High Speed Rail: HS2 Phase 2b Preferred Route

Sustainability Statement including Post Consultation Update

Appendix C4 – Water

A report by Temple-RSK for HS2 Ltd

TEMPLE

LEADERS IN ENVIRONMENT, PLANNING & SUSTAINABILITY.

RSK

November 2016

CONTENTS

1. INTRODUCTION

1.1.1. This report has been prepared to support the HS2 Phase 2b Sustainability Statement including Post Consultation Update report, which describes the extent to which the Government's preferred route for HS2 Phase 2b supports objectives for sustainable development. This document is a technical appendix which summarises the methodology for appraising water, and the key findings and conclusions that inform the Sustainability Statement main report. The Sustainability Statement places emphasis on the known key impacts only at this stage in the design, prior to commencing the Environmental Impact Assessment (EIA).

2. SCOPE AND METHOD

2.1. River diversions

Screening

2.1.1. The preferred route design has been appraised using the Geographic Information System (GIS) route alignment information alongside engineering plan and profile drawings. Using both, it is possible to identify locations where the route passes over or alongside watercourses at an acute angle to the direction of flow of a watercourse and lies above or close to the river channel. Each watercourse has been assigned a value based on the size of the receiving catchment and level of flood risk, as follows:

- **Major Watercourses**: Major watercourses are defined as those watercourses that have a catchment area of 50km^2 or greater.
- **Minor Watercourses and Cross Drainage**: Where catchment sizes are less than 50km^2, watercourses are defined as minor watercourses. However, special note is taken on an individual crossing basis where such watercourses are identified as either Environment Agency Main River or are associated with an area of flood risk as shown on the Flood Zone Maps (usually any watercourse with a catchment area of 4km^2 or greater).

2.1.2. The watercourses which may require diversions are presented in table format, together with a brief description of the potential issues. Minor watercourses would usually be conveyed across the route in a culvert of some description, and in most cases some degree of channel realignment would be expected which may incorporate small meanders or other ecological mitigation to compensate for adverse impacts of culverts on the Water Framework Directive (WFD) ecological status. In order to focus on areas where potentially greater work is required, the plan and profile drawings have been used to identify those watercourses where greater-than-usual river works are likely to be required.

Exclusions and assumptions

2.1.3. It is assumed that all diversions will be designed with sufficient capacity to convey the full peak flow during the predicted 1 in 100 year rainfall event, including the relevant increase to allow for climate change. It is noted that these allowances may require variation on a local basis due to the updated advice on climate change for planning purposes issued in February 2016[1].

[1] Environment Agency (2016). Flood risk assessments: climate change allowances

2.1.4. The analysis currently covers only the likely permanent impacts and risks of and to the preferred route. Additional temporary or semi-permanent complications and impacts may arise during construction but this is beyond the scope of appraisal at this stage of the design.

2.1.5. The methodology for classifying watercourse crossings in the Appraisal of Sustainability (AoS) is limited to high-level appraisals using flood zone mapping, the UK Digital River Network GIS database, Ordnance Survey mapping and approximate ground level estimates as presented in engineering long-sections. Using this approach only the most obvious non-compliant issues such as inverted siphons and drop-inlet culverts will be identified. More detailed assessment is likely to reveal alternative design solutions and other crossings which require design adjustments in order to ensure compliance with the relevant policy.

2.2. Groundwater

2.2.1. This report also provides a high-level screening assessment of the possible impacts of the preferred route on major groundwater abstractions, which includes all abstractions of more than 1,000m^3/day. The assessment considers the preferred route in the context of the geology, the relative position of the groundwater, the vertical alignment of the track (embankment, cut, at-grade, viaduct or tunnel) and the distance from the preferred route centre line to the abstraction point.

2.2.2. It is intended to provide advance warning of potential problems, to inform the detailed design process and to expose any major groundwater issues, which may require early engagement with regulating authorities or which might require long-term monitoring to establish a robust baseline.

2.2.3. Due to different levels of information for the potable abstractions and the non-potable abstractions, slightly different methods of appraisal were employed for each and these are set out below. They follow the same basic formula, namely to consider the structure of the preferred route (embankment, cut, at-grade, viaduct or tunnel), where possible, to identify the extent and depth of the aquifers from hydrogeological maps and publicly available borehole records. This information is then used to compile a high-level appraisal based on informed professional judgement and qualitative assessment.

Appraisal of potable abstractions

2.2.4. The difference between the potable abstractions and non-potable abstractions is that potable abstractions typically have associated groundwater Source Protection Zones (SPZ). Non-potable abstractions, for industrial or agricultural uses, have no mapped SPZs.

2.2.5. Potable abstraction data were obtained from the Environment Agency for all public water supply boreholes. For the purposes of this assessment, wherever the preferred route centre line passes below-ground level (in cut or tunnel) through defined SPZ1 or SPZ2, the associated abstraction has been appraised in detail. The Inner Zone (SPZ1) is defined as the 50-day travel time from any point below the water table to the abstraction with minimum radius of 50m, and the Outer Zone (SPZ2) is defined as a 400-day travel time with minimum radius of 250m or 500m from the abstraction, dependent on the size of the abstraction. These zones delineate areas where contaminating activities could cause pollution of the water supply. The closer the activity is to an abstraction, the greater the risk.

2.2.6. The assessment process includes: consideration of the size and importance of each abstraction, the likely geology and associated water table depth, the proximity and depth of the below-ground route, and the influence of any connected abstractions within the same catchment. Where the preferred route intersects with catchment SPZ3 (defined as the total catchment area), consideration has also been given to potential impacts on any connected abstractions.

Appraisal of non-potable abstractions

2.2.7. Non-potable abstraction data were obtained from the Environment Agency for all licensed abstractions with maximum allowable daily volumes greater than 1,000m^3/day. The locations of these boreholes were compared with the preferred route, with a 500m buffer either side. This 500m buffer was chosen as a reasonable nominal distance which coincides with the minimum radius of SPZ2 for any abstraction greater than 2000m^3/day. Any non-potable abstraction within 500m of the centre line of the preferred route was identified for further investigation.

2.2.8. All of these abstractions are of strategic importance for commercial, industrial and/or agricultural use. Whilst these abstractions do not necessarily yield the large quantities typical of such potable water supply abstractions, any interruption of this supply is likely to have implications for the industries which rely upon them.

2.2.9. Using GIS and the engineering plan and profile drawings of the preferred route, the likelihood of impacts of any below-ground works on the aquifer are considered as a first-pass appraisal to identify cases where there is unlikely to be an impact. Any abstractions within the 500m buffer which are not filtered out by this first-pass appraisal are then subjected to the same appraisal as for potable abstractions.

Exclusions and assumptions

2.2.10. This methodology relies on mapped Environment Agency SPZ and abstraction data available at the time of assessment, in addition to published geological mapping. While the accuracy of this approach is adequate for the purposes of a high-level appraisal required for the AoS, a more detailed assessment will be required at the next stage of design when an EIA will be required. Where accuracy of the method is considered to be insufficient or further detail is required to draw any meaningful conclusion, this is highlighted for further investigation.

2.2.11. It is assumed that standard best-practice construction techniques will be employed in order to protect groundwater resources from pollution, and that specific provision in this regard will be made clear in a construction waste management plan and construction method statements.

2.2.12. The analysis currently covers only the potential permanent impacts and risks to, and resulting from, the preferred route. Ancillary work, temporary and permanent construction and proposed mitigation will be assessed during the EIA stage, where groundwater risk assessments will be carried out as necessary for the protection of groundwater resources.

2.3. Floodplain crossings

Screening

2.3.1. The preferred route has been appraised using the GIS to determine where floodplain crossings occur, based on the location of Flood Zone 2. The length of each floodplain crossing (in terms of the length of line within Flood Zone 2) was then extracted.

Appraisal

2.3.2. A desk-based study was undertaken at each viaduct location to generate an understanding of the watercourse size and local importance together with likely flood flow mechanics using OS mapping, the Environment Agency Flood Zone Maps and the Flood Estimation Handbook Web Service.

2.3.3. Flood water levels for a 1,000-year event were estimated by comparing the outline of Flood Zone 2[2] with the Digital Terrain Model (DTM) by identifying the location of the flood zone edge on the profile drawing and taking the ground level at that point. This was then subject to a "sense check" by comparing the outline with the DTM contours on the plan drawing, and the water level rounded up to the nearest integer. At some locations, design flood water levels from flood risk mapping have been provided by the Environment Agency from previous assessments. Where available, these are used to define the flood water level.

2.3.4. Aerial and local photography was studied to determine existing floodplain flow restrictions and the location of man-made embankments, flood defences and other infrastructure.

Exclusions and assumptions

2.3.5. The analysis currently covers only the likely permanent impacts and risks to, and resulting from, the preferred route. The impact of any ancillary works as well as temporary and permanent construction impacts as a result of the preferred route will be considered, alongside options for mitigation, as part of the EIA.

2.4. Stations assessment

2.4.1. The location and extent of each station or depot was considered relative to watercourse and flood zone locations using the GIS alignment and station information. Each station was assessed and potential issues identified against the following considerations:

- Watercourse crossings – any instances where the footprint of the station falls directly over a watercourse would result in the need, as a minimum, to culvert the watercourse, and potentially result in the need for watercourse diversions;
- Watercourse diversions – in some cases, minor diversions to watercourses can prevent the need for any culverting of a watercourse. Where it is not possible to culvert a watercourse beneath the station structure, or to raise the station onto a viaduct, diversion would be inevitable;
- Flood flow obstruction – where the footprint of the station falls within the functional floodplain of a watercourse (i.e. across a flood flow path, usually defined in the absence of more detailed information as the extent of the 1 in 20 year return period flood), flood flow obstructions may result in significant increases in severity and frequency of flooding upstream; and
- Flood storage displacement – any built volume within the floodplain will occupy floodplain storage volume, which results in local increases to flood water levels during given flood events.

Exclusions, assumptions and limitations

2.4.2. Inevitably given the strategic nature of the AoS process, the appraisal is relatively high level and should not be confused with a full and detailed EIA. The level of detail of the appraisal is commensurate with the data available and the strategic nature of the preferred route.

2.4.3. The appraisal is limited to the information available on each station or depot design in its current form, which generally consists of operational and construction outlines only. It is therefore assumed that the operational outline is the extent of solid construction, except where it is clear that an area is not part of the building.

---

[2] Flood zones refer to the probability of river and sea flooding, ignoring the presence of defences, where Flood Zone 1 comprises land assessed as having a low probability of flooding (<0.1%), Flood Zone 2 comprises land assessed as having a medium probability of flooding (0.1 – 1%) and Flood Zone 3 comprises land assessed as having a high probability of flooding (>1%).

3. RIVER DIVERSIONS FINDINGS

3.1.1. At the EIA stage, any potential river diversions that remain in the design will be subject to a detailed assessment including, where relevant, hydraulic modelling to determine the measures needed to meet legal and planning policy standards. Where diversions are required, they will be undertaken in accordance with the usual requirements for Main River diversions, as specified by the Environment Agency. Opportunities for environmental enhancement will also be explored, particularly in cases where there may be opportunities to improve the WFD status in line with the 2027 targets.

3.1.2. Watercourse diversions for both the eastern and western legs are summarised in the following sections and listed in **Table 3-1 – 3-4**. These tables list major watercourses, sensitive minor watercourses (i.e. minor watercourses with nearby sensitive receptors) and minor watercourses.

3.1.3. The western leg comprises approximately 82km of new railway, including the mainline route section from Crewe to Golborne (HSM10B, HSM12, HSM21, HSM22 and HSM26) and a spur off the mainline into a new station at Manchester Piccadilly (HSM28).

3.1.4. The eastern leg comprises approximately 198km of new railway, including the mainline route section from Marston to Altofts (HSL01, HSL06, HSL09A, HSL09B, HSL12, HSL13A, HSL13B, HSL14, HSL15A, HSL16, HSL17A and HSL17B,) and a spur off the mainline into Leeds station (HSL21 and HSL22_31). The eastern leg also includes a connection onto the existing rail network south of Sheffield.

3.2. Western leg

3.2.1. In total, the western leg would incorporate 75 separate watercourse and canal crossings, comprising 11 major watercourses, 59 minor watercourses and 5 currently navigable canals. Based on the existing design, the need for permanent diversions to two major rivers, the River Dane and the Red Brook is envisaged at this stage, as well as nine minor watercourse diversions, including Waterless Brook, Holcroft Lane Brook, Coffin Lane Brook and Timperley Brook, which are defined by the Environment Agency as Main Rivers. Each watercourse diversion is numbered and presented in **Figure 10-1**.

3.2.2. The assessment notes that there is a potential diversion of the River Medlock, which is a major watercourse, at Manchester Piccadilly station. This is covered in the station assessment, **Section** Error! Reference source not found..

3.3. Eastern leg

3.3.1. In total, the eastern leg would incorporate a total of 283 separate watercourse and canal crossings, comprising 19 major watercourse crossings, 253 minor watercourse crossings, 7 navigable watercourse crossings and 4 formerly navigable watercourse crossings which may require safeguarding for future restoration. Permanent diversion of 35 minor watercourses along the preferred route eastern leg, including one Main River, the Bramcote Brook, are envisaged at this stage. Each watercourse diversion is numbered and presented in **Figure 10-2** to **Figure 10-5**.

3.3.2. The assessment notes that there is one diversion on the River Erewash, a major river, at East Midlands Hub station. Watercourse diversions are covered in the station assessment, **Section** Error! Reference source not found.. In addition, there are potential diversions of two minor atercourses within the boundary of New Crofton Rolling Stock Depot. This is covered in the depots assessment, **Section** Error! Reference source not found..

Table 3-1 – Major and sensitive minor watercourse diversions, straightening and channel works for the western leg

Route section	Reference no. in figure	Watercourse Name	Catchment Size (km^2)	Assumed Crossing Type	Design Informative
HSM10 (Mainline route)	1 (Figure 10-1)	River Dane (major watercourse) [1]	392	Viaduct	Placement of viaduct piers could potentially be engineered to avoid major channel works, however, there will be shadowing of the watercourse and potential flood risk impacts due to 1km viaduct parallel to flood flow direction.
HSM10 (Mainline route)	2 (Figure 10-1)	Waterless Brook (Main River) [2]	36	Viaduct	Approximately 100m of channel lies directly beneath viaduct footprint.
HSM21 (Mainline route)	3 (Figure 10-1)	Red Brook (major watercourse) [3]	50	Viaduct	Approximately 50m of channel lies directly beneath viaduct footprint. Placement of viaduct piers could potentially be engineered to avoid major channel works.
HSM21 (Mainline route)	4 (Figure 10-1)	Holcroft Lane Brook (Main River) [4]	1	Culvert	Approximately 500m of channel, including entire extent of Flood Zones 2 and 3, are obscured by the embankment footprint. Channel and floodplain diversion and remodelling would be required.
HSM22 (Mainline route)	5 (Figure 10-1)	Coffin Lane Brook (Main River) [5]	2	Culvert	Approximately 50m of meandering channel lies within the embankment footprint. The crossing is immediately downstream of the existing West Coast Main Line culvert, which could be extended, however, restoration of the watercourse may be required.
HSM28 (Manchester spur)	6 (Figure 10-1)	Timperley Brook (Main River) [6]	2	Inverted Siphon	The crossing at the Manchester Airport station would remove a substantial length of meandering channel at this location. Current plans for management of the watercourse are unknown and it is uncertain whether a satisfactory engineering and environmental solution can be found. (More detail in the station assessment, Section 6.1)

Table 3-2 - Minor watercourse and cross drainage diversions, straightening and channel works for the western leg

Route section	Reference no. in figure	Watercourse Name	Catchment Size (km^2)	Assumed Crossing Type	Design Informative
HSM10 (Mainline route)	7 (Figure 10-1)	Gad Brook [7]	6	Viaduct	Approximately 100m of channel lies directly beneath viaduct footprint.
HSM10 (Mainline route)	8 (Figure 10-1)	Witton Brook [8]	0.6	Viaduct	Approximately 100m of meandering channel lies directly beneath viaduct footprint.
HSM28 (Manchester spur)	9 (Figure 10-1)	Agden Brook Tributary [9]	0.7	Culvert	Approximately 100m of channel lies beneath the embankment footprint, but is relatively straight and an aligned culvert and diversion should be acceptable.
HSM28 (Manchester spur)	10 (Figure 10-1)	Birkin Brook Tributary [10]	0.4	Drop inlet culvert	Very minor realignment at issues of watercourse, however there is a culvert outfall in this location which may complicate the crossing.
HSM28 (Manchester spur)	11 (Figure 10-1)	Middle House Brook Tributary [11]	0.6	Diversion	Approximately 100m of channel lies beneath the embankment footprint. The diversion will remove the need for a culvert at this location.

