Options for phase two of the high speed rail network: Approach to design

A report to Government by HS2 Ltd

March 2012

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Preface to March 2012 reports

This report was submitted to Government by HS2 Ltd at the end of March 2012 and is part of a suite of documents produced to provide preliminary advice to Government on potential options for phase two of the high speed rail network.

For details of the initial preferred scheme selected by Government, please see the Command Paper[1]. The initial preferred scheme will form the basis of further engagement. A preferred scheme will be published in 2013 that will form the basis of full public consultation.

Anyone reading the March 2012 reports should be aware of the following:

- The reports describe the development of options. The base proposition referred to is not a recommended or preferred scheme.
- The reports describe route and station options serving Heathrow T5. The options do not reflect an initial preferred scheme. The Government has announced its intention to suspend work on high speed rail options to Heathrow until the Airports Commission has reported.
- Where the Ordnance Survey Licence Number is shown on maps it should read 100049190.

[1] *High Speed Rail: Investing in Britain's Future*
Phase Two: The route to Leeds, Manchester and beyond

Contents

List of acronyms

ECML	East Coast Main Line
IMD	Infrastructure Maintenance Depot
MSG	Mott MacDonald, Scott Wilson and Grimshaw
OHLE	Overhead Line Equipment
QRA	Quantitative Risk Assessment
RSD	Rolling Stock maintenance Depot
SCL	Sprayed Concrete Lining
S&C	Switch and Crossing
TBM	Tunnel Boring Machine
WCML	West Coast Main Line

Executive summary

1. This is HS2 Ltd's advice to Government which summarises the scope and technical requirements for a route engineering and alignment study for phase two of the HS2 network. This report also introduces the detailed engineering route descriptions, presented as three separate reports entitled:

   - Engineering options report – West Midlands to Manchester;
   - Engineering options report – West Midlands to Leeds; and
   - Engineering options report – Heathrow spur.

2. The route definition and selection process for phase two of HS2 commenced in the autumn of 2010 with engagement of engineering and environmental consultancies to deliver the necessary technical design and appraisal input. The methodology applied was in large part the same as that applied to the route selection between London and the West Midlands, with improvements to the process implemented as necessary following lessons learned from that first phase of the project.

3. The remit for our consultants was to identify a number of possible route and station options. This involved a process of identification of a long list with subsequent sifting to reduce the options for consideration down to a handful of alternatives that meet the remit set by the Government. At each sift, remaining options were developed to a greater level of detail in order to identify the key differences between options.

4. The scope for the Manchester leg includes Manchester city centre station locations and consideration of the potential for interchange/ intermediate station locations. Connections to the existing West Coast Main Line railway would provide routes further to the North West and Scotland.

5. The scope for the Leeds leg includes city centre station options in Leeds and options for stations in South Yorkshire and the East Midlands, including interchange options and city centre options. There is further consideration of classic compatible running into the city centres of Sheffield, Nottingham, Derby and Leicester. Connections to the existing East Coast Main Line railway would provide routes further to the North East.

6. The scope for the Heathrow spur includes Heathrow station options to connect with one of the terminals and the potential for the spur to be later extended to form a loop connection.

7. The technical requirements for line of route, stations and depot design are outlined in this report; each of the consultants has been following the requirements and guidance.

8. The consultants have provided journey times for input into the business case model. They have also provided quantities of materials required for each route and advised on technical and engineering risk as an input to the cost and risk model.

1 Introduction

1.1 This report

1.1.1 This is HS2 Ltd's advice to Government which summarises the scope and technical requirements for a route engineering and alignment study for phase two of the HS2 network. This report also introduces the detailed route descriptions, presented as three separate reports entitled:

- Engineering options report – West Midlands to Manchester
  - Produced by Mott MacDonald with the support of Scott Wilson and Grimshaw Architects (MSG);
- Engineering options report – West Midlands to Leeds
  - Produced by Arup; and
- Engineering options report – Heathrow spur
  - Produced by Arup.

1.1.2 Phase two of HS2 would see completion of the Y network running from the tie-in points on the proposed London to West Midlands section to the city centres of Manchester and Leeds. Phase two of HS2 also includes the potential for a spur to Heathrow Airport.

1.1.3 The Manchester leg includes connections to the existing West Coast Main Line (WCML) railway, and considers additional station locations prior to reaching Manchester. The Leeds leg includes stations to serve the East Midlands and South Yorkshire and a connection to the East Coast Main Line (ECML) railway prior to York.

1.2 Overview of methodology

1.2.1 We initially identified potential route corridors and potential station locations in each region to be served. From appointment, the respective consultants worked closely with us to develop these options and to consider further options. The remit is described in full in section 2 of this report.

1.2.2 Our respective consultants considered these options in successively greater detail as the options were refined and sifted through a series of sifting review stages that we led. This work was undertaken between September 2010 and January 2012, with sifting reviews held at four main stages.

1.2.3 We held these sift reviews using information on sustainability, engineering, journey time and capital cost. Using this information we identified which routes/ part routes should not be pursued, to focus attention on a shorter list of route options. For the city centre and regional station options, this process also included taking into account the views of key local stakeholders including local authorities, Highways Agency and Network Rail.

1.2.4 The final part of this sifting process focussed on the refinement of the remaining options and seeking to mitigate, where practicable, the critical environmental, sustainability and engineering issues identified at the previous stage. This process also sought to address the value engineering of complex route sections. For city centre, intermediate and interchange stations this process also involved optimising the concourse and forecourt layout, addressing the impact of the station on the surroundings, developing the access arrangements and highways, optimising interchange, reviewing the construction methodology and improving the station orientation.

1.2.5 During the later stages of this process as the route alignment options were reduced in number, we considered the potential location of infrastructure maintenance depots and rolling stock depots. Initial site options were confirmed following discussion with local stakeholders; these options were then developed and followed a similar sifting approach based on engineering, sustainability and capital cost information.

1.3 The layout of this report

1.3.1 This report is set out as follows:

- chapter 1 (this chapter) is introductory;
- chapter 2 discusses the remit for the engineering development work;
- chapters 3, 4 and 5 set out the technical requirements and assumptions underlying our work;
- chapter 6 discusses the approach to railway operations, in particular journey time modelling;
- chapter 7 sets out the approach taken to developing engineering quantities for capital cost estimating purposes; and
- chapter 8 summarises the potential route options, introducing the separate volumes for Manchester, Leeds and the Heathrow spur.

2 Remit

2.1 Remit to our consultants

2.1.1 As specified in HS2 Ltd's remits, the work for each leg of the Y network was undertaken in line with detailed technical parameters set out in HS2 Ltd's Project Specification. Apart from the particular requirements for each leg, the remits to our engineering consultants were identical.

