.6 The EIA process has so far identified that the new mainline link road may also have a potential adverse impact on Bickenhill Meadows Site of Special Scientific Interest (SSSI), which consists of two separate units located either side of the new mainline link road. The SSSI includes areas of wet woodland and wet meadows that support a range of plants and other species. The cutting and associated works are also in close proximity (within 300 m) of streams that flow through each SSSI unit, which may be impacted during the construction and operation phases.

1.7 Accordingly, the processes for maintaining the hydrology of the two SSSI units needs to be established in order to identify and understand the potential impacts of the Scheme on the SSSI, such that appropriate mitigation measures for any likely significant effects can be identified and, where possible, incorporated into its design. In particular, the importance of rainfall, groundwater, nearby streams and localised flooding needs to be investigated.

1.8 This Technical Note reports the outcomes of a hydrological investigation of the two SSSI units. It considers the soil and geological ground conditions from available data sources, the topography around the SSSI by reviewing LiDAR and contour data, and reports on the observations made during site visits (including one attended by Natural England). Based on preliminary findings, the note also considers the potential effects of the cutting and loss of surface water catchment, and sets out the scope of additional ground and field investigations, as requested by Natural England. The findings of the investigation are reported and developed into a conceptual model of each site, and potential mitigation and compensation measures are also discussed.

2. New Mainline Link Road

2.1 The current general arrangement for the new mainline link road is shown in Figure 1, set within its local context (note: this is based on Design Fix 3C – but Order Limits have since been altered).

2.2 From M42 Junction 5A, the new mainline link road would initially travel north westwards through open fields to the north of Hampton Lane Farm, where it would cross a number of public rights of way. A roundabout would be constructed (Barber's Coppice Roundabout) south of the SSSI which would provide a tie-in from the existing Catherine-de-Barnes Lane (both in a north and southbound direction) to the new mainline link road.

2.3 As the new mainline link road continues north, it would cross Catherine-de-Barnes Lane approximately 70m south of the T-junction of Shadowbrook Lane. Approximately 500m north of the crossing point with Catherine-de-Barnes Lane, a second local roundabout (Bickenhill Roundabout) would be constructed to provide a north and south tie-in with Catherine-de-Barnes Lane and St Peters Lane. Between these two local roundabouts, Catherine-de-Barnes would be realigned at its furthest point approximately 20m west of its current alignment.

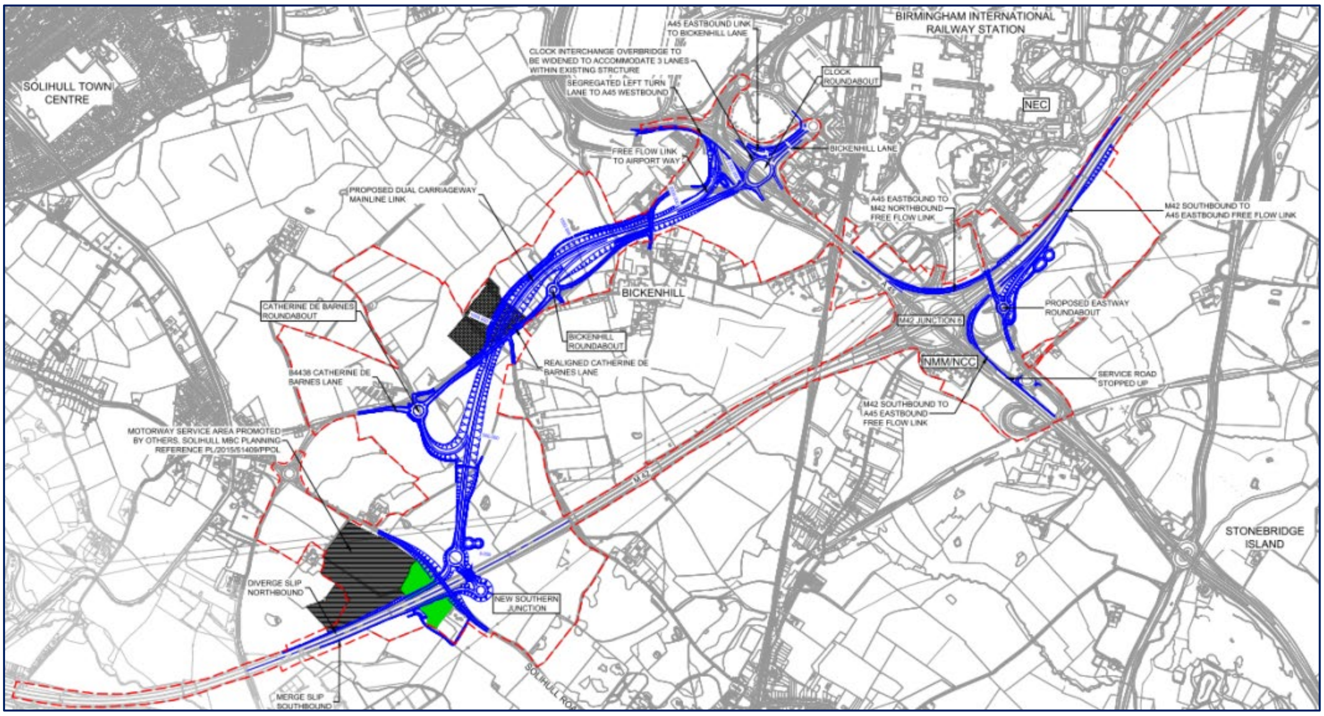


Figure 1: M42 Junction 6 Improvements Design Fix 3C – General Arrangement
(source: extract from drawing HE551485-ACM-HGN-M42_GEN_ZZ_ZZ-DR-CH-0012 P02.3)

2.4 Figure 2 shows the Scheme in relation in the SSSI units.

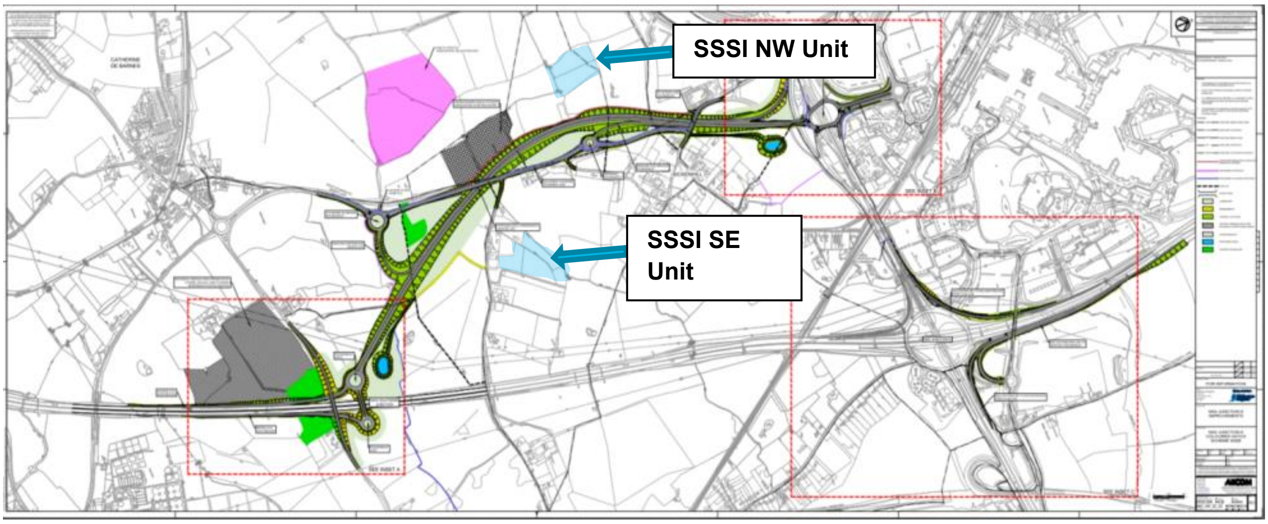


Figure 2: M42 Junction 6 design in relation to Bickenhill Meadows SSSI units (note that this is an earlier design). Figure 1 shows the latest Design Fix (3C).

3. Bickenhill Meadows SSSI Designation

3.1 Bickenhill Meadows SSSI is split between two units, located either side of Catherine-de-Barnes Lane (centred on approximate national grid references SP182822 and SP188816) as shown in Figure 2 and on Ordnance Survey mapping in Figure 3. The total area designated covers 7.2 hectares and was notified in 1991. The northwest unit is known as the ‘First Castle Meadow Unit’ (hereafter referred to as ‘NW Unit’) and the southeast unit is known as ‘Shadowbrook Meadows Unit’ (hereafter referred to as ‘SE Unit’).

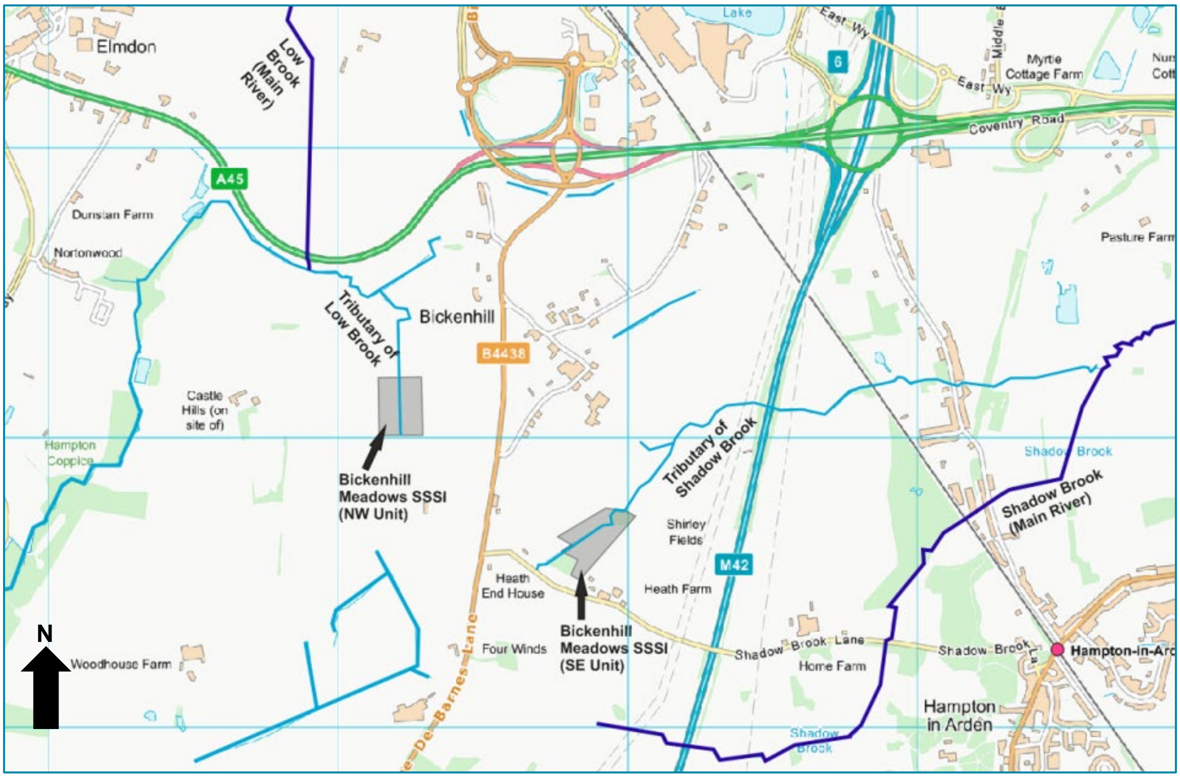


Figure 3. Location of the Bickenhill Meadows SSSI units to west of the M42 Junction 6 (source: Ordnance Survey © Crown copyright and database rights 2018).

3.2 The Natural England citation[1] for the SSSI is as follows.

"Bickenhill Meadows consists of two groups of fields comprising species-rich grassland situated to the south and west of the village of Bickenhill on predominantly neutral soils overlying Keuper Marl.

The meadows comprise one of the richest grassland floras in the county with good examples of both meadow foxtail (Alopecurus pratensis), great burnet (Sanguisorba officinalis), flood meadow and common knapweed (Centaurea nigra), crested dog's-tail (Cynosurus cristatus) meadow and pasture. Both grassland types have declined very severely nationally in the 20th century due to agricultural improvement. The West Midlands Region contains a major part of the national resource of the common knapweed – crested dog's-tail grassland type which is typically associated with level topography, loam or clay soils, moderately free drainage and the retention of traditional farming methods with small fields. There is a complex pattern of vegetation resulting from local variations in topography and drainage, such as the ridge and furrow pattern, evident in some of the fields. This has led to the development of mosaics where the main vegetation types intermingle, as well as to areas where each type can be recognised.

Further interest is provided by wetter areas characterised by rushes Juncus spp., sedges Carex spp. and tall herbs such as meadowsweet (Filipendula ulmaria) and great burnet. Both groups of meadows have streams and there is a good range of tree and shrub species in the hedgerows around the fields".

3.3 Both units of the SSSI have a status of 'Unfavourable – Recovering'. However, the Natural England condition notes indicate that the southeastern SSSI shows a good cover of desirable species and may move to favourable in the near future.

3.4 Natural England's Management Principles for the site includes the following information with regard to drainage, "*For both the damper pastures and meadows, regular and careful maintenance of surface drainage including ditches and drains can be essential to prevent adverse changes in the plant composition of the sward. Deepening of surface drainage should be avoided.*"

3.5 From the available information on the SSSI it is clear that the plant species in the wet meadows and woodland areas within the SSSI units require wet ground conditions, although subtle changes in topography and local features (such as the local ditches and spoil heaps from past clearing of them) exert an influence on the botanical communities and distinctive zones of MG4 (wetter) and MG5 (drier) plant communities according to the National Vegetation Classification (NVC). It is also not evident from Natural England's SSSI designation and management principles, or through consultation with Natural England and the Warwickshire Wildlife Trust (WWT), whether the maintenance of wet conditions in the SSSI is primarily dependent on surface water or groundwater inflow from the surrounding areas.

4. Shadowbrook Meadows Local Nature Reserve

4.1 The southeastern Unit is wholly encompassed by the larger Shadowbrook Meadows Local Nature Reserve (LNR), which is owned and managed by WWT. The WWT website[2] describes the site as follows:

"*The site contains old meadows and pasture with a stream and wet woodland. The small stream runs through the reserve and sumptuous hedgerows divide the site into two dry meadows, on the eastern side, with two wet meadows to the west. Unfertilised, unsprayed and unploughed, the meadows' diversity has been maintained over centuries by the unaltered, traditional haycutting and grazing regime*".

[1] https://designatedsites.naturalengland.org.uk/SiteDetail.aspx?SiteCode=S1002847

[2] Warwickshire Wildlife Trust – Shadowbrook Meadows website, http://www.warwickshirewildlifetrust.org.uk/reserves/shadowbrook-meadows, accessed 15/8/18.

5. Bickenhill Meadows SSSI / Shadowbrook Meadows LNR Site Visit Report

5.1 The Bickenhill Meadows SSSI was initially visited on 18 January 2018 in dry conditions but following a week of occasional heavy rain showers and some light snow and sleet showers. It was subsequently visited in spring with representatives of Natural England on 26 April 2018 in a period of prevailing dry conditions, and again on 2 May 2018 following 12 hours of heavy rain showers, which had resulted in some waterlogging of the surface. The NW Unit was visited during wintry showers on the 28 February 2018 and with Natural England on 26 April 2018 in fine weather. Numerous further visits have been taken to both units throughout the summer and autumn of 2018.

Southeast (SE) SSSI Unit / Shadowbrook Meadows LNR

5.2 The southeastern unit consists of four fields (three of which are in the SSSI boundary) and wet woodland at the far north of the site, and (along with the LNR) covers 4.4ha. The stream that flows through the centre of the site (from southwest to northeast) is a tributary of Shadow Brook. It meets Shadow Brook to the east of the M42 approximately 2km downstream at NGR SP 20625 82231. The dry meadows are to the east of the site, and wet meadows are to the west. General views of the wet meadows are shown in Photos 1 to 6 under different conditions.

5.3 The topography of the site is generally level, with a gentle rise in elevation away from the tributary of Shadow Brook, which flows through the approximate centre of the site. The wet meadow to the north of the brook is relatively flat and may have been the route of the former watercourse prior to digging of the new brook course to the south and the ephemeral ditch to the north (which collects runoff from the steeper hillside slopes but is essentially a soakaway).

5.4 Along the edge of the brook there is a slight rise in the elevation that may be a relic of digging out or maintaining the brook. From here north the land gently falls before rising towards the ditch along the northern boundary of the SSSI. Within this general topographic form are isolated depressions that form part of a complex ridge and furrow pattern extending across the site, and which are a relic of historic ploughing practices. This is very subtle with only small changes in elevation of the order of tens of centimeters, but sufficient enough to result in significant changes in plant communities as depicted by the varying position of MG4 and MG5 plant communities. Ground elevation decreases slightly to the north as the stream flows downslope, but the overall gradient across the site is minor.

5.5 To the south of the brook, the ground rises more steeply more the watercourse and the plant communities appear to be less diverse and well developed. A gas main runs east-west across this field, the route indicated by a line of flushes suggesting that soil hydrology has been locally affected. Due to the intervening presence of the brook, the elevation of this field, and the angle of the slope, it is unlikely to be affected by the Scheme.

5.6 There is a small pond towards the centre of the southern field of the LNR site (but not within the SSSI) with emergent reed vegetation and which is surrounded by a stock proof fence (see Photo 2). The origins of the pond are not known, but when observed in very wet conditions a ‘trickle’ of water flowed from the pond and overland to the north to ultimately meet the tributary of Shadow Brook, possibly as a result of any undersoil drainage being blocked. During the late summer of 2018 this pond was completely dry.






Photo 1 (top left) and Photo 2 (top right) Wet meadow fields at Bickenhill Meadows SSSI SE Unit / Shadowbrook Meadows LNR in cold/wet conditions; Photo 3 (middle left) Wet meadow fields at Bickenhill Meadows SSSI SE Unit in warm/dry conditions; Photo 4 (middle right) and Photo 5 (bottom left) Bickenhill Meadows SSSI SE Unit in warm/dry conditions; Photo 6 (bottom right) Bickenhill Meadows SSSI SE unit southern field after a prolonged period of hot summer weather.

5.7 The source of the tributary of Shadow Brook is mapped by Ordnance Survey as being immediately north of Shadowbrook Lane to the south of the SE Unit. Here lateral ephemeral drainage ditches from the road coalesce and flow north beneath the caravan park site and emerge at the southern border of the SSSI. There is a pond on the opposite (south) side of Shadowbrook Lane to the mapped source of the stream, which collects water from the adjacent road and agricultural drainage from the arable field opposite the LNR. This field includes a small ditch of around 0.5m width, which flows from Catherine-de-Barnes Lane in a northeasterly direction towards the LNR and SSSI. Catherine-de-Barnes Lane marks the watershed boundary, and all surface water in this upper section of the SSSI's catchment is expected to be channeled towards this agricultural ditch and collects in the pond adjacent to Shadowbrook Lane, which is a natural focal point for drainage to collect. Although there was no obvious culvert beneath the road it is believed that runoff finds its way under Shadowbrook Lane either through unknown drainage network or subsurface flow. Significant amounts of standing water have been observed in the ditches either side of Shadowbrook Lane after heavy rainfall in winter and spring and potentially indicate impeded flow beneath the road, presumably due to siltation and blockage by large woody debris and decomposing organic matter. In summary, it appears that the brook is likely to be rain fed, receiving drainage also from surrounding agricultural land and Shadowbrook Lane. There may also be drainage from the small caravan park site under which the brook flows prior to emerging in the SSSI.

5.8 Given its small size, intermittent and generally low flows, the brook is expected to suffer from water quality issues typical of an arable catchment, plus drainage from local roads and potentially other sources, such as runoff from the caravan site.

5.9 There is also an ephemeral drainage ditch bordering the northwest of the site (Photo 7), which varies between 1m and 1.5m wide. This was largely dry on the majority of site visits, with some ponded water in places of 1-2cm depth adjacent to the upper wet meadow. However, when observed after heavy rain there was obvious flow in the ditch, which presumably was sourced from runoff from the adjacent arable field which slopes significantly down to the SSSI. As the ditch enters the alder woodland at the northern extent of the SSSI there was a small amount of flow even during the drier site visits, which drains into the tributary of Shadow Brook (approximate NGR SP 18950 81743), see Photo 8.



Photo 7 (left) Ponded water in agricultural drainage ditch at NW border of SE Unit; Photo 8 (right) confluence of the tributary of Shadow Brook and the drainage ditch within the alder woodland; Photo 9. Furrows and depressions saturated with water following rainfall in meadow field of SE Unit.

5.10 Within the SE Unit the tributary of Shadow Brook is very straight and could have initially been an agricultural drainage ditch. It is around 0.5m wide and water depth was in the region of 3-5cm when observed on the site visits on the 2 May 2018 (Photos 10 and 11). The bed was generally covered by accumulations of fine sediment (and leaf litter in the autumn), although some small accumulations of gravel of 4-5mm in diameter were also evident.

5.11 Towards the centre of the SE Unit the brook is culverted under a grassed land bridge through a plastic pipe of around 400mm diameter (Photo 12). Upstream the culvert is partially buried, and there is potential for impoundment of flow during extreme rainfall events, which may result in occasional flooding of the immediate grasslands, although there was no evidence of this. Several blockages across the stream from woody debris and accumulations of leaves were observed during the site visits, which again could cause localised impoundment of flows and encourage local out of bank events. Connectivity to the surrounding floodplain is good in some sections, particularly on the left bank in the northern field. However, the stream is not considered significant enough in size to cause widespread out of bank events across the grasslands and woodland, and Natural England and WWT are not aware of any widespread flooding at the site resulting from out of bank stream flows. However, the brook may locally support groundwater levels in the close vicinity of the channel, and it is possible that soil on either side has been compacted in places due to the past placing of dredgings, and this may influence soil hydrology on the upslope side by helping to maintain wetter ground conditions.

5.12 In the northeastern (wet) field of the SE Unit, the ridge and furrow topography gives rise to diverse ecological communities. The furrows tend to be saturated and support grassland species designated as MG4 under the National Vegetation Classification (NVC). MG4 represents a nationally rare flood meadow community. Characteristic species include greater burnet (*Sanguisobra officinalis*) and meadowsweet (*Filipendula ulmaria*). The ridges are drier and support MG5 neutral grassland species with assemblages of English crested dog's tail (*Cynosurus cristatus*) and common knapweed (*Centaurea nigra*), amongst others. Subtle changes in colour across the wet meadow, shown in Photo 1, indicate the changes in vegetation across the site.

5.13 When the SE Unit was observed following heavy rainfall on 2 May 2018 the entire site was extremely wet, with most grassland areas appearing to be fully saturated (Photo 9). All furrows and depressions that were observed during the visit contained surface water, including in the generally drier meadow fields. This observational evidence indicates that the moisture source for the wet grasslands is most probably rainwater, which is slow to drain away due to the poor permeability of the subsurface layers.

Photo 10 (left) and Photo 11 (centre): Tributary of Shadow Brook within the wet woodland. Photo 12: (right) Culvert exit downstream of the grassed land bridge.

Northwest (NW) SSSI Unit

5.14 The NW Unit is a small, roughly square grassland area of 2.7ha, bordered on all sides by a scrub and woodland margin (Photo 13). A tributary of Low Brook flows from south to north and divides the field approximately in half, with the topography rising away from the tributary gently on both sides initially, becoming steeper further afield. The brook itself is surrounded by intermittent hedgerow vegetation. Immediately south of the site is a historic landfill site of raised elevation, from which groundwater (of unknown quality) may flow out towards the SSSI, as indicated by iron staining seeping from the embankment.

5.15 The watercourse appears to emanate from numerous ephemeral drainage ditches which flow around the elevated historic landfill area and coalesce at the south of the site to then flow north through the SSSI. A further drainage ditch flows north along the western boundary of the site. As the watercourse flows north through the SSSI unit it widens out into a very silted marshland area, with little discernable surface water flow (Photo 14), before reverting to a well-defined stream of up to 2.5m wide (Photo 15) which has generally good floodplain connectivity within the SSSI, and emergent macrophytic vegetation in places. The watercourse is not considered of sufficient size to cause significant flooding of the adjacent fields.



Photo 13 (left), Photo 14 (centre) and Photo 15 (right) - Bickenhill Meadows SSSI NW Unit.