Table 3-3 - Major and sensitive minor watercourse diversions, straightening and channel works for the eastern leg

Route section	Reference no. in figure	Watercourse Name	Catchment Size (km^2)	Assumed Crossing Type	Design Informative
HSL06 (Marston to Kegworth)	1 (Figure 10-2)	Bramcote Brook (Main River)	10	Culvert	Viaduct is immediately north of the crossing location, and spans the width of the flood zones. Realignment of the river to pass under the viaduct, especially if restoration is incorporated into the design, would potentially be beneficial, rather than detrimental, to the watercourse.

Table 3-4 Minor watercourse and cross drainage diversions, straightening and channel works for the eastern leg

Route Section	Reference no. in figure	Watercourse Name	Catchment Size (km^2)	Assumed Crossing Type	Design Informative
HSL01 (Marston to Kegworth)	2 (Figure 10-2)	Bodymoor Heath Drain	0.5	Viaduct	Approximately 100m of channel lies directly under the viaduct footprint, however, minor diversion would remove crossing entirely.
HSL01 (Marston to Kegworth)	3 (Figure 10-2)	Thistlewood Brook	3	Viaduct	Approximately 100m of channel lies directly under the viaduct footprint.
HSL01 (Marston to Kegworth)	4 (Figure 10-2)	Thistlewood Brook	3	Diversion	Diversion around east-side embankment toe to viaduct, approximately 100m in length, would remove need for culvert.
HSL01 (Marston to Kegworth)	5 (Figure 10-2)	Thistlewood Brook	0.7	Diversion	Approximately 300m of channel lies beneath the embankment footprint. Overland flow can be collected along west-side embankment toe and discharged to the viaduct.
HSL06 (Marston to Kegworth)	6 (Figure 10-2)	Duck Lake Stream	<0.5	Inverted Siphon	Approximately 100m of channel lies beneath the embankment footprint. There is also insufficient room for a culvert at the crossing location. Watercourse appears to feed ponds downstream, so diversion along the west-side to prevent the crossing would not be recommended.
HSL06 (Marston to Kegworth)	7 (Figure 10-2)	River Mease Tributary	<0.5	Embankment	Approximately 200m of the watercourse lies beneath the embankment footprint, however, approximately 100m of this is below ground or in culvert. Diversion along the east-side would remove the need for a culvert crossing
HSL06 (Marston to Kegworth)	8 (Figure 10-2)	Cole Orton Brook Tributary	<0.5	Diversion	Approximately 200m of the watercourse lies beneath the embankment footprint. Watercourse appears to be a cut-off drain associated with local earthworks, diversion should be relatively straightforward.
HSL09 (Marston to Kegworth)	9 (Figure 10-2)	Westmeadow Brook Tributary	2	Culvert	Approximately 50m of channel lies directly under embankment footprint. Watercourse is relatively straight, and a perpendicular culvert and upstream/downstream realignment should be relatively straightforward.
HSL12 (Kegworth to Heath)	10 (Figure 10-3)	Erewash Canal	n/a	Viaduct	Difficult to avoid placing viaduct piers in the canal due to an overlap of approximately 150m. Space for realignment is limited by Ilkeston Road, however, in order to avoid obstructing navigation, the canal will require realignment, likely to the western side.
HSL13 (Kegworth to Heath)	11 (Figure 10-3)	River Erewash Tributary	2	Diversion	Approximately 300m of the watercourse lies beneath the embankment footprint. Diversion along the west-side would remove the need for additional crossing provisions.

Route Section	Reference no. in figure	Watercourse Name	Catchment Size (km^2)	Assumed Crossing Type	Design Informative
HSL13 (Kegworth to Heath)	12 (Figure 10-3)	Beauvale Brook	2	Culvert	Approximately 200m of the watercourse and an on-line fishing pond lie beneath the embankment footprint. Crossing is immediately upstream of the existing M1 culvert for the watercourse, which could be extended, however, restoration of the watercourse is likely to be required.
HSL13 (Kegworth to Heath)	13 (Figure 10-3)	Maghole Brook Tributary	<0.5	Diversion	Approximately 200m of the watercourse lies beneath the embankment footprint, however, the watercourse could be diverted along the east-side to the viaduct immediately south of the crossing.
HSL13 (Kegworth to Heath)	14 (Figure 10-3)	Maghole Brook Tributary	<0.5	Diversion	Approximately 200m of the watercourse lies beneath the embankment footprint, however, the watercourse could be diverted to the south along the west-side to avoid the need for provision of a crossing.
HSL13 (Kegworth to Heath)	15 (Figure 10-3)	Nunn Brook Tributary	0.6	Culvert	Approximately 200m of the watercourse lies beneath the embankment footprint. The watercourse meanders within this area and diversion would need to include restoration features.
HSL15A	16 (Figure 10-3)	River Rother Tributary	2	Diversion	Approximately 400m of the watercourse lies beneath the embankment footprint. This is the assumed route of the watercourse from the Environment Agency records, however the watercourse is in culvert, and not visible on the Ordnance Survey mapping. The culvert may require diversion, or could be opened into a surface watercourse.
HSL13 (Heath to Barnburgh)	17 (Figure 10-4)	The Goit	2	Viaduct	Two separate diversions of The Goit would be required. To the south of the viaduct, careful placement of viaduct piers could avoid the need to divert, though the watercourse would still experience significant shadowing. To the north of the viaduct, approximately 300m of the watercourse lies directly beneath the viaduct footprint.
HSL13 (Heath to Barnburgh)	18 (Figure 10-4)	The Goit			
Staveley Depot Spur	19 (Figure 10-4)	Hawke Brook	11	Culvert	Approximately 100m of the watercourse lies beneath the embankment footprint. However, the route lies along an existing dismantled railway embankment, and the required diversion would be a minor extension of the existing realignment.
HSL14 (Heath to Barnburgh)	20 (Figure 10-4)	County Dike	0.5	Culvert	Three separate diversions of County Dike would be required. The valley is steep, and it is unlikely to be feasible to divert along one side only though it may be possible to divert along both sides subject to the natural fall of the landscape. In this case, the southerly two diversions would carry the watercourse along the embankment toe north to the viaduct. However, there would not be sufficient space (when considering associated groundworks) to maintain flow path lengths and watercourse quality, and substantial mitigation may be required at the viaduct. The viaduct crossing passes through Woodall Pond, and directly over approximately 100m of channel downstream (north) of the pond, which would require diversion.
HSL14 (Heath to Barnburgh)	21 (Figure 10-4)	County Dike	0.5	Culvert	
HSL14 (Heath to Barnburgh)	22 (Figure 10-4)	County Dike	0.6	Viaduct	

Route Section	Reference no. in figure	Watercourse Name	Catchment Size (km^2)	Assumed Crossing Type	Design Informative
HSL14 (Heath to Barnburgh)	23 (Figure 10-4)	Ulley Brook Tributary	<0.5	Inverted Siphon	Approximately 100m of the watercourse lies beneath the embankment footprint. Further investigation is required to determine the route and importance of this watercourse.
HSL14 (Heath to Barnburgh)	24 (Figure 10-4)	Morthen Brook	1	Viaduct	Approximately 100m of the watercourse lies directly beneath the viaduct footprint, however lies between the two spurs of the M1/M18 northern junction. Watercourse already heavily modified, however diversion could be difficult.
HSL16 (Heath to Barnburgh)	25 (Figure 10-4)	St. Helen's Spring	0.8	Culvert	Approximately 300m of the watercourse lies beneath the embankment footprint.
HSL16 (Barnburgh to Church Fenton)	26 (Figure 10-5)	Frickley Brook	4	Viaduct	Approximately 100m of the watercourse lies directly beneath the viaduct footprint.
HSL16 (Barnburgh to Church Fenton)	27 (Figure 10-5)	Howell Beck	2	Culvert	Approximately 100m of the watercourse lies beneath the embankment footprint. The watercourse is meandering within a steep valley and specific restoration may be required.
HSL16 (Barnburgh to Church Fenton)	28 (Figure 10-5)	Hague Hall Beck Tributary	0.5	Drop Inlet Culvert	Approximately 100m of the watercourse lies beneath the embankment footprint. The valley is relatively steep, and the embankment clearance is limited at the upstream extent of the crossing.
HSL17 (Barnburgh to Church Fenton)	29 (Figure 10-5)	Red Beck Tributary	<0.5	Culvert	Approximately 400m of the watercourse lies beneath the embankment footprint. Watercourse appears to be artificial, though more investigation is required. Diversion along the east-side may remove the need for additional crossings.
HSL17 (Barnburgh to Church Fenton)	30 (Figure 10-5)	Red Beck	0.7	Culvert	Approximately 300m of the watercourse lies beneath the embankment footprint, immediately upstream of an underground or culverted section of watercourse. Diversion along the east-side, if feasible, may remove the need for additional crossings.
HSL17 (Barnburgh to Church Fenton)	31 (Figure 10-5)	Oulton Beck Tributary	<0.5	Culvert	Approximately 200m of the watercourse lies beneath the embankment footprint. Diversion north along the west-side to the viaduct may be feasible.

Route Section	Reference no. in figure	Watercourse Name	Catchment Size (km^2)	Assumed Crossing Type	Design Informative
HSL17 (Barnburgh to Church Fenton)	32 (Figure 10-5)	River Aire Tributary	1	Culverts	Approximately 300m of the watercourse lies beneath the embankment footprint. Diversion along the east-side would avoid the need for crossings, however the valley is steep and this may not be feasible. Mitigation for lost flow length and meanders will be required.
HSL17 (Barnburgh to Church Fenton)	33 (Figure 10-5)	River Aire Tributary	0.7	Culvert	Approximately 300m of the watercourse lies beneath the embankment footprint. Mitigation for lost flow length and meanders will be required.
HSL17 (Barnburgh to Church Fenton)	34 (Figure 10-5)	Cock Beck Tributary	2	Diversion	Approximately 100m of the watercourse lies beneath the embankment footprint. Diversion along the east-side would avoid the need for additional crossing provision.
HSL17 (Barnburgh to Church Fenton)	35 (Figure 10-5)	Stream Dike Tributary	<0.5	Culvert	Approximately 100m of the watercourse lies beneath the embankment footprint. Minor diversion north to the viaduct along the west-side embankment toe would be feasible.

4. FLOODPLAIN CROSSINGS FINDINGS

4.1.1. A high-level review of floodplain crossings has been completed for the preferred route based on the design at this stage of scheme development. At the next stage of design, a detailed assessment of all affected water bodies will be undertaken as part of the EIA, with due consideration given to requirements of the WFD, the NPPF, local byelaws, riparian ecology and land ownership.

4.2. Western leg

Floodplain crossings

4.2.1. **Table 4-1** presents a summary of the findings of the floodplain crossing analysis for the preferred route from Crewe into Manchester and to the West Coast Main Line (WCML). The crossings are presented in chainage order (as detailed in the engineering plan and profile drawings) from south to north along the main route, with the Manchester city centre spur listed from west to east. Design constraints and nearby flow constrictions are listed, together with a brief summary of potential impacts, as well as the potential effects of alternative designs. Each floodplain crossing is numbered and presented in **Figure 10-6**.

4.2.2. In addition to those listed below, it is noted that an indicative vent shaft location on the tunnelled approach into Manchester is within the Flood Zone 3 extent of the Baguley Brook in the Northenden area.

4.3. Eastern leg

Floodplain crossings

4.3.1. **Table 4-2** presents a summary of the findings of the floodplain crossing analysis for the preferred route from West Midlands to Leeds and to the ECML. The viaducts are presented from south to north in chainage order (as detailed in the engineering plan and profile drawings) along the main route, with the Leeds city centre spur listed from east to west. Each floodplain crossing is numbered and presented in **Figure 10-7** to **Figure 10-10**.

4.3.2. Design constraints and nearby flow constrictions are listed, together with a brief summary of potential impacts, as well as the potential effects of alternative designs.

Table 4-1 - Summary of floodplain crossing findings for the western leg

Watercourse Name	Reference no. in figure	Floodplain Crossing Length (m)	Design Constraints	Upstream Restriction	Downstream Restriction	Design Informative	Other considerations
River Dane (HSM10 – Mainline route)	1 (Figure 10-6)	880 (Viaduct 1160)	Trent & Mersey Canal	None	None	Limited flood flow restrictions in area. Steep sided valley at southern edge of floodplain. North of channel crossing viaduct is away from channel and to the edge of the floodplain. Viaduct is parallel to flood flow direction. Scour and localised flood flow obstruction may be a factor.	Should support piers be required within the River Dane channel, consideration of the impact on flow velocities under the WFD may be required.
Puddinglake Brook (HSM10 – Mainline route)	2 (Figure 10-6)	160	Trent & Mersey Canal	None	Whatcroft Lane, Trent & Mersey Canal	No vulnerable uses in floodplain within the vicinity of the crossing. Relatively wide flat floodplain for small watercourse, appears to be backing up behind Trent & Mersey Canal.	Detailed WFD assessment may be necessary if culverting or diversion of the brook is required.
Gad Brook (HSM10 – Mainline route)	3 (Figure 10-6)	70 (centre line) 170 toe to toe	None	Davenham Road and King Street	Trent & Mersey Canal	Viaduct width of 170m required due to angle of crossing; embankments at either end abut the floodplain. Relatively constrained floodplain at this point but reasonable space for replacement flood storage if necessary. Peak Tree Farm Cottages close to floodplain within 400m upstream, so impacts on flood risk will need careful consideration.	If embankment with culvert option is pursued, a detailed WFD assessment may be required to ensure no detrimental impact on River Dane downstream. Diversion at viaduct, so it is likely that WFD assessment will be required anyway.
Wade Brook (HSM10 – Mainline route)	4 (Figure 10-6)	40 (centre line) 100 upstream (Viaduct 270)	A556	Pipe line	Lostock Gralam Bridge	HS2 crossing relatively straightforward and coincides with existing A556 crossing. Potential for flood risk impacts to Fieldhouse Farm upstream and The Bungalow downstream as closest sensitive flood risk receptors.	A556 realignment will need to be factored into impact assessment.
Peover Eye	5 (Figure 10-6)	30 (Peover Eye)	A556, Linnards Lane	None	None	A556 crossing of Peover Eye upstream appears to be relative flow	Opportunities may arise to contribute positively to riverine

Watercourse Name	Reference no. in figure	Floodplain Crossing Length (m)	Design Constraints	Upstream Restriction	Downstream Restriction	Design Informative	Other considerations
Smoker Brook (HSM10 – Mainline route)		80 (S.B.) (Viaduct 1170)				constriction. Viaduct clearance and position relatively straightforward, however associated road diversions will need careful consideration with two river confluences in close proximity.	ecology and assist in achievement of future WFD status.
Waterless Brook (HSM10 – Mainline route)	6 (Figure 10-6)	80	Parallel to Channel	Waterless Bridge	Pickmere Lane	Reasonably constrained floodplain with few sensitive receptors.	Detailed WFD assessment will be necessary since diversion of the brook is required.
River Bollin and Old Bollin Brook (HSM12 – Mainline route)	7 (Figure 10-6)	340	Disused Railway	None	Disused railway embankment	Wide floodplain with floodplain flow restriction downstream. No vulnerable uses in floodplain in crossing vicinity.	Ground levels suggest viaduct may be 4.1m above flood water level and would obstruct flood flows at the peak, though a slender viaduct deck would suffice to remove this potential effect. Consideration of the WFD may be required, should culverting or diversion be required as a result of embankment introduction. Opening up the Old Bollin Brook culvert may contribute positively to WFD.
Warburton Park Brook (HSM21 – Mainline route)	8 (Figure 10-6)	70 (Viaduct 180)	None	None	Warburton Park access track embankment	Floodplain heavily influenced by Manchester Ship Canal. Flooding arising from downstream, or slow moving floodwaters.	Detailed WFD assessment may be necessary if option is taken to culvert the brook.
Red Brook and Manchester Ship Canal (HSM21 – Mainline route)	9 (Figure 10-6)	310 (Viaduct 1320)	MSC Clearance Hollins Green	None	None	No scope to shorten due to other constraints. Viaduct design will be dominated by required clearance and pier placement for the Manchester Ship Canal.	Diversion of the Red Brook means that a detailed WFD assessment is likely to be required.