2.1.2 The remit specified that investigation be carried out for each of the main engineering disciplines, working closely with us and our environmental consultants, Temple-ERM.

2.2 Remit for the leg to Manchester

2.2.1 The scope of work as set out in remits from HS2 Ltd to MSG for the Manchester leg included consideration of the following core elements:

- provision of a route from the London to West Midlands route to a station within Manchester;
- the station within Manchester is to have four platform faces, each suitable for a 400 metre long train;
- provision of one connection onto the existing WCML railway;
- provision of one infrastructure maintenance depot, ideally to be located towards the centre of the West Midlands to Manchester route; and
- provision of one rolling stock depot, ideally to be located towards Manchester.

2.2.2 The scope of work also included the following optional elements:

- interchange stations within / on the edge of the Manchester conurbation;
- intermediate stations south of the Manchester conurbation;
- additional connections onto the existing WCML;
- high speed route from the route into Manchester to the north of Preston;
- high speed connection to Liverpool; and
- 'delta' connection to allow services from the Manchester city centre station to route to the north onto the WCML connection and vice versa.

2.3 Remit for the leg to Leeds

2.3.1 The scope of work as set out in remits from HS2 Ltd to Arup for the Leeds leg included consideration of the following core elements:

- provision of a route from the tie-in from the London to West Midlands route to a station within Leeds. The station within Leeds is to have five platform faces (lately increased from four), each suitable for a 400 metre long train;

- the route shall provide a station to serve the East Midlands, which for the purposes of this study shall be considered to be the region defined by the three cities of Derby, Nottingham and Leicester;
- the route shall provide a station to serve South Yorkshire;
- provision of one connection onto the existing ECML railway north of Leeds;
- provision of one infrastructure maintenance depot, ideally to be located towards the centre of the West Midlands to Leeds route; and
- provision of one rolling stock depot, ideally to be located towards the Leeds end of the route.

2.3.2 The scope of work also included the following optional elements:

- interchange stations between Leeds and York;
- 'delta' connection to allow services from the Leeds city centre station to routes to the North East onto the ECML connection and vice versa; and
- classic compatible running of train services to the city centres of Sheffield, Nottingham, Derby and Leicester.

2.4 Remit for the Heathrow spur

2.4.1 The scope of work as set out in remits from HS2 Ltd to Arup for the Heathrow spur included consideration of the following core elements:

- Provision of a route from the two tie-in points, one outside the Chiltern tunnel portal and the other between the Colne Valley and West Ruislip on the London to West Midlands route to a station serving one of the Heathrow terminals; and
- The station at Heathrow is to have four platform faces, each suitable for a 400 metre long train.

2.4.2 The scope of work also included the following optional elements:

- Provision of an extension of the spur to form a loop connecting to the London to West Midlands route near Northolt.

2.5 Other studies

2.5.1 This report addresses engineering, layout, geographical location and journey time modelling. Along with our consultants, we undertook a number of other studies in parallel to inform the decision making. These are reported separately and include:

- demand modelling to provide transport patronage forecasts;
- business case appraisal;
- environmental and sustainability assessment; and
- cost and risk modelling.

3 Technical requirements for Line of Route

3.1 HS2 Technical specification

3.1.1 HS2 Ltd has a technical specification, entitled "HS2 Technical Specification and Strategies", which sets out the engineering operational and performance requirements for the route, and sets out the engineering design parameters.

3.2 Alignment design assumptions

3.2.1 The alignment development work was generally carried out using Ordnance Survey MasterMap data, supplemented with elevation information from five metre resolution terrain data and one metre resolution surface data which we provided. This mapping has been used to support the alignment design.

3.2.2 Our consultants undertook the alignment design in line with a combination of industry standards and best practice:

- the HS2 "Technical Specification and Strategies";
- European Standards, the TSI 2002/732/EC (Technical Specification for Interoperability relating to the infrastructure sub-system); and
- Network Rail Standard, NR/SP/TRK/0049 (Track Design Handbook).

3.2.3 Key alignment parameters from the Project Specification include:

- the project shall assume a maximum line speed of 400kph where topographical, train performance and sustainability issues permit;
- the line shall be designed to permit trains to maintain consistent high speeds;
- the maximum achievable turnout speed is assumed to be 230kph;
- the maximum vertical acceleration experienced due to the effect of vertical curvature shall normally be 2.25% of g; under exceptional circumstances, this can be increased to 4.25% of g; and
- the maximum vertical curve radius shall be 56,000m.

3.3 The width of the railway

3.3.1 For the majority of its length, the new route would be a twin-track railway.

3.3.2 The separation between the centre lines of the pair of tracks would be 5.0m where 400kph running was required. The track-bed width shall make provision for Overhead Line Equipment (OHLE), access tracks wherever practicable, staff walkways, drainage, and fencing. The normal track-bed width would be 22m wide.

3.3.3 For cuttings and embankments, it is assumed that the side slope of the earthworks would be between 1:2 (one vertical to two horizontal) and 1:2.5 on average. This is an appropriate design assumption. In practice it may be possible to use steeper cutting slopes or apply retaining walls to reduce the fence-to-fence dimensions. Elsewhere, shallower cutting and embankment slopes may be required where the ground conditions are less stable.

3.3.4 Where tracks enter tunnels in two separate tunnel bores, the distance between tracks would be dependent on the tunnel diameter, but would typically be 21m instead of the usual 5m.

Construction assumptions

3.3.5 Construction of HS2 would require some additional width beyond the corridor footprint, together with larger discrete areas to act as construction compounds. Individual larger worksites would also be required at areas of major works including bridges and major structures, and entrances to tunnels.

3.3.6 At this early design stage, consideration of construction issues has generally included identifying risks and opportunities, and identifying typical working methods and techniques. Given the more constrained nature of the station sites, further work has been undertaken including initial identification of potential construction boundaries to assess the land take and demolition required.

3.4 Geotechnical assumptions

3.4.1 As one might expect from a project with such a large geographical scope, the geological conditions across the legs to Manchester and Leeds and the spur to Heathrow are variable. As such it is not possible to apply a common approach across the project without importing risk.

3.4.2 At this early stage of design a common side slope has been adopted for earth structures. We will develop the designs to a greater level of detail with desk-based and later intrusive geotechnical investigations, our assumptions will need to be modified.