5.16 Vegetation patterns on the eastern side of the SSSI indicate that there may be an isolated wetter area just upslope of the tributary of Low Brook towards the centre of the site. This is indicated by a slightly raised area with a distinct and 'spongey' vegetation assemblage, which is different in character from the surrounding communities of MG4 grasslands (including great burnet (*Sanguisorba officinalis*) and meadowsweet (*Filipendula ulmaria*) and MG5 grasslands (including knapweed (*Centaurea nigra*)) that are found across the eastern field of the site. The wetter ground conditions may also be influenced by dredged material placed in a bund along the eastern bank, which may be compacting the soil below and reducing permeability.

5.17 The western field has a generally drier and more uniform character than the eastern field (Photo 16), and is at a slightly greater elevation than the eastern field. The spatial distribution of the MG4 and MG5 grasslands across both fields is a likely consequence of local variability in moisture content in the upper 30-40 cm of soil, with tussocks and ridges across the site providing slightly drier conditions than localised depressions and troughs.

Photo 16 (left) – eastern field within the NW Unit showing the fringing blackthorn trees.

Photo 17 (right) tributary of Low Brook immediately north of the SE Unit boundary looking towards Birmingham Airport.

5.18 As the tributary of Low Brook flows out of the SSSI to the north of the site, the watercourse becomes a perfectly straight (artificially straightened), deeply incised drainage channel with a width of around 1m (see Photo 17). This flows north to Low Brook, which is then culverted beneath the Birmingham Airport runway.

6. Ground Condition and Soils

6.1 According to the British Geological Survey's Geology of Britain website (http://mapapps.bgs.ac.uk/geologyofbritain3d/) the bedrock geology beneath both SSSI units is Sidmouth Mudstone Formation (Mercia Mudstone) (Figure 4). No superficial deposits are recorded below the SE Unit, while alluvium (clay, silt, sand and gravel) is mapped around the stream through the NW Unit (Figure 5).

6.2 The alluvium deposits at the NW Unit are Secondary 'A' aquifer. The Sidmouth Mudstone Formation is classified as Secondary 'B' aquifer. Secondary A aquifers are permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. Secondary B aquifers are predominantly lower permeability layers which may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering.

6.3 Borehole records collected from historic ground investigations undertaken during the development of the M42 motorway in the 1970s and 1980s showed that groundwater was generally encountered within 10m of the ground surface adjacent to the M42 at Junction 6. The nearest borehole records for the NW Unit shows a depth to groundwater of 6.75m at the western extent of the SSSI (within 50m of the NW corner of the SSSI), as recorded in 1978 (reference SP18SE/511)[3], and the borehole log indicates sand and gravel pockets within clay to a depth of 4.7m. Another borehole approximately 130m to the south of the SSSI had a depth to water of 3.0m, also in 1978 (reference SP18SE/510)[4]. The borehole log here indicated sandy clay and gravel to a depth of 1.3m, with stiffer clay below to a depth of 5.8m, underlain by mudstone.

6.4 Further ground investigations were undertaken to the north of the NW Unit in 2011 in relation to the Birmingham Airport runway extension and re-routing of the A45[5]. The nearest borehole was located approximately 250m north of the SSSI unit, adjacent to the tributary of Low Brook (i.e. towards the valley bottom). This borehole (reference CP26) indicated slightly gravelly sandy clay with gravelly sand lenses to 2.2m, underlain by Mercia Mudstone, with groundwater struck at 4.2m depth (in October 2011). A borehole approximately 380m north of the SSSI (reference CPRC31) recorded slightly sandy clay to 1.65m underlain by Mercia Mudstone. No groundwater was encountered in October 2011.

6.5 There are no historic borehole records in the immediate vicinity of the SE Unit. The nearest is 340m to the east of the site (SP18SE/26B) and was drilled as part of the ground investigation for the M42 in 1970. This borehole had a depth to water of 11.05m. The borehole log indicates that the upper layers consisted of silty clay (weathered mudstone), with lumps of hard mudstone apparent from 4.45m depth, and weathered mudstone extending to the borehole base at 13.55m.

6.6 According to the Environment Agency there are no groundwater abstractions within 3km of either SSSI unit. Solihull Metropolitan Borough Council has confirmed that there are five known Private Water Supplies within 2km of the site, although exact locations have not been provided.

6.7 No springs are marked on current Ordnance Survey mapping in the immediate vicinity of the SSSI units, or on historical mapping that is available online. The nearest spring is marked ('*issues*' on Ordnance Survey mapping) approximately 500m to the southeast of the SE Unit at the source of Shadow Brook. When visited on site on 27 October 2017, Shadow Brook was completely dry at its source and along its channel until east of the M42. This suggests that there may be low groundwater levels, or that there may only be an ephemeral groundwater input to the stream at times of high groundwater level conditions. While several pockets of sand and gravel that could contain groundwater are mapped in the area, particularly on higher ground, these do not extend to

[3]British Geological survey, Geology of Britain website, available at http://mapapps.bgs.ac.uk/geologyofbritain3d/index.html (accessed 20/5/18)
[4]British Geological survey, Geology of Britain website, available at http://mapapps.bgs.ac.uk/geologyofbritain3d/index.html (accessed 20/5/18)
[5] Birmingham Airport (December 2011) Factual Report on Ground Investigation for the Proposed Runway Extension at Birmingham Airport,

the SSSIs, although it is not currently known whether this is simply due to a lack of available information. The ground investigation for the Scheme will help clarify the full spatial location of the sand and gravel pockets.

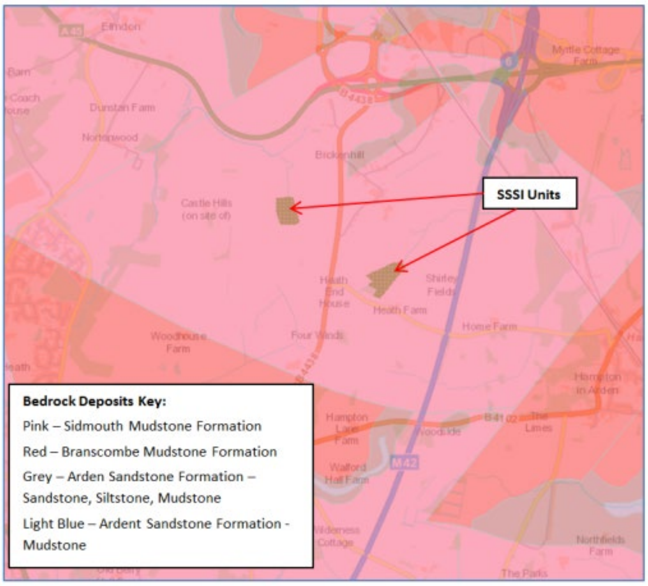


Figure 4. Bedrock deposits in the area around Bickenhill Meadows SSSI (source: British Geological Survey Geoindex website, http://www.bgs.ac.uk/geoindex).

Figure 5. Superficial deposits in the area around Bickenhill Meadows SSSI (source: British Geological Survey Geoindex website, http://www.bgs.ac.uk/geoindex).

6.8 Cranfield University's Soilscapes website (http://www.landis.org.uk/soilscapes/) indicates that the soil across the study area, including both SSSI units, is slowly permeable seasonally wet slightly acid base-rich loamy and clayey soils. Habitats typically associated with such soils are seasonally wet pastures and woodlands.

7. Topographic Survey

7.1 LiDAR topographic data has been obtained from the UK Government's Open Data website (https://data.gov.uk/) for the area covering the two SSSI units. This is shown in Figure 6 overlain onto Ordnance Survey Mapping. The surrounding topography is also shown in contour form in Figure 7. Areas of the highest elevation (shown as pale green shading in Figure 6) are located: i) immediately to the east of the NW Unit; ii) at Bickenhill village; iii) at Catherine-de-Barnes Lane north of the Shadowbrook Lane junction; and iv) close to Four Winds to the south of the SE Unit. Areas of progressively lower elevation are found along the streams that flow through each SSSI (yellow to light brown to dark brown shading).

7.2 Around the SE Unit the topography gently declines in elevation from the east, south and west towards the tributary of Shadow Brook, which has gentle valley slopes surrounding it as it flows to the northeast. Similarly, the NW Unit has slopes falling away from the east, south and west, with a gentle valley forming to the north as the stream in the SSSI flows towards Low Brook. A series of topographic sections have been derived from the LiDAR data. The section lines are indicated and labelled in Figure 6, and are all presented in Annex A.

7.3 It is clear from the sections that there is a general decline in elevation from east to west towards the NW Unit (sections A-C). This is essentially a valley side to the tributary of Low Brook. As the new dual carriageway would be located to the east of the NW SSSI (see Figures 1 and 2) there is potential for flow pathways between the Scheme and the downslope SSSI. If construction and operational runoff was not properly controlled, and appropriate mitigation measures not put into place, then there could be adverse impacts to habitats and water quality within the SSSI unit from this runoff. However, the Scheme includes mitigation for all potential adverse impacts from road drainage and spillage incidents during construction and operation.

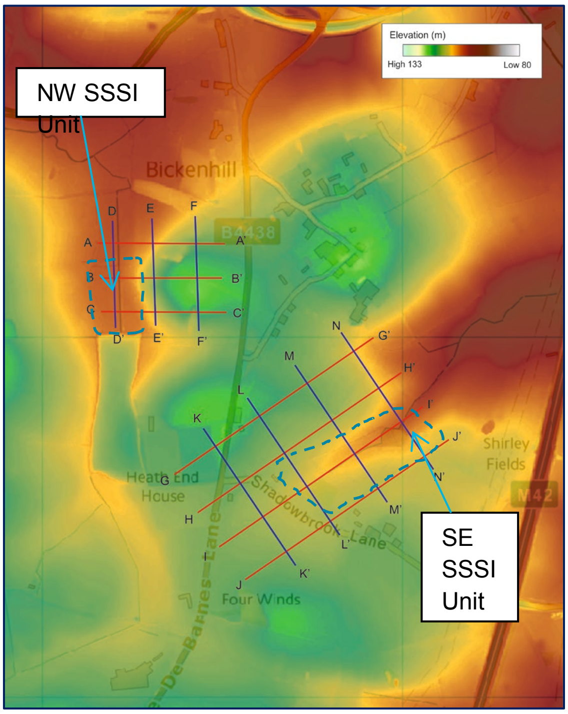


Figure 6. LiDAR data (source: UK open data website) overlain on Ordnance Survey data (crown copyright and database rights 2018 Ordnance Survey). Solid lines indicate locations of topographic sections, as shown in Annex A. Dashed lines indicate approximate SSSI locations. The figure shows a surface water divide between the two sites running NE-SW.

7.4 There is also a decline in elevation from south to north towards the NW Unit (sections D-F). This includes a field directly south of the SSSI unit which is elevated in comparison to the surrounding land, and is a former landfill site.

7.5 The topographic long sections for the SE Unit (sections G-J) indicate a general decline in elevation from the south of Shadowbrook Lane towards the SSSI, while the cross sections (sections K-N) indicate gentle valley slopes rising each side of the watercourse. As designs indicate that the new dual carriageway will cross Catherine-de-Barnes Lane just south of the Shadowbrook Lane junction, and will continue in a southeast direction (Figure 8), there is potential for surface water flows between the Scheme and the SSSI unit.

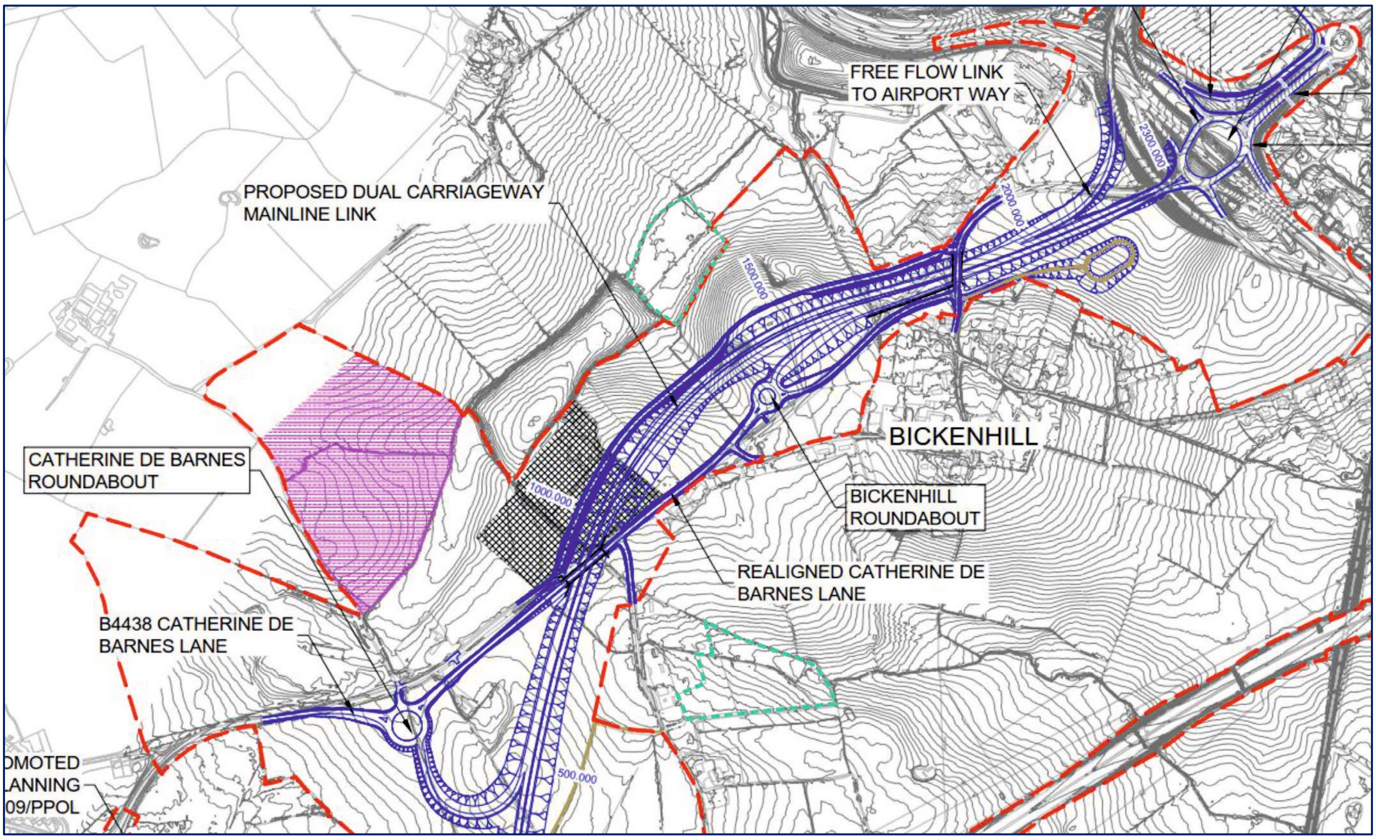


Figure 7. Contour map to show topography surrounding the two SSSI units. SSSI units are outlined in a green dashed line, with the Scheme red line boundary shown in red (which has since been modified). Contours were derived from topographic survey undertaken at PCF Stage 2 for the Scheme.

7.6 In Figure 8, the surface water catchments for each SSSI unit have been derived from the LiDAR data. The NW Unit has a noticeably larger catchment than the SE Unit, and extends a considerable distance to the southwest where it is interrupted by the Grand Union Canal near Catherine-de-Barnes. On the basis of the approximate road alignment shown in Figure 8, the proportion of the catchments that is lost below the footprint of the road and is cut off from the catchment due to the new mainline link road for each SSSI unit would be 4.7% for the NW Unit and 21.4% for the SE Unit, based on Design Fix 3C.

7.7 The site observations and topographic investigation of LiDAR data suggest that surface water flows are important contributors to the habitats in the two SSSI units, particularly in the close vicinity of the channels. However, significant flooding of the units is very unlikely and it is more likely that rainfall combined with the ridge and furrow topography and localised hillslope runoff is the most significant source of water controlling the hydrology of the wet meadows. The role of groundwater flow is uncertain.

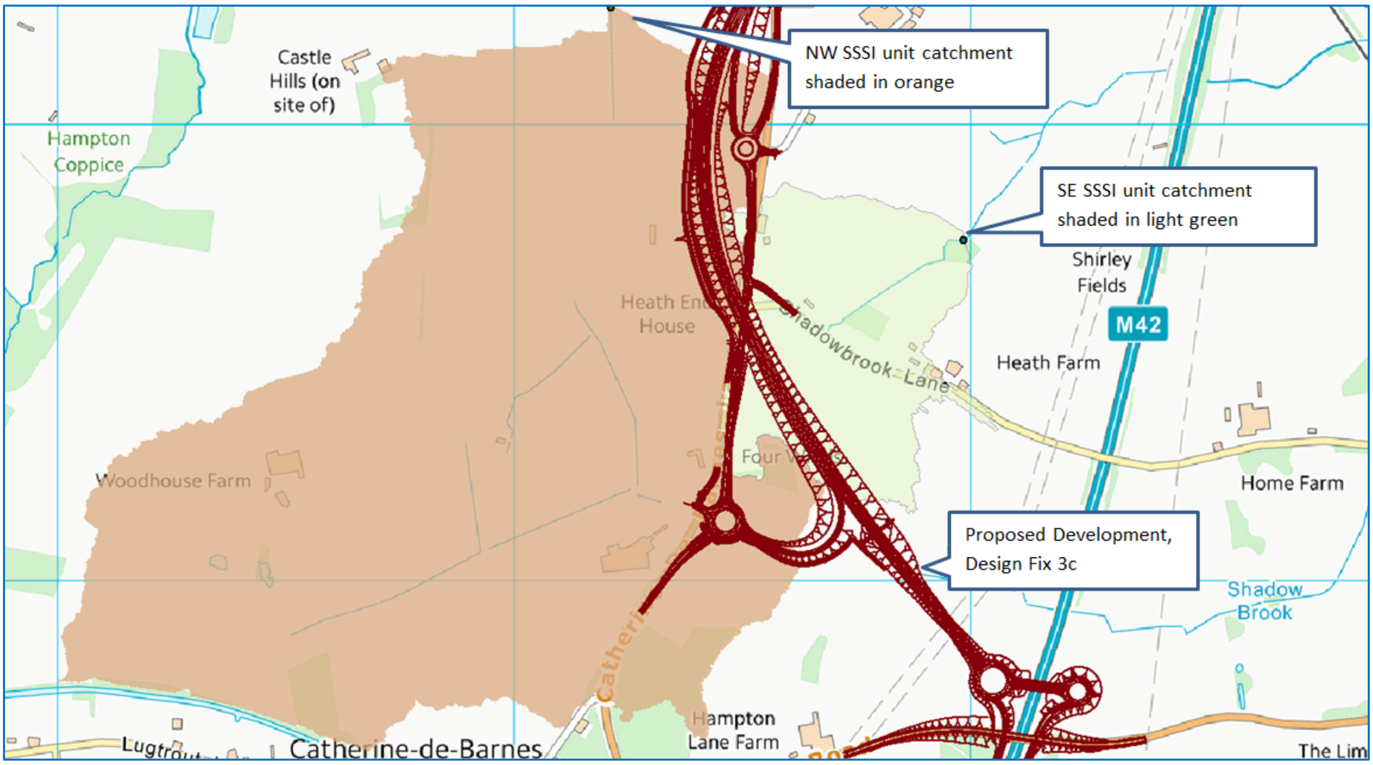


Figure 8. Catchment boundaries as determined from GIS catchment analysis, with the Design Fix 3C road alignment overlain in red.

8. Ground Investigation

8.1 The main Ground Investigation undertaken as part of the Scheme provided some understanding of groundwater levels across the area, but did not initially include investigations in the immediate vicinity of the SSSI units and determination of the extent to which groundwater levels may intersect with the wet meadows and woodlands.

8.2 The design of the new mainline link road indicates that in places the cuttings will have a depth of up to 10 m below existing ground level. Adjacent to the SE Unit, the cutting would have depths varying between 5 and 8m below existing ground level, while adjacent to the NW Unit depths would be between 0 and 9m lower than existing levels. The potential for drawdown of groundwater is thought to be greatest where the cutting will intersect patches of glacial sands and gravel and Arden Sandstone. There are no mapped Arden Sandstone outcrops adjacent to the SSSIs that would be impacted by the cutting (see Figure 4), but there are deposits of glacial sands and gravels as indicated in Figure 9 and 10. Dewatering of these deposits due to the road could impact on lateral groundwater flow towards the SSSIs, and it remains a possibility that they are more extensive than current mapping suggests. While there is potential for drawdown in areas of Mercia Mudstone, the impact is likely to be much reduced in comparison to the areas of sand and gravel deposits.

8.3 Given that groundwater in the area has historically been within 10m of the surface, and that in places the cutting is to be up to 10m deep, there is some potential for disruption of groundwater flows. While groundwater flow is not currently considered to be the primary source of water maintaining wet conditions and streamflow in the SSSI units, it is not ruled out as having a contributory role, particularly if the sands and gravels are more spatially extensive than mapped. As such, the relationship between groundwater levels at the site of the proposed road and at the two SSSI units required greater understanding to determine whether the cutting would have any impact. To achieve this, the main Ground Investigation for the Scheme was extended to take account of the SSSI units.

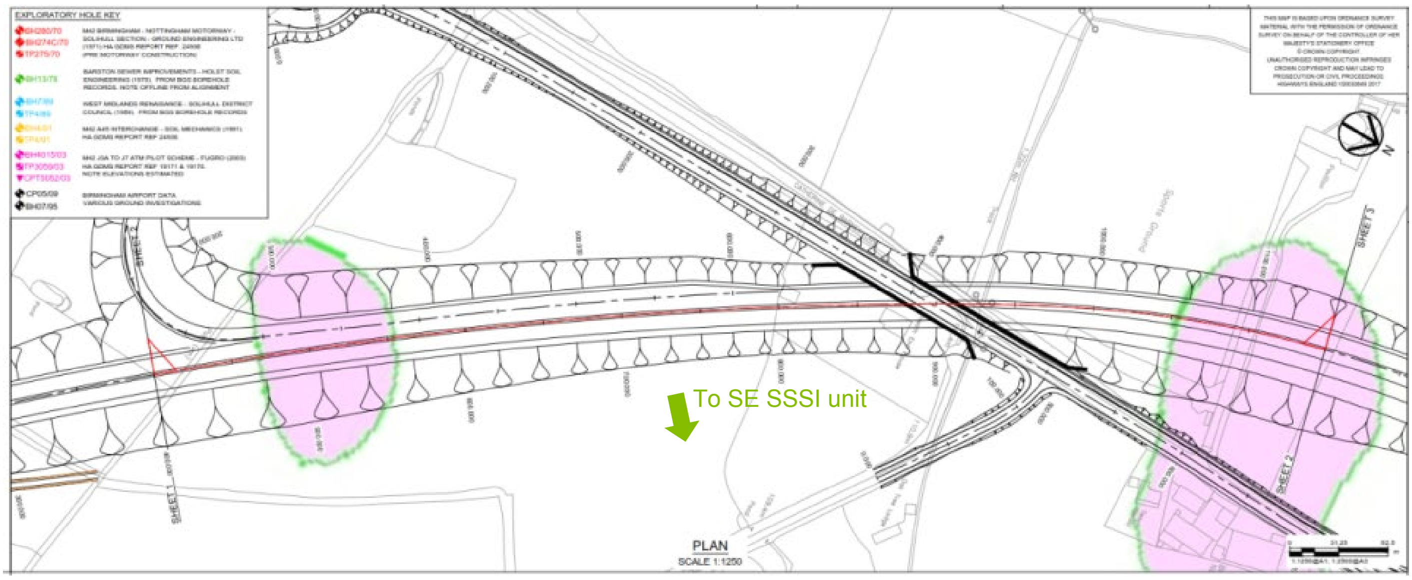


Figure 9. Location of Glacial Sands and Gravels along the new mainline link road (shown by Pink shading) in the vicinity of the southeastern SSSI unit.

