TRANSPORT AND WORKS ACT 1992

TRANSPORT AND WORKS (INQUIRIES PROCEDURES) RULES 2004

NETWORK RAIL (HUDDERSFIELD TO WESTTOWN (DEWSBURY) IMPROVEMENTS) ORDER

APPENDIX to ADDITIONAL REBUTTAL PROOF

“Grade Separation Supporting Information”

RELATING TO PROOF OF EVIDENCE HARGREAVES (GB) LTD, NEWLAY ASPHALT LTD, NEWLAY READYMIX LTD, NEWLAY CONCRETE, DEWSBURY SAND AND GRAVEL LTD, AND WAKEFIELD SAND AND GRAVEL LTD (OBJ/18-22,29)

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Document Reference	NR/PoE/REB/GT/02.3
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GLOSSARY

Abbreviation	Definition
GRIP	Governance for Railway Infrastructure Projects
NTSN	National Technical Specification Notices
PoE	Proof of Evidence
S&C	Switches and Crossings

APPENDIX - GRADE SEPARATION SUPPORTING EVIDENCE

1. INTRODUCTION

1.1.1 This Appendix of supporting information has been prepared alongside an additional Rebuttal Proof (ref. NR/PoE/REB/GT/02.2), which has been submitted by Network Rail in response to a revised PoE received from Mr. James Taylor representing OBJ 18-22 and 29.

1.1.2 In the light of Mr Taylor's revised PoE, the purpose of this Appendix is to draw out further detail on some of the key aspects of the engineering and design that underlies the development of the Ravensthorpe flyover grade separation, and associated station relocation works. In the interests of guiding the reader I have repeated and reinforced some points previously made in my PoE dated 5th October 2021, and where necessary I have referenced back to specific sections and points in my PoE.

1.1.3 I will summarise the key points under the following three main headings:

- **New Fast Line Alignment Geometry**
- **Slow Line Alignment Geometry** (includes Wakefield Line re-alignment, Thornhill LNW Junction re-modelling and Ravensthorpe Station positioning)
- **Vertical Geometry Development**

2. NEW FAST LINE ALIGNMENT GEOMETRY

2.1 Introduction

2.1.1 The development of the new Fast Line alignment was constrained within a narrow footprint. This is defined by existing physical features, land and property boundaries, and tie-ins into the existing railway corridor at the west and east extremities of the Ravensthorpe area. Some key points I considered in developing the railway alignment are described in following sub-sections:

Alignment Effect on Plan Position of the Grade Separation.

2.1.2 A simple study of the plan geometry of the proposed railway intersection shows that the fast line alignment should be positioned as far South as reasonably possible, so that the key intersection point with the Wakefield lines is pushed eastwards, away from the critical headroom location at Calder Road. Moving the fast line alignment further north would be detrimental to the grade separation position (effectively moving it west) and limit the ability of the Scheme to construct “off-line” through the existing Ravensthorpe cutting and then into the “Ravensthorpe Triangle”.