3.4.3 The following issues are typical of the influences that there have been so far on route selection:

- subsidence of natural cavities, in particular gypsum;
- areas with a known history of landslides or unstable ground;

- compressible deposits include alluvium, and on the approaches to Manchester, peat, which poses a settlement risk to loads placed on it;
- shallow mine workings occur widely, although primarily coal mining, there are also shallow mine workings associated with ironstone, sandstone and gypsum. Deep mine workings are limited to coal and significant lengths of the routes cross coal mine workings; and
- backfilled opencast coal sites (OCCS) are very common in the coalfields of Nottinghamshire, Leicestershire, South Yorkshire and West Yorkshire. It is common for landfill cells within the backfill to contain significant contamination.

3.5 Structures assumptions

3.5.1 Our consultants have sought to provide sufficient vertical clearance within the alignment design where HS2 would cross, or be crossed by, roads and other major obstacles including other railways, rivers and canals. For short bridges, such as those used to carry the railway over local roads, or roads over the railway, bridges would likely be straightforward single spans. For longer structures, our consultants have assumed provision of a viaduct structure. In particular, viaducts have been assumed where the designed rail level would be greater than 15m above existing ground level, or where the feature to be spanned is longer than 60m, for example, where HS2 would cross a flood risk zone.

3.6 Tunnelling assumptions

3.6.1 The range of tunnel configurations used was as follows:

- twin bore, single track tunnels (with cross passages where required);
- single bore, twin track tunnel (with or without central dividing wall); and
- cut and cover tunnels.

Driven tunnels

3.6.2 The tunnelling methods considered were:

- tunnel boring machine (TBM) driven tunnels with precast tunnel linings, with the machine type dependent on ground conditions; and
- sequentially excavated tunnels, generally utilising sprayed concrete lining (SCL) for initial ground support.

3.6.3 Our consultants have assumed that tunnels would be provided where the track alignment is at 22m or below existing ground level. The size of tunnel required would be dependent on design speed and length of tunnel. This is subject to an absolute minimum size of 7.25m for each bore of a twin-bore tunnel which is determined by the space required to accommodate the train and ancillary equipment such as the electrification system, emergency walkways, and drains. Aerodynamically, this tunnel size would allow speeds up to 250kph – above this speed, larger tunnels would be required up to an internal diameter of 10.1m for each bore of a twin bore tunnel.

3.6.4 For tunnels less than 400m in length we have assumed that these tunnels would be constructed as a single bore, with internal widths varying from 11m to 15m.

3.6.5 Our consultants have allowed for vertical intervention shafts of 12m diameter at a spacing of approximately 1000m, providing for tunnel ventilation and emergency access and evacuation. Cross passages between twin bore tunnels have been assumed at a spacing of approximately 500m.

Cut and cover tunnels

3.6.6 In some locations, cut and cover tunnels are proposed. These would be formed by excavating what would be a normal cutting, then, in the cutting, a box type of structure would be constructed, before re-filling over its roof slab to restore the original ground level and surface features such as footpaths or woodland. Such tunnels would be constructed where a very deep cutting is not economically viable and where a driven tunnel would be impracticable due to insufficient cover depth to the surface.

3.6.7 In some locations, a "green tunnel" could be used. These would be formed by enclosing the railway (where otherwise it would be in partial cutting or even on the surface) with a box type of structure, with a mounded area provided over the roof element of the structure. Such tunnels would be constructed as an environmental mitigation for noise, visual intrusion or habitat.

3.7 Interfaces with existing transport infrastructure

3.7.1 Where HS2 would cross the path of an existing highway or railway the route alignment design would provide sufficient vertical clearance to permit construction of an overbridge (infrastructure over HS2) or underbridge (infrastructure under HS2).

Interface with existing trunk roads

3.7.2 The routes encounter major highways, including motorways. Where HS2 crosses the highway, either above or below, there would often be a requirement to locally modify the highway to accommodate the HS2 structure. Where HS2 crosses beneath the highway, new bridge structures would be incorporated.

3.7.3 Where the HS2 route options attempt to follow an existing highway corridor there would often be a requirement to apply a permanent realignment of the highway so that HS2 would share the existing and sometimes widened corridor.

Interface with existing railways

3.7.4 The routes would also cross existing railway infrastructure, the engineering solutions for many of the crossings would be similar to those described for the interface with highways above.

3.7.5 There are locations along the routes where significant modifications to the existing railway network would be required, such as closure and diversion of existing lines or the realignment of tracks, so that HS2 would share an existing and possibly widened corridor. Specific solutions are described in the relevant volume of this suite of engineering options reports.

3.8 Environmental mitigation

3.8.1 For a major project such as this, environmental mitigation would be required. This could include significant earthworks and bunding / screening, planting areas, balancing ponds, replacement facilities, habitat enhancement and noise/visual screens. Along with our environmental consultants, Temple ERM, we have identified initial potential opportunities for environmental mitigation as part of the iterative design process to date. These matters will be addressed as the design of the scheme is developed.

4 Technical requirements for stations

4.1 Introduction

4.1.1 The quality of station design will shape the passenger experience of the HS2 network. The station should promote a positive experience of the network through a design that provides passengers with a smooth, convenient and pleasant passage through the station with effective management of pedestrian throughput.

4.1.2 Station design will impact not only passengers but also people who live and work in the area where the stations are built. The design of stations and their integration with the surrounding built environment should create the opportunity not only to engender positive experiences of the network, but also to act as catalysts for improvements to the surrounding cityscapes.

4.1.3 Stations fall into two groups;

- terminal stations, generally in a city centre; and
- intermediate stations on the line of route, of a parkway or interchange nature.

Assessment Criteria and selection

4.1.4 With, on average, thirty potential station locations initially identified for each city or region it has been necessary to define the selection criteria for each of the station options in increasing levels of detail at each stage of the design process. The assessment criteria at the highest level considered:

- site availability and fit;
- integration with line of route options and approaches to city centres;
- impact upon and integration with existing transport infrastructure;
- constructability;
- passenger dispersal;
- cost;
- demand, as far as location will impact upon demand; and
- a range of sustainability considerations.

4.1.5 At the later stages of option selection it sometimes became difficult to differentiate between certain station locations, even with higher levels of granularity within the selection criteria. In such instances, a significant extra amount of design development was required. This level of detail is reflected in the relevant sections of the engineering reports for each of the Leeds and Manchester legs.

4.2 Station design

4.2.1 The station design encompasses a wide range of criteria. This includes designs that enable train dwell times to match service patterns, considerations of passenger comfort and safety, capitalising on commercial opportunities and working within the confines of the budget. Provision for perturbed situations and future growth must also be considered.

4.2.2 Station design and layout will vary across the network depending on station location, operational requirements, land availability, etc, and therefore the design of each station will be unique. However, whilst recognising the constraints of individual sites, all stations on the high speed network should maintain a common feel and standard that promotes passenger familiarity regardless of where the station is.