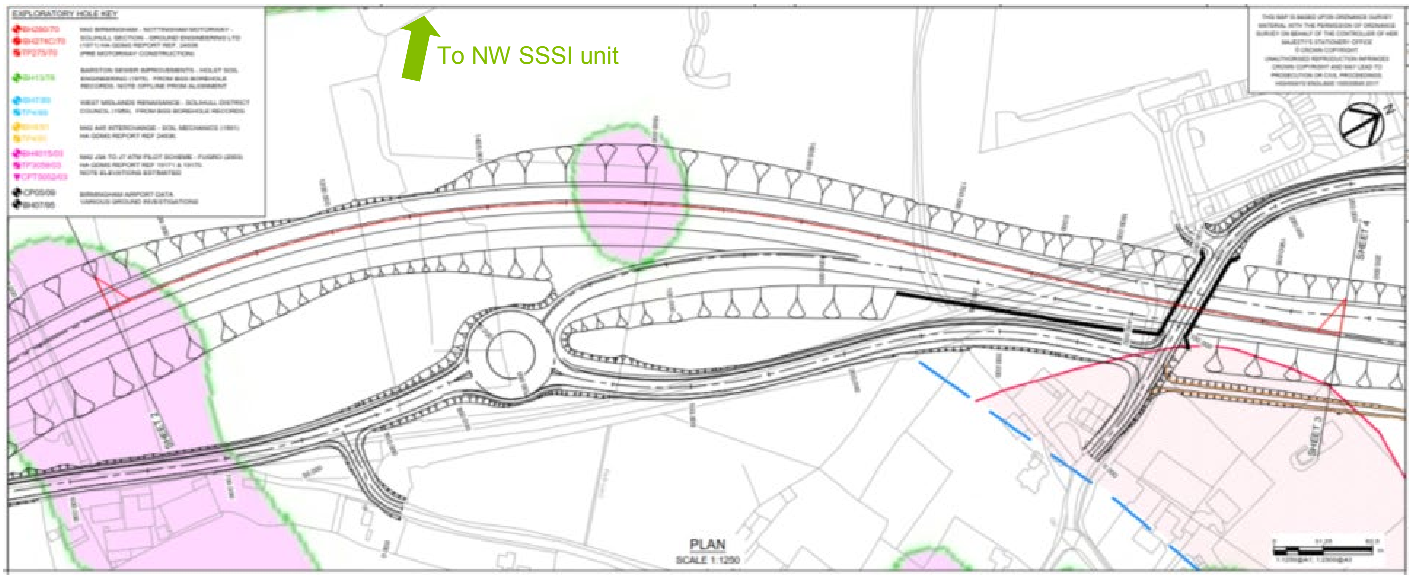
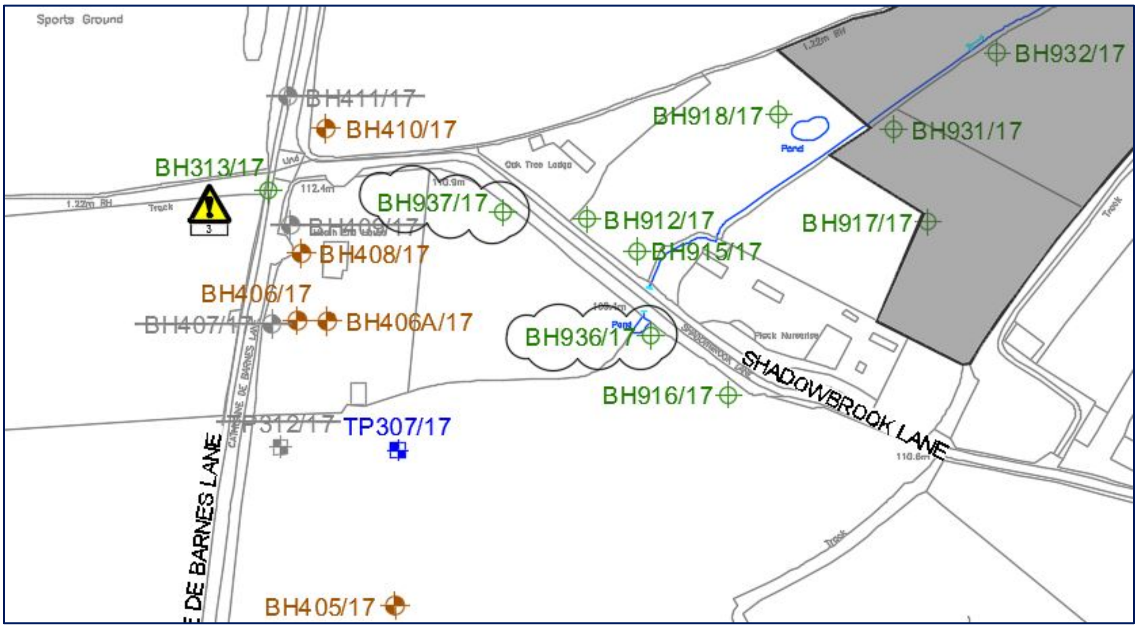


Figure 10. Location of Glacial Sands and Gravels along the new mainline link road (shown by Pink shading) in the vicinity of the NW SSSI unit.

8.4 Figure 11A and 11B show the location of the Ground Investigation works in and around the SSSI units, which were completed in October 2018. The works now include boreholes around the periphery of both SSSI units and within the SSSI units. Those on the periphery of the units are window samples with a standpipe installation to allow monitoring of groundwater levels over time. The standpipes terminate on proving the surface of the Mercia Mudstone Formation. The boreholes within the SSSI units are not long-term installations for monitoring, but have been included to prove the underlying geology and provide a snapshot of groundwater conditions that can be related to the levels around the periphery of the sites.

8.5 The proposed monitoring of groundwater levels around the periphery of the SSSIs will help understand the groundwater dependence of the two SSSI units, and hence the likelihood of any adverse impact from the Scheme that would need to be mitigated.



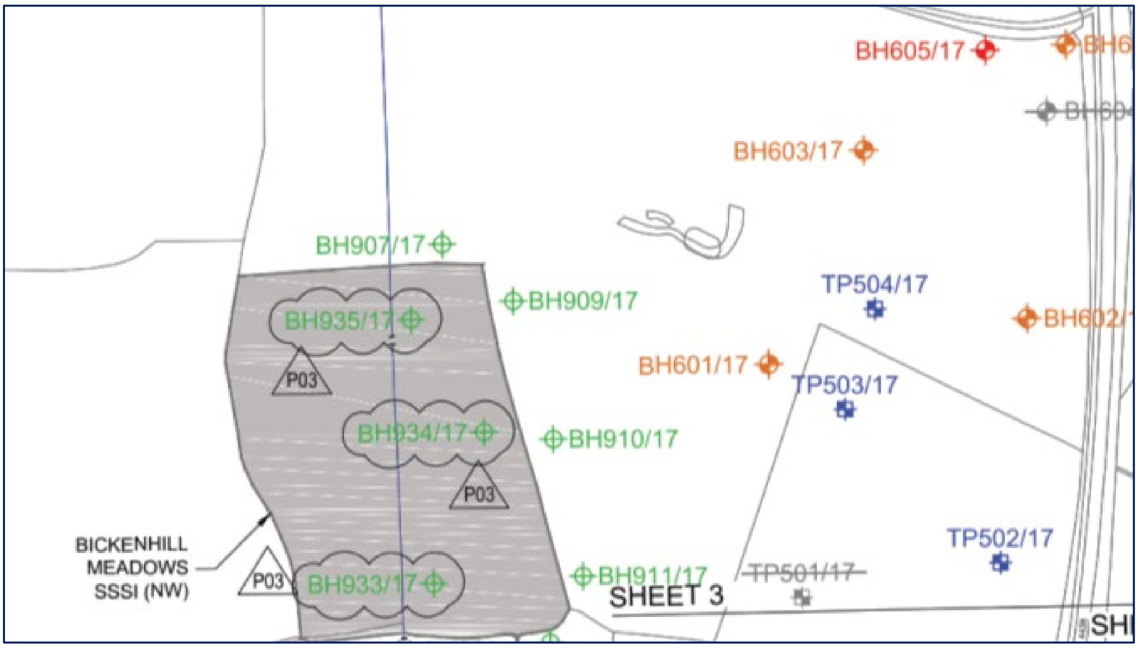


Figure 11A (top) and 11B (bottom) Ground Investigation locations – extended to include the SSSI units. Red – cable percussion boreholes; orange – rotary coring boreholes; green – window sample; blue – trial pit.

9. Soil Saturation Monitoring

9.1 During site visits to the SE Unit following heavy rainfall events, it has been apparent that rainfall can periodically accumulate on the ground surface and be slow to drain away. This is particularly the case in depressions and furrows across the site. This supports the assertion that maintenance of wet ground conditions required for many of the grassland species may be rainwater fed to a large extent, perhaps supported by localised out of bank flows very close to the stream, and/or limited groundwater flows from any surrounding glacial sand and gravel deposits. These glacial deposits may act somewhat like a sponge, filling with groundwater in response to rainfall. In the wet meadow at the SE Unit, it appears that the MG4 species are more successful in the saturated furrows across the site, while MG5 species are more successful on the slightly elevated and therefore drier ridges.

9.2 To better understand the variability in soil saturation and how long it takes the SSSI sites to drain following heavy rainfall, it was agreed in discussions with Natural England (on site on 26 April

2018) to install a series of dipwells on the wet meadow field at the SE Unit and within the NW Unit. Soil water levels and conductivity would then be measured fortnightly within the dipwells over a period of at least 6 months to build an understanding of subsurface moisture conditions, and whether they are indeed largely rainwater fed. While less than 6 months of monitoring was available at the point that the Environmental Statement was finalised and the Development Consent Order (DCO) application submitted, it is intended that the monitoring would continue post submission for at least 2 years, with Natural England kept informed with data and technical interpretation. The findings presented in the Environmental Statement would be updated at DCO Examination if necessary, and monitoring could potentially be maintained during construction of the Scheme to assess any impact on the two SSSI units, subject to landowner and Natural England consent.

9.3 Prior to land owner consent being granted for installation of dipwells at the two SSSI units, ground conditions at both sites were inspected visually every fortnight. The streams through both sites had dried up by 1 July 2018 and the pond immediately outside the SE Unit had dried up by mid August (13 August 2018). At both sites the grass was also straw-like in colour and wilting by late July, and no ground moisture was apparent on any visit between July and early September. As such, if dipwells had already been installed earlier in the summer of 2018, there is a strong likelihood that they would have been dry throughout the period (between mid-May and September) due to the especially dry summer conditions.

9.4 Dipwells were installed in the SE Unit on 13-14 August 2018 (see Figure 12A for locations and Photo 18 for an example). A total of 10 dipwells were installed, covering MG4 grassland, MG5 grassland and transitional grassland areas. The dipwells were prefabricated from a perforated plastic pipe of 32mm diameter. They are sealed above ground to prevent rainwater from filling the pipe. The plastic pipe is perforated at regular intervals along its length on all sides, to allow throughflow of soil water, and to allow equilibration to be achieved with the surrounding water table.

Figure 12A. Locations of dipwells installed in the wet meadow field at the SE Unit

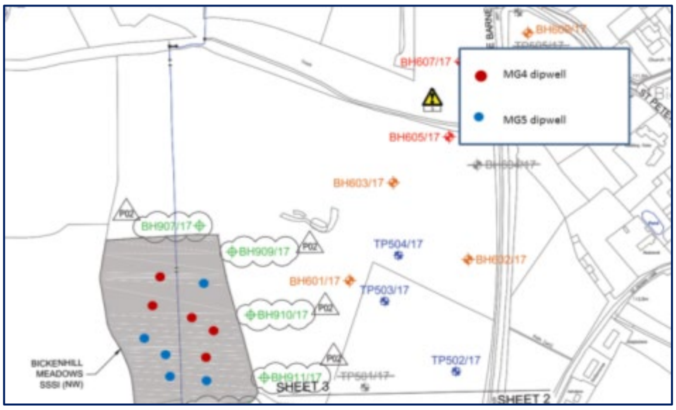


Figure 12B. Locations of dipwells in the NW Unit.

9.5 Of the 10 dipwells installed at the SE Unit, 6 were installed to a depth of 90 cm and 4 to a depth of 50-60 cm (due to difficulty penetrating the substratum with hand held soil augering equipment). Environment Agency Ecohydrological Guidelines[6] for MG4 grasslands suggest an indicative target mean water table depth range from 35cm depth in winter to 70cm depth in summer, and so ordinarily the installed dipwells should be of sufficient depth to monitor the water table for these grasslands. Soil conditions beneath the site were variable, with a mix of upper dark brown sandy silt layers and stiff dark grey clay layers generally encountered to around 50cm depth. Light grey and orange sand layers and gravel layers were commonly found beneath

[6] Environment Agency (2004) Protective and Enhancing Wetlands: Ecohydrological Guidelines for Lowland Wetland Plant Communities.

this, including isolated pockets of large cobbles (mix of rounded and angular cobbles, 10-20cm diameter), as well as some layers of blue-grey clay. A full description of the soils encountered during augering at each dipwell as well as further details on location and depth are described in Annex B.

9.6 The dipwells in the NW Unit were installed on 5-6 September 2018 (see Figure 12B for locations, and an example in Photo 19). Despite sporadic rainfall in the period since the installation of the SE unit dipwells, the ground conditions at the NW unit remained extremely dry with no groundwater encountered during augering of any of the holes. In total, 4 dipwells were installed to 90cm depth, two to 70cm depth, and additional dipwells to 66cm, 60cm, 50cm and 43cm depth. The shallower depths of some dipwells are a result of impenetrable stiff clay layers being encountered. In general, the top soil at the NW Unit was up to 20cm to 40cm depth below ground, before trending to extremely stiff, dark grey clay to the base of the dipwells. The main exceptions were the two dipwells towards the centre of the eastern half of the SSSI, where sand and gravel layers were encountered at depths below 50cm. Further details are described in Annex B.

9.7 The dipwells have been monitored fortnightly since installation to capture water table recharge in response to rainfall. The regular measurement of water levels is undertaken using a dip tape inserted into the pipe. Conductivity is measured in selected dipwells using a Hanna Instruments conductivity meter, when enough water accumulates to enable measurement. One dipwell at each site has also been fitted with a water level data logger to allow continuous measurement of soil water levels.

9.8 Rainfall data from the nearest Environment Agency meteorological stations and/or the Birmingham Airport Meteorological Station will be obtained to compare with the water level record once a more significant period of monitoring has been undertaken.

Photo 18. Dipwell T2-D at the SE SSSI unit.

Photo 19. Dipwell N2-B on the NW SSSI unit.

10. Ground Investigation Results at the SSSIs

10.1 The boreholes shown in the SE SSSI and immediate periphery in Figure 11A were installed in July 2018. The boreholes in the immediate periphery of the NW Unit (Figure 11B) also were installed in July 2018, and those inside the NW Unit in September 2018. Additional boreholes on the periphery of the SE Unit were installed in October 2018.

10.2 A summary of the preliminary results is given in Table 1.

Table 1 Ground Investigation findings for the SE and NW SSSI units and periphery. [For borehole locations refer to Figure 11A and 11B].

Borehole	Geology Summary	Groundwater strike
SE SSSI		
BH932 (within SSSI)	4m depth - gravelly sand to 0.8m, very sandy clay to 2.25m, sandy clay with weak mudstone fragments to 4m.	Water strike at 2.25m rising to 2.18m after 20 minutes.
BH931 (within SSSI)	3m depth – gravelly sand to 0.8m, sandy slightly gravelly clay to 1.2m, silty clay to 3m.	Water strike at 1.96m rising to 1.8m after 20 minutes.
BH917 (within SSSI)	3m depth – gravelly sand to 0.8m, slightly sandy slightly gravelly clay to 1.75m, sandy clay to 3.0m	Water strike at 2.19m.
BH918 (within nature reserve but not SSSI)	3m depth – fine to coarse sand with some gravel to 1.15m, sandy clay to 1.5m, gravelly fine to coarse sand to 3m.	Water strike at 1.48m.
BH912 (within nature reserve but not SSSI)	4m depth – gravelly sand to 0.8m, sandy slightly gravelly clay to 1.5m, sand to 1.6m, sandy clay to 2.10m, slightly sandy slightly gravelly clay to 2.6m including extremely weak mudstone, sandy clay to 4m.	Water strike at 2.6m, rising to 1.74m after 20 minutes.
BH915A (within nature reserve but not SSSI)	6.4m depth – gravelly fine to coarse sand to 0.8m, sandy gravelly clay to 3.10m, sandy clay to 5.0m, fine to coarse sand to 5.6m, sandy clay to 6.1m, clay tending to extremely weak mudstone to 6.4m	Water strike at 3.10m, rising to 1.8m after 40 minutes.
BH916 (SW periphery, outside of SSSI and LNR, opposite side of Shadowbrook Lane)	6.0m depth – gravelly silty sand to 1.8m, slightly gravelly silty clay to 2.5m, sandy silty clay to 3.5m, interlaminated sandy silt to 4.0m, clay to 5.0m, Mercia Mudstone to 6.0m.	Water strike at 4.0m
BH936 (SW periphery, outside of LNR, opposite side of Shadowbrook Lane)	6.0m depth – sandy slightly gravelly clay to 0.35m, slightly gravelly sandy clay to 2.3, Mercia Mudstone to 6.0m.	Water strike at 1.6m
BH937 (SW periphery, outside of LNR, opposite side of Shadowbrook Lane)	4.0m depth – slightly sandy slightly gravelly clay to 0.5m, slightly sandy slightly gravelly silt to 1.0m, sandy clay 1.7m, slightly clayey sand to 2.3m, slightly gravelly very sandy clay to 4.0m	No water strike
BH410 (western periphery, outside of SSSI and LNR, adjacent to Catherine-de-Barnes Lane.	25.0m depth – gravelly clay to 0.6m, sandy gravelly clay to 3.0m, Mercia Mudstone to 25.0m.	Water strike at 11.3m
NW SSSI		
BH933 (within SSSI)	2.65m depth – sandy gravelly clay to 0.2m, very stiff clay to 0.4m, silt clay to 0.9m, sandy gravelly clay to 1.1m, gravelly silty clay to 1.2m, gravelly silt to 1.5m, Mercia Mudstone to 2.65m.	Water strike at 1.40m.
BH934 (within SSSI)	2.0m depth – stiff slightly gravelly clay to 0.2m, sandy gravelly clay to 1.3m and Mercia Mudstone to 2.0m.	No water strike
BH935 (within SSSI)	2.1m depth – slightly gravelly clay to 0.15m, slightly sandy clayey gravel to 0.9m, gravelly sandy clay to 1.10m, grey sandy clay to 1.3m, sand to 1.4m, Mercia Mudstone to 2.1m.	No water strike
BH907 (northern periphery of SSSI)	2.0m depth – slightly sandy slightly gravelly clay to 0.6m, Mercia Mudstone to 2.0m	No water strike
BH909 (eastern periphery of SSSI)	2.3m depth - slightly sandy slightly gravelly clay to 0.6m, Mercia Mudstone to 2.3m	No water strike
BH910 (eastern periphery of SSSI)	2.7m depth - slightly sandy slightly gravelly clay to 0.6m, Mercia Mudstone to 2.7m	No water strike
BH911 (eastern periphery of SSSI)	2.0m depth - slightly sandy slightly gravelly clay to 0.5m, Mercia Mudstone to 2.0m	No water strike

11. National Vegetation Classification (NVC) Surveys

11.1 A Phase 2 NVC survey was undertaken of the identified homogenous stands of grassland vegetation within the Bickenhill Meadows SSSI in summer 2018. The survey followed the standard published methodology (Rodwell, 2006)[7] and comprised recording a minimum of five quadrats in each identified grassland type and at least one in each parcel of each grassland type. Following this, the data sets identified were matched to the published grassland community types using the keys provided in Rodwell (1992)[8] and using the software TABLEFIT[9]. The survey was undertaken on the 27 June and the 7 August 2018.

11.2 The vegetation in all the fields on the days of the survey was tall and coarse and because of this appeared uniform with the subtle changes in ground level apparent earlier in the year masked by the dense growth.

11.3 The SE Unit comprises three fields separated by a small watercourse (dry on the day of the survey); two of the fields are on the eastern side and the third on the western side. A fourth field is not within the SSSI but along with the fields in the SSSI is managed as a nature reserve by Warwickshire Wildlife Trust.

11.4 The two fields on the eastern side slope down to the watercourse and the vegetation on the day of the survey was grass dominated (tall and lodging in places) and dry (Photo 20 and 21). Yorkshire fog (*Holcus lanatus*) was abundant with other grasses such as cock's foot (*Dactylis glomerata*), common bent (*Agrostis capillaris*), red fescue (*Festuca rubra*), crested dog's tail (*Cynosurus cristatus*) and meadow fescue (*Schedonorus pratensis*). A range of generally common forbs were recorded and included ribwort plantain (*Plantago lanceolata*), common knapweed (*Centaurea nigra*), bird's foot trefoil (*Lotus corniculatus*) and red clover (*Trifolium pratense*). Less common species included yellow rattle (*Rhinanthus minor*) and tormentil (*Potentilla erecta*).

Photo 20 (left) and Photo 21 (right) - typical vegetation in the SE SSSI unit eastern fields.

11.5 Seven quadrats were recorded in the two fields, as they were uniform in appearance and structure. The data obtained was run through TABLEFIT and the goodness of fit to the NVC community type MG5; *Cynosurus cristatus* - *Centaurea nigra* was around 83% and classed as very good fit. The second best fit was to the MG5a *Lathyrus pratensis* sub-community type.

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[7] Rodwell, J. S. (2006) National Vegetation Classification; Users' Handbook. Joint Nature Conservation Committee, Peterborough
[8] Rodwell, J. S. (ed.) 1992. British Plant Communities. Volume 3. Grassland and montane communities. Cambridge University Press.
[9] Hill (2015) TABLEFIT Version 2; A program to identify types of vegetation by measuring goodness-of-fit to association tables. Centre of Ecology and Hydrology, Wallingford

11.6 The field within the SE Unit on the western side of the watercourse was generally flat but with an apparent rise towards the northern boundary; the grasses did not dominate to the degree they did in the dry fields and there were patches of meadowsweet (*Filipendula ulmaria*) and great burnet (*Sanguisorba officinalis*) (Photo 22 and 23). Meadowsweet and other wetland species such as wild angelica (*Angelica sylvestris*) seemed to be more frequent towards the watercourse where the vegetation was taller and coarser. Interesting species recorded here were betony (*Stachys officinalis*) and tormentil (*Potentilla erecta*). It has been reported that meadow thistle (*Cirsium dissectum*) is also present but this was not found during the current survey.

Photo 22 (left) and Photo 23 (right) - typical vegetation in the SE SSSI unit wet meadow field.

11.7 Five quadrats were recorded in this western field and along with the data collected from similar vegetation recorded in the NW section of the SSSI (described below) were run through TABLEFIT. The goodness-of-fit to the NVC community type MG4; *Alopecurus pratensis* – *Sanguisorba officinalis* was around 63% and classed as a fair fit. Any variation in the vegetation from topographical variation was masked by the tall growth and a better understanding of this would be obtained once the field has been cut. This will provide information on the relationship of the community boundaries to topography, depth to water and ditch levels, and enable the communities to be tied with soils information to determine the mechanism whereby any vegetation changes are driven.

11.8 The NW Unit comprises two fields separated by a small, ephemeral watercourse, which was dry on the day of the survey. The western field appeared to be uniform in structure and was generally a mix of patches of larger forbs such as great burnet (*Sanguisorba officinalis*) and meadowsweet (*Filipendula ulmaria*), and grasses with a range of smaller forbs including several legumes scrambling through the vegetation (Photo 24 and Photo 25). This field appeared to be more diverse than the corresponding field in the SE Unit and here saw-wort (*Serratula tinctoria*), quaking grass (*Briza media*) and devil's bit scabious (*Succisa pratensis*) were recorded in addition to the more typical and commoner forb species. When visited in August 2018, tufted hair grass (*Deschampsia cespitosa*) was the dominant species in this field.

Photo 24 (left) and Photo 25 (right) - typical vegetation in the NW SSSI unit western field.

11.9 Five quadrats were recorded in the field and along with the data collected from similar vegetation recorded in the SE SSSI unit were run through TABLEFIT. The goodness-of-fit to the NVC community type MG4; *Alopecurus pratensis – Sanguisorba officinalis* was around 63% and classed as a fair fit.

11.10 The eastern field of the NW Unit was only visited in August 2018 and had much coarser vegetation and the dominant grass across large areas was tufted hair grass (*Deschampsia cespitosa*) but with meadowsweet and great burnet also frequent throughout the field. Sedges appeared to be more common in this field and included hairy sedge (*Carex hirta*), false fox sedge (*Carex otrubae*), common sedge (*Carex nigra*) and tufted sedge (*Carex acuta*). Otherwise it was very similar to the western field (Photos 26 and 27).