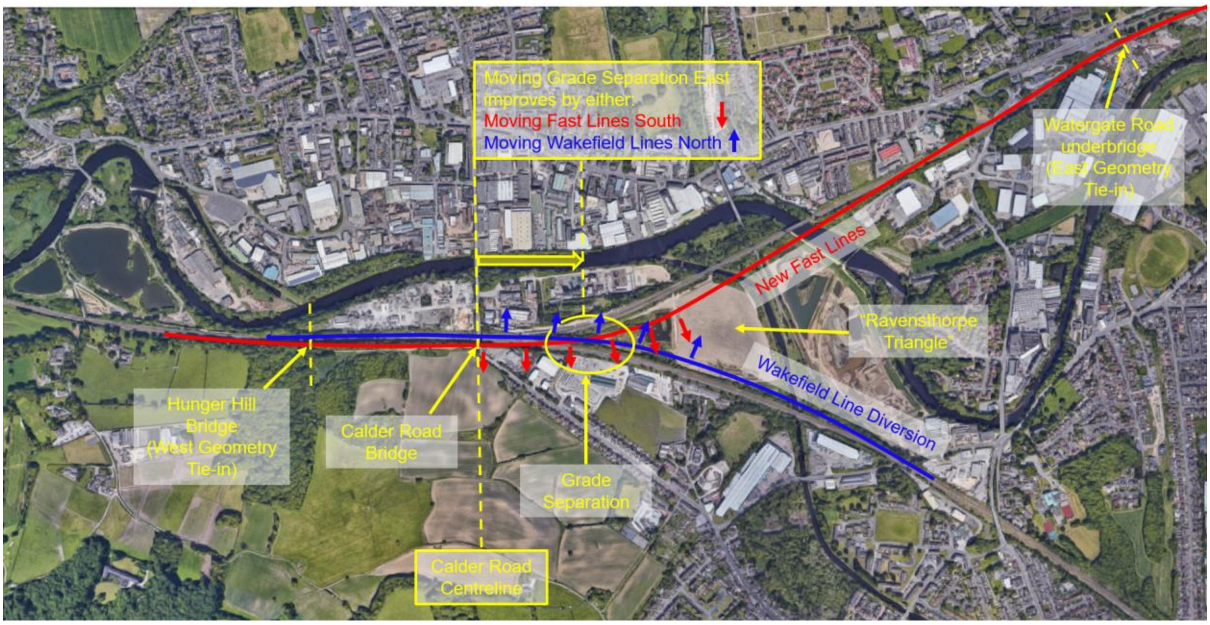


Figure 1: Ravensthorpe Grade Separation, simple alignment study

Ravensthorpe East Junction Operational Layout

2.1.3 The location and operational layout chosen for Ravensthorpe East junction is explained in detail in my PoE Section 3.1 (points 3.1.57 to 3.1.64) and relevant diagrams are repeated below in Figure 2. This layout positions the new fast lines between the slow line chords emerging from the re-modelled Thornhill LNW Junction to the west. The Slow Line chords split left and right of the main through fast line alignment eliminating any junction conflicts. This arrangement then relies on the secondary grade separation of the Up Slow chord where it passes below the fast lines to the at-grade junction with the Wakefield Lines. This feature is vital for the reliable performance of the ITSS, which is based on a proposed fast train clockface timetable. This is demonstrated in Figure 3.

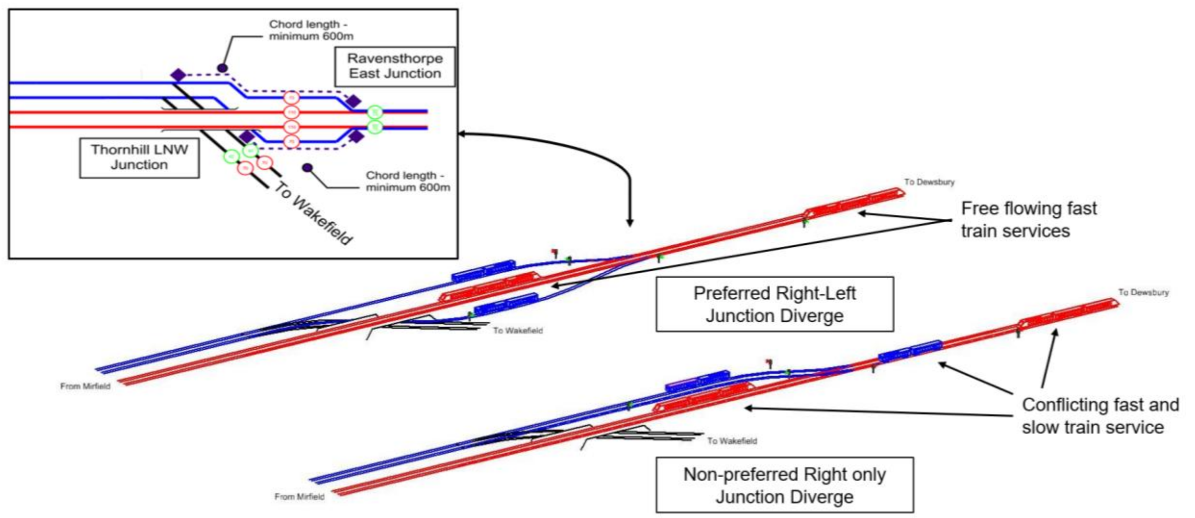


Figure 2: Ravensthorpe East Junction, Operational Layout (Figures 3-11 and 3-12 from PoE)