Functional requirements

4.2.3 Station design will be developed to address the following factors critical to station functionality:

- accommodate network operational requirements;
- station capacity planning;
- functional zoning;
- passenger movements, wayfinding and accessibility;
- safety and security;
- interchange with other transport modes; and
- passenger environment.

Technical requirements

4.2.4 The useful length of HS2 station platforms shall be at least 415m and the project shall identify where longer platform lengths are required. The platforms shall be designed to GC gauge, the height of such platforms being 760mm above rail level.

4.2.5 Where interchange facilities with the national rail networks are provided the platforms shall be designed to UK national railway standards.

4.2.6 Platform width shall be determined to accommodate expected passengers flows with reasonable practicable allowances made for perturbation of peak flows. Design shall also comply with relevant design standards for minimum clearances to fixed infrastructure. Minimum width of platforms has been assumed to be 12m.

4.2.7 Tapering at platform ends shall be permitted where there is justifiable reason to do so. Where a taper is applied it should taper from full width to no less than a width of 8m and the radius of platform curvature shall not be less than 1000m radius. The remaining length of the platform shall be straight to facilitate splitting and joining of trains. Platform obstructions shall be kept to a minimum in the tapered section of the platform.

Number of platforms

4.2.8 The number of platforms required at each station is determined by the operational requirements that drive the timetable and necessary turnaround time to meet that timetable. This is further influenced by the length of the route sections, demand requirements and loading factors.

4.2.9 The Manchester terminal station will make provision for four platform faces.

4.2.10 The Leeds terminal station will make provision for five platform faces. The requirement for the extra platform at Leeds (as compared to Manchester, which would have a similar service provision) is a result of Leeds extra journey time and the impact that that has on the turnaround cycle of trains on the Leeds leg.

4.2.11 The interchange stations on the Leeds leg in South Yorkshire and the East Midlands will make provision for four platform faces each. These stations will normally include two through tracks (one northbound and one southbound) to cater for non-stopping trains travelling through the station at high speed.

4.2.12 The intermediate station options on the Manchester leg make provision for two platform faces only. Two through tracks would be provided for non-stopping trains.

4.3 Station approaches

Terminal stations

4.3.1 For terminal stations, the approach alignment attempts to maximise entry and exit speeds and their associated track layouts to permit unimpeded acceleration and braking of trains. This aspiration would sometimes be compromised by physical constraints on the station approach.

Through stations

4.3.2 The through stations require a facility to slow down and stop a train without impeding the passage of a following train, and conversely to enable that train to re-join the railway without being impeded by an overtaking train. The lengths of these acceleration and deceleration lanes, or stopping lanes, are defined by the speed and frequency of the service on that particular leg. Invariably, these lanes are much longer than a platform stopping lane would need to be for a slower railway or one that did not have such an intense service pattern.

4.3.3 Most of our through station options therefore incorporate two through running tracks with line speed potential of up to 400kph. Platform faces serve lines that run parallel to the through running lines. Depending upon the frequency of service these through stations could have either two or four platform faces (one or two platforms in each direction).

4.3.4 In general, therefore, the normal two-track route would widen to four tracks for a station with only two platform faces, and then to six for a station with four platform faces.

4.3.5 Where line speed through a station is limited to 160kph or less there is no longer a requirement for through running lines to run separate to the platform stopping lines.

5 Technical requirements for depots

5.1 Requirements for rolling stock depot

5.1.1 Each of the legs to Manchester and Leeds will include provision for a rolling stock maintenance depot (RSD).

General

5.1.2 The RSD for each of the Manchester and Leeds legs would be configured for stabling and light maintenance, with heavier maintenance activities carried out at the Washwood Heath depot proposed for phase one of the HS2 network.

5.1.3 The RSD would be positioned with access to the HS2 route, ideally within ten minutes from the terminus station on each leg if running on the existing railway network, and the connection to HS2 would be made without introducing conflicting moves or loss of existing main line operational capacity. Access to the existing rail network to facilitate delivery of rolling stock and other materials by rail is desirable yet not essential.

5.1.4 The RSD would provide immediate access to the trunk road network to facilitate access by large goods vehicles. Good transport links will enable a suitable and relatively local workforce, and as such, the potential for access by public transport would be considered.

5.1.5 The site would be required to operate for 24 hours, seven days a week, and as such, the potential impacts upon local residential areas have been a factor in the decision making process. Brown field sites are preferable with ready access to existing utilities networks. Adverse sustainability impacts have been avoided.

Capacity

5.1.6 The RSD would be configured to be able to routinely deal with 30 train sets and provide stabling for up to 40 sets in exceptional circumstances. This requirement approximates to a footprint one kilometre in length and 250m wide, an area of 25 hectares. Each train set is up to 200m long, although a number may be up to 260m long for services running onto the existing railway network. Each depot would handle a mixture of full GC gauge sets and classic compatible sets. Consideration has been given to the potential for long term expansion of the depot without disturbance to operations once established.

Facilities

5.1.7 In addition to overnight stabling of train sets, the RSD would undertake rolling stock inspection, repair, cleaning, light maintenance, re-watering and replenishing of consumables. The depot would therefore provide a large covered maintenance building and the following typical, but not exhaustive, range of facilities:

- carriage washing plant;
- sufficient toilet-emptying and water replenishment facilities with appropriate discharge consents;
- overhead cranes;
- signalling and overhead power for all depot lines;
- wheel turning facility;
- office and stores facilities for depot production control, technical support, drivers signing on, messing, etc;
- depot lighting for safe operations at night; and
- site security.

5.1.8 The maintenance patterns and flow through the depot will be defined to ensure sufficient capacity remains to move trains around the depot and prevent 'grid lock'.

5.2 Requirements for infrastructure maintenance depot

5.2.1 Each of the legs to Manchester and Leeds will include provision for an infrastructure maintenance depot (IMD).

General

5.2.2 Each IMD would provide a base from which all infrastructure maintenance activities are resourced and materials supplied. It shall be a central store and supply point for all engineering (civils, track, signalling and OHLE) material that requires to be delivered to site by rail or road, plus strategic materials stocks. Each IMD would have a specific geographical area for which it is responsible.

5.2.3 Each IMD would provide a maintenance, servicing and stabling facility both for HS2 on-track plant (including vehicles up to GC gauge which would be too large to travel on the national rail network) and for HS2 maintenance rescue and recovery locomotives. It would be capable of acting as an incident control centre in the event of a serious accident or incident on the HS2 route.

5.2.4 Each IMD would ideally be placed close to the mid-point of the respective leg, with direct access to the HS2 route. Access to the existing rail network to facilitate delivery of rolling stock and other materials by rail would be essential.