Photo 26 (left) and Photo 27 (right) - typical vegetation in the NW SSSI unit eastern field.

11.11 Part way along the western boundary of the field, there was a distinctive change in vegetation and whilst this will have to be shown by survey, it appeared to be delineated by a low spot, possibly linked to the ditch and was demarked by young alders (*Alnus glutinosa*). The vegetation here was dominated by tall rushes including soft rush (*Juncus effusus*), hard rush (*Juncus inflexus*) and sharp flowered rush (*Juncus acutiflorus*), along with sedges with abundant great hairy willowherb (*Epilobium hirsutum*) and in the wettest areas patches of fool's watercress (*Apium nodiflorum*). This is the area considered to be a potential spring in the preceding discussion (Photo 27 and Photo 28).

Photo 27 (left) and Photo 28 (right) - typical vegetation in the distinct wetter area within the NW SSSI unit eastern field.

11.12 Five quadrats were recorded in this area and the data was run through TABLEFIT. The goodness-of-fit to the NVC community type OV26; *Epilobium hirsutum* community was around 58% and classed as a fair fit. A similar fit was obtained from the MG9 community; *Holcus lanatus-Deschampsia cespitosa* grassland. This community is found in area where the ground is seasonally waterlogged and can be found in association with MG4 grassland but is not usually as species diverse and is tolerant of less free draining soils.

11.13 It is clear from the surveys that the two dry grassland fields in the SE Unit fit closely to the MG5 community type and that for the most part, the wetter field in the SE unit and the two fields in the NW unit fit to the MG4 community type. Within the wetter fields, there may be localised variation and this seems to have been picked up by the walkovers earlier in 2018 but by summer the tall vegetation was masking much of this variation.

12. Conceptual Model

12.1 The baseline information described in this Technical Note, along with the extended Ground Investigation results[10], vegetation surveys (described in Section 11) and further observations of subsurface conditions derived during dipwell installation have informed the development of a conceptual model of each SSSI unit. The purpose of the conceptual model is to illustrate the hydrological processes that have been observed or inferred from the collated evidence in order to better understand how the two SSSI units maintain suitable conditions to support the sensitive grassland species contained within. The two conceptual models are presented in Annex C. The following provides an explanation to accompany the two conceptual models.

Southeast SSSI Unit

12.2 The SE Unit consists of a wet meadow field to the west, two dry meadow fields to the east, and wet alder woodland in the north of the site. The wet western field and dry eastern fields are separated by a small watercourse with a ditch-like character, which is a tributary of Shadow Brook. A further ditch is located on the northwestern boundary of the site. Both are ephemeral but would flow towards the northeast of the site where they combine and continue north to the tributary of the Shadow Brook. The central ditch was observed to flow between around November 2017 to May 2018, but no regular flow has ever been observed in the western ditch and it is believed to act more like a soakaway with lateral flow only following extremely heavy or persistent rainfall. The ground elevation rises either side of the central ditch, but with greater relief on the eastern side. The low point of the site is in the alder woodland to the north. The

[10] Socotec, 2018, Factual Report on Ground Investigation, Report E8005-18

western field contains ridge and furrow micro-topography from past agricultural practices, while the eastern field rises steadily away from the watercourse and does not have such obvious ridges or depressions.

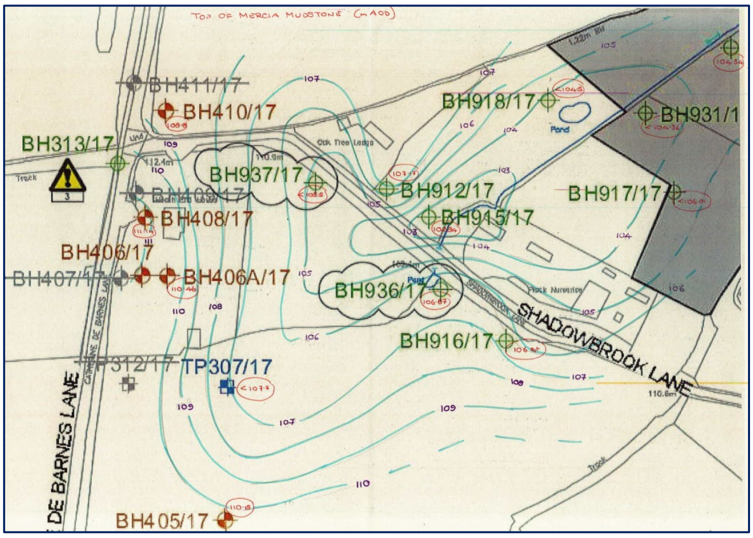
12.3 The geological logs for the boreholes, probeholes and trial pits on and in the vicinity of the SE Unit, show that across much of the area there is a surface layer of sand between 0.8m and 1.15m thick. This is typically underlain by a layer of sandy clay, resting on the Mercia Mudstone. In some of the ground investigation boreholes a second thin sand layer has been proved below the sandy clay layer. The results of the Ground Investigation indicate that there is a ‘bowl’ of mixed superficial deposits that reaches up to 6m thickness below ground level, and which is centred on the Shadowbrook Meadows Nature Reserve, immediately SW of the SSSI. From this central point the superficial deposits extend across the SSSI to the northeast where thicknesses of up to 3m were recorded, and west/southwest into the arable field where thinner deposits of around 1.2m were recorded adjacent to Catherine-de-Barnes Lane (Figures 13A and 13B).

12.4 The superficial deposits are able to support groundwater and therefore provide a local water source to the surrounding grassland communities. Boreholes within the SSSI in the late summer, after a prolonged period of dry weather, indicated groundwater levels between 1.8 - 2.25m below ground level (BGL), while much shallower levels would be expected in winter and spring. The bowl of superficial deposits is surrounded by, and underlain by, low permeability Mercia Mudstone (where deeper water strikes were generally recorded e.g. over 11m BGL in BH410 adjacent to Catherine-de-Barnes Lane). Figure 13A shows the likely contours of the surface of the Mercia Mudstone, and indicates that it is present at a shallow depth in the vicinity of the proposed road alignment at approximately 110m AOD (2m BGL). The surface of the Mercia Mudstone falls to the north east and at Shadowbrook Lane is at a level of 102.84m AOD (6.1m BGL). Groundwater flows through the more permeable units (i.e. the sand and gravel) in the superficial deposits above the Mercia Mudstone, generally following the topography of the land towards the SE Unit and the northeast. As such, the SSSI receives groundwater flows from the east, south and west, and this ultimately flows towards the north-eastern area of the SSSI in the wet alder woodland. The watercourse flowing through the centre of the SSSI Unit is ephemeral, but may provide a contribution to the supply of water for recharging the thicker superficial deposits beneath the SSSI unit during the late autumn-winter-spring period when it has been observed as flowing. It is likely that the watercourse is in connectivity with the superficial deposits due to the shallow depth below ground level and the possible flow from groundwater back to the watercourse at the downslope extent of the SSSI unit.

12.5 The superficial sands, clays and gravels across the SE Unit and the surrounding area are thought to allow drainage through to the Mercia Mudstone, at which point water will tend to flow laterally over these less permeable deposits to the northeast and ultimately out of the SSSI at its lowest point. More constant streamflow has been observed in the watercourse at this location in the SSSI than elsewhere, presumably because it is supported by the lateral groundwater flows at this low point. During the late autumn-winter-spring period the water table is expected to generally be high due to greater amounts of rainfall and low rates of evapotranspiration, resulting in the predominant recharging of groundwater in the superficial deposits at a rate that exceeds flows to the northeast. Due to the permeability of the superficial deposits, surface saturation and surface water ponding is expected to be limited to the periods immediately following heavy rainfall when the infiltration capacity is exceeded. However, a high water table may also encourage saturation of the upper soil layers during rainfall events, especially in the spring when monthly rainfall amounts may be at their lowest.

12.6 The watercourse flowing through the centre of the site will also help to prevent over-saturation of the surface layers by draining away excess water. The flows in this ephemeral watercourse are thought be maintained from a mix of subsurface flow pathways and occasional surface drainage pathways during periods when surrounding soils are fully saturated. It is possible that in extreme rainfall and runoff events, the watercourse may overtop and cause very localised out of bank floods (which are unlikely to spread fully across the wet meadow noting that along part of the ditch is a shallow earth bund likely created when the channel was dug or last cleared out), although this is expected to be a rare occurrence and the WWT were unaware of this ever occurring. The ditch on the northwestern boundary of the SSSI may occasionally flow following receipt of surface water runoff and sub-surface egress from the arable field that rises away to the west of the SSSI. This ditch is usually ponded and may already act as an infiltration trench providing some additional recharge to the wet meadow field through the surface sand layer.

12.7 MG4 grasslands are found in the furrows across the western wet meadow field of the SSSI. They are dependent on wet conditions being maintained in the surface layers through winter and spring, but are relatively intolerant of flooding and prolonged saturation. MG5 grasslands are found in drier locations and so are located on the ridges across the wet meadow field and across the eastern dry meadow. It is considered likely that the water table in winter and spring is generally just below the surface, and rises regularly after rainfall to temporarily intersect the furrows, whereas it will rarely intersect the ridges. The water table intersection of furrows will be short-lived as the water drains away through the superficial deposits, although water tables are kept reasonably high throughout the winter and spring by the groundwater recharge that also occurs.



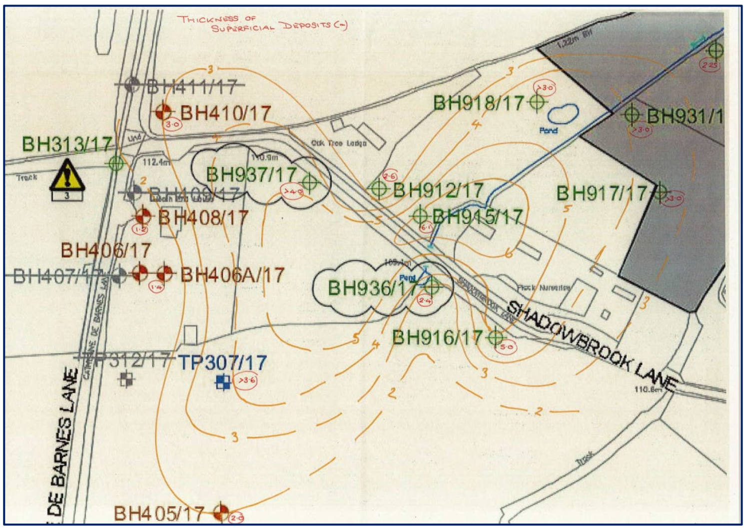


Figure 13A (top) Contours showing top of the Mercia Mudstone (m AOD) and 13B (bottom) Contours showing thickness of superficial deposits (m). Plots are based on available information (November 2018).

12.8 The eastern dry meadow field has a greater relief than the western wet meadow field, and so rainwater is encouraged to drain more rapidly away downslope and towards the central watercourse and therefore fails to maintain a sufficiently high water table for MG4 communities. There is also an absence of furrows and depressions which reduces the potential for the hydrological conditions seen on the wet meadow where MG4 communities have developed. As a result, the dry meadow is wholly dominated by MG5 grasslands. A Cadent gas pipeline is orientated southwest to northeast through the dry meadow field. This may cause some interruption of groundwater flows from the east of the SSSI with potential for preferential flow to occur northeast along the pipeline's backfill material. There was some evidence of a change in plant types along the route of this gas main during a site visit in April 2018, although no significant difference in grass species across the Site was observed when the NVC survey was undertaken in the summer, suggesting that the effect may be seasonal and insufficient to provide MG4 plants a sufficient competitive advantage over MG5 species.

12.9 In the summer and autumn, when there is typically reduced rainfall and greater evapotranspiration rates, the water table beneath the SSSI is lowered (i.e. to more than 90cm BGL as observed from dipwell monitoring in late summer 2018, and dry ditches). However, although the water table is generally deeper than the furrows in the wet meadow field, the grassland communities may be supported through the drier summer months by deeper groundwater in the superficial deposits rising by capillary action to the root zone. This may be important for sustaining the plant communities across the SSSI, but is less important in determining the mix of species and grassland types.

Potential Impact of the Scheme on the Hydrology of the SE Unit

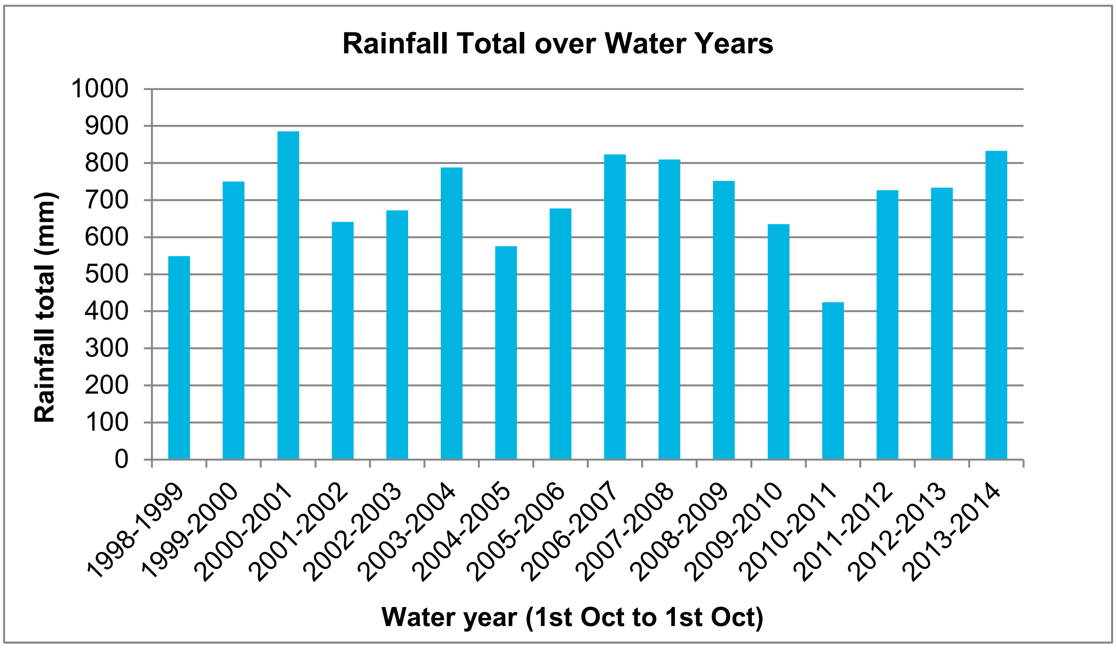
12.10 The geometry and orientation of the 'bowl' of superficial deposits (Figures 13A and 13B) that underlie the SE Unit thin out in a westerly direction towards the new mainline link road. Along the new mainline link road, the superficial deposits are generally less than 2 m thick and consist principally of clay rather than the more permeable sands and gravels. There is no evidence that the cutting will intersect significant thicknesses of sand or gravel, which could provide groundwater recharge to the SSSI. The majority of the cutting will intersect the low permeability Mercia Mudstone. As it is considered that the cutting will not intersect permeable superficial deposits which could provide groundwater to the SSSI, it is concluded that the cutting will not have a marked impact on groundwater flows to the SE Unit.

12.11 While interception of groundwater inflows by the cutting is considered insignificant, the route of the new mainline link road will result in the severance and loss (beneath the Scheme footprint) of approximately 21%[11] of the surface water catchment to the SE Unit. This severed area currently drains to the ditch in the arable field southwest of the SSSI and is thought to flow beneath Shadowbrook Lane and into the watercourse that flows northeast through the SSSI. However, the connectivity between the surface water catchment upstream of Shadowbrook Lane and that downstream of this road could not be established through non-intrusive survey. Any culvert may be buried beneath silts and this would limit surface water flows across Shadowbrook Lane. As such, direct rainwater is considered the most significant source of water to recharge the superficial deposits beneath the SSSI unit. Nevertheless, given the size of the surface water catchment that would be potentially cut off or lost beneath the Scheme footprint, it is possible that interruption of flows along this watercourse when it is flowing (which has been observed in winter and spring) could have an influence on groundwater levels beneath the SE Unit. Reduction in recharge from the watercourse to the surrounding ground would depress groundwater levels and potentially encourage more rapid draining of the soil layers and reduced

[11] Catchment area based on the latest design 3c (October 2018).

surface water ponding. In wet springs this may not be significant, but in drier years it is possible that the lower water table could encourage MG5 grass species in place of MG4 species.

12.12 Long term rainfall records for the region obtained from the Environment Agency's Coleshill rain gauge at SP 21102 86956 are shown in Figure 14A and 14B for the 16 year period between 1998 and 2014. The rainfall total for water years (Figure 14A) ranges from 424mm to 886mm per year, with an average of 705mm per year. There is clearly significant year-on-year variability in rainfall inputs to the SSSIs and their catchment, and it appears that the loss of 21% of the surface water catchment would fall within this range of natural fluctuations in water availability from rainfall.



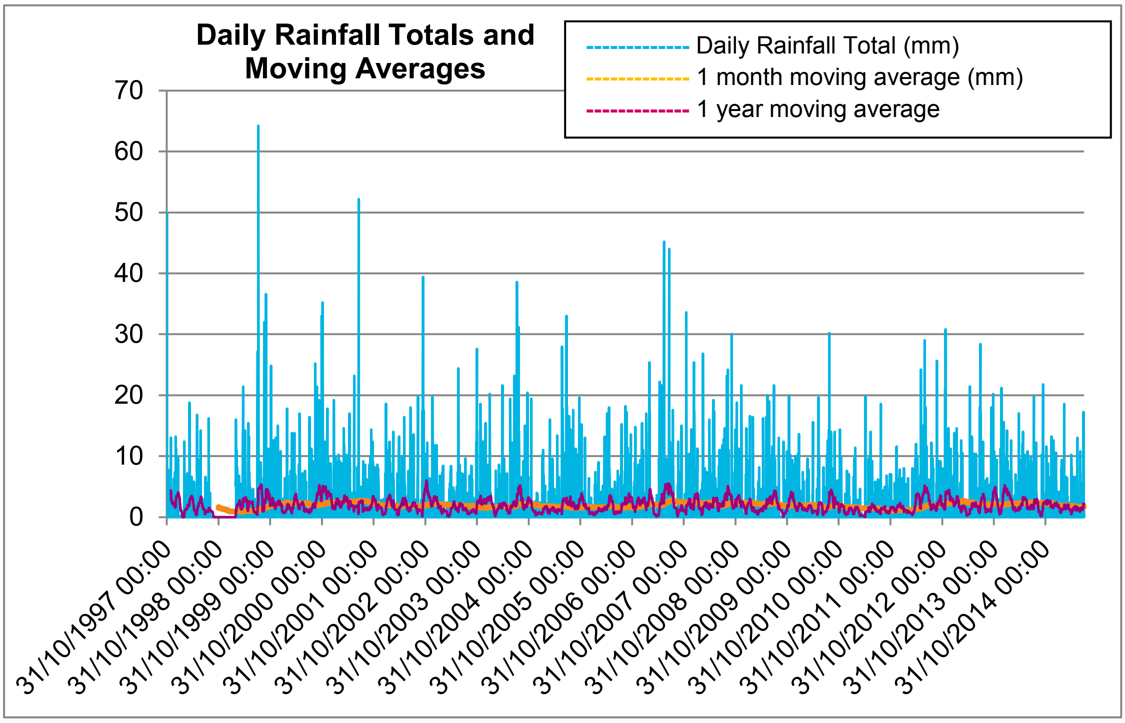


Figure 14A (top) Rainfall total for water years at Coleshill rain gauge (1998-2014); and 14B (bottom) Daily rainfall totals and moving averages at Coleshill rain gauge (1998-2014). Data provided by the Environment Agency.

12.13 Further investigation has been undertaken into the expected surface water losses using the Wallingford Hydrosolutions ReFH2 Calibration Utility tool, which enables users to calibrate the parameters and initial conditions of the ReFH and ReFH2 rural models using observed event rainfall and flow datasets. The ReFH and ReFH2 methods takes into account a loss model, a routing model and a baseflow model, which all influence the total amount of water that will reach the SSSI. Further details are described in Annex D.

12.14 This modelling approach was first used to determine the percentage of total rainfall that runs off from the catchment as surface water flow, using a design rainfall event (100 year return period, 4.25 hour event). This analysis indicates the percentage of total rainfall that contributes surface water to the SSSI is 25%.

12.15 Analysis was then undertaken into the total expected volumetric loss of water from the SSSI, due to 21% of the surface water catchment being isolated or lost beneath the Scheme footprint. The analysis indicates that for the average water year (based on the Coleshill rainfall record 1998-2014) 11,800m^3 of water would be lost from the SSSI due to the new mainline link road. Using the wettest year in the rainfall record (2011-2012) the loss would be 21,530m^3, and the using the driest year in the record the loss would be 6,414m^3. This indicates that natural variability in rainfall quantities from this portion of the catchment is substantial, and consequently the annual variability in surface water supply to recharge the superficial deposits beneath the SSSI also fluctuates markedly.

12.16 Although, the loss of a proportion of surface water catchment may not cause a volumetric loss of surface water greater than would be expected from year-on-year natural variability, the rainfall record does not include a run of consecutive dry years that would enable longer term resilience to be determined. Particularly dry years, such as 1998-1999, 2004-2005 and 2010-2011 (Figure 14A), have occurred in isolation. In addition, although Figure 14B shows that the number of days of heavy rainfall greater than 30mm / day has declined between 1997 and 2014, the longer term averages (monthly and yearly) appear less affected and remain stable implying no obvious long term trend of declining rainfall (Figure 14B). As the effect of substantially reduced volumetric surface water inputs to the SSSI unit over a period of several years is not known, it is proposed to provide mitigation.

Northwest SSSI Unit

12.17 The NW Unit consists of two grassland meadow fields separated by an ephemeral watercourse with a ditch-like character that flows north through the site to eventually reach Low Brook. The elevation of both fields rises relatively rapidly away from the watercourse and both contain a series of ridges and furrows which support both MG4 and MG5 grasslands.

12.18 The Ground Investigation indicates that Mercia Mudstone is located at a shallow depth of between 0.5 and 0.6m BGL to the east of the Site between the new mainline link road and the SSSI boundary, but is slightly deeper beneath the SSSI itself (i.e. up to 1.4m BGL). Similar to the SE Unit, the Ground Investigation thus implies that there is also a ‘bowl’ of thicker superficial deposits across the NW Unit surrounded by shallower Mercia Mudstone, but that the thickness of the superficial deposits is much less than what is found at the SE Unit. The shallow Mercia Mudstone around the periphery of the NW Unit and between it and the cutting for the new mainline link road suggests that there is not a significant groundwater pathway that would be interrupted by the proposed development.

12.19 In the winter and spring, because the Mercia Mudstone is relatively shallow and has a low permeability, it will not require much rainfall to cause a high water table to develop in the overlying deposits beneath the NW Unit. The greater amount of stiff clay substrate across this SSSI unit also impedes infiltration and encourages frequent saturation of the near surface soil layers, particularly in hollows and depressions. There may be pockets of sands and gravels with improved drainage, but in general infiltration is expected to be slow. Due to the thinner superficial deposits rainwater recharge onto these slowly permeable upper substrate layers is considered to be the principal mechanism supporting the higher water table during the winter and spring. As in the SE Unit, MG4 grasses occupy the depressions and furrows across the Site, which are periodically, but not permanently, saturated. MG5 grass species tend to occupy the more elevated and drier ridges which are less regularly saturated.

12.20 The ephemeral central watercourse helps prevent over-saturation of the grassland communities by draining away excess water, although there is a relatively pronounced artificial bund along sections of the bank on both sides, which will block overland flow and sub-surface flow (by compacting the soil beneath and making it less permeable). A particularly wet area is located behind the bund towards the centre of the eastern field, and this has a distinct vegetation community (classified as NVC OV26/MG9), including young alders and rushes. This area has a discrete substrata with more sands and gravels noted during dipwell installation than at adjacent locations. The combination of the more permeable substrata and the adjacent bund downslope means that this area acts like a sump, retaining groundwater and surface water runoff and resulting in a different vegetation community than elsewhere on the SSSI unit. There is no evidence that this feature is supported by a spring, that it extends outside the boundary of the SSSI, or that it is supported by groundwater flows from further east. As the mainline link road cutting to the east is predominantly in the impermeable Mercia Mudstone, it is predicted that the proposed development will not influence the hydrogeology of this localised feature.