Watercourse Name	Reference no. in figure	Floodplain Crossing Length (m)	Design Constraints	Upstream Restriction	Downstream Restriction	Design Informative	Other considerations
Holcroft Lane Brook (HSM21 – Mainline route)	10 (Figure 10-6)	415	Lakes, landfill and Taylor Industrial Estate	None	Dismantled railway	No significant scope to improve crossing without changing horizontal alignment.	Embankment is along base of valley, and would remove 415m of watercourse and floodplain. Floodplain and watercourse diversion and regrading will be required. WFD considerations could be significant.
Agden Brook (HSM28 – Manchester spur)	11 (Figure 10-6)	60	None	None	None	Constrained floodplain and limited space for replacement flood storage, as well as proximity of Millington Hall suggest limited potential to shorten viaduct.	
Blackburn's Brook and Birkin Brook (HSM28 – Manchester spur)	12 (Figure 10-6)	80 (Blackburn’s) 140 (Birkin) (Viaduct 390)	Rostherne Mere	None	M56 embankment and culvert	Flood flows restricted downstream by M56. Steep sided valleys. Detailed modelling would be required to understand flooding mechanisms. Birkin House is a sensitive receptor upstream.	Ground levels suggest viaduct may be 3.4m above flood water level and would obstruct flood flows at the peak. Detailed modelling required to quantify effect and mitigation.
River Bollin (HSM28 – Manchester spur)	13 (Figure 10-6)	60 (Viaduct 125)	None	None	M56	Well defined valley with no sensitive receptors in the immediate vicinity. Potential to shorten subject to mitigation.	WFD assessment would be required.

Table 4-2 - Summary of floodplain crossing findings for the eastern leg

Watercourse Name	Reference no. in figure	Floodplain Crossing Length (m)	Design Constraints	Upstream Restriction	Downstream Restriction	Design Informative	Other considerations
River Tame (HSL01 – Marston to Kegworth)	1 (Figure 10-7)	1020 (Viaduct 2240)	Bodymoor Heath Road	None	M42 Embankment (crossing location)	M42 Embankment creates barrier to floodplain flow. Preferred HS2 crossing immediately upstream. Replacing viaduct with embankment mirroring M42 embankment would not create additional floodplain obstructions.	Change to embankment may result in a need to divert minor tributary. Detailed WFD assessment may be required if culverting or diversion of River Tame is necessary. Diversion may present opportunities to enhance current 'poor' ecological status.
Thistlewood Brook (HSL01 – Marston to Kegworth)	2 (Figure 10-7)	270	Watercourse Channel	Tamworth Road (crossing location)	None	Narrow floodplain, with route running parallel to valley bottom. An embankment would obliterate the watercourse and completely fill the majority of the floodplain. There is vulnerable development nearby (Kingsbury). Limited scope for floodplain compensation.	
River Anker and Bramcote Brook (HSL06 – Marston to Kegworth)	3 (Figure 10-7)	420 (Viaduct 900)	WCML and Linden Lane	Linden Lane, Railway Embankment	M42 Embankment	M42 Embankment creates barrier to floodplain flow. Preferred HS2 crossing immediately upstream. Replacing viaduct with embankment mirroring M42 embankment would not create additional floodplain obstructions.	The viaduct needs to fully cross the Bramcote Brook to avoid any channel or confluence works. Placement of viaduct piers will be critical to avoiding watercourse impacts under the WFD.
Bramcote Brook (HSL06 – Marston to Kegworth)	4 (Figure 10-7)	310	None	M42 Embankment	None	M42 embankment creates barrier to flow upstream.	Change to embankment would result in the need to culvert Bramcote Brook and detailed WFD assessment may be required.

Watercourse Name	Reference no. in figure	Floodplain Crossing Length (m)	Design Constraints	Upstream Restriction	Downstream Restriction	Design Informative	Other considerations
River Mease and Duck Lake Stream (HSL06 – Marston to Kegworth)	5 (Figure 10-7)	510 (Viaduct 880)	Atherstone Road, Clay Pits	None	None	Floodplain is a confluence between River Mease and Duck Lake Stream.	River Mease is a SAC and impacts, including mitigation and all temporary effects, will need to be minimised.
Gilwiskaw Brook (HSL06 – Marston to Kegworth)	6 (Figure 10-7)	40	None	A42	Mill Street	Though downstream of flow restriction from A42, floodplain widens immediately. Downstream SAC and Packington residential area means no-tolerance approach to impacts is required.	WFD and Habitat Regulations Assessment will be required, given the downstream SAC.
Ramsley Brook (HSL06 – Marston to Kegworth)	7 (Figure 10-7)	40 (Viaduct 170)	Dismantled Railway, Cloud Hill Quarry	Dismantled Railway Culvert	Stocking Lane	Ramsley Brook passes through a dismantled railway line culvert at the crossing location. Impact of HS2 crossing would be minimal, though opening the culvert may present additional challenges. No significant vulnerable receptors within the floodplain, with the exception of Cloud Hill Quarry buildings which are likely to be demolished.	There may be WFD implications to opening up the culvert, though this may benefit the stream quality in the long term. Alternatively, there may be potential to shorten the viaduct substantially due to the pre-existing restriction.
Diseworth Brook (9) and Westmeadow Brook (8) (HSL09 – Marston to Kegworth)	8,9 (Figure 10-7)	30 (Viaduct 680)	The Green, M1	A42 Culvert	M1 Culvert	No sensitive receptors between the M42 and M1 flow restriction, and impact is therefore likely to be minimal. However, viaduct design is likely to be dictated by M1 crossing.	Also minor floodplain incursions south of this point on Westmeadow Brook, though no floodplain crossings. Obstruction minimal.

Watercourse Name	Reference no. in figure	Floodplain Crossing Length (m)	Design Constraints	Upstream Restriction	Downstream Restriction	Design Informative	Other considerations
River Soar (12), inc Lockington Brook (10), Long Land Farm Ditch (11) and Village Drain (13) (HSL09 – Kegworth to Heath)	10,11,12,13 (Figure 10-8)	3060 (Viaduct 3240)	A453, Local Roads, Existing Railway, River Channels	A453 Embankment	None	Strong interactions between Soar and Trent floodplains. Complex network of tributaries. Floodplain well confined between high embankments (M1, A453, Melbourne Line railway). Detailed 2D hydraulic modelling required to understand flooding mechanisms.	Diversion of Lockington Brook may be required if converting design to embankment at this location. Detailed WFD assessment may therefore be required to ensure no detrimental impact to Lockington Brook or to River Soar downstream.
River Trent (14), inc New Sawley Brook (15) and Golden Brook (16) (HSL09 – Kegworth to Heath)	14,15,16 (Figure 10-8)	4470 (Viaduct 4640)	Trent Flood Defences, Midland Main Line and other railways, Cranfleet Cut, Trent Meadows, New Sawley Pumping Station, Urban Extent	Midland Mainline Embankment	None	South of Midland Main line Crossing at Long Eaton Potential to shorten viaduct with sections of embankment due to upstream floodplain flow restrictions, though hydraulic modelling would be required to determine extent of impact and mitigation required. North of Midland Mainline Crossing at Long Eaton Area is heavily built up with sensitive receptors on both sides of the line all within the floodplain. The exact flooding mechanism is uncertain, although the Erewash Valley Line may restrict functional flows. No space for floodplain compensation for built volume.	Provided that all structures are clear-span, implications on the WFD should be minimal. However should support piers be necessary within the River Trent, detailed WFD assessment may be required. For more detail, see East Midlands Hub station assessment, Section 8.1.

Watercourse Name	Reference no. in figure	Floodplain Crossing Length (m)	Design Constraints	Upstream Restriction	Downstream Restriction	Design Informative	Other considerations
River Erewash (HSL12 – Kegworth to Heath) (For crossings of River Erewash in the East Midlands Hub vicinity, see East Midlands Hub station assessment Section 8.1)	17 (Figure 10-8)	1360 (Viaduct 1150)	Erewash Canal, Erewash Valley Railway	None	Erewash Valley Railway (crossing location)	Upstream of existing restriction to floodplain flows. Very little space for floodplain compensation therefore built volume within floodplain needs to be minimised. Vulnerable residential development within the floodplain upstream: may need to provide flood defences. Northern section of viaduct required to cross railway and canal.	Realignment of Erewash Valley railway and Erewash Canal will also affect local flood risk. For more detail, see East Midlands Hub station assessment Section 8.1.
River Erewash (HSL13 – Kegworth to Heath)	18 (Figure 10-8)	770 (Viaduct 1510)	Erewash Canal, M1	M1 - to be diverted	Local Road Crossing	Proposed viaduct should replicate existing M1 embankment as far as possible to prevent increasing flood risk downstream. Detailed 2D hydraulic modelling is likely to be required.	Realignment of M1 will also affect local flood risk. Any diversion required to facilitate crossings would need detailed assessment under the WFD.
River Erewash (HSL13 – Kegworth to Heath)	19 (Figure 10-8)	80 (Viaduct 440)	Mineral Railway	Mineral Railway Culvert	M1 Culvert	River Erewash passes through a culvert in the disused branch of the Mineral Railway immediately upstream of the HS2 viaduct crossing. Impact of HS2 crossing would be minimal, though opening the culvert may present additional challenges. No significant vulnerable receptors within the floodplain in the vicinity.	There may be WFD implications to opening up the culvert, though this may benefit the stream quality in the long term. Alternatively, there may be potential to shorten the viaduct substantially due to the pre-existing restriction.
Normanton Brook (HSL13 – Kegworth to Heath)	20 (Figure 10-8)	120	None	Culvert of former Derbyshire Line embankment	None	Flood zone outline does not appear to match contours on ground model. It's likely that this viaduct could be significantly shortened, if required, subject to more detailed investigation.	Spur junction at this location means multiple crossings of the watercourse and there may be shadowing implications.

Watercourse Name	Reference no. in figure	Floodplain Crossing Length (m)	Design Constraints	Upstream Restriction	Downstream Restriction	Design Informative	Other considerations
Stainsby Brook (HSL13 – Heath to Barnburgh)	21 (Figure 10-9)	60 (Viaduct 150)	Mill Lane	Brookside Bridge	M1 Culvert	Width of viaduct is constrained by other factors, however proximity of upstream and downstream constrictions to flow indicate that a shorter viaduct or culvert would be acceptable with limited additional flood flow impact.	There may be WFD implications to using a culvert, though the M1 culvert downstream would be a substantial factor in the assessment.
The Goit (HSL13 – Heath to Barnburgh)	22,23 (Figure 10-9)	460 (Viaduct 540)	Dismantled Railway, former workings	None	None	The floodplain crossing is at the edge of the River Doe Lea floodplain, rather than an independent floodplain associated with The Goit. However, there is still potential to displace flood water and replacement flood storage may be required.	Detailed WFD assessment will be required for diversion of The Goit. There is potential to improve watercourse quality by opening up the disused railway culverts on both The Goit and River Doe Lea at this location, though this will require careful analysis to determine both quality and flood risk implications.
River Doe Lea (HSL13 – Heath to Barnburgh)	23 (Figure 10-9)	160 (Viaduct 130)	Former Workings	A632 – to be realigned	None	Embankment in Flood Zone 2 on north-side of crossing may affect flood flows. Sensitive receptors (Bolsover Business Park) immediately upstream of crossing, therefore this will need careful assessment. Limited scope to shorten viaduct due to proximity of local receptors.	A632 realignment is stated to pass under HS2, which is likely to result in insufficient clearance at the existing A632 crossing of the River Doe Lea upstream of the HS2 crossing. This will also affect local flood risk and WFD assessments.
Hawke Brook (HSL13 – Heath to Barnburgh)	25 (Figure 10-9)	40 (Viaduct 490)	Woodthorpe Road, Mineral Railway, M1	None	Combined culvert for M1 and Woodthorpe Road	Viaduct design is dictated by M1 and location of local roads.	Impact on watercourse would be limited due to location immediately upstream of substantial flow restriction.

Watercourse Name	Reference no. in figure	Floodplain Crossing Length (m)	Design Constraints	Upstream Restriction	Downstream Restriction	Design Informative	Other considerations
Pigeon Brook (HSL14 – Heath to Barnburgh)	26 (Figure 10-9)	20 (Viaduct 170)	Existing Railway Line	M1	Culverts in Waleswood	According to OS mastermap, watercourse is culverted or underground at crossing location and downstream. Impact of HS2 viaduct likely to be negligible and could potentially substantially reduce length of viaduct subject to other constraints.	Interaction of watercourse with surrounding woodland may require consideration.
River Don (HSL16 – Heath to Barnburgh)	27 (Figure 10-9)	630 (Viaduct 740)	Denaby Lane, Existing Railway, Sheffield and South Yorkshire Navigation, A6023 Doncaster Road	None significant	Grey's Bridge, Doncaster Road	Viaduct design appears to be dictated by other constraints. Introduction of embankments would obstruct flood flow, and vulnerable receptors are in close proximity. Consideration of location for replacement flood storage should be a priority.	
River Dearne (HSL16 – Heath to Barnburgh)	28 (Figure 10-9)	800 (Viaduct 880)	Dismantled Railway, Twin Channels, Drains	None	None	Hydraulics in the area are complex and have been previously modified. This appears mostly due to construction of the now-dismantled railway embankment. Flood defences line the banks of the diverted watercourse, however these do not appear to be sufficient for defence to the 100 year return period standard. The closest vulnerable receptors are Earnburgh Grange downstream and Harlington upstream. Detailed modelling will be required to determine viaduct impact, especially if design is to be modified to include embankments.	Heavily modified watercourse, and there is potential for restoration of the river, however, the presence of flood defences, which would need to be replaced if restoration was undertaken, makes this a complex engineering issue.