5.2.5 Each IMD would provide immediate access to the trunk road network to facilitate access by large goods vehicles for materials delivery. Good transport links would enable a suitable and relatively local workforce, and as such, the potential for access by public transport has been considered.

5.2.6 Each site would be required to operate for 24 hours, seven days a week, and as such, the potential impacts upon local residential areas would need to be a factor in the decision making process. Brown field sites are preferable with ready access to existing utilities networks. Adverse sustainability impacts have been avoided.

5.2.7 Each IMD site would have the potential to be used as a construction depot for the works, thus avoiding additional land take.

Capacity

5.2.8 The depot would be designed to serve both the HS2 route and the existing railway in both directions where possible. This would allow engineering trains to access and egress the depot with maximum flexibility. A Switch and Crossing (S&C) assembly area would be provided to enable the pre-assembly of the S&C units to be installed. Overhead cranes would be provided to handle large and heavy materials/equipment. Areas to stock large OHLE and S&C components would be provided with facilities to enable forklift trucks to handle them safely. The depot would also store standard components and consumables.

Facilities

5.2.9 The IMD would stable and service / maintain a variety of on-track plant and Engineering Supply Train equipment. It would also provide strategic engineering material stores. HS2 ballast and spoil wagons would need to be able to run on and off the existing rail network, bringing supplies.

5.2.10 It is assumed that engineering trains would only operate on HS2 after the last passenger trains have ceased to run, and would return to the IMD before morning train operations commence.

5.2.11 Provision would be made for ancillary buildings and facilities such as offices, car parking, incident control rooms, workshops and storage.

6 Operational inputs

6.1 Modelling for journey times

6.1.1 Our consultants have undertaken journey time modelling for the potential routes on the legs to Manchester and Leeds and for the Heathrow spur.

6.1.2 This modelling was undertaken using an in-house software package, taking into account the designed track horizontal and vertical alignments. This was based on train performance data for HS2 Ltd's standard reference train.

6.1.3 The maximum train speeds assumed in the modelling are generally lower than the theoretical permissible speeds. For example, for permissible speeds of 250kph and above the maximum train speed has been assumed to be the permissible speed minus 30kph and rounded down to the nearest 10kph. This is subject to a maximum capped speed of 330kph.

6.1.4 Journey times for destinations on the existing railway network beyond HS2 were estimated by adding together the two elements of the journey time. For example, HS2 journey times from Lichfield to existing railway network tie-in points are added to journey time information from the existing railway network tie-in point to the final destination (such as Glasgow and Preston).

6.2 Journey time results

6.2.1 The journey time modelling gave a range of results for the various route options under consideration. These journey times are described in section 6 of each of the relevant volumes in this suite of engineering options reports.

6.2.2 The journey times in the engineering report differ from those used for demand modelling. For demand modelling the times are relatively conservative and include buffers to take account of minor perturbations and the practicalities of timetable configuration. Timings quoted in the route engineering report are valid for route option comparison only.

7 Cost and risk

7.1.1 We have prepared construction cost estimates, based on engineering quantities provided by our consultants in a standard format against standard quantity headings.

7.2 Quantities

7.2.1 For each section of the potential route options, our consultants prepared engineering quantities based on the engineering design. This included quantities for all main engineering elements, including tunnels, structures, earthworks, track work, highway modifications, stations and associated works, existing railway modifications, and discrete 'specials' (i.e. one off cost items not adequately captured under the other headings).

7.3 Risk assessment

7.3.1 As part of the quantification of engineering costs, route specific risks and opportunities were highlighted particularly in relation to ground conditions, including landfill sites.

7.3.2 We also undertook a quantitative risk analysis (QRA) process to assess the level of risk allowance appropriate to each of the route cost estimates. This followed industry-standard practice of identifying individual risks and opportunities, estimating the likelihood of that risk / opportunity occurring as a percentage, and estimating the minimum, most likely and maximum cost implication if this risk occurred. Engineering and sustainability specialists for each main engineering discipline inputted into this process by contributing to the identification and quantification of risks in risk workshop sessions.

8 Route description

8.1 Introduction

8.1.1 This report so far has summarised the scope and technical requirements for a route engineering and alignment study for phase two of the HS2 network. The following sections provide a high level description of the route options which are described in detail in subsequent volumes of the engineering options report:

- Engineering options report – West Midlands to Manchester;
- Engineering options report – West Midlands to Leeds; and
- Engineering options report – Heathrow spur.