12.21 In the summer and autumn when there are higher evapotranspiration rates and lower amounts of rainfall, the water table within the SSSI will be depressed towards the Mercia Mudstone. With no significant groundwater flow contributing to this SSSI unit, the water table is reliant on rainfall recharge. Sub-irrigation and capillary rise through the thin superficial deposits above the Mercia Mudstone may provide some moisture to the root zone, but the water table is likely to be low throughout this period, other than the area with the OV26/MG9 plant communities.

Potential Impact of the Scheme on the Hydrology of the NW SSSI Unit

12.22 Due to the shallow Mercia Mudstone deposits between the new mainline link road and the SSSI, there is no significant groundwater pathway between the two that would be disturbed by construction of the cutting. A maximum of 5% of the surface water catchment to the east would be cut off by the proposed development and under the footprint of the new road, but this area is not well connected to the site other than through limited surface and sub-surface flows, and is not likely to significantly influence the flows along the central watercourse which drains from the south/southwest. The Site is also underlain only by relatively thin superficial deposits, containing more clay than found across the SE Unit, which also suggests that rainfall is the predominant factor controlling hydrological conditions on the Site, suitable for the formation of the grass communities that are found.

12.23 There is also no evidence that the particularly wet area with distinct vegetation in the eastern field has a hydrogeological connection that extends beyond the SSSI, or that any disruption would be caused to this feature by the proposed road cutting. Instead, this feature appears to be a consequence of an isolated pocket of more abundant sand and gravel holding water that is impounded by the artificial bund, which inhibits drainage to the watercourse.

12.24 Overall, it is considered that based on the available data it is unlikely that the proposed development would have any significant adverse effects on the hydrology of the NW Unit, and thus no mitigation measures are needed to protect the hydrology of this SSSI unit from the road construction. However, it is recommended that the monitoring of surface saturation conditions by the network of dipwells is continued.

Limitations

12.25 The conceptual models presented here are based on the best available data at the time of writing in November 2018. Monitoring of groundwater levels is ongoing for the boreholes that are located around the periphery of the SSSIs, and for the dipwells that have been installed within the SSSIs. It is anticipated these will support the initial interpretations which indicate that rainwater recharge is the dominant mechanism driving water table levels in both SSSI units, albeit with the hydrology of the SE SSSI also being supported by surface water recharge from the central and northwestern watercourses. Initial monitoring data gathered to date currently reflects only the summer and early autumn seasons only, when water tables have been low following a summer of particularly dry conditions. If additional monitoring requires any changes to the interpretation in this technical note a revision will be issued.

12.26 Based on the current data, the disruption of groundwater flows is expected to be insignificant at the SE Unit, and so mitigation is focused on mitigating the loss of surface water catchment in order to replicate the natural recharge that surface water provides. As above, if additional monitoring requires any changes to the interpretation in this technical note a revision will be issued.

13. Summary of Findings

13.1 The NW Unit appears to be most dependent on direct rainwater recharge to maintain its water table at a suitably high level in the winter and spring to support MG4 grass species. Low permeability Mercia Mudstone is at shallow depth around the periphery of the site and prevents any significant groundwater flow between the new mainline link road and the SSSI. Superficial deposits are also thinner than across the SE Unit with greater amounts of lower permeable clay and limited sands and gravels, which help to reduce infiltration and maintain surface saturation. Around 5% of the surface water catchment will be cut off by the development, but this portion of the catchment is not well connected to the SSSI unit (as the main flow pathway would be subsurface flow) and so is unlikely to significantly alter the flow in the watercourse that flows occasionally through the Site. As no adverse effects on the Unit's hydrology are predicted no mitigation measures are proposed, although as a precautionary measure ongoing monitoring of vegetation and surface saturation conditions using dipwells will be continued.

13.2 The SE Unit has deeper superficial deposits which stretch out in a wide 'bowl' around the site. There will be groundwater movement within the granular layers in these thicker superficial deposits, which will generally flow into the SSSI from the south, north, and west and then out towards the northeast. The water table at the Site is maintained through winter and spring by a combination of this groundwater flow, rainwater recharge, infiltration from the northern ditch and potentially recharge flows along the central watercourse. Analysis of the thickness and spatial extent of the superficial deposits indicates that they thin out towards the new mainline link road cutting. There is no evidence that the proposed cutting will intersect significant thicknesses of sand or gravel in the thin superficial deposits at this location, which could be contributing to groundwater recharge of the SSSI. The majority of the cutting will instead intersect the low permeability Mercia Mudstone, and so it is concluded that the cutting will have negligible impacts on the hydrogeological conditions of the SSSI.

13.3 More significant is the loss of 21% of the surface water catchment to the west of the mainline link road and beneath the Scheme footprint. While the amount of water lost could be within that expected with natural climatic variability 'year on year', it cannot be confirmed that this would not have consequences for the sensitive grassland species in a given year or over a number of consecutive 'drier' years in terms of depressing the water table to the extent that surface conditions become drier, especially in the spring. As such, a mitigation approach has been proposed whereby the water lost from the surface water catchment is collected and reintroduced into the SSSI. The proposed mitigation hierarchy and options are considered in the next section.

14. Mitigation Hierarchy and Options Considered

14.1 During the site meeting with Natural England on 26 April 2018 it was requested that options are presented for the approaches that may be taken in the event that the Scheme results in an adverse effect upon the SSSI. This may be the case at the SE Unit due to the loss of approximately 21% of the surface water catchment. In accordance with best practice the mitigation options would follow the mitigation hierarchy, which seeks to avoid, reduce (i.e. mitigate) or offset (i.e. compensate) for any adverse impact.

14.2 At the current stage of design it is acknowledged that it is highly unlikely that the horizontal or vertical alignment of the new mainline link road could be altered to avoid potential effects on the SSSI. Accordingly, the approaches focus on options for mitigation and compensation.

14.3 A potentially adverse effect would comprise alterations to the type or extent of the grassland communities that are the interest features of the SSSI. This may occur as a result of changes to the existing hydrological regime. In the event that an impact to the interest features of the SSSI is considered likely then options for mitigation or compensation may include the following, which are listed below in Table 2 in order of preference with regards to Natural England's hierarchy of mitigation approach:

Table 2 Mitigation Options for the SSSI Units in hierarchical order

Option (in order of preference)	Mitigation Type	Mitigation Description
1	Avoid and Reduce	Measures to maintain the existing hydrological regime of the SSSI. This may include the pumping of water across the cutting to replicate the existing natural water supply to the SSSI or an alternative water supply, if one could be identified (these are discussed below). This is the best outcome for the SSSI as water supply would be maintained.
2	Reduce	Physical changes within the SSSI to extend the existing habitat types. This would involve carefully planned and localised changes to the topography of the SSSI, and would be based on detailed modelling of the existing vegetation communities. As an example, the approach could seek to extend the topographical variations (such as deeper depressions and furrows) that have established the existing pattern of vegetation communities, to compensate for potential reduction in groundwater and surface water inflows.
3	Offset	Establish habitats similar to the interest features in land immediately adjacent to the SSSI (or otherwise at another location entirely). The aim would be to create a parcel of land with a varied topography and a related hydrological regime, and to establish grassland using green hay from the SSSI. This is an offsetting solution and so is the worst case for the existing SSSI.

14.4 All of the approaches above would be informed by ongoing monitoring of the SSSI grasslands to ensure that they are effective. An outline options appraisal for these various approaches is provided in Table 3. At the time of writing (December 2018) the options listed apply to both SSSI units. As discussed above, the conceptual model indicates that the NW Unit will be unaffected by the proposed development, but ongoing monitoring will be continued.

14.5 A further mitigation option was previously proposed in discussion with Natural England. This was to implement measures to re-store natural flow along streams flowing through the SSSI units by re-routing each stream through the low point of each valley and restoring a more natural planform. However, there are limitations as to what could be done within the application boundary, and after further consideration and appraisal of the conceptual model it is thought that improved drainage could potentially cause the sites to dry out further. As such, the option has not been included in the options appraisal.

14.6 For the SE Unit, the conceptual model indicates that the bowl of superficial deposits under the SSSI gets shallower towards the new mainline link road, and so the new cutting will not intersect significant superficial deposits that would hold significant groundwater. However, a significant portion of the surface water catchment would be intersected by the new mainline link road.

14.7 For the SE Unit the ditch on the northwestern border of the site has been identified as a potential means of recharging/reintroducing replacement water to maintain the existing ‘natural’ water supply that has been interrupted by the cutting. A number of potential water sources to feed this ditch have been identified and these are discussed in Table 3. These include:

Source 1): Run-off from local roads.

Source 2): The collection and pumping of water to the SSSI units from the severed catchment area and cutting slopes.

Source 3): Borehole pumping.

Source 4): Potable water supply to apply water to the site, either through direct spray application or discharge to ditches and streams.

14.8 Based on early assessments, Source 1 is likely to be delivered via a passive gravity fed system (with appropriate treatment as required) and is currently considered the most sustainable and value for money solution. However, due to the limited data available and lack of opportunity to discuss and agree the options with the affected parties a decision was taken to proceed with the EIA on the basis of Source 2. Although not a fully sustainable solution it could be fully delivered through the DCO process and it therefore represents a reasonable back-stop position.

14.9 Consequently a pumped mitigation solution has been developed to mitigate the loss of surface water catchment. The design principles of the pumped solution consist of a collection drain on the western slope of the new mainline link road cutting to intercept surface water flows that would otherwise have drained towards the SSSI. The collection drain would discharge to a sealed collection sump, from where water would be pumped and/or captured from an alternative water source(s) to an appropriate water feature in the vicinity of Bickenhill Meadows SSSI SE unit. This feature would act as a recharge trench, from which water would drain through to the sand, gravel and clay deposits in the upper layers of the substrata within the SSSI. The proposed solution is shown in Annex E.

14.10 Using this approach 11% of the surface water catchment that is cut off from the SSSI can be reconnected, but the 10% of catchment falling under the Scheme footprint would be lost from the SE unit. To further mitigate for this loss, the proposed collection drains could be extended north and south to collect greater amounts of water from the west of the new mainline link road, and thereby compensate for the loss beneath the Scheme footprint. The proposed mitigation should therefore maintain surface water flows to the SE unit. Furthermore, given the uncertainty over whether surface water from the south of Shadowbrook Lane can cross beneath the road to the northern side and into the SSSI, the mitigation solution may actually improve the water supply to the SE Unit.

14.11 Highways England will continue to refine the proposed mitigation solution using: data obtained from the ongoing dipwell monitoring; and information gathered from further analysis of the local topography and existing water sources. These refinements will seek to identify a sustainable drainage mechanism to mitigate the effects of the Scheme on Bickenhill Meadows SSSI (SE unit). Highways England will seek to agree any refinements to the mitigation approach with Natural England prior to commencement of the Scheme.

14.12 For Source 3, the possibility of installing a compensation borehole has also been considered. A borehole into the shallow superficial sands and gravels above the Mercia Mudstone is not feasible as water in these layers is required by the sensitive grassland species, and so removal of any water from these layers could amplify any potential adverse effects on the SSSI. A deep compensation borehole into the Sherwood Sandstone which underlies the Mercia Mudstone is a possibility as it is a major aquifer, although it has not been exploited for water supply at the site or in the vicinity. As the Sherwood Sandstone is over 150m deep (and may be >200m deep), extraction would not impact on the surface features of the SSSI. However, there are substantial costs involved with installation of a borehole and pumping regime to exploit groundwater at such great depths. There would also be long term pumping and maintenance requirements, which mean that this option provides no benefit over the proposed use of a collection drain for surface water and pump to transfer the water to the existing ditch at the site.

14.13 For Source 4, an alternative option to maintain the hydrological regime of the SE Unit would be to use a potable water supply to recharge the SSSI, either by direct spraying or through discharge to the existing ditch and tributary of Shadow Brook. While such an approach would ultimately achieve the same outcome as the pumped solution, it would require direct application of the water to the field or ditches, whereas the pumped solution is passive system requiring routine maintenance but no direct ongoing action once correctly established. The advantages of using a potable supply would include that no long term maintenance and inspection of pumps would be required indefinitely, and the approach is not susceptible to equipment failure. The system may also only have to operate at key times of the year when the sensitive grasslands require high water tables, particularly late winter and early spring. On the other hand, there would be substantial ongoing costs involved with utilising water from the mains supply. Based on the Severn Trent Water guidance[12] for metered charges of £1.14-1.46 per m^3, the cost of compensating all water in an average year would be between approximately £13,500-£17,250 per annum (if it was assumed water was taken from the supply all year round on an average year). Furthermore, at times of dry weather, the possibility of hosepipe bans implemented by the local authority may preclude use of potable supply for replenishing the SSSI. Finally, the approach would also require direct interventions by Warwickshire Wildlife Trust and Natural England rather than being passive, and ultimately using treated water for irrigation is not the most sustainable use of potable water.

[12] Severn Trent Water (2018) How we calculate your bills: Scheme of Charges for 2018-2019.

Table 3 Potential Hydrological Impacts on Bickenhill Meadows SSSI – Mitigation Options Appraisal – Option 1.

Mitigation Option (in order of preference)	Description	Mitigation Type	Implications					
			Design	Third Party and Land Ownership	Planning and Deliverability	Future Maintenance	Cost
1. Maintain the existing hydrological regime of the SSSI.	For the SE unit the ditch on the northwestern border of the site has been identified as the potential means of recharging/reintroducing replacement water to maintain the existing 'natural' water supply that has been interrupted by the cutting. A number of potential water sources to feed this ditch have been identified. These include: 1) Run-off from local roads. 2) The collection and pumping of water to the SSSI units from the severed catchment area and cutting slopes. 3) Borehole pumping. 4) Potable water supply to apply water to the site, either through direct spray application or discharge to ditches and streams.	Reduction of impact	The recharge ditch to the north west of the SSSI needs to be a continuous means of transferring water in a controlled manner along the boundary of the SSSI. Run-off from Shadowbrook and Catherine-de-Barnes Lanes could be collected and directed to the recharge ditch under gravity. Treatment of water from local roads would require space for SuDS/reed beds. The pumped option would require new infrastructure (and associated power supplies) to collect water from the catchment area that has been lost and to pump it up to an existing ditch running alongside the SSSI. Borehole pumping could be from shallow or deep aquifers – pump tests would be required but desk study indicates shallow pumping is unfeasible and that deep drilling would be required to reach a viable aquifer. New infrastructure may also be required if potable supply was used, in order to transfer water from the mains to the SSSI (spray application or discharge to watercourses).	All options will require agreement with Natural England (NE) and Warwickshire Wildlife Trust (WWT). The local road network is the responsibility of Solihull Metropolitan Borough Council (SMBC) - all proposals are subject to agreement with SMBC and appropriate treatment/spillage containment measures. The SE unit is below the Birmingham Airport (BA) flightpath - airport safe guarding requirements will restrict bodies of open water. The location of new infrastructure is yet to be determined and may require land take currently outside of the application boundary.	Engagement with NE, the EA, and the WWT is key to understand the deliverability of chosen solution. In summary - they do not want a pumped solution and prefer a passive, low cost "natural" intervention. The ditch is only partly within the current redline (order limits) – general provisions allow Highways England the rights to outfall to ditches and watercourses but this will require negotiations with the land owners/ affected parties. Access would also be required for creating and maintaining all of the proposed systems. The continuity, ownership, current maintenance regime and control of the ditch are uncertain. The application boundary and scheme description could potentially require amendment to ensure any infrastructure associated with the pumped solution could be constructed, operated and access provided for long term maintenance purposes. The potable water supply option is unlikely to require works outside of the application boundary.	The new pumping network and recharge trench would need to be regularly maintained with access provided. Drains, pumps and chambers in the verge of the mainline link road will require cleaning and maintaining – this will require maintenance laybys or lane closures which will negatively impact on customers. For pumped solutions, the pumps will not operate continuously – they will only operate between Autumn and Spring. leading to pump reliability issues meaning that a spare pump would need to be maintained at all times. Maintenance is unlikely to be required for the potable water supply option, but this is likely to require regular direct interventions from WWT and NE.	Capital costs associated with the new infrastructure and operating costs associated with operating and maintaining it. Source 1) Low / medium capital costs (potential to save costs based on current highways drainage designs)/ low maintenance/operating costs. Source 2) - Medium capital costs/ medium operating costs/ high maintenance costs. Source 3) – High capital cost/ medium maintenance costs Source 4) – Low capital costs/ low maintenance costs/ medium operating costs (potable water supply expected to be in the region of £13,500-£17,250 per year, based on STW's metered rates in 2018)

Table 3 Potential Hydrological Impacts on Bickenhill Meadows SSSI – Mitigation Options Appraisal – Option 2.

Mitigation Option (in order of preference)	Description	Mitigation Type	Implications				
			Design	Third Party and Land Ownership	Planning and Deliverability	Future Maintenance	Cost
2. Physical changes within the SSSI to extend the existing habitat types.	This would involve carefully planned and localised changes to the topography of the SSSI, and would be based on detailed modelling of the existing vegetation communities. As an example, the approach could seek to extend the topographical variations (such as deeper depressions and furrows) that have established the existing pattern of vegetation communities, to compensate for potential reduction in groundwater and surface water inflows.	Offsetting impact	Unlikely to require any changes to the infrastructure design. A detailed Habitat Enhancement Plan would need to be prepared.	The greatest opportunity would be on the NW site that is owned by BA. There may be some options for the SE Unit that is owned and managed by WWT, although less so. Other landowners may be affected. Both BA and WWT (as well as NE) would need to be carefully consulted on the Habitat Enhancement Plan to ensure it can be agreed and delivered.	The current application boundary incorporates the extents of land designated within the boundary of the SSSI, within which it is expected that these measures could be delivered and managed without requiring additional land beyond that already identified. Scheme description would need to be amended to incorporate these measures. Although works may be of a soft nature, the use of some equipment and small plant cannot be ruled out. This would require Assent from NE and permission from the landowners. Experience with BA to date is that this may not be straight forward and could even be objected to or require acceptance of unreasonable levels of liability.	It would be expected that any changes to the SSSIs would need to be carefully monitored for 3+ years.	Costs associated with the development of the Habitat Enhancement Plan and its implementation including monitoring.

Table 3 Potential Hydrological Impacts on Bickenhill Meadows SSSI – Mitigation Options Appraisal – Option 3.

Mitigation Option (in order of preference)	Description	Mitigation Type	Implications				
			Design	Third Party and Land Ownership	Planning and Deliverability	Future Maintenance	Cost
3. Establish habitats similar to the interest features, either in land immediately adjacent to the SSSI or at a new site.	This would include creating a parcel of land with a varied topography and a related hydrological regime, and establishing grassland using green hay from the SSSI.	Offsetting impact	The conditions of the SSSI would be re-created, ideally from land parcels flanking the brooks in/out of the SSSI, while avoiding significant risk of impacts from the new mainline link road. Requires careful design, alterations to topography and specialised planting in consultation with NE. A detailed Habitat Management Plan would likely be required to demonstrate to the relevant bodies how these habitats would be established and managed in the long term.	Discussions with landowners would need to be advanced, as their land would either need to be secured by way of prior agreed purchase to implement these measures, or via the DCO as essential land take for mitigation purposes. With regards to the NW Unit, and assuming some tasks will require the use of equipment and plant, discussions with BA would be required to understand any safeguarding issues that may limit how the work is undertaken.	The application boundary and scheme description would need to be amended to ensure this mitigation could be implemented. Although works may be of a soft nature, the use of some equipment and small plant cannot be ruled out. Permission will be required from the landowners. Experience with BA to date is that this may not be straight forward and could even be objected to or require acceptance of unreasonable levels of liability.	Maintenance of site would be undertaken on an annual basis under a management / legal agreement that would be needed in perpetuity. This could be adopted by the land-owner or a third party via the legal agreement	Cost associated with the compulsory purchase of land, development of a Habitat Enhancement Plan and its implementation and any post works monitoring.

15. Conclusions

15.1 It has been predicted that the Scheme will not have adverse effects on the Bickenhill Meadows NW Unit's hydrology and no mitigation measures are proposed, although as a precautionary measure ongoing monitoring of vegetation and surface saturation conditions using dipwells will be continued.

15.2 It has been determined that the Bickenhill Meadows SE Unit will lose around one fifth of the surface water catchment to the west of the new mainline link road and beneath the Scheme footprint. While the amount of water lost could be within that expected with natural climatic variability 'year on year', it cannot be ruled out that this would not have consequences for the sensitive grassland species in a given year or over a number of consecutive 'drier' years in terms of depressing the water table to the extent that surface conditions become drier, especially in the spring.

15.3 A number of options have been considered for mitigating the loss of around one fifth of the surface water catchment, including use of run-off from local roads, developing a pumped solution, groundwater abstraction, and potable water supply to convey water towards the SSSI. The second of these is currently the preferred solution, although other options are to be explored.

15.4 The design principles of the pumped solution consist of a collection drain on the western slope of the new mainline link road cutting to intercept surface water flows that would otherwise have drained towards the SSSI. The collection drain would discharge to a sealed collection sump, from where water would be pumped and/or captured from an alternative water source(s) to an appropriate water feature in the vicinity of Bickenhill Meadows SSSI SE unit. This feature would act as a recharge trench, from which water would drain through to the sand, gravel and clay deposits in the upper layers of the substrata within the SSSI. Using this approach, 11% of the surface water catchment is maintained, but the 10% of catchment falling under the Scheme footprint would be lost from the SE SSSI. To further mitigate for this loss, the proposed collection drains could be extended north and south to collect greater amounts of water from the west of the proposed new mainline link road, and thereby compensate for the loss beneath the Scheme footprint. The proposed mitigation should therefore maintain surface water flows to the SE Unit.

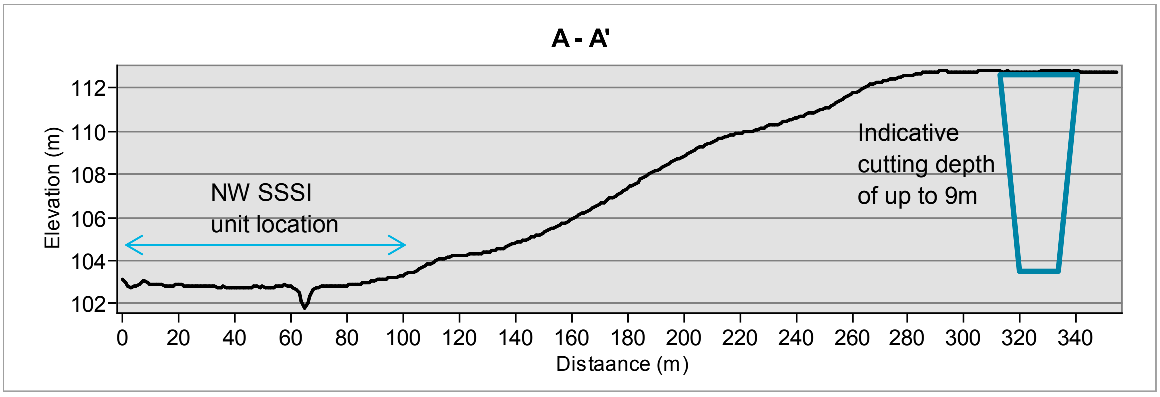
15.5 Highways England will continue to refine the mitigation solution using: data obtained from the ongoing dipwell monitoring; and information gathered from further analysis of the local topography and existing water sources. These refinements will seek to identify a sustainable drainage mechanism to mitigate the effects of the Scheme on Bickenhill Meadows SSSI. Highways England will seek to agree any refinements to the mitigation approach with Natural England prior to commencement of the Scheme.

15.6 Furthermore, it is proposed that the vegetation communities are monitored at both sites during construction and during initial operation to ensure that there is no detrimental impact resulting from the Scheme. This will be augmented by the continued monitoring of water table levels. Should any adverse effects be discovered then further mitigation would need to be implemented.