Watercourse Name	Reference no. in figure	Floodplain Crossing Length (m)	Design Constraints	Upstream Restriction	Downstream Restriction	Design Informative	Other considerations
Frickley Brook (HSL16 – Barnburgh to Church Fenton)	29 (Figure 10-10)	100 (Viaduct 490)	Church Field Road	Church Field Road	None	Viaduct could be shortened at northern end, though this would likely result in a need to divert the Frickley Beck to join the Frickley Brook upstream of the HS2 route. Southern extent of viaduct is dictated by Church Field Road.	Detailed WFD assessment will be required for diversion of Frickley Brook. Frickley Beck also passes under the viaduct and confluence is shortly downstream.
River Calder (HSL17 – Barnburgh to Church Fenton)	30 (Figure 10-10)	940 (Viaduct 1880)	Aire and Calder Navigation, Floodplain Lakes, Flood Defences, Three Channel Crossings	None	None	Limited space within floodplain, occupied by canal, channels and lakes, Constrained Floodplain. Minimal space within main floodplain area for floodplain compensation. Floodplain area south of canal may not carry functional flows. Viaduct extends north of floodplain to M62, not necessary for hydraulic reasons but dictated by position of M62.	Assuming piers are not present within the River Calder, implications on the WFD should be minimal.
Oulton Beck (31) and River Aire (32) (HSL17 – Barnburgh to Church Fenton)	31,32 (Figure 10-10)	220 (Oulton Beck) 910 (River Aire) (Viaduct 2230)	Metro Railway Line, Aire and Calder Navigation, Swillington Lakes, Flood Defences, Methley Lane, Wakefield Road	None	On Oulton Beck: Metro railway line	Viaduct design likely to be heavily constrained by possible pier locations in relation to local roads and the navigation. There is potential to use an embankment between the Oulton Beck and the River Aire, though these would be substantial and would result in a long culvert crossing of a tributary.	Assuming piers are not present within the River Aire, implications on the WFD should be minimal.
Stream Dike (HSL17 – Barnburgh to Church Fenton)	33 (Figure 10-10)	30 (centre line) (Viaduct 100 toe to toe)			Existing railway line	Viaduct is 100m long due to skewed crossing of floodplain. There are no vulnerable receptors in close proximity, and it may be possible to shorten the viaduct or use a culvert-however, this would mean realigning the watercourse.	Unlikely to be significant WFD assessment impact, unless crossing width is reduced and/or culvert used, in which case a detailed WFD assessment may be required.

Watercourse Name	Reference no. in figure	Floodplain Crossing Length (m)	Design Constraints	Upstream Restriction	Downstream Restriction	Design Informative	Other considerations
Dorts Dike and River Wharfe (HSL17 – Barnburgh to Church Fenton)	34 (Figure 10-10)	2610 (Viaduct 2170)	ECML	None	ECML	Wide, flat floodplain. Flood risk arises mostly from River Wharfe. Crossing at edge of floodplain, unlikely to be on functional flow pathway. Alongside ECML, construction would be mostly widening. Plenty of space for floodplain compensation, although this may have to be away from the rail line due to the width of floodplain.	Detailed WFD assessment may be required to appraise impact of culverting watercourse. Extension of existing culverts would require consideration of the impact of elongated length on macrophyte growth and fish migration.
Oulton Beck (HSL21 – Leeds Spur)	35 (Figure 10-10)	60 (Viaduct 90)	None	None	None	Relatively shallow floodplain gradient and no sensitive receptors in the immediate vicinity indicate that this viaduct could potentially be shortened without significant impact on flood risk.	Introduction of a culvert could require a detailed WFD assessment to be undertaken.
Tributary of River Aire (Hunslet) (HSL22 – Leeds Spur)	36 (Figure 10-10)	300	Metro Railway Line, urban extent	N/A	N/A	Floodplain is natural valley with no surface watercourse identified. Leeds underground watercourses in this area are very complex, initial information suggests at least four catchments combine and discharge to the east of this location. Flood Zone Maps would not necessarily represent these combined catchments. Preferred HS2 route is in cutting, and would therefore be at risk of flooding. Provision of flood defences would potentially impede an existing flood flow route, increasing the flood risk of properties on the west-side of the route.	Further investigation is required to determine flood source and mechanisms.

Watercourse Name	Reference no. in figure	Floodplain Crossing Length (m)	Design Constraints	Upstream Restriction	Downstream Restriction	Design Informative	Other considerations
Hawke Brook (Staveley Depot Spur)	37 (Figure 10-9)	80	Existing Mineral Railway	M1 culvert	Mineral Railway culverts	Construction would widen and raise the existing Mineral Railway. Whilst no viaduct is proposed, the culvert capacity will be maintained as a minimum. Detailed modelling may be required to ensure no downstream impacts.	
Hawke Brook and River Doe Lea (Staveley Depot Spur)	38 (Figure 10-9)	810	Existing Mineral Railway, Erin Road	Mineral Railway culverts	None	Construction would widen and raise the existing Mineral Railway. Where crossings exist, culvert capacity will be maintained. The increased embankment footprint in the floodplain could displace floodwaters, increasing the risk of flooding to properties in Poolsbrook. Detailed modelling would be required to ensure no off-site impacts.	There is an opportunity for river restoration in the area.
Pools Brook (Staveley Depot Spur)	39 (Figure 10-9)	170	Existing Mineral Railway, River Doe Lea, Pools Brook Country Park	None	None	Construction would widen and raise the existing Mineral Railway, however, estimated flood levels suggest the line may be only 2.5m above the estimated flood height, whilst the ground to rail height is only 3.1m, i.e. there is insufficient space for a standard culvert.	There is an opportunity for river restoration in the area.
River Rother (Staveley Depot Spur)	40 (Figure 10-9)	310 (Viaduct 370)	Existing Mineral Railway, Hall Lane, Disused Quarry	Hall Lane	None	Limited scope to alter viaduct design. Any embankments should avoid extending further into the River Rother floodplain than the existing Mineral Railway embankments.	
Normanton Brook (Sheffield Spur)	20 (Figure 10-8)	60	None	Culvert of former Derbyshire Line embankment	None	Embankments extend into area at risk of flooding, however flood zone outline does not appear to match contours on ground model. It's likely that this viaduct length is sufficient, subject to detailed investigations.	Triple viaduct due to junction at this location means multiple crossings of the watercourse and there may be shadowing implications.

Watercourse Name	Reference no. in figure	Floodplain Crossing Length (m)	Design Constraints	Upstream Restriction	Downstream Restriction	Design Informative	Other considerations
Westwood Brook (Sheffield Spur)	42 (Figure 10-8)	90	Existing Railway Embankment	None	None	Online widening construction is on the upstream side and therefore is unlikely to substantially affect flood flows in the area. Increasing the length of the culvert is undesirable, however, residential development in the floodplain immediately downstream of the crossing would mean that opening the culvert could have significant implications on flood risk.	
River Rother (Sheffield Spur)	43 (Figure 10-8)	350	Tying into existing railway embankment	None	None	Options are limited due to proximity of the conventional rail connection point, however, the existing line is shown to be at risk of flooding and therefore the preferred route is also at risk. Minimal alterations are proposed to existing infrastructure, however, and there is therefore no significant likelihood of off-site impacts.	

5. GROUNDWATER ANALYSIS FINDINGS

5.1.1. A high-level screening assessment of the possible impacts of the preferred route on major groundwater abstractions has been undertaken as part of the groundwater analysis. The analysis summarised in the following sections considers all abstractions of more than 1,000m^3/day. The assessment considers the preferred route in the context of the size and importance of each abstraction, the likely geology and associated water table depth, the proximity and depth of the below-ground route, and the influence of any connected abstractions within the same catchment.

5.2. Western leg

5.2.1. The western leg intersects a number of areas of groundwater SPZ, and passes close to several water supply boreholes. At Pocket Nook, the route passes in cutting through an area of SPZ2, potentially affecting abstraction from a nearby borehole. The route also passes through an extensive area of linked catchment SPZ associated with several water supply boreholes in the Golborne area. Potable groundwater abstractions on the western leg are summarised below in **Table 5-1**Error! Reference source not found.. The EIA will assess potential impacts on groundwater resources in detail, in consultation with the Environment Agency and water companies, to ensure continuity of supply and protection of water quality in accordance with the relevant policy and national guidance.

5.2.2. In addition to potable water supply boreholes listed in **Table 5-1**, the western leg passes close to an industrial supply borehole at Origin Development, as summarised in **Table 5-2**. The EIA will assess potential impacts on groundwater resources in detail, in consultation with the Environment Agency and the registered groundwater abstraction licence holder.

5.3. Eastern leg

5.3.1. There are no occurrences on the eastern leg of any below-ground route (cut or tunnel) within SPZ1 or SPZ2, and therefore no direct interaction with any potable groundwater abstractions. Despite some intersection of below-ground route within catchment SPZ, all associated abstractions are a considerable distance from the line of route. As a result, it is considered unlikely that there would be any significant impacts on any potable groundwater abstractions for this leg.

5.3.2. The eastern leg passes close to four non-potable water supply boreholes, three for industrial use and one for agricultural use, as summarised in **Table 5-3**. The EIA will assess potential impacts on groundwater resources in detail, in consultation with the Environment Agency and the registered groundwater abstraction licence holders.

Table 5-1 - Summary of potable groundwater abstractions western leg, south to north

Abstraction Name (and location)	Maximum Daily Abstraction volume (m^3/day)	Type	Possible impact
Boreholes at Little Town, Croft	6,819	Multiple borehole (2)	The preferred route passes in shallow cutting close to two public water supply boreholes at Little Town. There is no SPZ1 or SPZ2 associated with this abstraction, however the route passes approximately 360m from the abstraction location. In addition, the borehole is located with a large catchment SPZ3 associated with multiple large water supply boreholes. The proposed cutting would extend approximately 2.4m into the superficial deposits, shown on British Geological Survey mapping as laminated clays and silts. Based on publicly available borehole records, the cutting is entirely above the groundwater level (also known as the water table) which is shown to lie within the sandstone bedrock aquifer. Consequently, it appears unlikely that the preferred route would have any significant adverse impact of groundwater abstractions at Little Town.
Borehole at Pocket Nook, Golborne	7,956	Single borehole	The preferred route crosses approximately 410m of SPZ2 associated with the abstraction at Pocket Nook in cutting. The proposed cutting would extend to a maximum of 10m deep within superficial clay deposits or potentially into the top few metres of the sandstone aquifer layer. Based on available borehole records, the proposed cutting is expected to be entirely above the water table. In addition, the sandstone aquifer is of substantial thickness and consequently, it appears unlikely that the preferred route cutting would have any permanent significant adverse impact on the groundwater abstraction at Pocket Nook. In addition, the SPZ associated with this abstraction is linked to two other large potable water supply boreholes. No permanent significant adverse impacts are expected on any connected groundwater abstractions.
Borehole at Lowton Golborne	7,728	Single borehole	The route passes through an extensive area of catchment SPZ3 associated with multiple large potable abstractions in the Golborne area. This includes two boreholes which are in close proximity of the route centre line. The preferred route passes on embankment between these two abstractions, and consequently, it is unlikely that the preferred route would have any adverse impact on these water supply abstractions.
Borehole at Golborne	4,564	Single borehole	

Table 5-2 - Summary of large (>1000m^3/day), non-potable groundwater abstractions within 500m of preferred route, western leg, south to north

Abstraction Name (and location)	Use	Maximum Daily Abstraction volume (m^3/day)	Type	Possible impact
Boreholes at Origin Developments, Manchester NGR location SJ843977	**Industrial, Commercial and Public Services** Non-Evaporative Cooling	1,010	Single Point / Single Purpose	Preferred route and all station platforms are above ground and approximately 480m from the abstraction borehole. The preferred route and station is unlikely to have any significant adverse impact on groundwater flows or available water supply.

Table 5-3 Summary of large (>1000m^3/day), non-potable groundwater abstractions within 500m of preferred route, eastern leg, south to north

Abstraction Name (and location)	Use	Maximum Daily Abstraction volume (m^3/day)	Type	Possible impact
Action Road Works, Long Eaton NGR location SK495326	**Industrial, Commercial and Public Services** Process water for Leather and textiles industry	1,954	Single Point / Single Purpose	Preferred route is on viaduct approximately 210m from the abstraction and therefore, notwithstanding the impact of any deep intrusions associated with the viaduct piers, the above ground route is unlikely to have a significant impact on groundwater flows.
Stourton Dairy, Stourton, Leeds NGR location SE332299	**Industrial, Commercial and Public Services** Process water for dairies	1,400	Single Point / Single Purpose	Preferred route is on embankment with centre line approximately 170m from borehole and therefore unlikely to have a significant impact on groundwater flows.

Abstraction Name (and location)	Use	Maximum Daily Abstraction volume (m^3/day)	Type	Possible impact
Tetley Brewery, Hunslet Road, Leeds NGR location SE304330	**Industrial, Commercial and Public Services** Process water for brewery	1,200	Single Point / Single Purpose	Preferred route and all station platforms are above ground and approximately 490m from the abstraction borehole. As a result, the preferred route and station is unlikely to have any significant adverse impact on groundwater flows or available water supply.
Land North of Micklefield (Grange Farm), Leeds NGR location SE442345	**Agriculture** Direct Spray Irrigation	1,640	Single Point / Single Purpose	Preferred route in shallow cutting (approximately 4m deep) with centre line approximately 140m from abstraction borehole. Borehole draws directly from Principal bedrock aquifer which is exposed at the surface, with no superficial deposits. Impact on groundwater flows is possible, however bedrock aquifer is likely to be substantial in thickness and it is therefore anticipated that there would be minimal long term impact on flows to the abstraction as a result of the preferred route.

6. WESTERN LEG STATIONS

6.1. Manchester Airport station

Description

6.1.1. The proposed Manchester Airport station is located near Davenport Green, just west of the M56 motorway. The operational area of the station is 186,200m^2 (18.62 ha) and a specific detailed surface water management strategy is therefore required by the Environment Agency in accordance with the technical guidance for flooding under the National Planning Policy Framework (NPPF). The construction boundary has an area of 217,400m^2 (21.74ha).

Watercourse crossings

6.1.2. The construction boundary of the proposed station crosses both branches of the Timperley Brook. The crossing is immediately downstream of the M56 motorway, and the brook is assumed to be conveyed beneath the motorway in a suitably sized culvert.

6.1.3. The Timperley Brook (northern branch) has a heavily urbanised catchment with an area of 1.7km^2 and an estimated peak runoff rate of 3.4m^3/s in the 100-year return period event with an allowance for climate change (30% for small watercourses consistent with the approach used in the Phase One design). The southern branch, which appears to be in culvert to the upstream side of the station boundary, arising beneath the station footprint to the east of Hasty Lane, has an additional catchment area of 1km^2.

6.1.4. In terms of the WFD, the upper reaches of the Timperley Brook are not classified, and therefore its WFD status is inherited from approximately 2km downstream. However, the northern branch of the river is a designated “Main River” and will therefore be subject to similar scrutiny as the classified section downstream. The Timperley Brook is designated a ‘heavily modified water body’ in recognition of the heavily urbanised nature of the watercourse. The 2015 Cycle 2 classification of the Timperley Brook is “Moderate” overall, with “Moderate” ecological and “Good” chemical quality. Targets for the watercourse include “Good” biological and physico-chemical quality by 2027 and a mitigation measures assessment for surface water of “Good” by 2027. Recent improvements in the biological quality of the Timperley Brook (improving invertebrates from “Bad” to “Moderate”) are such that works to the watercourse will attract a high level of scrutiny. Given the heavily modified and culverted nature of the watercourse upstream of the station site, it is expected that there will be limited impact on migratory species.