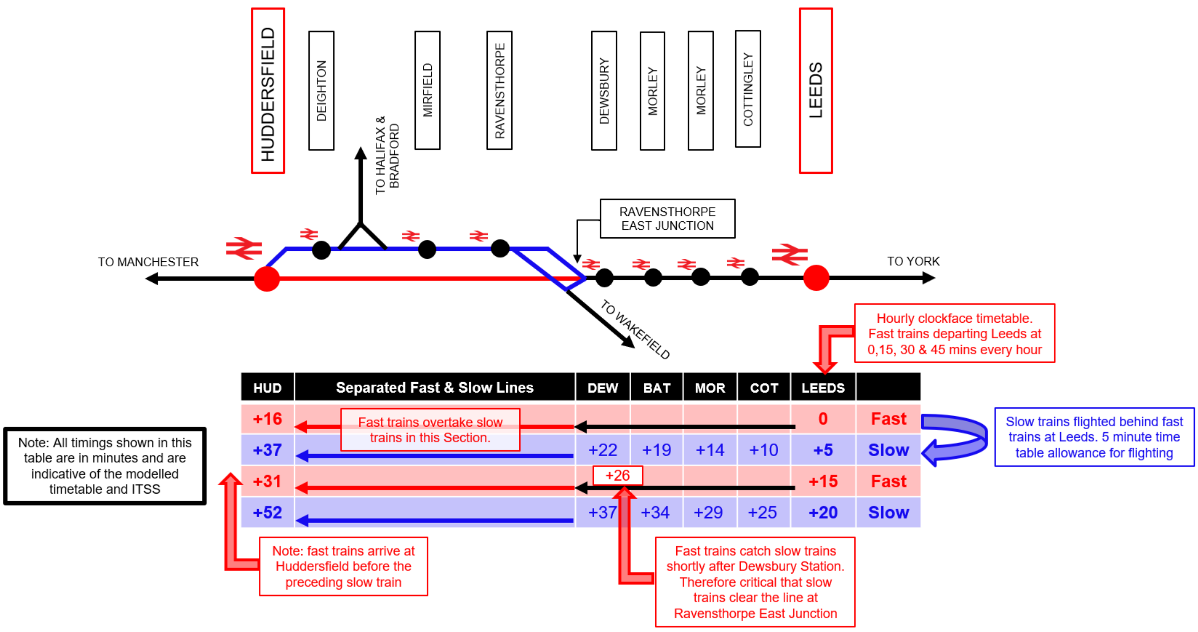


Figure 3: Example Clockface Timetable Operation, Up direction Leeds to Huddersfield

Enabling off-line Construction

2.1.4 The Scheme has been developed to construct as much of the major works, as far as reasonably possible, off-line from the existing railway, therefore keeping train services operational during construction. The section of railway between the existing Thornhill LNW and Heaton Lodge junctions is critical to railway operations across the North of England due to extent of passenger and freight services operating through this area with very limited diversion opportunities.

Enabling Linespeed and Journey Time Improvements

2.1.5 The TRU programme brief was for Network Rail to explore all reasonable options (within the overall business case framework) for improving journey times to achieve the strategic project outcomes. Although this Scheme is principally designed to provide vital increases in capacity, it also offers the best available opportunity (between Leeds and Manchester) to provide high-speed running, with a minimum of 100mph achievable all the way from Westtown to Huddersfield on separated fast lines. The geometry developed for the grade separation at Ravensthorpe creates a high-speed alignment, whilst at the same time, enables an optimal positioning of the grade separation structure.

2.2 West Alignment Tie-In

2.2.1 The new alignment ties into the existing rail corridor at Hunger Hill Bridge (refer to Figure 1 above for tie-in location). The Scheme proposes to retain this bridge as existing, albeit with minor parapet raising works to provide safe separation above the 25KV OLE system. Hunger Hill Bridge carries a major electricity distribution network comprising of multiple 33KV electricity cables. These cables would require diversion or re-location if the bridge was to be re-constructed.

2.2.2 In addition, the Scheme aims to avoid environmentally sensitive works to the west of Hunger Hill Bridge as the railway passes an existing culvert headwall and then an existing steep cutting slope in the Lady Wood area (Refer to Figure 5 below for location of Lady Wood). Therefore, the Scheme considered Hunger Hill Bridge as a pinch point vertically and horizontally for the development of the fast line alignment. (Note: At the time of writing the design has been developed sufficiently to avoid, as far as reasonably possible, significant works to re-grade the hillside west of Hunger Hill Bridge, adjacent to Lady Wood.)