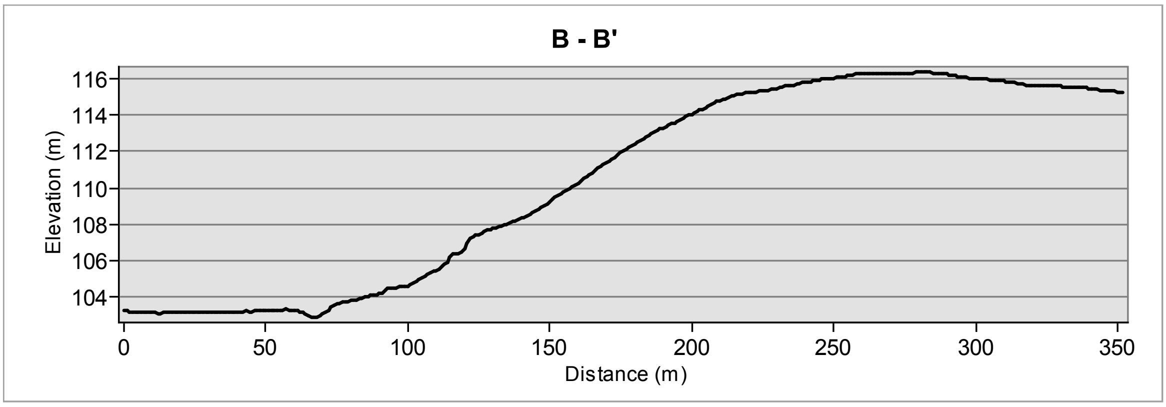
Annex A: Sections

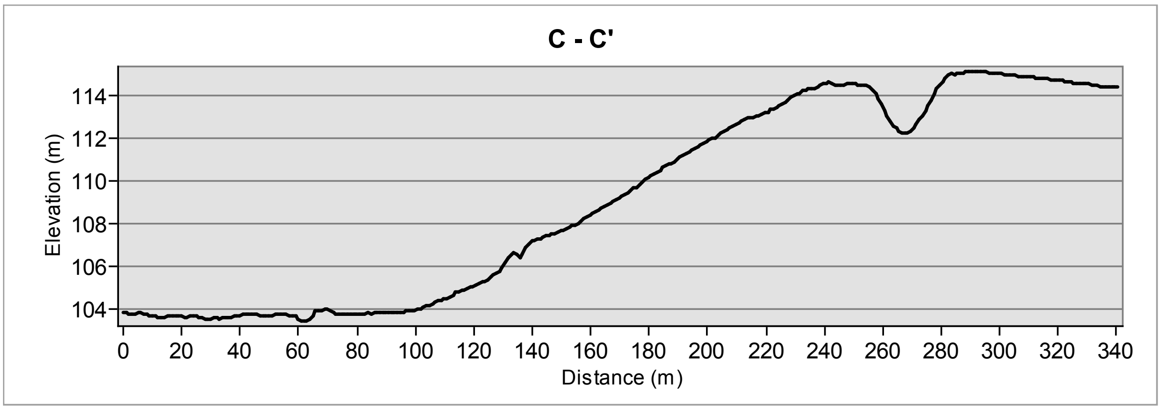
Annex A: Sections

NW SSSI unit



Note. Indicative cutting of up to 9m depth shown in blue.






D' to D
Eleavation (m)
103.8
103.6
103.4
103.2
103
102.8
102.6
102.4
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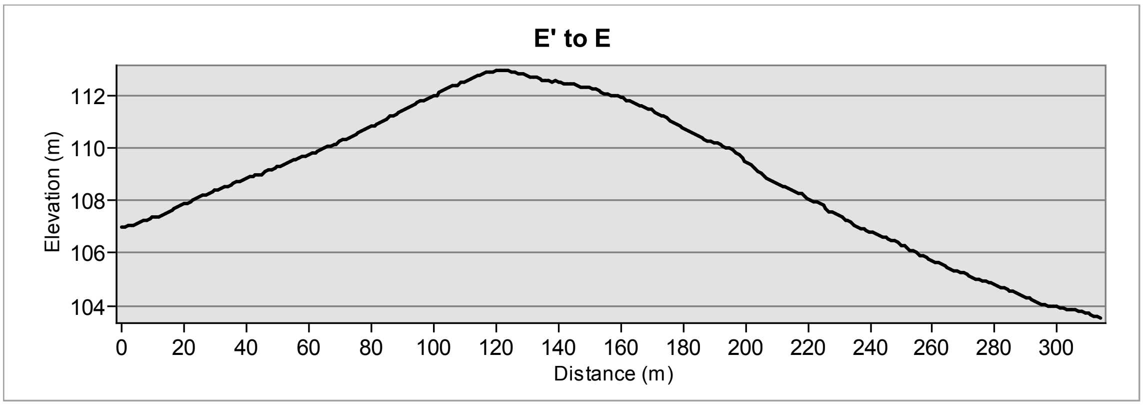
Distance (m)


E' to E
Elevation (m)
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110
108
106
104
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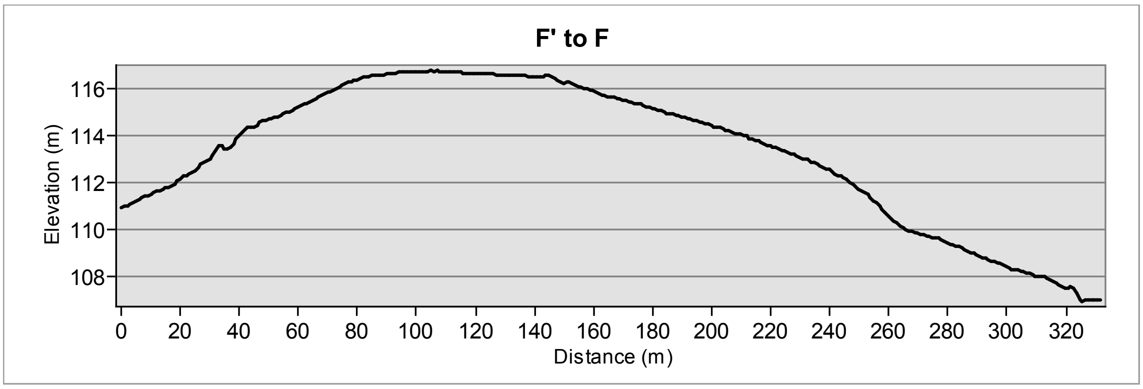
Distance (m)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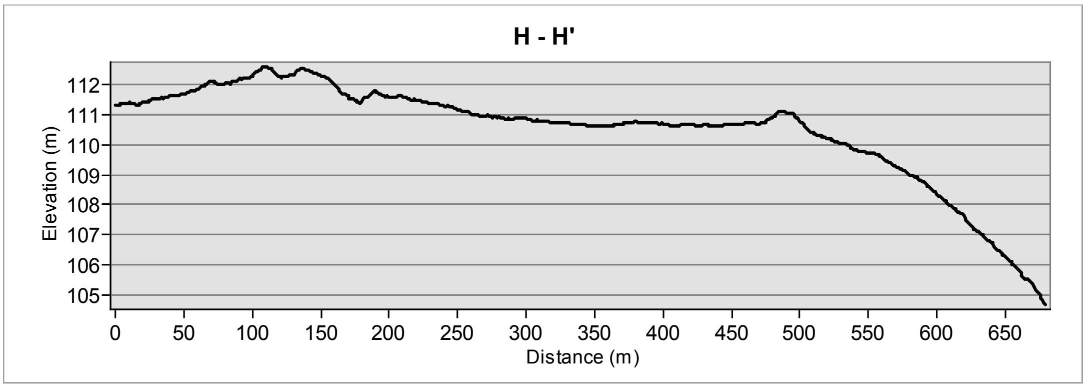
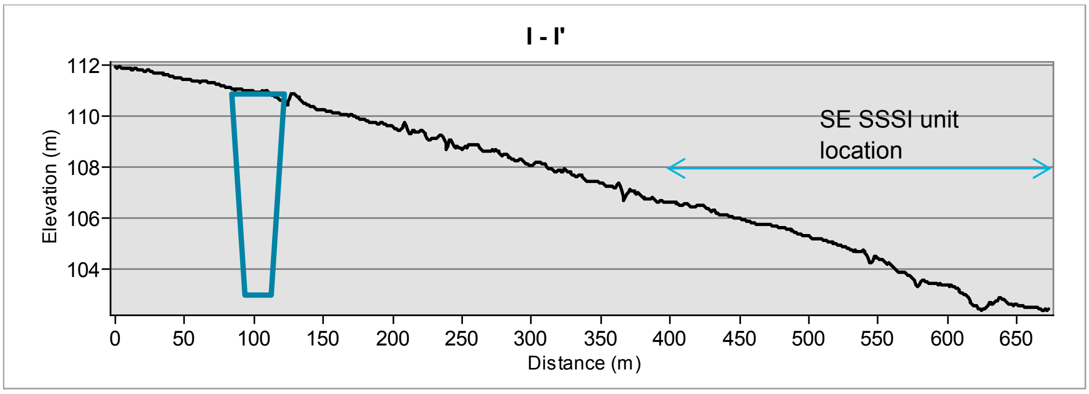
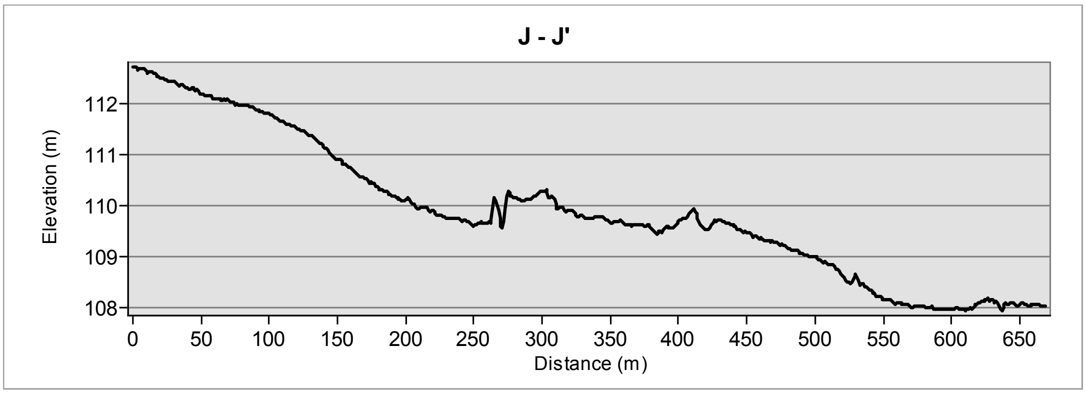
Distance (m)

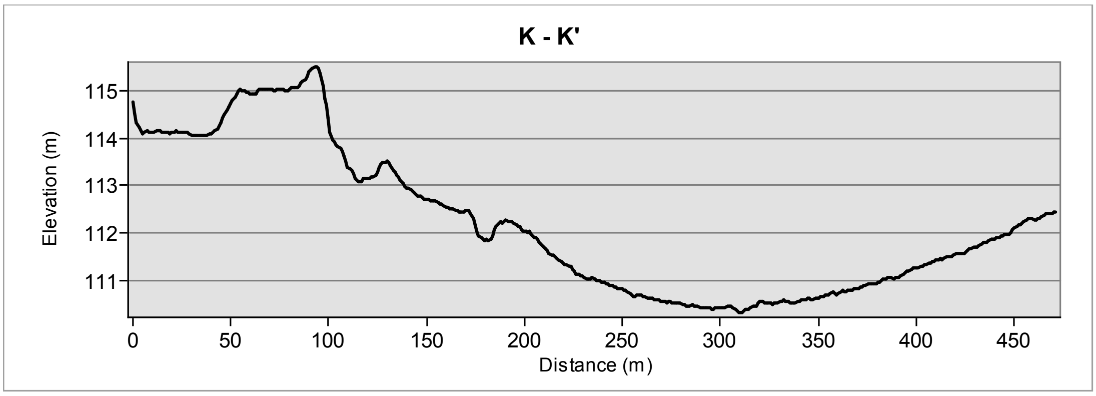
SE SSSI unit





Note. Indicative cutting of up to 8m depth shown in blue in this topographic section.




K - K'
Elevation (m)
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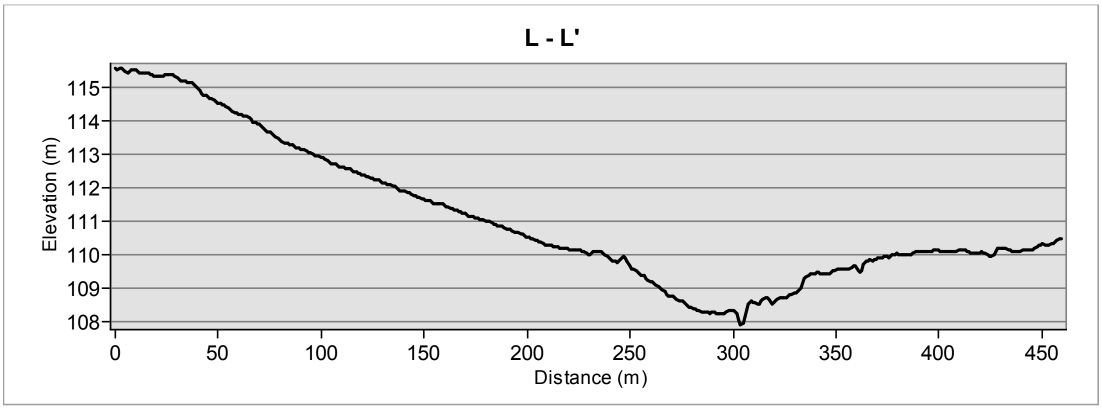
114
113
112
111
0 50 100 150 200 250 300 350 400 450
Distance (m)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Elevation (m)
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109
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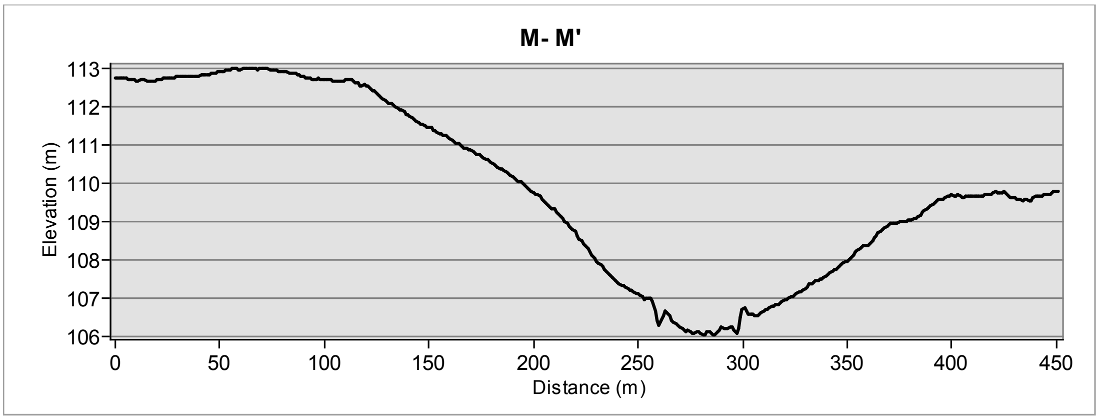
Distance (m)


M- M'
Elevation (m)
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106
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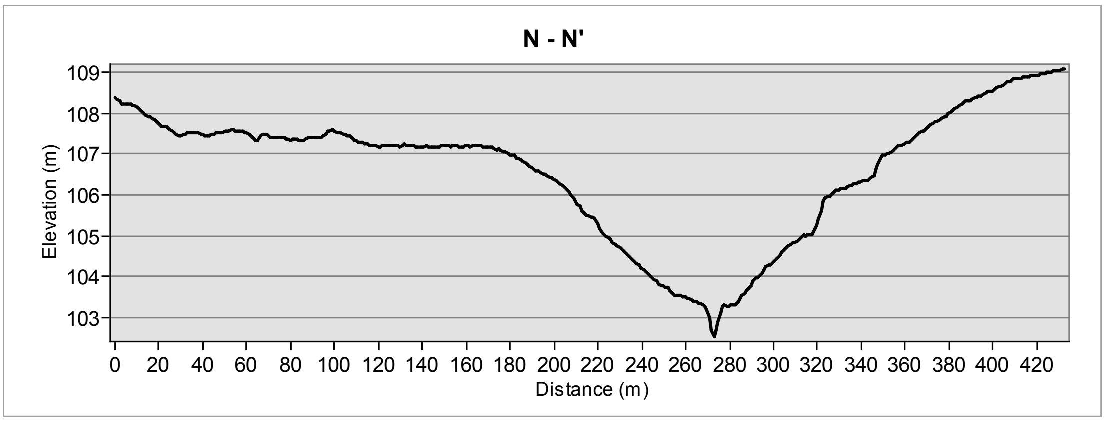
Distance (m)


N - N'
Elevation (m)
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106
105
104
103
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Distance (m)

Annex B: Dipwell Details and Soil Description

Table A1 Location, depth, soil description and initial data from the dipwell installation and monitoring (SE SSSI)

SE SSSI												
Site	Latitude, Longitude	Soil Description / Notes	Depth (m)	Grassland	14/08/2018	16/08/2018	31/08/2018	13/09/2018	25/09/2018	12/10/2018	25/10/2018	08/11/2018
T1A	52.432467, -1.724967	Top soil silty sand dark brown to light brown, semi-fibrous. Gradual transition to lighter grey sand less fibrous and becoming much drier at 50cm, where it ws not possible to penetrate with handheld equipment.	0.50	MG4	Dry	Dry	Dry	Dry	Dry	Dry	Dry	0.23
T1B	52.4326, -1.72465	Topsoil is dark grey semi-fibrous fine silt continuing to 35cm depth, then trending to stiff dark grey (mottled with brown) clay without roots which continues to 45cm depth. Sandy clay from 45cm-50cm with some large cobbles up to 10cm diameter. This layer could not be penetrated.	0.90	MG4	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
T1C	52.432733, -1.72425	Dark brown silty sand with a few small cobbles and slightly moist to 45-50cm, here it becomes a drier, greyer layer of silty sand. At 80cm becomes dark grey-black slightly mottled moist sand, and at 90cm black sandy clay. Various cobbles (mix of rounded and angular) throughout the 90cm, from 2-7cm diameter.	0.90	MG5	Dry	Dry	Dry	Dry	Dry	Dry	0.78	Dry
T1D	52.432817, -1.72415	Dark brown silty sand with abundant cobbles (mix of rounded and angular), semi-fibrous to 40-50cm. Then transitions to sandy clay with a fewer, larger cobbles. Sand becomes light grey/white from 55cm before transitioning to orange. Becomes more clay dominated and mottled from 80cm.	0.90	MG4/MG5 transition	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
T1E	52.43305, -1.7231	Brown sandy silt topsoil to 20cm, before becoming greyish mottled clay with brown specks. Surface of ground much damper her compared to elsewhere with more clay near the surface. Hit light grey pure sand at 55cm turning to orange sand at 60cm. Became moister again at around 75cm.	0.90	MG5	Dry	Dry	0.88	Dry	0.87	0.88	0.55	0.23
T2A	52.432583, -1.7251	Grey to brown dry silty sand, semi-fibrous, compact to 35cm. Drier, greyer, semi-fibrous compact coarse sand from 35-46cm	0.50	MG5	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
T2B	52.432717, -1.72475	Brown silty sand, very dry and containing cobbles (3-5cm). Extremely compact sand at 45cm, requires chisel to penetrate.	0.45	MG5	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
T2C	52.432817, -1.724333	Dark brown silty sand, very dry and semi-fibrous to 30cm, before tranisitoning to compact and very solid sand that could not be penetrated.	0.50	MG4	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
T2D	52.432933, -1.724033	Brown silty sand topsoil, dry and semi-fibrous. Distinct layer of large rounded cobbles of 5-12cm diameter at 30-40cm depth. Then becomes dark brown sand at 55cm. Gradually becomes clayey at 70cm, this is blue grey clay mottled with brown strands and very cobbly.	0.90	MG4/MG5 boundary	Dry	Dry	Dry	Dry	Dry	Dry	Dry	0.83
T2E	52.433133, -1.723183	Brown sandy silt, semi-fibrous, dry with big cobbles (rounded and up to 10cm diamter) to 25-30cm where it becomes clayey. Trends to light grey coarse sand at 45cm, still with cobbles (4-5cm diameter). At 65cm transitions to light grey sand with cobbles and then to silvery blue sandy clay from 75cm.	0.90	MG4	Dry	Dry	0.86	Dry	0.82	0.8	0.58	0.27

Table A1 Location, depth, soil description and initial data from the dipwell installation and monitoring – continued (NW SSSI)

NW SSSI												
Site	**Latitude, Longitude**	**Soil Description / Notes**	**Depth (m)**	**Grassland**	**14/08/2018**	**16/08/2018**	**31/08/2018**	**13/09/2018**	**25/09/2018**	**12/10/2018**	**25/10/2018**	**08/11/2018**
N1A	52.436970, -1.7336798	Topsoil is dry, dark brown semi-fibrous fine silt continuing to 40cm depth, then trending to stiff dark grey silty clay without roots. Small cobbles of maximum 3-4cm in diameter at 45cm depth, then trending to lighter grey clay towards the base of the dipwell at 70cm.	0.70	MG4	n/a	n/a	n/a	Dry	Dry	Dry	0.53	0.38
N1B	52.436772, -1.7337987	Topsoil is dry, dark brown semi-fibrous fine silt continuing to 35cm depth, then trending to stiff dark grey (mottled with brown) clay without roots which continues to 45cm depth. Sandy clay from 45cm-50cm depth with some large cobbles up to 10cm diameter. This layer could not be penetrated.	0.50	MG4	n/a	n/a	n/a	Dry	Dry	Dry	Dry	0.35
N1C	52.436503, -1.7339474	Topsoil is dry, dark brown semi-fibrous fine silt with cobbles of 3-4 cm in diameter. Topsoil transitions to red-brown sandy clay at 25cm, which continues through to the base of the dipwell at 90cm. Some cobbles of up to 5cm diameter found throughout the sandy clay.	0.90	MG5	n/a	n/a	n/a	Dry	Dry	Dry	0.82	0.53
N1D	52.436349, -1.7337130	Topsoil is dry, dark brown semi-fibrous fine silt with cobbles of 3-4 cm in diameter. Topsoil transitions to very stiff, mottled grey-brown clay at 30cm. The clay continues but contains angular cobbles of up to 7-8cm diameter from 60cm, with an impenetrable layer (potentially a very large rock) at 70cm depth.	0.70	MG5	n/a	n/a	n/a	Dry	Dry	Dry	0.57	0.35
N1E	52.436169, -1.7336258	Topsoil is dry, dark brown semi-fibrous fine silt with cobbles of 3-4 cm in diameter. Transitions to extremely stiff thick dark grey-brown clay at 20cm, which continues to the base at 60cm, which was a solid impenetrable layer.	0.60	MG5	n/a	n/a	n/a	Dry	Dry	0.48	Dry	0.24
N2A	52.436950, -1.7330327	Topsoil is dry, dark brown semi-fibrous fine silt with some angular cobbles of 4-5cm diameter. At 15cm depth it transitions to a stiff, dry, dark brown clay layer. This continues to 60cm depth where there is dark brown sandy clay which is extremely stiff. This continues to the base at 90cm.	0.90	MG5	n/a	n/a	n/a	Dry	0.975	Dry	0.7	0.71
N2B	52.436527, -1.7329470	Topsoil is dry, dark brown semi-fibrous fine silt. At 25cm depth it transitions to a stiff semi-moist, dark brown clay layer. From 32cm depth there are small infrequent gravel stones of less than 1cm diameter. These gravels are increasingly frequent from 50cm and increase in size to between 2-5cm in diameter. Clay transitions to light grey fine sandy clay from 60cm, with increasingly coarse sand at 75-80cm. From 80cm-90cm the sand content decreases and there is light grey stiff clay.	0.90	MG4	n/a	n/a	n/a	Dry	Dry	Dry	0.82	0.65
N2C	52.436663, -1.7332404	Topsoil is semi-moist, dark brown semi-fibrous fine silt. Transitions to moist mottled grey clay at 24cm depth with red lines along root lines. Small gravels appearing from 30cm depth, around 2-3cm in diameter. Larger gravels from 40cm, with a mix varying between 1 and 10cm diameter.More sand gradually mixed with the clay before it transitions to blue sandy clay with gravel at 50cm depth. At 60cm depth there is another blue clay section without sands and gravels, before becoming increasingly sandy again from 75cm. It remains semi-moist blue sandy clay until the base at 90cm.	0.90	MG4	n/a	n/a	n/a	Dry	0.79	0.88	0.48	0.12
N2D	52.436312, -1.7330807	Topsoil is dry, dark brown semi-fibrous very fine silt. Transitions to extremely stiff thick dark grey-brown clay at 10cm. This continues to 43cm which was the base of the dipwell due to a hardened layer (which could be rock) that could not be penetrated.	0.43	MG4	n/a	n/a	n/a	Dry	Dry	Dry	Dry	0.28
N2E	52.436105, -1.7330966	Topsoil is dry, dark brown semi-fibrous very fine silt. Transitions to extremely stiff thick dark grey-brown clay at 15cm. Clay changes to light grey at 60cm, and continues to the base of the dipwell where it was too hardened and compact to break through.	0.66	MG5	n/a	n/a	n/a	Dry	0.74	0.54	0.49	0.32