8.2 Routes to Manchester

Geography of the Manchester Leg

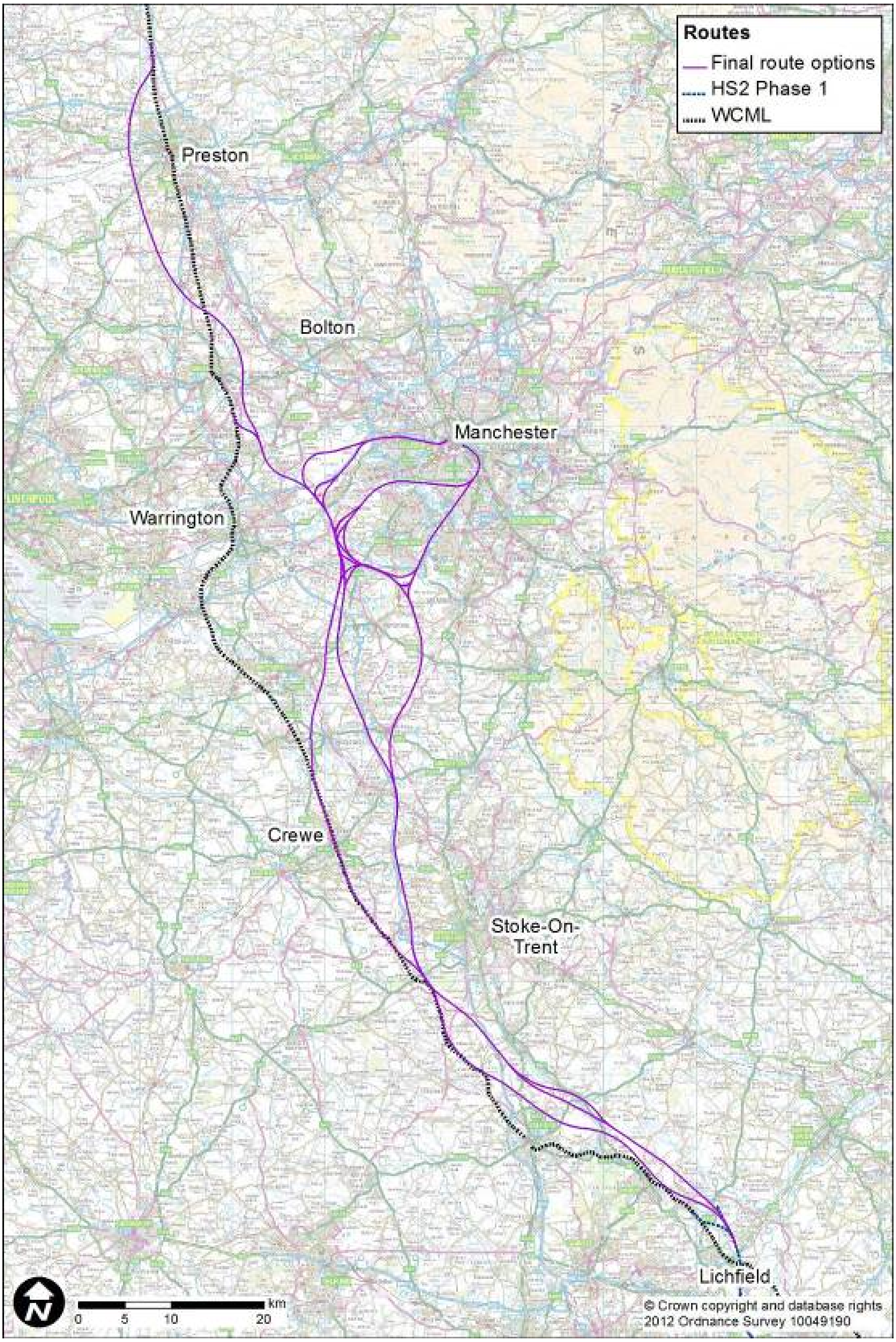
8.2.1 The topography of the southern part of the alignment (Lichfield through east of Stafford and beyond) is generally low lying, relatively flat land, while the central region (west of Stoke-on-Trent) is of higher relief. Further north, approaching Manchester from the west, the alignments are within the predominantly low lying Cheshire basin. Beyond Manchester to the north the alignment options continue on similarly low lying ground.

8.2.2 Between the outskirts of the metropolitan West Midlands conurbation and the outskirts of Greater Manchester the main centres of population are the Stoke-on-Trent / Newcastle-under-Lyme conurbation and the town of Crewe. Population density is relatively light elsewhere along the route.

8.2.3 The rail transport corridors are defined by the WCML railway and its spurs, with Crewe sitting at the hub of the railway network.

8.2.4 The main highway corridors are the M6 and the A51/A34 trunk road which passes through Stoke-on-Trent.

8.2.5 The major rivers are the River Trent at the southern part of the route and the River Mersey at the Manchester end.


Routes
Final route options
HS2 Phase 1
WCML
Preston
Bolton
Manchester
Warrington
Crewe
Stoke-On-Trent
Lichfield
km
0 5 10 20
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Route Description

8.2.6 All options would start at the junction connecting to the WCML north-east of Lichfield. There are two routes to a point near Baldwin's Gate to the south-east of Stoke-on-Trent, one of which would pass north of Stafford and then broadly follow the route of the existing WCML, and the other would be slightly further north passing south of King's Bromley, with an alternative section that would pass north of Weston.

8.2.7 North of Baldwin's Gate there are two route options. One would broadly follow the WCML corridor through Crewe, to a point west of Knutsford. There would be a connection to the WCML at Crewe to allow classic compatible trains to serve Liverpool and North Wales. The other would run west of Stoke-on-Trent.

8.2.8 There is an option for an intermediate station adjacent to the M6. The route would broadly follow the M6 corridor to a point east of Sandbach where it would split into two route options. One leg would follow the M6 corridor to a point west of Knutsford. The second leg would run north passing east of Goostrey to Mobberley.

8.2.9 From Mobberley the route would run east past Manchester Airport to then follow the route north from Lymm. A junction at Mobberley would provide a route past the airport and then in a long tunnel to a station option at Manchester Piccadilly. There are three options for an interchange station close to the airport.

8.2.10 Both routes would run north from a point west of Knutsford. From Knutsford, where interchange stations could be accommodated, route options would cross over the Manchester Ship Canal and onward between Golborne and Lowton. At Golborne a connection to the WCML would be provided to allow classic compatible trains to continue north.

8.2.11 An alternative route would continue north from Golborne. After crossing the M6 the route would run through New Longton and Hutton before crossing the River Ribble on a long viaduct. There is an option for an interchange station adjacent to the M55. The route would connect to the WCML north of Bilsborrow, allowing classic compatible trains to serve north to Scotland.

8.2.12 Route options to the centre of Manchester from Knutsford would provide access to the station at Piccadilly via either the Airport and the long tunnel or east of Partington, along the Mersey Valley and in a long tunnel.

8.2.13 North of the Manchester Ship Canal there are three route options towards station options in Salford. Two follow the M62 corridor to the outskirts of Eccles and the other follows the existing Chat Moss railway corridor. All three then run alongside the existing railway before using a tunnel to Salford.

8.3 Routes to Leeds

Geography of the Leeds Leg

8.3.1 The study area can be divided into four broad sections of terrain and geography. Between the West Midlands and the Derby/Nottingham area the route options pass through undulating and largely rural landscapes, with settlements of former coal mining towns.

8.3.2 Beyond the broad valley created by the confluence of the Trent and Derwent rivers, the route options pass through an area defined by the Peak District to the west, and the Nottinghamshire Coalfield to the east. The topography to the west and the scattered towns and mining villages of the Nottinghamshire Coalfield imposes constraints upon route identification and selection.

8.3.3 Northwards from South Yorkshire into West Yorkshire, the terrain is a particular constraint upon route choice and selection. There are interwoven hills and valleys running perpendicular to the route. The area is densely populated with scattered towns and villages of varying size which give a clue as to the former industrial heritage.