6.1.5. Envisaged local catchment measures for the Upper Mersey catchment of which the Timperley Brook forms a part include “identify and take opportunities to improve ecology through habitat creation”[3], in order to meet the target for mitigation measures. General measures projected beyond 2021 for the North West river basin include “removal or modification of engineering structures”. Consequently, there may be resistance to hard-engineered solutions to the watercourse crossing, with river restoration a high priority.

6.1.6. The width of the operational boundary at the crossing point of the northern branch is approximately 140m. The spur is approaching the Manchester tunnel at this location, and the preferred route rail level is approximately 5m below ground.

---

[3] Environment Agency and DEFRA (2015). Water for life and livelihoods Part 1: North West river basin district River basin management plan

6.1.7. Due to the station superstructure, platforms and headroom required, it is unlikely that an aqueduct solution would be acceptable at the watercourse location. Without diverting the watercourse, therefore, the only cross drainage solution would be an inverted siphon.

Watercourse diversions

6.1.8. The diversion of the Timperley Brook would not be required were an inverted siphon to be employed at the current watercourse location. However, inverted siphons are the least favourable form of cross drainage, and it would be preferable to divert the watercourse to a location where an aqueduct or simple culvert could be used.

6.1.9. Since there is no above ground construction for some distance in either direction, the best surface option would be to divert the watercourse north to the start of the tunnel. However, this would require a 750m uphill diversion, with associated technical difficulties. Holistically, the best solution would therefore be to divert the watercourse a minimum of 300m north to a point where the headroom is sufficient to construct a gravity fed aqueduct.

6.1.10. Although the upper reaches are not classified under the WFD, any alterations may have an impact downstream on the classified reach of the Timperley Brook. Provided that sensitive diversion design is undertaken to ensure that existing channel conditions and habitats are maintained as a minimum, and an ecological study confirms this has no detrimental impact on water quality or riverine ecology, diversion of the tributary should be acceptable under the WFD.

6.1.11. Further ecological assessment and survey would be required in order to determine the scale and value of any potential impacts, and to determine whether there is likely to be a detrimental impact on the Timperley Brook downstream. Since alternative design options are limited, negotiations with the Environment Agency would be required to discuss what would be acceptable for this crossing in terms of ecology and the WFD.

Flood flow obstructions and floodwater displacement

6.1.12. The Timperley Brook at this location does not have a formally associated fluvial flood risk due to the small catchment size. The cross drainage design should be sufficient to convey the full 100-year return period flow, including an allowance for climate change, in order to prevent increasing the risk of flooding upstream. Any inverted siphon would need to be subject to a detailed maintenance programme to prevent blockages causing upstream flood effects. The upstream culvert beneath the M56 should limit the extent of upstream effects.

6.1.13. Potential increases in conveyance due to low friction culverts or pipes and the loss of natural meanders over around 100m would ideally also be accounted for to prevent increases in peak flows downstream. However, this effect is likely to be extremely localised.

6.2. Manchester Piccadilly station

Description

6.2.1. The proposed Manchester Piccadilly station is located adjacent to the existing Network Rail Piccadilly station, on the northern side. The operational area of the station is 75,400m^2 (7.54 ha) and a specific detailed surface water management strategy may therefore be required by the Environment Agency in accordance with the technical guidance for flooding under the NPPF. The construction boundary is 181,500m^2 (18.50 ha).

Watercourse crossings

6.2.2. The station crosses one watercourse – the River Medlock. The crossing is to the east of the extent of the station platforms, and is immediately upstream of Fairfield Street Road Bridge and the existing Manchester Piccadilly station approaches.

6.2.3. The River Medlock has a very heavily urbanised catchment with an area of 57km^2 and an estimated peak runoff rate of 70m$^{3/}$s in the 100-year return period event with a 20% allowance for climate change. In this area, the river is conveyed within a substantial artificial channel.

6.2.4. In terms of the WFD, the River Medlock is classified as a 'heavily modified water body' along this reach. The 2015 Cycle 2 classification of the River Medlock is "Moderate" overall, with "Moderate" ecological and "Good" chemical quality, although biological quality is "Poor". Targets for the watercourse include "Moderate" biological quality by 2027 and a mitigation measures assessment for surface water of "Good" by 2027. Recent improvements to the overall quality of the River Medlock are such that any solid structures over the river will be subject to a high level of scrutiny.

6.2.5. The crossing is at the eastern extent of the station itself, and the river is within a culvert for the majority of the operational boundary width. The rail construction type at the crossing is a viaduct, with the track level raised some 10m above surrounding ground, consistent with the existing Manchester Piccadilly approach viaduct. Envisaged local catchment measures for the River Irwell catchment, of which the River Medlock forms a part, include "remove or bypass significant physical modifications that act as barriers to fish migration", in order to meet the target for mitigation measures. General measures projected beyond 2021 for the North West river basin include "removal or modification of engineering structures" and "removal or easement of barriers to fish migration". Consequently, there will be resistance to increasing the culvert length and channel shadowing at this location, and there is likely to be pressure to open out the existing culvert if possible.

Watercourse diversions

6.2.6. The River Medlock is contained within an artificial channel of significant capacity, and passes through a culvert beneath the existing railway viaduct within the extent of the proposed station boundary. The route is proposed on viaduct at this location, and it is therefore assumed that there is no direct need to culvert the river.

6.2.7. However, due to the sweeping meander that is present within the extents of the station, it may be necessary to reposition the watercourse in order to enable the structure to cross without impeding flows, or alternatively to allow space for extension of the existing culvert. Any diversion (including culverting) should be designed to maintain the capacity and flow mechanics of the existing channel, and detailed hydraulic modelling is likely to be required to demonstrate the impact and assist in the design of any required mitigation.

6.2.8. Since diversion and possibly culverting of the River Medlock is likely to be necessary in order facilitate the crossing, a detailed WFD assessment would be required. Designs must ensure that there is no negative impact on channel hydromorphology or ecological habitat within watercourse. As biological quality is currently "Poor" (as a result of fish levels, which have deteriorated since 2009), extra care must be taken to ensure there is no further detrimental impact as a result of the works, and where possible, opportunities should be sought to improve conditions.

6.2.9. Should the River Medlock remain in open channel, in theory, as long as flow and water quality conditions and associated habitats are maintained, diversion of the watercourse should not have a significant impact in terms of the WFD. However, given space constraints, ensuring the meander is maintained beneath the new platforms could be a challenge and therefore sensitive design, with consideration of the WFD throughout, will be necessary.

6.2.10. If a new culvert or extension of the existing culvert is proposed, there may be negative implications in terms of the WFD. Culverting of watercourses can alter hydromorphological conditions, and given the likely length, consideration must be given to any negative impacts on riverine ecology, particularly in terms of light availability and fish migration.

6.2.11. Further ecological assessment and survey may be necessary in order to determine the scale and value of any potential impacts. Negotiations with the Environment Agency may be required to discuss what is acceptable for this crossing in terms of ecology and the WFD. However, it is likely that an open channel solution would be preferable. Although there appears to be little space for significant improvements, careful design of the river diversion could present opportunities to add small areas of ecological habitat.

Flood flow obstructions

6.2.12. According to the flood zone mapping, the capacity of the artificial channel in this area is sufficient to convey the 100-year return period and the majority of the 1,000-year return period flood flows without overtopping. Thus, any culvert that may be required due to the proposed station development, so long as it is adequately sized to convey the 1,000-year return period flood flow (including allowances for climate change and blockage), would not significantly obstruct flood flows.

Floodwater displacement

6.2.13. The construction boundary overlaps with only 5m^2 of Flood Zone 3. Approximately 6,000m^2 of the construction boundary for the station falls in the area of Flood Zone 2, with substantially less (only 260m^2) of the operational extent coinciding with the area of flood risk. In general, replacement floodplain storage provision is not usually required for areas of Flood Zone 2. However, the outline of Flood Zone 2 would sometimes be used as a surrogate outline to account for climate change relative to Flood Zone 3. Depending on the type of construction, a small amount of floodplain compensation may be needed. However, it is likely that this can be incorporated into any river works should these be required.

7. WESTERN LEG DEPOTS

7.1. Crewe North Rolling Stock Depot

Description

7.1.1. The Crewe North Rolling Stock Depot (RSD) is located where the preferred route deviates from the WCML north of Crewe, in the Wimboldsley area. The depot occupies a 619,000m^2 (61.90 ha) area between the preferred route and the WCML, and has a north facing depot connection, with a provision for connections to the West Coast Main Line.

Watercourse crossings

7.1.2. The RSD crosses one minor watercourse, an unnamed tributary of the River Weaver at the extreme south of the depot extent. The watercourse rises between the preferred route and the WCML, before passing into culvert beneath the latter. The extremely small catchment size for this watercourse suggests that collection of surface water into the integrated drainage design for the depot would suffice to manage the expected flows in the short section of watercourse removed by the depot area, and such treatment would have very little effect on the ecological and chemical status of the River Weaver some 1km downstream. Subject to detailed drainage design, the implementation of sustainable drainage solutions could be beneficial.

Watercourse diversions

7.1.3. No watercourse diversions would be required.

Flood flow obstructions and floodwater displacement

7.1.4. The depot does not occupy any areas of flood risk from rivers.

8. EASTERN LEG STATIONS

8.1. East Midlands Hub station

Description

8.1.1. The proposed East Midlands Hub station at Toton, north of the Trent crossing, is located alongside the existing Erewash Valley railway line, taking in part of Toton sidings, and spans either side of the A52.

8.1.2. The station has an operational area of approximately 0.15km^2 (15 ha) and a specific detailed surface water management strategy may therefore be required under the NPPF.

Watercourse crossings

8.1.3. The operational boundary crosses three separate watercourses (River Erewash and two minor tributaries) and the Erewash Canal. The River Erewash is crossed twice by the operational boundary of the station, on the northern approach and the southern approach. The construction boundary crosses the River Erewash three further times, although all three additional crossings relate to road modifications. The station footprint is partially located within Flood Zone 2 of the River Erewash and partially within Flood Zone 3 at both the southern and northern extents, though these areas are on the station approach rather than populated station areas.

River Erewash

8.1.4. The River Erewash is crossed by the operational extent of the station at two locations. At the southern, downstream crossing, the river has a moderately urbanised catchment with an area of 188km^2 and an estimated peak runoff rate of 112m^3/s in the 100-year return period event with an allowance for climate change (20% in accordance with HS2 Deliverable Approach Statement (DAS) for Flood Risk). At the downstream crossing, the total width of the operational boundary is approximately 130m. However this part of the station would be mostly rail connections, with no platforms or other buildings.

8.1.5. The northern crossing of the River Erewash occurs where the connections from the station are re-joining the main through line, with an additional connection enabling access to and from the Erewash Valley line. The Erewash Valley connection would require a new viaduct crossing of the River Erewash, with the HS2 connection raised to pass over both the Erewash Valley line and the Erewash Canal north of the watercourse. Replacement of the two adjacent existing Network Rail crossings of the River Erewash will be required in order to mitigate the impacts of the main HS2 viaduct at Sandiacre and the associated flood defences which will be required to prevent flooding of the northern station approach as it passes beneath the A52.

8.1.6. In terms of the WFD, the River Erewash reach in this location (from Gilt Brook to River Trent) is currently classified as “Moderate” overall, with “Moderate” ecological and “Good” chemical quality. Based on the 2015 Cycle 2 assessment, measured biological elements are considered to be “Moderate” due to moderate invertebrate and moderate macrophyte and phytobenthos levels. However, fish levels are currently “High” and must therefore be protected. In terms of hydromorphological supporting elements, the hydrological regime currently “Supports Good” ecological conditions and therefore changes to the hydrological regime or to channel morphology will attract a high level of scrutiny.

8.1.7. The proposed scheme would require new viaduct crossings and is likely to require local widening, realignment and re-profiling of the River Erewash at several locations in order to ensure an acceptable solution in terms of flood risk. The requirement for diversion of the River Erewash is discussed further in the following sections. Further ecological assessment and survey would therefore be required at EIA stage in order to determine the scale and value of any potential impacts, and to determine whether there is likely to be a detrimental impact on the River Erewash. A detailed WFD assessment will be required for the East Midlands Hub station, to consider any impacts associated with the new crossings and any required in-channel mitigation. Consolidation of crossings might present an opportunity for improvement of the watercourse under WFD criteria.

8.1.8. The smaller tributaries of the River Erewash are not classified under the WFD. However, alterations within these small watercourses can have a wider impact within the River Erewash and therefore similar consideration should be given to tributaries to ensure there is no deterioration to ecological quality or WFD status.

Erewash tributary – south

8.1.9. The station operational boundary crosses a minor tributary of the River Erewash approximately 100m south of the downstream River Erewash crossing. The tributary appears to emerge from a culvert just upstream of the existing line. The tributary has a very heavily urbanised catchment with an area of $0.7km^2$ and an estimated peak runoff rate of $0.9m^3/s$ in the 100-year return period event with an allowance for climate change (30% for small catchments). The width of the operational boundary at the crossing point is approximately 130m. However, the watercourse is already culverted beneath existing railway lines, and no significant additional work to the watercourse is anticipated.

Erewash tributary – north

8.1.10. At the far northern extent of the station, the operational boundary crosses a second tributary of the River Erewash. The tributary has an essentially rural catchment with an area of $0.6km^2$ and an estimated peak runoff rate of $0.8m^3/s$ in the 100-year return period event with an allowance for climate change (30% for small catchments). The operational boundary appears to be limited to the rail extents at this location, and no work over and above that assessed under the preferred route is anticipated.

Watercourse diversions

River Erewash

8.1.11. Between the two identified crossings of the River Erewash, the watercourse runs parallel to the proposed East Midlands Hub station. Although the proposed station operational boundary does not cross the River Erewash, maintenance access and ecological buffers would necessitate a major diversion at this location.

8.1.12. Between the A52 Brian Clough Way and Station Road, the channel meanders to the east and passes under an access bridge serving the DB Schenker railway yard. At this location, the river Erewash is wholly contained within a rectangular concrete channel. The proposed operational boundary is sufficiently close to the top of bank that, depending on the type of construction required at this location, would require the river to be re-aligned.

8.1.13. Due to the density of urban development in this area, space is extremely limited and detailed design of the station approach and operation of Network Rail services would need to give due consideration to possible diversion to the east of the River Erewash between the A52 and Station Road. Furthermore, the DB Schenker access bridge at this location would require removal. Subject to discussions with affected parties, reinstatement of any structure at this location would need to be undertaken at a level which avoids the obstruction of flood flows.

8.1.14. Although the length of watercourse affected by the operational boundary is relatively short, the presence of flood defences along the banks of the River Erewash in this location mean that any proposed diversion of the watercourse and flood defences would need to allow sufficient room for maintenance access to all flood defences.

8.1.15. Diversion of the River Erewash would require that a detailed WFD Assessment be undertaken. Detailed diversion design should ensure that existing conditions and habitats are maintained as a minimum. The nature of the River Erewash in this location is a rectangular concrete channel, and consequently minor realignment of the channel is unlikely to have any significant impact on channel morphology or flow regime. With thoughtful design, habitat (particularly for fish) could be maintained or even improved.

Flood flow obstructions

8.1.16. At the downstream (south) crossing of the River Erewash, the EMH approach is on high viaduct and will not itself result in the obstruction of flood flows provided that piers are located outside of the river channel and floodplain. Where replacement crossings are proposed for other infrastructure, further detailed modelling work will need to be undertaken to better understand the impacts and inform the design at EIA stage.