Annex C: Conceptual Models

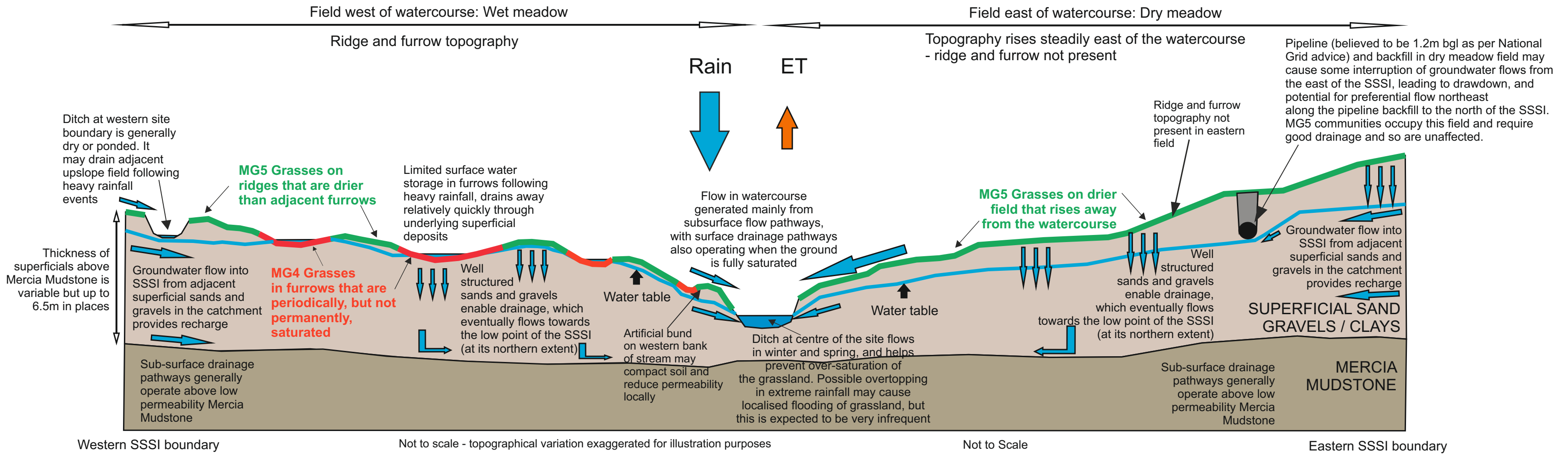
Drawing Numbers:

HE551485-ACM-AGM-M42_SW_ZZ DR_HD-001

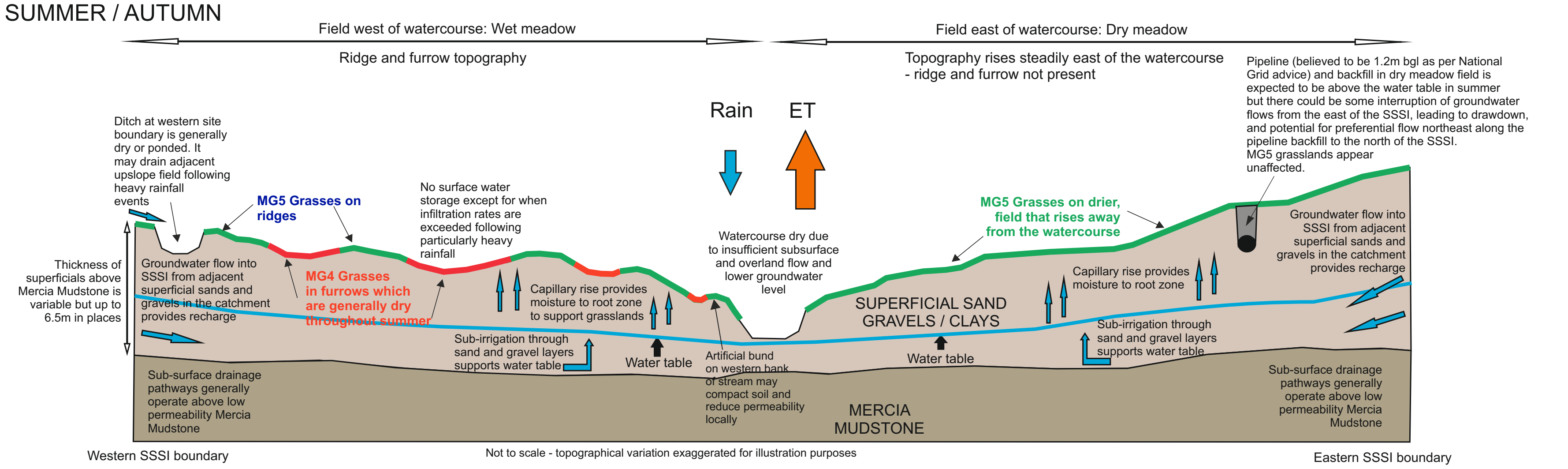
HE551485-ACM-AGM-M42_SW_ZZ DR_HD-002

A. SE SSSI CONCEPTUAL MODEL

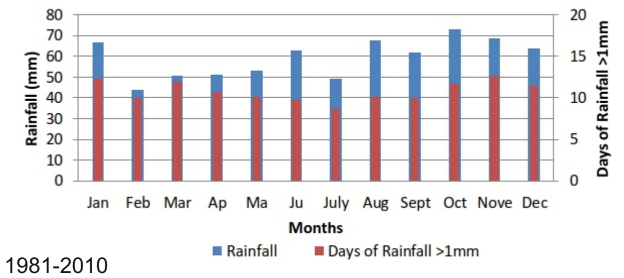
WINTER / SPRING



SUMMER / AUTUMN



C. COLESHILL RAINFALL



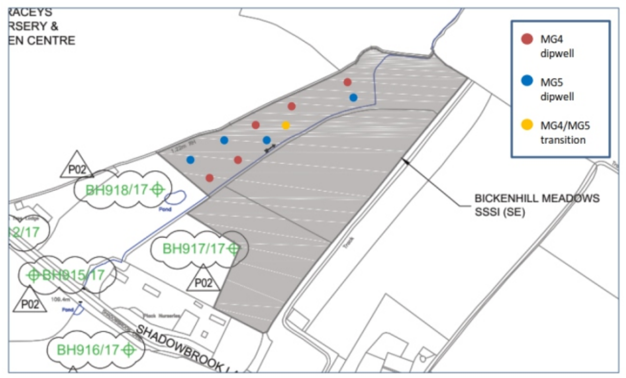
1981-2010

D. CATCHMENT LOSS

WET MEADOW - SE SSSI

CENTRAL DITCHCOURSE - SE SSSI

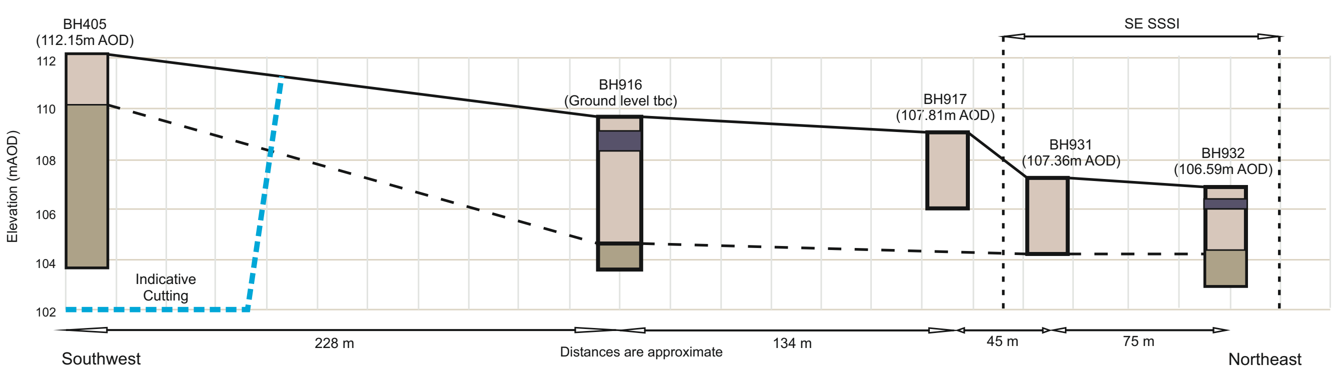
E. DIPWELL MONITORING LOCATIONS

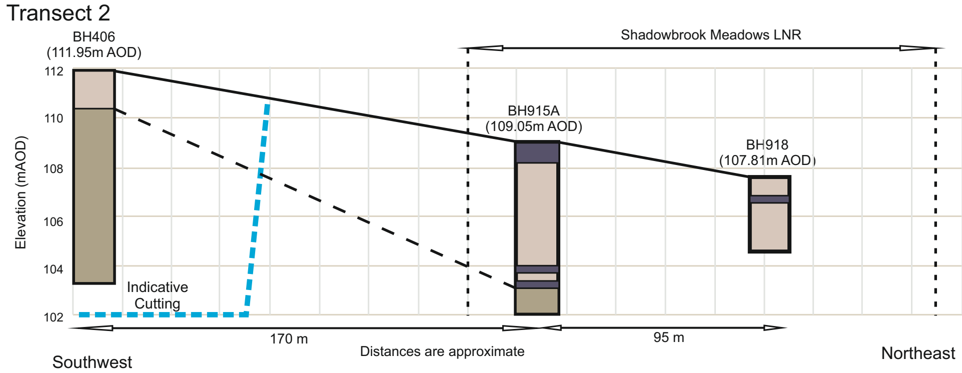


CONCEPTUAL MODEL & CROSS SECTION LEGEND

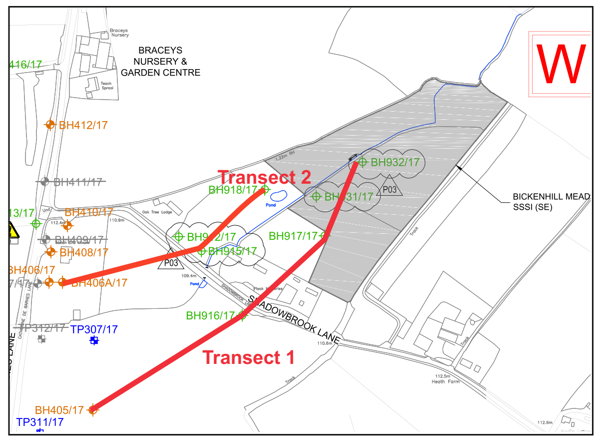
- Mercia Mudstone
- Superficial Clays, sands and gravels (clay dominated)
- Superficial Sand Layers
- Flow Direction
- Water Table
- MG5 Community
- MG4 Community

B. SE SSSI GEOLOGY CROSS SECTIONS





GI & TRANSECT LOCATIONS



Purpose of Issue: PURPOSE OF ISSUE	Project Title: M42 JUNCTION 6 IMPROVEMENT	Drawing Title: BICKENHILL MEADOWS SE SSSI UNIT CONCEPTUAL MODEL	
Client: Highways England, 2 Colmore Square, Birmingham. B4 6BN. Working on behalf of highways england			

Designed	Drawn	Checked	Approved	Date
TJ	TJ	OT	GC	03/10/18

Internal Project No: 60543032 — Suitability:
Scale @ A3: NA — Zone: X

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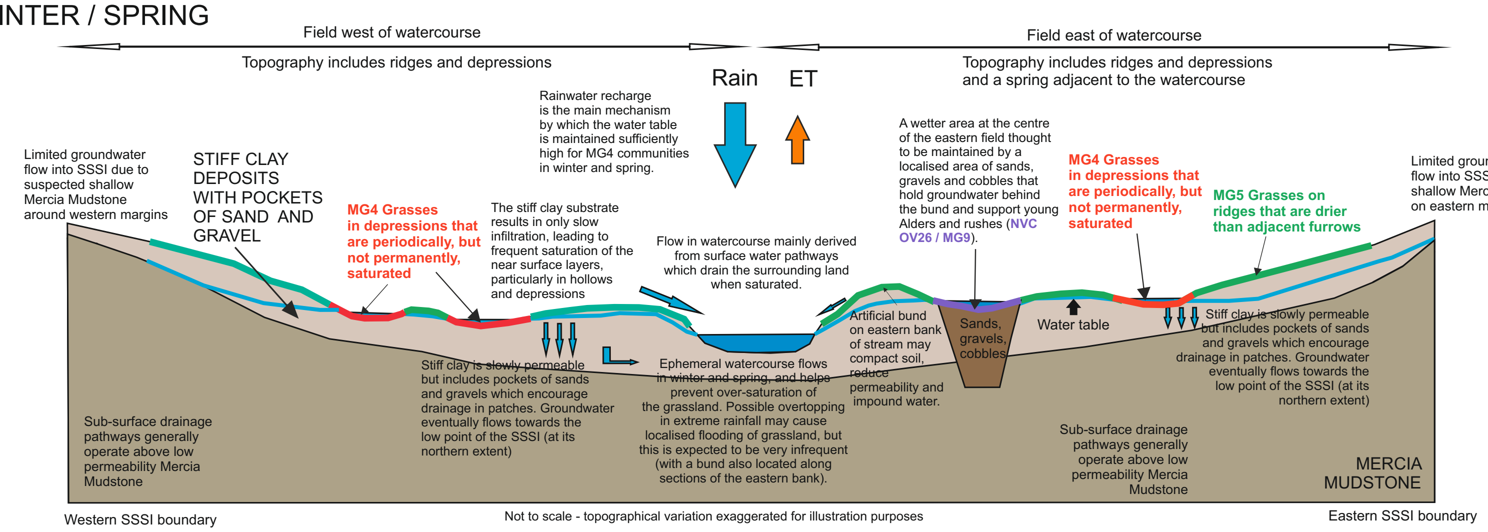
Registered in England Registered number: 880328
Registered office: Midpoint, Alencon Link, Basingstoke, Hampshire RG21 7PP

Drawing Number
Highways England Pin | Originator | Volume
HE551485 -ACM -EGN
M42_SW_ZZ_ZZ DR_HD_001
Location | Type | Role | Number

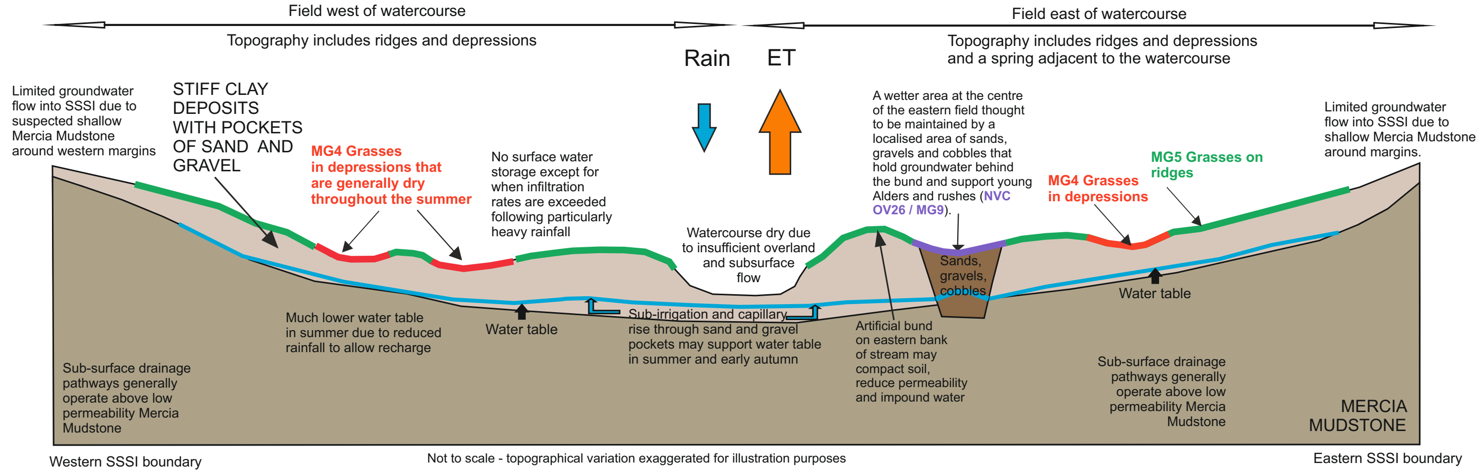
Rev
P01

A. NW SSSI CONCEPTUAL MODEL

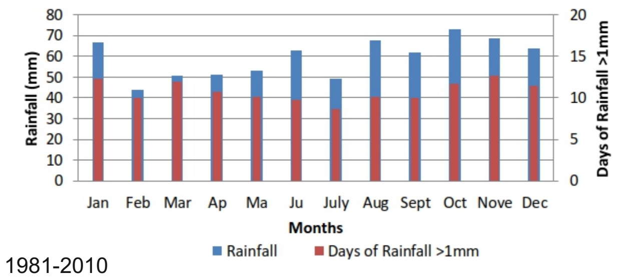
WINTER / SPRING



SUMMER / AUTUMN



C. COLESHILL RAINFALL



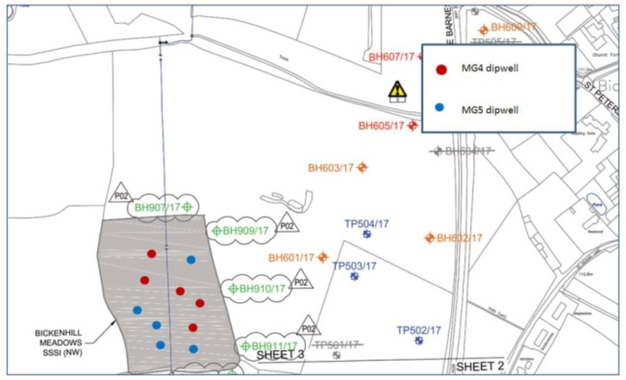
1981-2010

NW SSSI - EASTERN FIELD

NW SSSI - CENTRAL DITCHCOURSE

D. CATCHMENT LOSS

E. DIPWELL MONITORING LOCATIONS

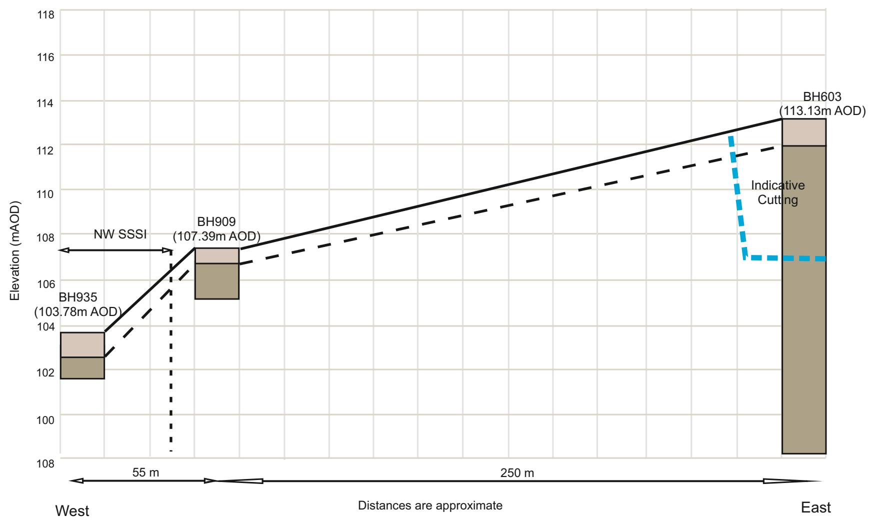


CONCEPTUAL MODEL & CROSS SECTION LEGEND

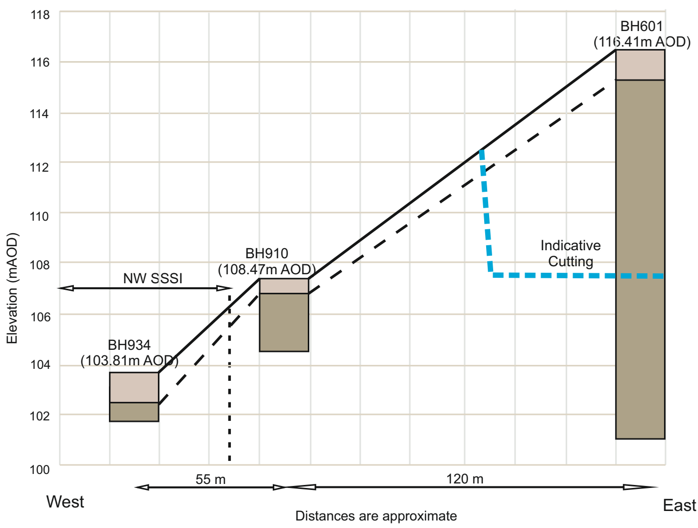
- Mercia Mudstone
- Flow Direction
- Water Table
- Superficial Clays
- Wetter Area Supported by Sands and Gravels
- MG5 Community
- MG4 Community
- MG9/OV26 Community

B. NW SSSI GEOLOGY CROSS SECTIONS

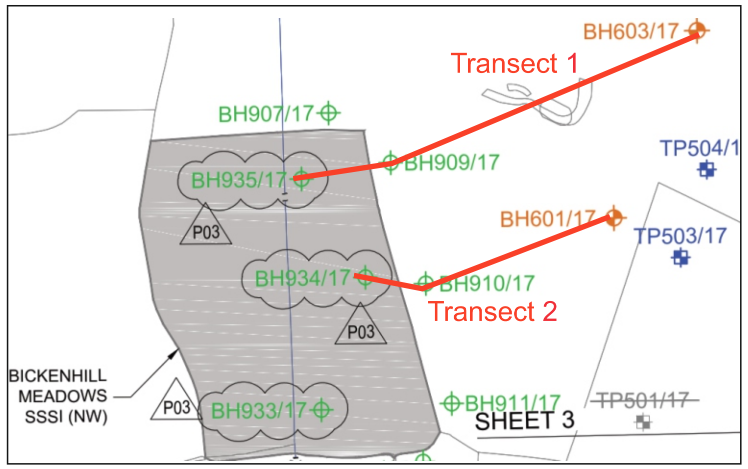
Transect 1



Transect 2



GI & TRANSECT LOCATIONS



Purpose of Issue PURPOSE OF ISSUE Client Highways England 2 Colmore Square, Birmingham. B4 6BN. Working on behalf of highways england	Project Title M42 JUNCTION 6 IMPROVEMENT	Drawing Title BICKENHILL MEADOWS NW SSSI UNIT CONCEPTUAL MODEL	Designed TJ · Drawn TJ · Checked OT · Approved GC · Date 03/10/18 Internal Project No 60543032 · Suitability Scale @ A3 NA · Zone X

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Drawing Number
Highways England Pin | Originator | Volume
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M42_SW_ZZ_ZZ DR_HD_002
Location | Type | Role | Number

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P01

Annex D: Hydrological Investigation into catchment loss

Annex D

AECOM Imagine it. Delivered.

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Project name:
M42 J6 Improvement Scheme

To:
Tim Jones

Project ref:
60543032

CC:
Helen Harfoot
Sarah Waite

Written:
Lucy Rushmer
Checked:
Andrew Heath-Brown

Date:
13th November 2018

Memo

Subject: Impact of Scheme on Bickenhill Meadows SSSI

SSSI designation

Bickenhill Meadows Site of Special Scientific Interest (SSSI) is a floodplain meadow designated for its rich grassland floras, comprising wet grasslands. Bickenhill Meadow SSSI has a small area of 0.07km^2. Despite its small area, the SSSI will be susceptible to any reduction in the catchment area contributing water to the SSSI, because it is specifically designated for wet woodland and wet meadows that support a range of plants and other species.

Proposed scheme

The proposed route of the M42 J6 Improvement Scheme will create a new cutting which will intercept 21% of the surface water catchment draining towards the SSSI. The hydrological catchment within which the SSSI lies, which contributes water to the SSSI, is approximately 0.28 km^2. This catchment will be reduced to 0.22 km^2 after the road is built.