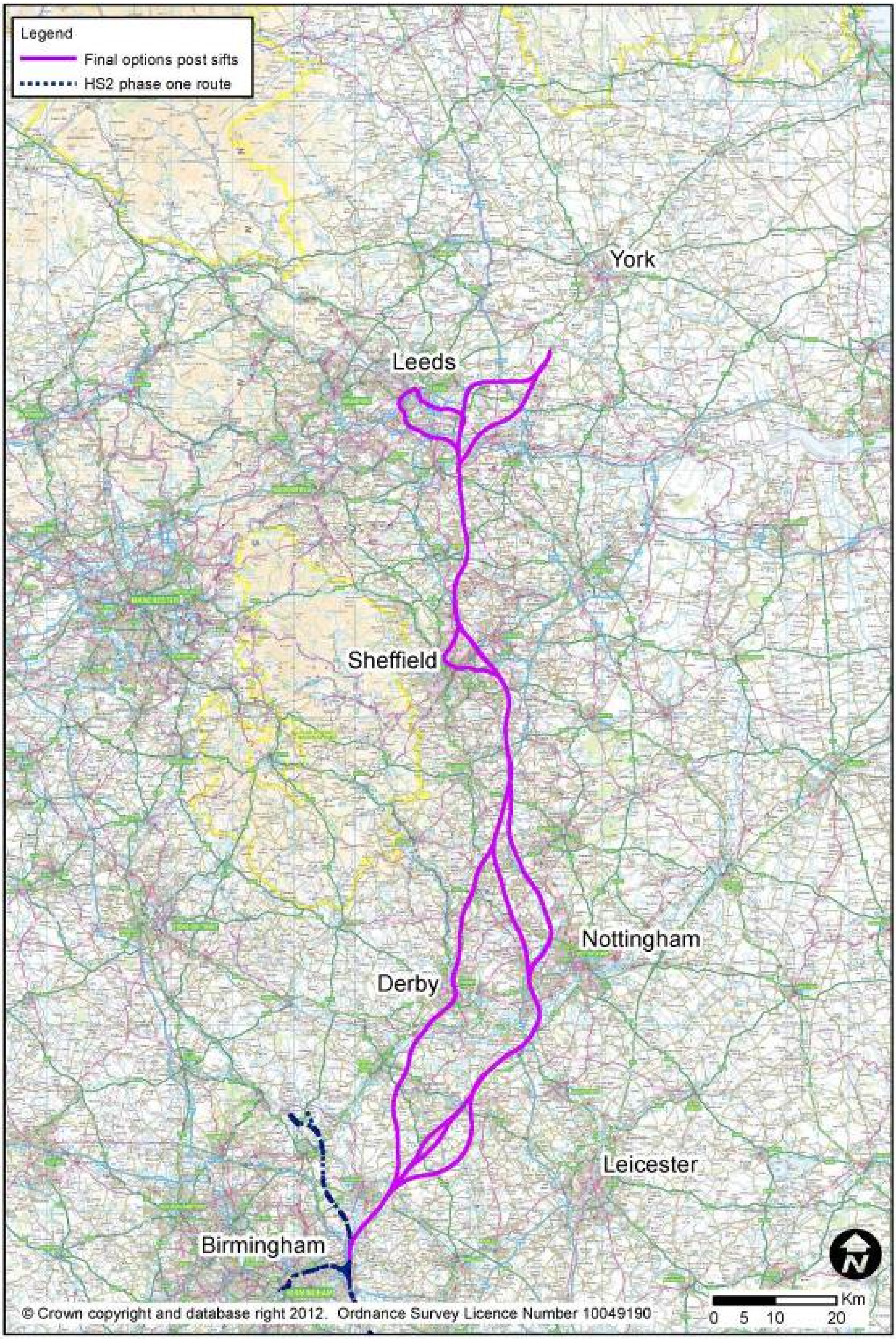
8.3.4 After crossing the valleys created by the Aire and Calder rivers the terrain becomes less challenging for the approach into Leeds and the connection to the ECML south of York, with open agricultural land, modest rolling terrain, and far fewer settlements.

8.3.5 The major cities of the East Midlands are Derby, Nottingham and Leicester and their associated conurbations. The City of Sheffield dominates South Yorkshire with its satellites of Rotherham and Barnsley merging to create the Sheffield and Dearne Valley conurbation. The City of Leeds dominates West Yorkshire with the Leeds urban area prevented from expanding farther west by the confluence of the Aire and Calder, to the east of which lie Castleford and Pontefract.

8.3.6 The main railway corridors are the Midland Main Line between Leicester and Sheffield via Derby and the ECML spur and Transpennine routes between South Yorkshire and Leeds.

8.3.7 The main highway corridors are the M42/A42 between the West Midlands and Nottinghamshire and the M1 from Leicester all the way to Leeds. The A38/A61 corridor connects Derby and Sheffield. Several other main highway corridors cut across the route such as the A52 and A610 in the East Midlands and the M62 in West Yorkshire.

8.3.8 In addition to the main river systems already mentioned, other major rivers are the Erewash running from North Derbyshire to Nottingham, and the Rivers Don, Dearne and Rother in South Yorkshire.


Legend
Final options post sifts
HS2 phase one route
York
Leeds
Sheffield
Nottingham
Derby
Leicester
Birmingham
Km
0 5 10 20
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Route description

8.3.9 All options would start at the north point of the "Delta Junction" at Water Orton on the London to West Midlands section of HS2. All route options would run alongside the M42 to the south-east of Tamworth. Between Tamworth and Tibshelf (near Junction 29 of the M1) there are two main route options, one via Derby and one via Toton.

8.3.10 The route via Derby would pass east of Burton-on-Trent and then would approach Derby alongside the existing railway. There would be a station in central Derby integrated with the present station. North from Derby, the route would pass Belper and Alfreton running on towards the M1 near Long Duckmanton.

8.3.11 The route via Toton runs alongside the M42/A42 corridor passing beneath the East Midlands Airport and then crosses the Trent/Derwent floodplain towards Toton, where a station would be provided. There would be extensive alterations to Network Rail tracks in this area.

8.3.12 North from Toton, the routes could either follow the M1 towards Long Duckmanton, or follow the Erewash Valley. Via the Erewash Valley, the route would generally follow the existing railway to Alfreton, before diverging towards the Long Duckmanton area; and via the M1, the route would run to the east of Nuthall, crossing the A38 east of the M1, before passing to its east in the Hardwick Hall area.

8.3.13 North from Long Duckmanton, the route runs via Kilamarsh and Tinsley to a station at Meadowhall, alongside the M1's Tinsley Viaduct. The route would then climb out of the Don Valley, to pass in tunnel under Hoyland and Ardsley, before crossing Wintersett Reservoir. A loop off this route could serve central Sheffield, at a reinstated Victoria station, followed by a tunnel under northern Sheffield towards Chapeltown.

8.3.14 From Wintersett, a route towards the North East has been considered and from this route, there are two options towards central Leeds and two towards York and the ECML.

8.3.15 Towards Leeds, the options are via the Transpennine rail corridor to a new station immediately north-west of the present one, or via Woodlesford towards two station options, both south-facing, south of the present station.

8.3.16 Towards York and the ECML are two options, one running north of Castleford and one north of Garforth. Both would join the existing railway near Church Fenton, so that trains could continue to York and the North East.