8.1.17. To the north of the station, approximately 2km of the preferred route (starting at the northern extent of the existing Toton sidings area and extending to the Erewash Canal) lies within the floodplain of the River Erewash. North of the A52, the station footprint spans Flood Zone 3, initially along the eastern edge of the floodplain, before crossing the floodplain at Sandiacre Viaduct. Detailed analysis and hydraulic modelling of the proposed crossings in this location has revealed that in order to prevent the line from flooding as it passes beneath the A52, flood defences would be required, presenting an obstruction to flood flows. The analysis also demonstrates that the existing Network Rail bridge connecting to the Erewash Valley line presents a significant obstruction to flood flows. Removal of this bridge and the associated embankment would mitigate the effect of the introduction of flood defences, thereby maintaining existing flood water levels.

Floodwater displacement

8.1.18. The operational extent of East Midlands Hub station occupies approximately 75,000m^2 of Flood Zone 3 and 123,000m^2 of Flood Zone 2 at the northern crossing. An additional 60,000m^2 of Flood Zone 2 east of the operational boundary would potentially be blocked from the floodplain as a result of the introduction of flood defences. At the southern floodplain crossing, the operational extent occupies approximately 32,000m^2 of Flood Zone 2. Any built volume within the floodplain would occupy existing floodplain storage volume, resulting in displacement of flood waters onto neighbouring land. This would potentially result in an increase in the frequency and severity of flooding to neighbouring third party property.

8.1.19. The surrounding floodplain extends into densely populated residential areas, where potential increases in flood water levels resulting from losses in floodplain storage would not be tolerated. Consequently, in order to develop in this area, measures would need to be implemented to ensure that there is no increase in the risk of flooding as a result of the station development. Early hydraulic modelling and analysis suggests that, through the introduction of flood defences and channel modifications at the next stage of design, significant increases in flood water levels on third party land could be avoided.

8.1.20. Normal procedure would require a detailed floodplain compensation strategy to replace any loss in floodplain storage volume, preferably on a level-for-level basis. Due to the close proximity of sensitive receptors within the floodplain, compensation would need to be distributed along the length of the station boundary to replace losses as close as possible to the area of loss.

8.1.21. The limited available space for floodplain compensation, particularly in the area between the A52 and Station Road, and the scale of the floodwater displacement means that a level-for-level floodplain compensation strategy is unlikely to be feasible. Alternative mitigation strategies may therefore need to be developed in consultation with the Environment Agency at the next stage of design. Although early hydraulic modelling has demonstrated how proposed changes in the river channel, viaducts and flood defences on the River Erewash between the A52 and the M1 motorway can be configured without any significant impact on flood water levels, there exists the potential to significantly alter the hydromorphology and ecology of the watercourse. A detailed WFD assessment will be required, in order to ensure there would be no detrimental impact upon the WFD status of the River Erewash as a result of the proposed mitigation.

8.2. Leeds station

Description

8.2.1. The proposed Leeds terminal station is located immediately south of the existing (Network Rail) Leeds station, across the River Aire. The station construction boundary area provided is 207,600m^2 (20.76 ha) and a specific detailed surface water management strategy may therefore be required under the NPPF.

Watercourse Crossings

8.2.2. The operational extent of the proposed station crosses the River Aire where the Leeds and Liverpool Canal joins the river. The tracks and platforms span the floodplain from south to north.

8.2.3. The River Aire has a moderately urbanised catchment with an area of 755km^2 and an estimated peak runoff rate of 600m^3/s in the 100-year return period event with an allowance for climate change (20% as recommended in the NPPF). The river in this area is tightly confined with development under a variety of land uses extending close to the riverbank.

8.2.4. A substantial portion of the station's operational area lies to the south of the river. The construction boundary area provided extends from just south of Parkfield Street north to overlap with the existing Leeds station. The minimum construction boundary width at the river crossing is 100m. The rail level within the station will be some 10m above surrounding ground levels, however, no detail has been provided as to the content or structure of the remaining station elements.

8.2.5. In terms of the WFD, the River Aire is heavily modified along this reach. The 2015 Cycle 2 classification of the River Aire is "Moderate" overall, with "Moderate" ecological and "Good" chemical quality. Targets for the watercourse include “Good” biological quality by 2027, improved pollutant concentrations to “High” by 2027 and a mitigation measures assessment for surface water of “Good” by 2027. Recent improvements to the overall quality of the River Aire are such that any solid structures over the river will be subject to a high level of scrutiny. In particular, shadowing of the watercourse and lengthy dark passes, as would occur due to the 100m building width and surrounding massing, would require substantial mitigation which may not be feasible. Further work is being undertaken by HS2 Ltd to understand impacts on ecology and the WFD.

Watercourse diversions

8.2.6. It is not anticipated that any watercourse diversions would be required at Leeds station.

Flood flow obstructions

8.2.7. The extents of the latest flood zone maps suggest that the floodplain of the River Aire narrows to the width of the channel just upstream of the Neville Street Bridge, widening again on the downstream side. On the basis of the flood zone mapping, the construction boundary of Leeds station is not on any functional flow path, except where it crosses the River Aire. On this basis, and subject to provision of a clear-span crossing of the River Aire, there would be no obstruction of floodplain flows as a result of the proposed station.

8.2.8. In general, the latest information from the Environment Agency is assumed to be the best available information, and therefore the observation that no floodplain flow obstruction is expected holds true. Nevertheless, it is worth bearing in mind that there is potential for floodplain flow in this area for greater return period events, and applying this as a consideration within the design, where practicable.

8.2.9. There is a section of Flood Zone 3 that extends south from Pottery Field to the M621 and existing conventional rail cutting. The preferred route crosses this limb of floodplain with a rail level at the same level as surrounding ground. Thus, the approach to the station is potentially at risk of flooding. Were defence from flooding to be provided, or the preferred route raised to 1m above the flood water level as per design standards, this route for floodwater would be cut-off, removing an additional 5,400m^2 of flood storage.

Floodwater displacement

8.2.10. The construction boundary of Leeds station occupies approximately 59,000m^2 of Flood Zone 3 and 144,000m^2 of Flood Zone 2. Any built volume within the floodplain would occupy existing floodplain storage volume, resulting in displacement of flood waters onto neighbouring land. This would potentially result in an increase in the frequency and severity of flooding to neighbouring third party property. There are current proposals for a flood alleviation scheme in Leeds to provide defences for the city centre against flood events from the River Aire and the Hol Beck.

8.2.11. The surrounding floodplain extends into densely populated residential areas, and potential increases in flood water levels resulting from losses in floodplain storage would not be tolerated. Consequently, in order to develop in this area, measures would need to be implemented to ensure that there is no increase in the risk of flooding as a result of the station development. There could be multiple demolitions within the area at risk of flooding, and this has the potential to significantly offset the amount of built volume added to the floodplain. The construction type for the preferred route is shown as viaduct, and it is assumed that the station would be built at a high level with some form of voided space beneath. Given the type of construction, and the scale of likely demolitions, it is probable that the proposed station design could be argued to adequately balance the available floodplain storage, as long as sufficient consideration is made for this within the detailed design.

9. EASTERN LEG DEPOTS

9.1. Staveley Infrastructure Maintenance Depot

Description

9.1.1. The proposed Staveley Infrastructure Maintenance Depot (IMD) is located near Barrow Hill to the north west of Staveley, and is served by a spur that passes along the existing Mineral Railway embankment from Woodthorpe and Bolsover. The depot occupies a 257,400m^2 (25.74 ha) area of the former Devonshire iron and chemical works.

9.1.2. Any potential river and floodplain works along the Doe Lea and Rother Valleys are complicated by the presence of the Upper Don flood management strategy. However, the depot boundary does not fall within any of the functional washland areas that form the flood defence scheme.

9.1.3. The depot connection spur is covered in the line of route assessment.

Watercourse crossings

9.1.4. The operational boundary of the depot lies within an area of land bounded by a large meander of the River Rother, with the far western extent adjacent to a secondary channel of the River Rother which appears to serve as an aqueduct carrying water to the works.

9.1.5. The River Rother has a moderately urbanised catchment with an area of 185km^2 and an estimated peak runoff rate of 133m^3/s in the 100-year return period event with an allowance for climate change of 20%.

9.1.6. Whilst the proposed depot approaches would cross the River Rother on an existing viaduct, the operational boundary of the depot itself does not cross the watercourse, coming to only 100m from the river at the eastern extent and 90m from the river at the western extent.

Watercourse diversions

9.1.7. It is not anticipated that any watercourse diversions would be required as a result of the proposed depot.

Flood flow obstructions and floodwater displacement

9.1.8. The operational extent of the Staveley depot occupies approximately 3,000m^2 of Flood Zone 2 between the existing mineral railway lines and Hall Lane. This area of risk is at the edge of the floodplain, and appears to flood only when the existing mineral railway line is overtopped from north of the proposed depot. Thus, no obstruction of floodplain flow is anticipated. However, there is potential to affect the risk of flooding elsewhere due to displacement of flood storage.

9.1.9. In general, replacement floodplain storage provision is not usually required for areas of Flood Zone 2. However, the outline of Flood Zone 2 would sometimes be used as a surrogate outline to account for climate change relative to Flood Zone 3. Depending on the type of construction, replacement floodplain storage may be needed. There appears to be sufficient space in the surrounding areas to provide replacement floodplain storage if required.

9.2. New Crofton Rolling Stock Depot

Description

9.2.1. The New Crofton Rolling Stock Depot (RSD) is located between Crofton and Walton, south-east of the urban extent of Wakefield and north of Anglers Country Park. The depot occupies a 388,800m^2 (38.88 ha) area south of the Wakefield Line conventional railway.

9.2.2. The depot connections are covered in the line of route assessment above.

Watercourse crossings

9.2.3. The proposed depot lies on a watershed between the Drain Beck and Hardwick Beck catchments. The natural catchments appear to be altered due to the presence of the existing railway line, together with the former Nostell and Wintersett junctions, with the majority of the Hardwick Beck head catchment forced to discharge to the Drain Beck or the Hessle Beck to the east. The Hardwick Beck channels are therefore carrying very low flows, and are only present to the north of the existing railway line. The operational extents of the depot remain south of the existing line, and therefore the Hardwick Beck would not be crossed.

9.2.4. A minor tributary of the Drain Beck lies within the operational boundary of the proposed depot. This watercourse does not have a sufficient natural catchment to be defined in the Flood Estimation Handbook Web Service (the industry-standard resource for assessing the hydrological characteristics of catchments in the UK), however does appear to carry a modest flow from areas south of the Wakefield Line and potentially from Crofton via Santingley Lane. It is estimated that the construction of the depot would be at-grade at this location and therefore diversion of the watercourse or the provision of an inverted siphon would be required. However, it could be difficult to maintain sufficient constant flow conditions for a siphon to work. It may be feasible to collect the flows from the watercourse into the new perimeter drainage for the depot.

9.2.5. A second watercourse crossing was identified from Ordnance Survey mapping along the toe of the dismantled railway between Nostell North junction and Wintersett junction. This could be part of the cut-off drain for the dismantled railway or a surface feature; however, it does not appear to have connectivity with local watercourses. If site investigations reveal that it carries a flow, diversion or collection into perimeter drainage will be required, as with the Drain Beck tributary.

Watercourse diversions

9.2.6. It is not anticipated that any watercourse diversions would be required beyond those previously mentioned. Diversions of such minor watercourses are not anticipated to require significant assessment under the WFD.

Flood flow obstructions and floodwater displacement

9.2.7. The local watercourses do not have a formally associated fluvial flood risk due to the small catchment sizes. All cross drainage design should be designed sufficient to convey the full 100-year return period flow including an allowance for climate change in order to avoid affecting the risk of flooding elsewhere.

10. OVERVIEW MAPS

10.1.1. The following section presents the overview maps for river diversions, viaduct crossings and groundwater for the western and eastern leg.