Study aim

A qualitative desk study has been undertaken to determine:

- The likely impact of the catchment loss to the SSSI;
- How significant the catchment loss is for the SSSI;
- Whether this loss in catchment area is within the range of natural variability of rainfall;
- The amount of surface water that might be lost through construction of the road.

Catchment characteristics

The SSSI is located in an area which is dominated by Mercia mudstone bedrock geology and is overlain by glaciofluvial deposits of sand, gravels and clay. The Standard Percentage Runoff (SPRHOST) value taken from the FEH Catchment Descriptors is 41%; and a Base Flow Index (BFIHOST) of 0.318. Both SPR and BFI are derived from the Hydrology of Soils Types classification, which groups soil types by hydrological properties, and in particularly their ability to transmit water both vertically and horizontally[13]. It is a rural catchment.

[13] https://www.ceh.ac.uk/services/hydrology-soil-types-1km-grid

The topography of the SSSI is generally level, with a gentle rise in elevation away from the tributary of Shadow Brook, which flows through the approximate centre of the site. The surrounding catchment has steeper hillside slopes.

Geology and soil characteristics

The SPRHOST, BFIHOST, geology and superficial deposits indicate that there is a high amount of water that runs off the land due to relatively impermeable geology and soils. The mudstone has impermeable properties because the extremely fine-grained clast sizes mean that the rock is not porous or permeable, so little water will percolate into the rocks and soils. The fine grained, hard and cohesive properties of the clay superficial deposits also inhibit water percolation through the rocks and soils. The well-structured sands and gravels enable drainage, which eventually flows towards the low point of the SSSI.

Surface water map

According to the Environment Agency's flood risk map from surface water[14], the SSSI lies in an area which is at high risk of flooding from surface water (Figure 1). **High risk** from surface water means that each year this area has a chance of flooding from surface water of greater than 3.3% (1 in 30 year return period). Flooding from surface water is difficult to predict as rainfall location and volume are difficult to forecast. In addition, local features can greatly affect the chance and severity of flooding. This implies that surface water flows off the land and down into the valley which causes surface water ponding along the watercourse that flows through the SSSI.

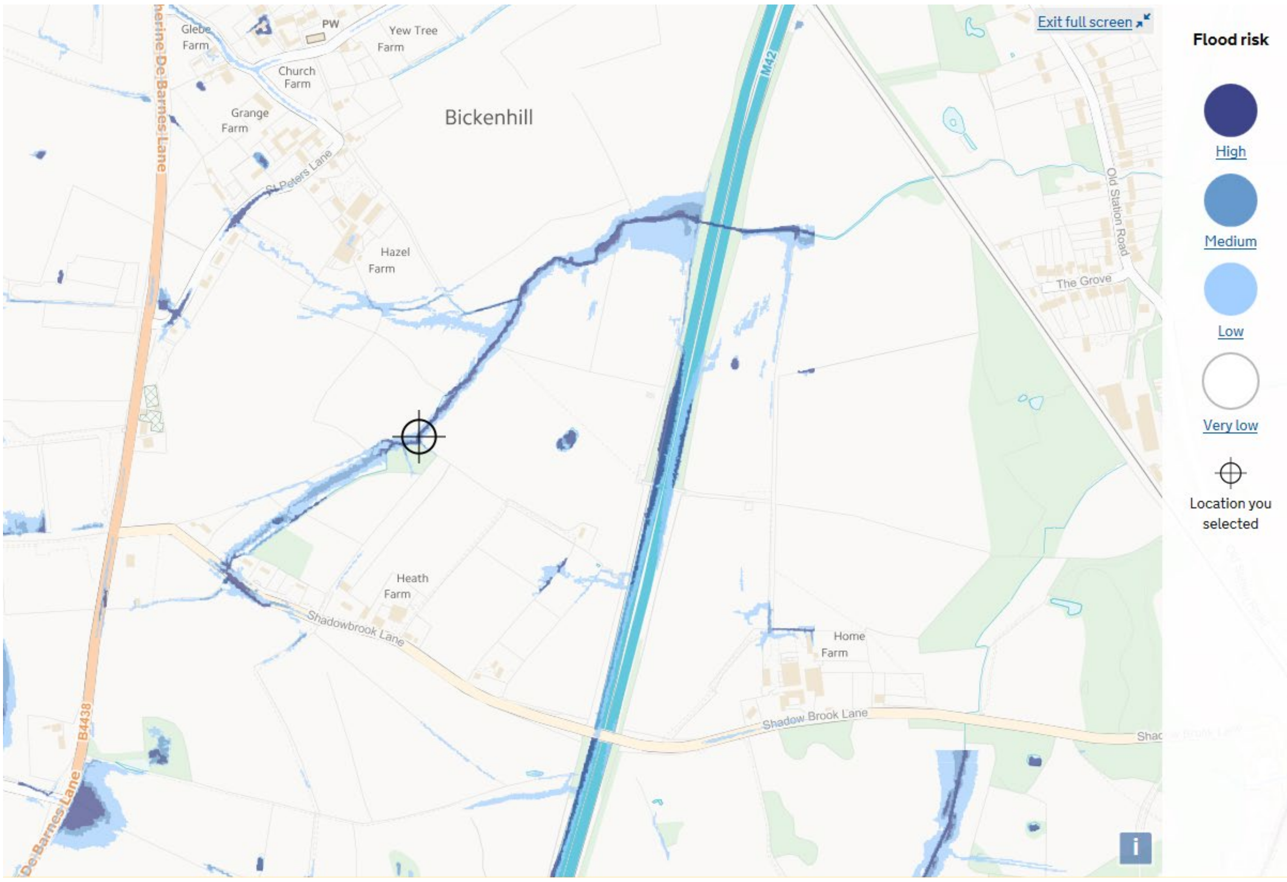


Figure 1: Environment Agency's flood risk map from surface water for the SSSI

The loss in catchment area could potentially have an impact on the amount of water reaching the SSSI. However the geology and soil characteristics indicate that little water will percolate into the rocks and soils, therefore there is a relatively high amount of runoff from the surrounding catchment into the watercourse that flows through the SSSI.

[14] https://flood-warning-information.service.gov.uk/long-term-flood-risk/map

Topography (LiDAR)

Analysis of the LiDAR data overlain with the catchment area of the SSSI indicates that the majority of the land surrounding the SSSI is relatively high, and the SSSI lies in a flat bottomed valley (Figure 2). The topography of the site is generally level, with a gentle rise in elevation away from the tributary of Shadow Brook, which flows through the approximate centre of the site. The catchment contributes flow to the SSSI through runoff from the surrounding hillslopes, and overland flow along the valley bottom, which then flows into the SSSI. The amount of water reaching the SSSI is maximised by the topography of the catchment surrounding the SSSI.

Figure 2: LiDAR data showing the elevation of land in the catchment area contributing to the SSSI

Rainfall

Rainfall data from the nearest gauge has been analysed. There is a rainfall gauge located at Coleshill, approximately 7km north west of the site. Daily rainfall totals have been analysed to determine if there is an annual pattern of rainfall (wet and dry years). Figure 3 shows the daily total rainfall between 1998 and 2015 from the Coleshill rain gauge.

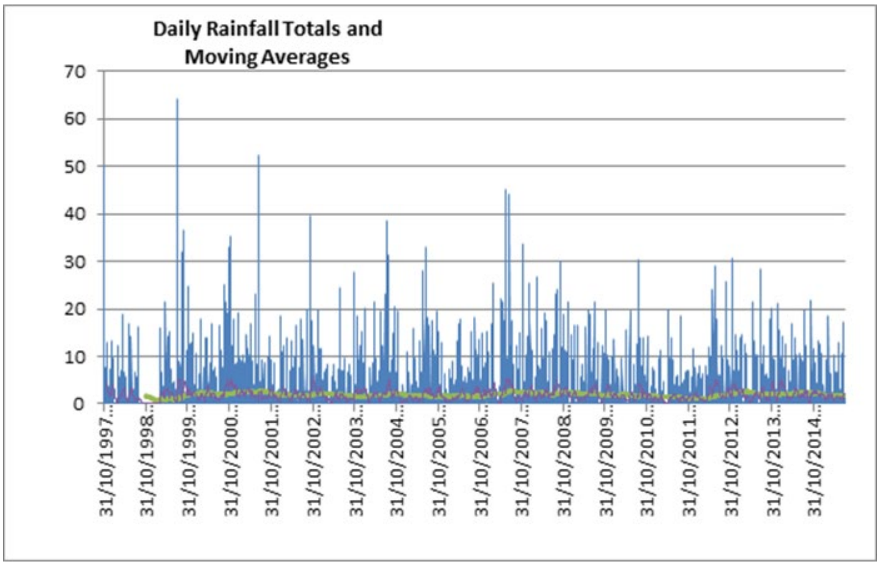


Figure 3: Daily total and moving averages of rainfall data from the Coleshill rain gauge

Figure 3 shows a variation of rainfall over time within close proximity to the site. Some natural variation in rainfall (as with any climatic conditions) is to be expected.

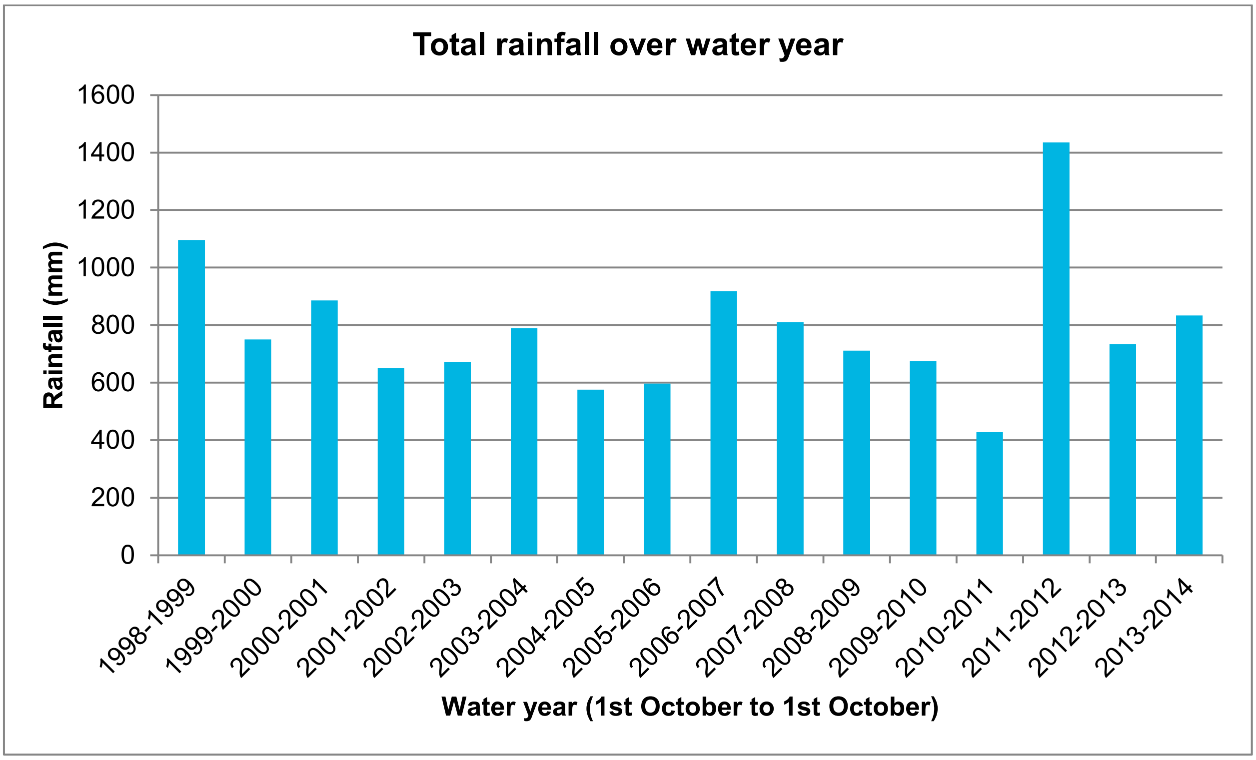


Figure 4: Rainfall total over water years (1st October to 1st October) from the Coleshill rain gauge

Rainfall data from the Coleshill gauge has been analysed further by water year, which runs from 1st October one year to 30th September the following year, to determine if there are any wet/dry patterns over the period of record (Figure 4). It can be seen that the water year 2011-2012 is the wettest, and that the water year 2010-2011 is the driest, within the period of record (Figure 4). This equates to a 1007mm variation between the highest and lowest rainfall amount in any given water year. This is a significant variation in rainfall over the record.

This data illustrates that there are natural variations in rainfall in the vicinity of the SSSI. We can therefore make an assumption that the SSSI functions through these natural variations in rainfall, and it is part of the natural variation in climate in the area. Observations made at the SSSI throughout 2018 indicate that the site has been very dry, with the central watercourse having been dry between August and November, and the northwestern ditch dry for the majority of the year. Fortnightly observations are ongoing.

Catchment runoff analysis

Loss analysis

In order to estimate the amount of surface water that may be lost through the construction of the road, rainfall data from the Coleshill rain gauge has been analysed using the ReFH2 Calibration Utility tool. The ReFH2 Calibration Utility tool enables users to calibrate the parameters and initial conditions of the ReFH and ReFH2 rural models using observed event rainfall and flow datasets.

The ReFH and ReFH2 methods takes into account a loss model, a routing model and a baseflow model, which all influence the total amount of water that will reach the SSSI.

The Cini parameter, which describes the initial soil moisture content (mm) at the commencement of a runoff event, can provide an indication of the catchment's ability to produce runoff from rainfall input. As such, the ReFH2 Calibration Utility tool was used to estimate the average Cini value for each water year in the gauged rainfall record, as well as an overall average Cini value. The tool estimates the Cini value taking into account natural variability in rainfall, as well as long term average annual trends for evapotranspiration losses.

A ReFH boundary was set up, and populated with FEH Web Service catchment descriptors were imported for the SSSI catchment.

This boundary was generated using the following parameters:

- Overriding the ReFH2 design package value with the average Cini value determined from the gauged data;
- Using a random return period – 100 years in this instance; and
- Using a time step and duration recommended by ISIS – 4.25 hr duration and 0.25 hr time step.

The boundary calculates the flow hydrograph from the design rainfall profile, applying a loss factor to determine net rainfall, and convoluting the associated unit hydrograph to generate the design event quick/ surface runoff hydrograph. A separate baseflow component is then added to determine the full event hydrograph. The boundary enables volumetric analysis of rainfall and runoff from the catchment, thereby allowing an estimate of the percentage of surface water runoff that will reach the SSSI to be made.

Note that the return period and duration of the event have a limited impact on the loss percentage.

Rainfall-runoff volumetric analysis

In order to assess annual volumes of quick/surface runoff reaching the SSSI, the average loss percentage needed to be applied to the rainfall input volume. Daily total rainfall data recorded by the Coleshill rain gauge was used to estimate the average annual rainfall depth. This was then multiplied by the catchment area to calculate an estimate of average annual rainfall volume. Finally, the volume of surface water runoff was estimated by multiplying the average annual rainfall volume by the calculated percentage of surface water runoff (as detailed above).

Verification

The rainfall-runoff percentage and volumetric loss analysis was verified using daily flow data from the NRFA Cole at Coleshill river gauge (station number 28066). Based on the mean gauged daily flow record for this river gauge, the total volume of runoff was calculated for a random water year within the record. The Standard Average Annual Rainfall (SAAR) value applicable to the catchment upstream of the river gauge (686mm) was multiplied by the catchment area to get a typical annual rainfall volume input. Division of the annual runoff volume by the annual rainfall volume gave a similar surface water runoff percentage (approximately 20%), to that estimated using the method described above for the ungauged catchment draining to the SSSI.

Results

Loss analysis

Of particular interest is the change in surface water flow as a result of the construction of the road. The percentage of total rainfall that runs off the catchment as surface water flow was estimated by dividing the total volume of quick runoff by the total volume of rainfall, based on an example ‘design’ event as described above. This calculation illustrates that the percentage of total rainfall that contributes surface water to the SSSI is 25%.

Table 1: Calculation of loss percentage (based on average Cini and a 100-year, 4.25-hour design event)

	Area (km^2)	Total volume of rainfall (m^3)	Total volume of surface water runoff (m^3)	Total volume of rainfall contributing surface water to SSSI (%)
Existing catchment	0.28	10,883	2,671	25%

Rainfall-runoff volumetric analysis

An average annual rainfall of 785mm was estimated from the daily total rainfall recorded by the rain gauge located at Coleshill. The volume of surface water runoff was estimated by multiplying the average annual rainfall by the catchment area, and then by the calculated loss percentage, to determine the annual surface water runoff volume contributing to the SSSI.

Completing this calculation using the catchment area before and after construction of the road provided an estimation of the change in surface water runoff volume due to construction of the road over a water-year.

This analysis indicates that, based on average annual rainfall, potentially 11,800 m^3 of surface water may be lost through construction of the road over a year, as shown in Table 2. This equates to a 21% reduction in surface water runoff volume that will reach the SSSI.

Table 2: Average volume of surface water flow to the SSSI comparison following road development

	Area (km^2)	Total volume of rainfall contributing surface water to SSSI (%)	Average rainfall depth over a water year (mm)	Average rainfall volume over a water year (m^3)	Volume of surface water runoff over water year (m^3)
Before road	0.28	25	785	219,823	55,000
After road	0.22	25	785	172,718	43,200
Difference	0.06	-	-		11,800
Percentage difference	-21%	-	-		-21%

These calculations are based on the following assumptions or factors:

- All of the catchment area contributes surface water to the SSSI;
- The nearest, local gauged rainfall data (located at Coleshill, which is 7 km away from Bickenhill) provides a representative estimate of average annual rainfall;
- Any baseflow contribution made to the SSSI are relatively negligible in comparison to surface runoff; and
- Local variations in evapotranspiration rates do not significantly affect runoff volumes (as mentioned previously, the ReFH2 Calibration Utility tool does take evapotranspiration into consideration over the course of the water year, when estimating the initial soil moisture content (Cini)).

‘*Wet’ years and ‘dry’ years*

The same calculation was completed for ‘wet’ year and a ‘dry’ year, by identifying the annual rainfall of the wettest and driest years, amongst the gauged rainfall record.

The wettest water year in the record was identified as 2011-2012 with a total annual rainfall of 1435 mm.The driest water year in the record was identified as 2010-2011 with a total annual rainfall of 428 mm.

Table 2 and Table 3 demonstrate the change in surface water runoff based on the wettest and the driest water years on record respectively. In both wet and dry years, there is still a 21% reduction in surface water that will reach the SSSI following construction of the road. However, the volumetric contributions are different (this is controlled by the rainfall input only).

Table 2: Change in the volume of surface water during a representative wet water year

	Area (km^2)	Total volume of rainfall contributing surface water to SSSI (%)	Average rainfall depth over a water year (mm)	Average rainfall volume over a water year (m^3)	Volume of surface water runoff over water year (m^3)
Before road	0.28	25	1435	401,890	100,472
After road	0.22	25	1435	315,770	78,943
Difference	0.06	-	-		21,530
Percentage difference	-21%	-	-		-21%

Table 3: Change in the volume of surface water during a representative dry water year

	Area (km^2)	Total volume of rainfall contributing surface water to SSSI (%)	Average rainfall depth over a water year (mm)	Average rainfall volume over a water year (m^3)	Volume of surface water runoff over water year (m^3)
Before road	0.28	25	428	119,728	29,932
After road	0.22	25	428	94,072	23,518
Difference	0.06	-	-		6,414
Percentage difference	-21%	-	-		-21%

Conclusions

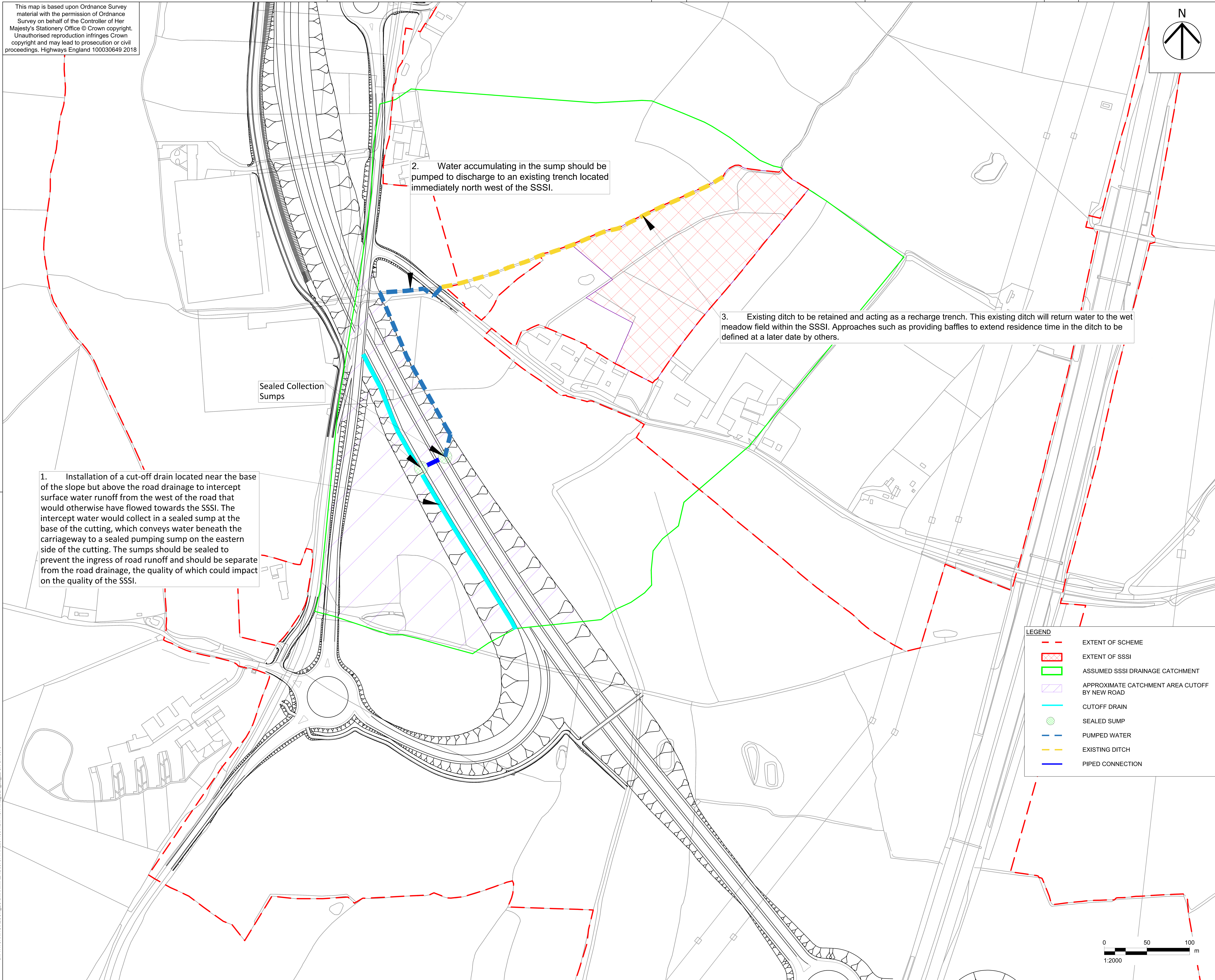
The analysis estimates that there will be a 21% reduction in surface water that will reach the SSSI following construction of the road over an average water year. This corresponds with the reduction on contributing catchment area. There may be some variation on this value associated with flow path accumulation variation within the original catchment area – more detailed modelling would be required to assess this further.

It is recommended that mitigation measures are implemented to minimise the impact of any reduction in surface water reaching the SSSI, once the new road scheme has been built.

Annex E: Pumped mitigation solution

Drawing Number:

HE551485-ACM-AGM-M42_SW_ZZ DR_SK-0075



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Revision Details	By / Check	Date	Suffix

Purpose of issue

FOR INFORMATION

Client
Highways England
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Two Colmore Square
38 Colmore Circus
B4 6BN

Working on behalf of
highways england

Project Title

M42 JUNCTION 6 IMPROVEMENT

Drawing Title

BICKENHILL MEADOWS SSSI SHADOWBROOK MEADOWS UNIT SKETCH PUMPING SOLUTION

Designed	Drawn	Checked	Approved	Date
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