8.4 Routes to Heathrow

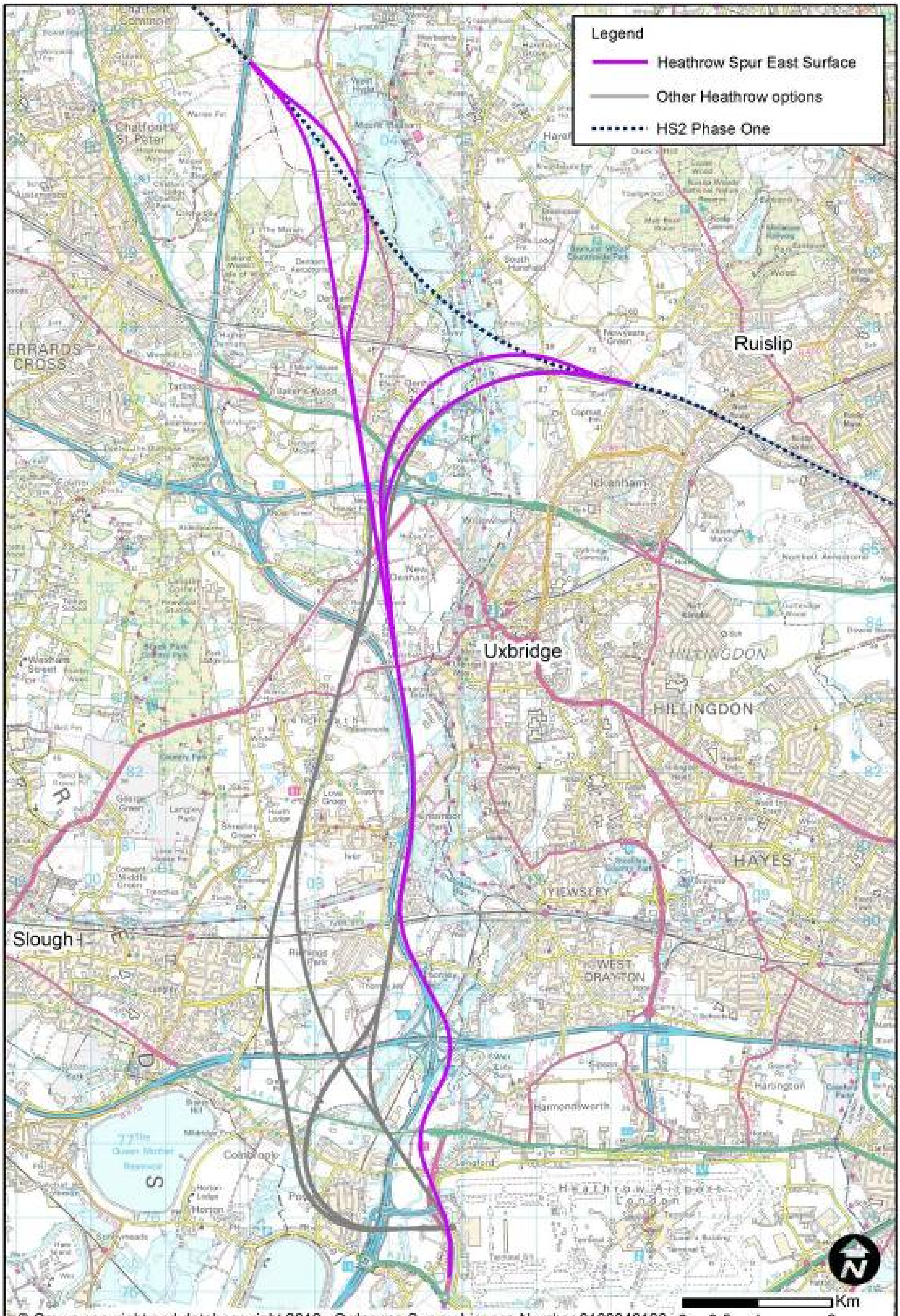
Geography of the Heathrow spur

8.4.1 The study area runs north-south, broadly aligned with the broad valley of the River Colne, in which the M25 is situated, again running north-south. The valley bottom features a number of gravel extraction sites, the historic ones often now filled with water bodies used for recreational purposes.

8.4.2 This north-south axis is interrupted at regular intervals by major east-west transport axes: the Chiltern Railway, the A40, the Great Western Main Line (GWML), the M4 (whose interchange with the M25 is a four-level junction presenting obstacles to route location), and the A4. These present major constraints on both horizontal and vertical alignments.

8.4.3 Uxbridge lies to the immediate east of the Colne Valley, while to the west of the M25 are Denham and Iver Heath, with Wraysbury Reservoir further south.

8.4.4 Heathrow Airport is situated at the southern end of the study area, and its complex of approach roads, motorway junctions and perimeter roads present more obstacles. The study assumes that Terminal 5 is the ultimate aim of the Heathrow spur or loop, and sub-surface options would overcome the constraints, while a surface solution is highly constrained.


Legend
Heathrow Spur East Surface
Other Heathrow options
HS2 Phase One
Ruislip
Uxbridge
Slough
Km
0 0.5 1 2

Route Description

8.4.5 The Heathrow station is located immediately west and alongside the Terminal 5 building. It would have four platforms, two for domestic and two for International use.

8.4.6 The station is set in a shallow open box approximately six metres below existing ground level.

8.4.7 The platforms are curved to give a footprint which minimises the impact on existing roads and water-bodies.

8.4.8 Passenger access is a central concourse with escalators down to a connecting concourse into the unused mezzanine level of the existing Terminal 5 station. This gives modal connectivity to LUL, Heathrow Express, future Airtrack as well as Terminal 5 itself.

8.4.9 The station would require some permanent and temporary diversions of existing roads and waterways. The River Colne would not have to be diverted. The existing twin rivers would have to be diverted around the station box. The existing roads and services would have to be temporarily diverted and reinstated as bridges over the station and in particular the access from the M25 to Terminal 5 would have to be amended.

8.4.10 Departing from the station, the tracks pass below ground level in a cut and cover box to pass below the northern runway exclusion zone. They then climb sharply to pass over the M25 / M4 junction on a viaduct before returning to ground level on the immediate eastern side of the M25. The route continues to follow alongside the motorway until Uxbridge Moor, where the motorway turns westwards and the route continues northwards. The route splits into two, with both parts falling into cutting before entering tunnel at the A40.

8.4.11 These two pairs of tunnels then head towards the main high speed route. One pair provides a connection to the north, rejoining immediately outside the Chiltern tunnel portal, and the other provides a connection to the Continent, rejoining the main line between the Colne Valley and West Ruislip.