Figure 10-1 River Diversions – Western Leg

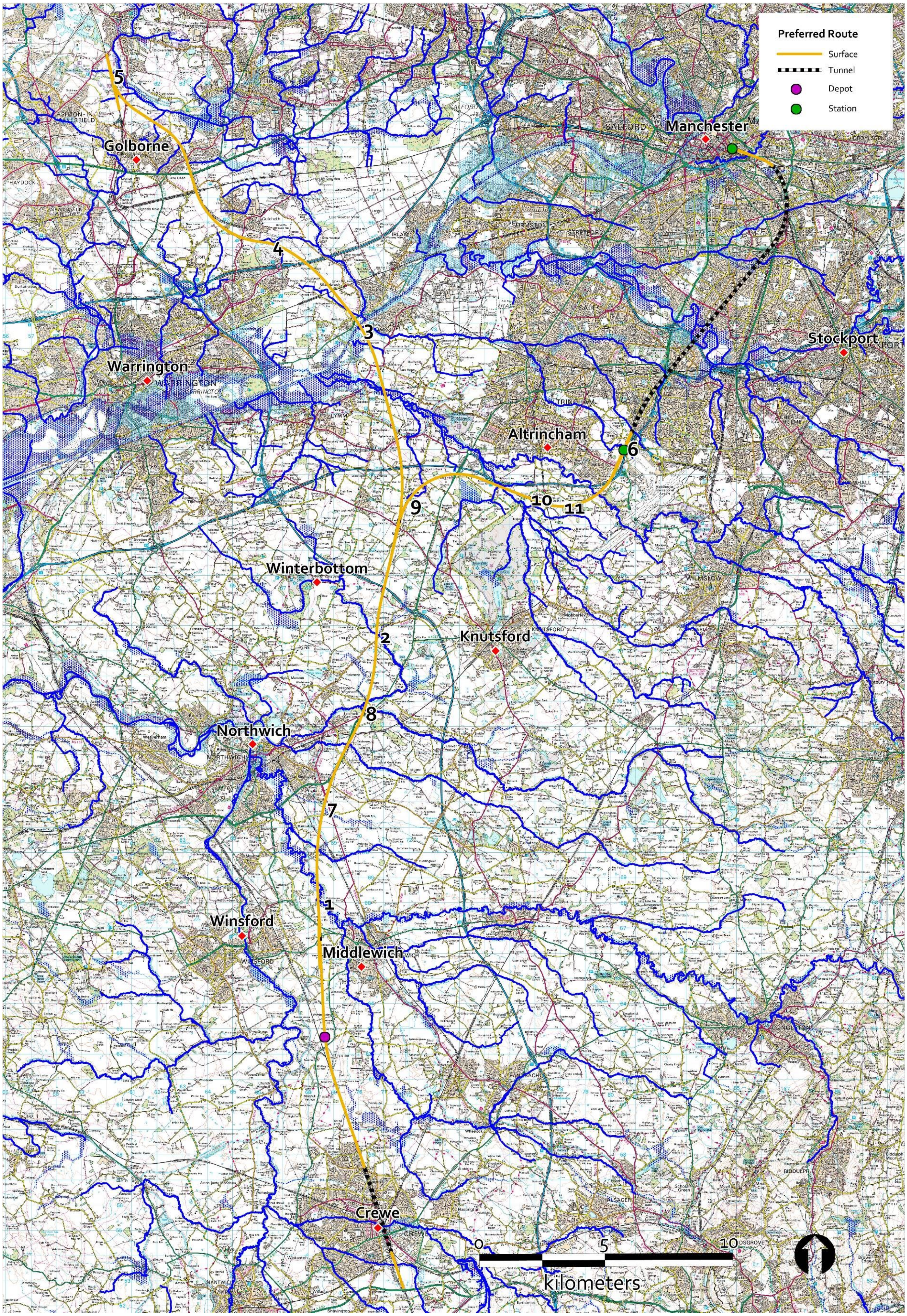


Figure 10-2 River Diversions – Eastern Leg: Marston to Kegworth

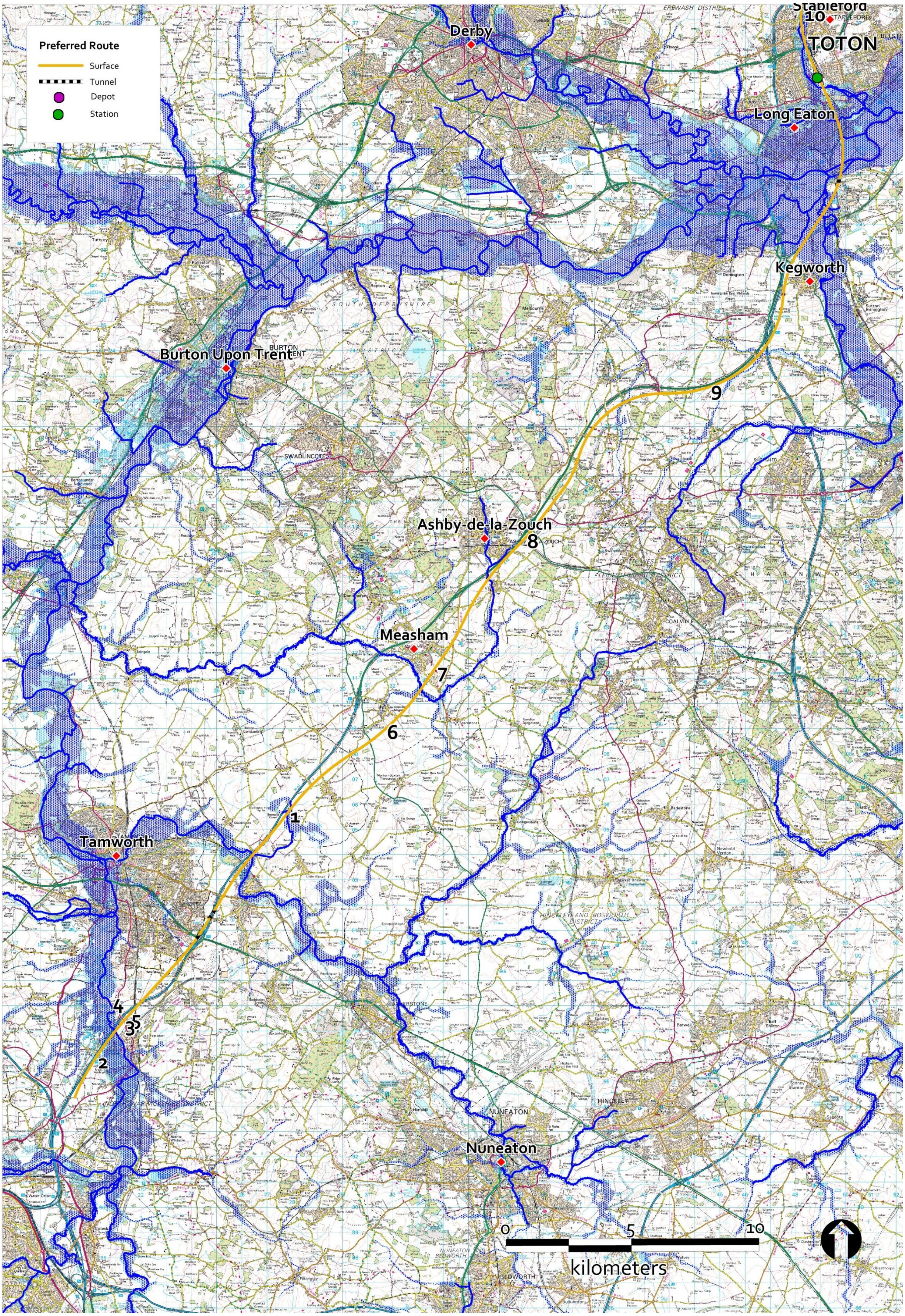


Figure 10-3 River Diversions – Eastern Leg: Kegworth to Heath

Figure 10-4 River Diversions – Eastern Leg: Heath to Barnburgh

Figure 10-5 River Diversions – Eastern Leg: Barnburgh to Leeds and ECML

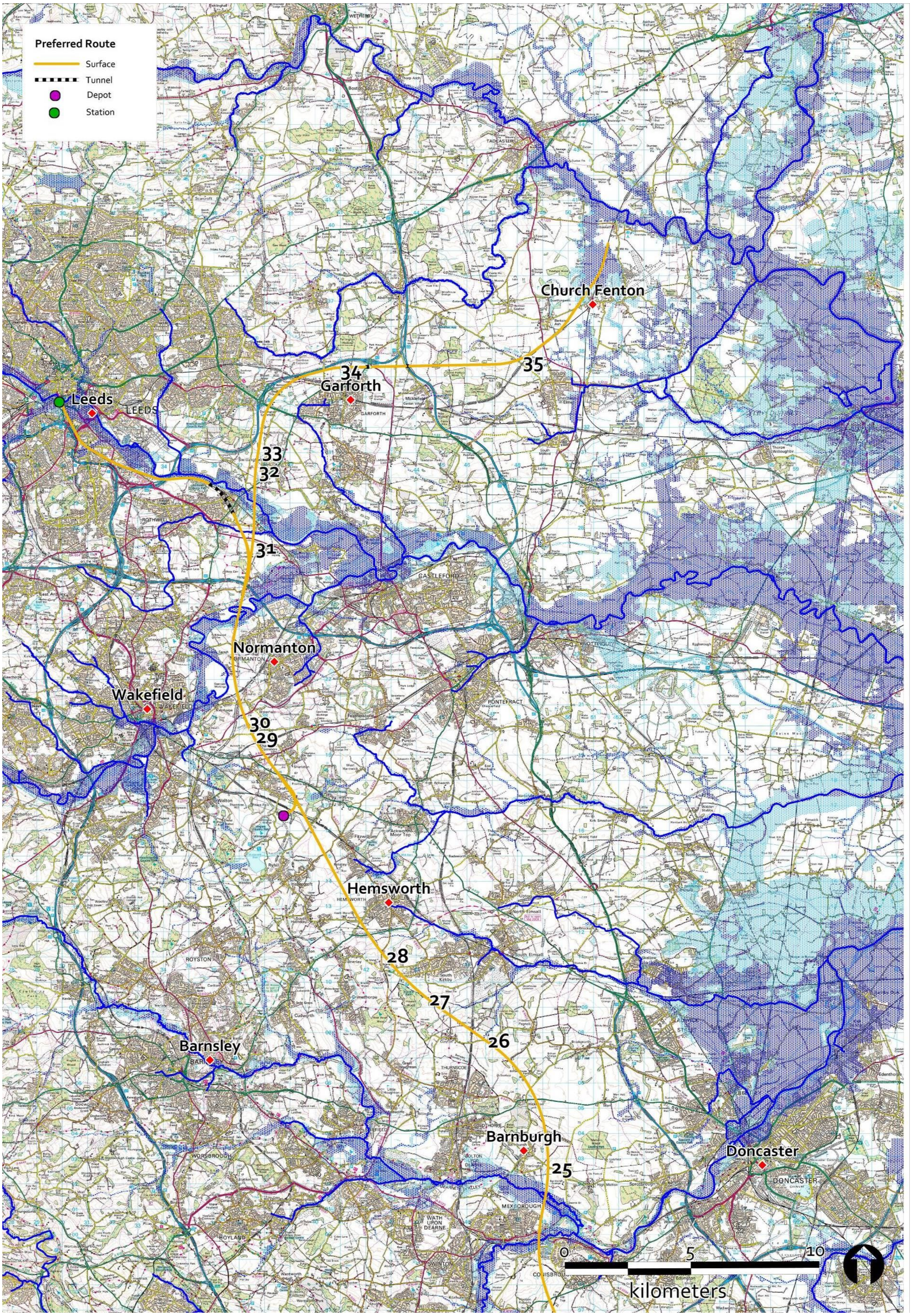


Figure 10-6 Floodplain Crossings – Western Leg

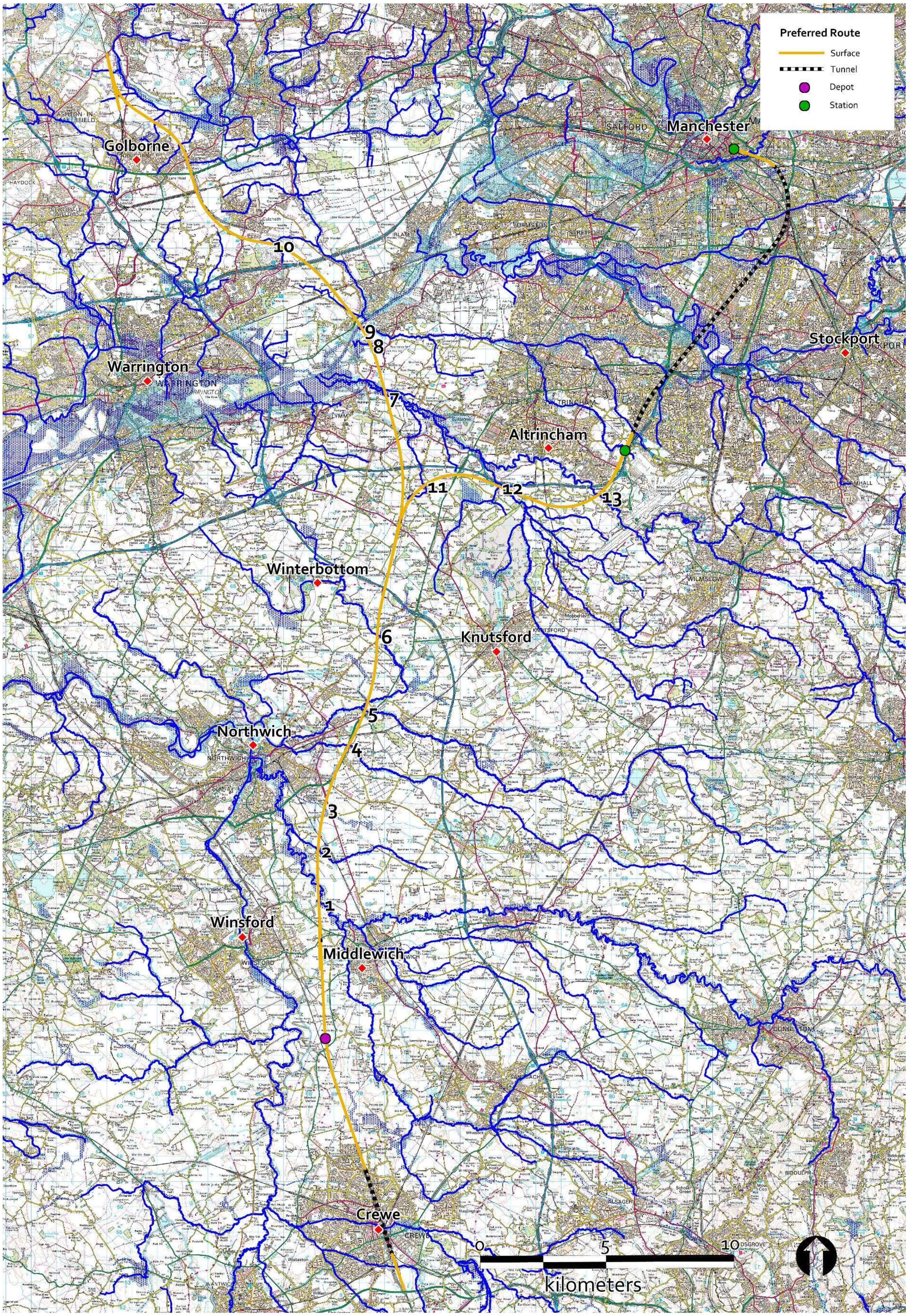


Figure 10-7 Floodplain Crossings – Eastern Leg: Marston to Kegworth

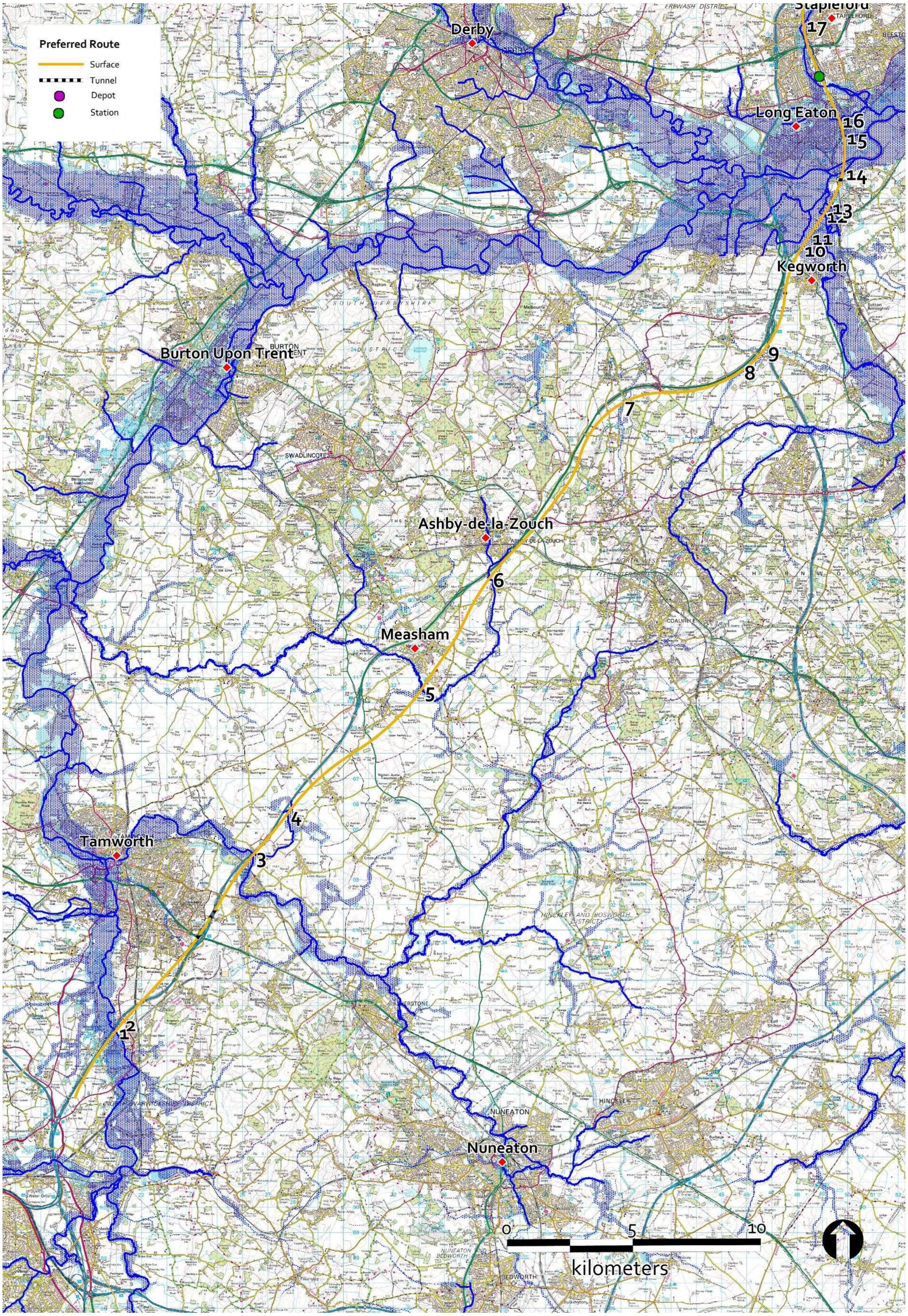


Figure 10-8 Floodplain Crossings – Eastern Leg: Kegworth to Heath

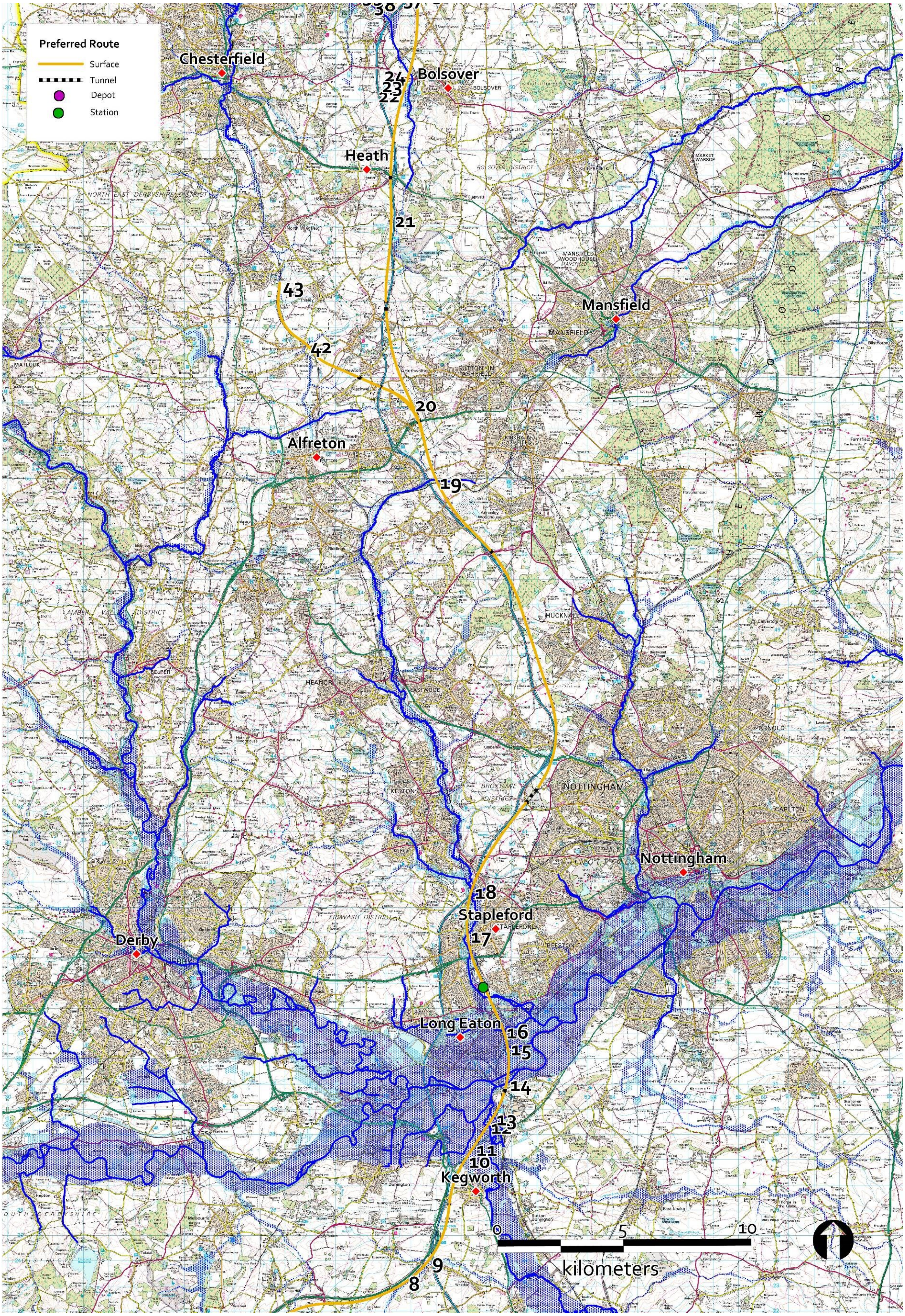


Figure 10-9 Floodplain Crossings – Eastern Leg: Heath to Barnburgh

Figure 10-10 Floodplain Crossings – Eastern Leg: Barnburgh to Leeds and ECML

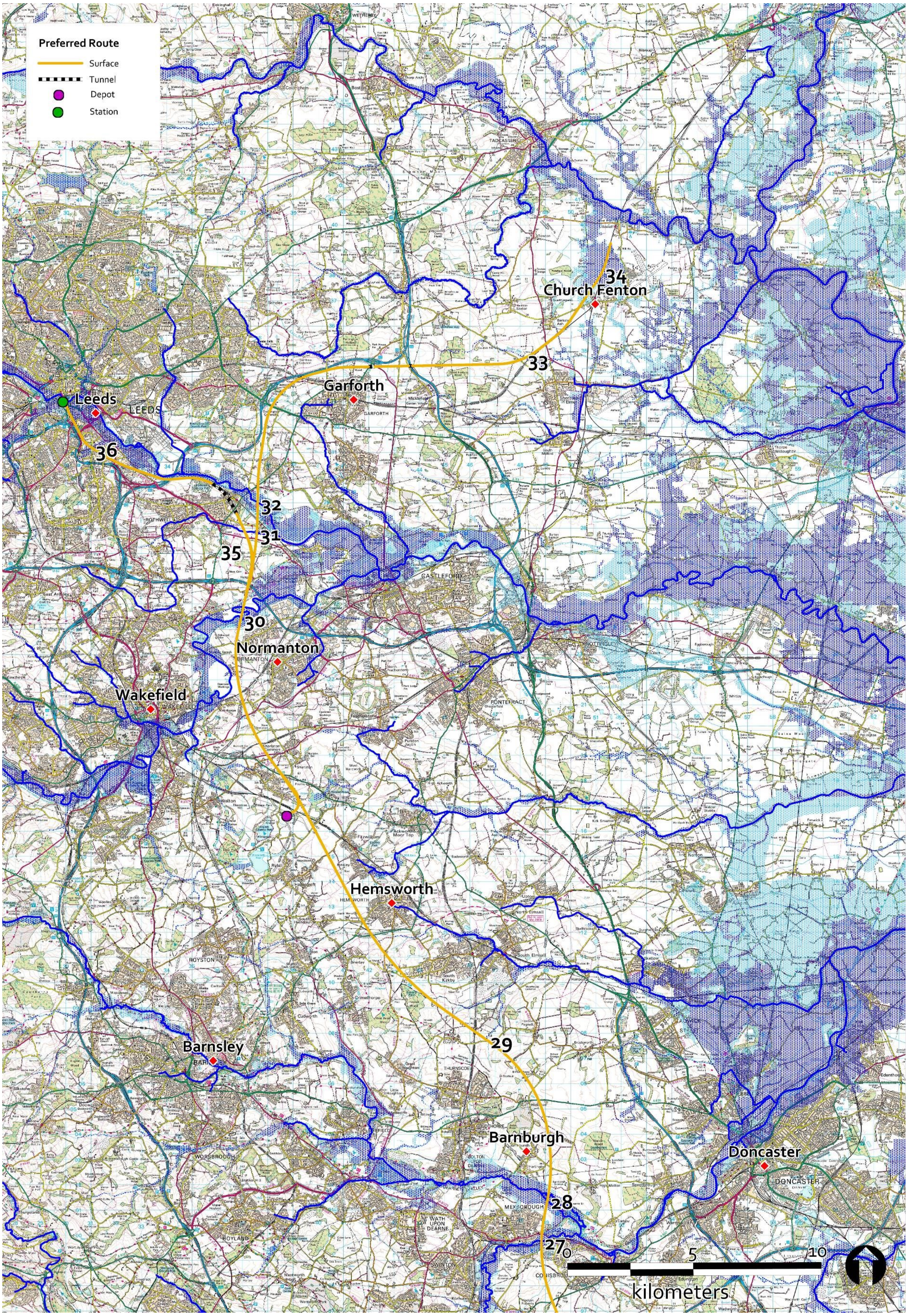


Figure 10-11 Groundwater SPZ – Western Leg

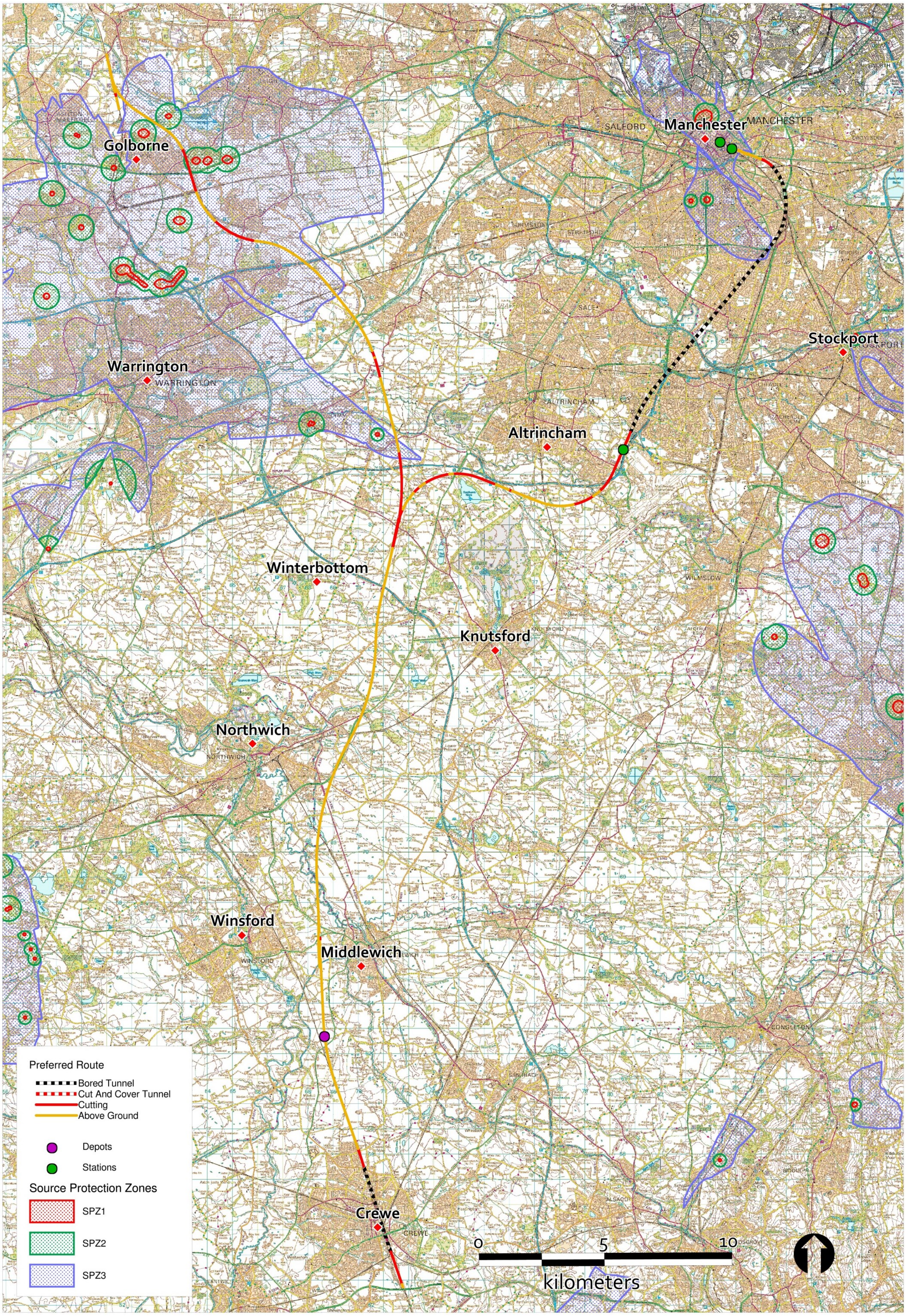
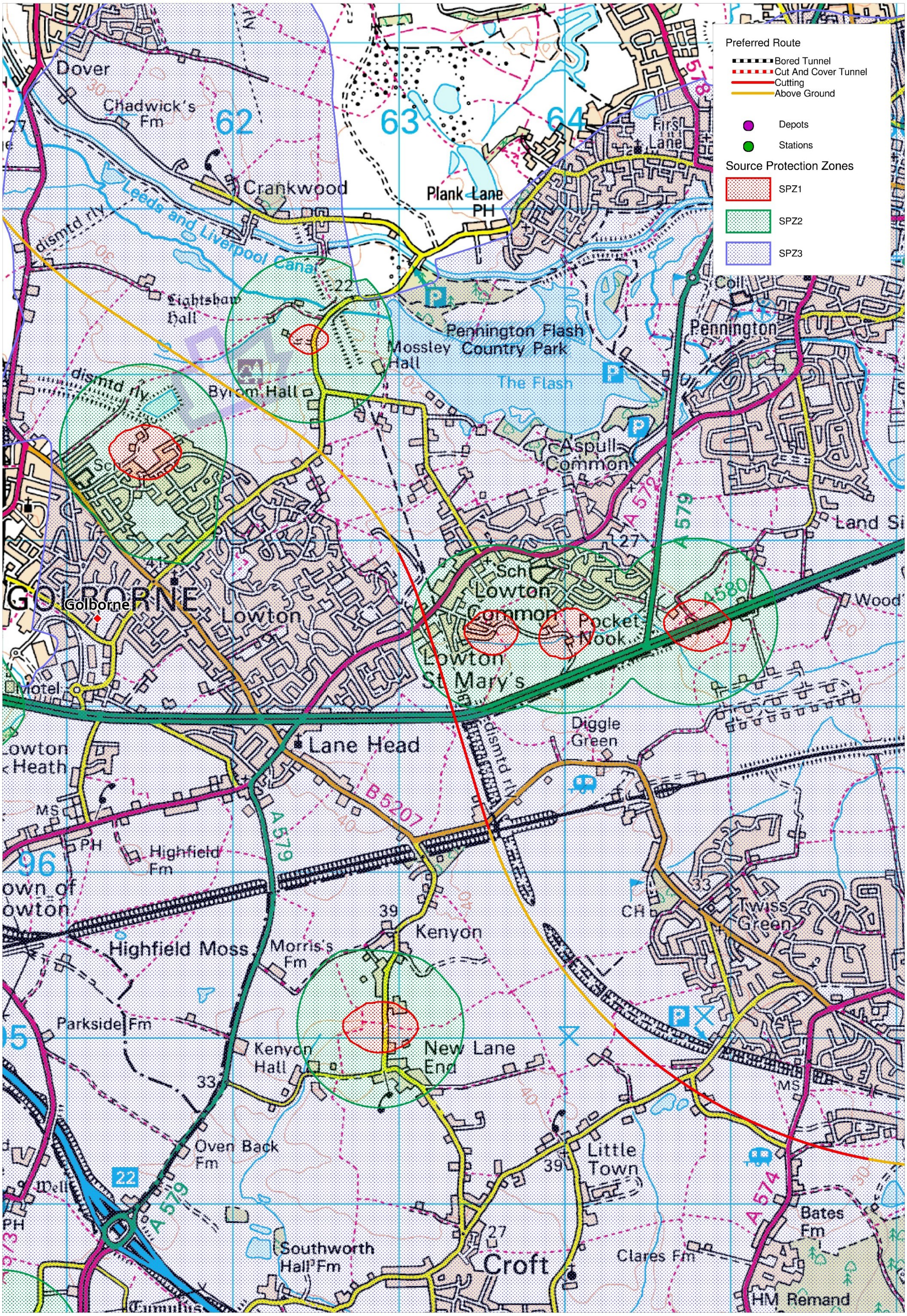


Figure 10-12 Groundwater SPZ – Western Leg, Golborne



TEMPLE

LEADERS IN ENVIRONMENT,
PLANNING & SUSTAINABILITY.

RSK