2.3 East Alignment Tie-In

2.3.1 The tie-in with the existing railway corridor is achieved at Watergate Road underbridge just to the east of Weaving Lane and Thornhill Road area of Westtown, Dewsbury. This is described in my PoE Section 3.2 (points 3.2.60 to 3.2.66).

2.3.2 The northern edge of the Weaving Lane recycling centre was taken as a fixed boundary, which the Scheme proposes not to infringe. It was judged an imperative that the Scheme, as far as reasonably practicable, maintained the ability to operate this important public facility both during and post construction. The railway alignment in this area is also developed around the proposed removal of the existing Thornhill reverse curve to obtain the desired line speed improvements. Figure 4 below is repeated from my PoE to demonstrate the development of the alignment geometry against the site constraints.

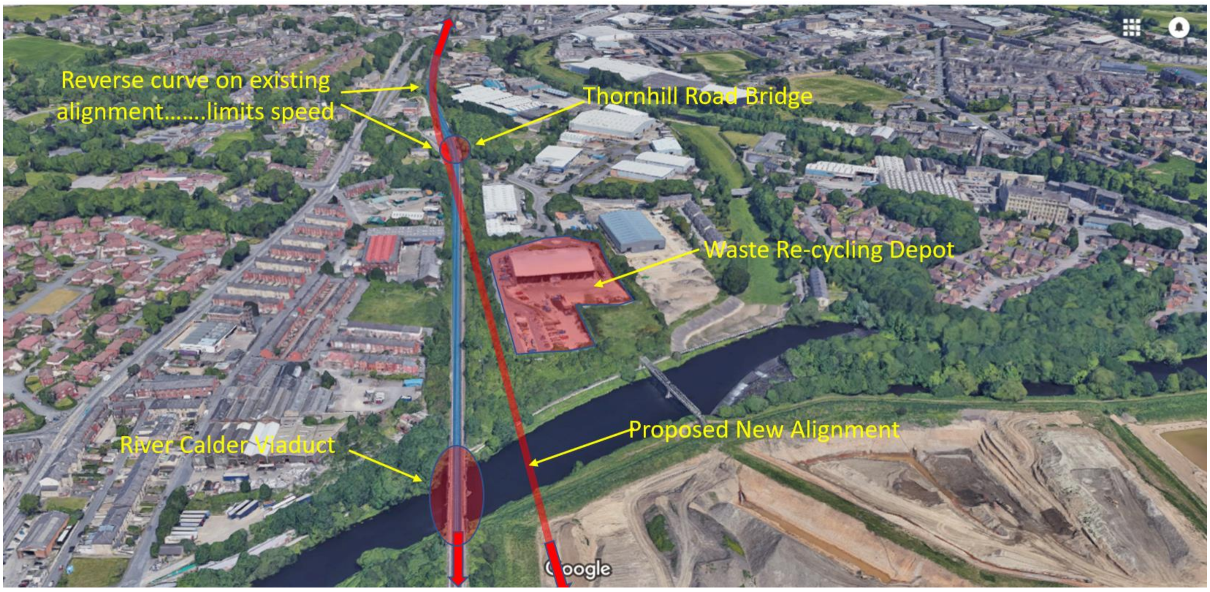


Figure 4: New Railway Alignment East of the River Calder (Figure 3-28 from PoE)

2.3.3 This alignment geometry developed enables the Scheme to carry out most of the civil engineering works to the east (at Thornhill Road) and to the west (in the Ravensthorpe Triangle) in an off-line (off railway) environment thereby keeping the existing railway operational and reducing disruption during construction.

2.4 Southern Alignment Boundary

2.4.1 The amount the railway can be realistically positioned to the south is restricted by the westerly tie-in at Hunger Hill Bridge (as described above), and therefore the alignment bearing (direction) that the lines can take to tie into the new alignment emerging from the east through the Ravensthorpe Triangle.

2.4.2 Several land parcels defining the edge of the “Dewsbury Riverside” land allocation and Veolia are potentially affected by the proposed alignment, and the preferred design gives due consideration to these. The developed alignment geometry therefore fringes these land parcels, as close as reasonably possible, whilst minimising detrimental impacts.

2.4.3 It should be noted that several compromise decisions have been made in this area balancing temporary and permanent land impacts, versus the related development of the grade separation geometry:

- The new railway alignment has been positioned far enough south to enable off-line construction in the existing Ravensthorpe cutting to maintain train services with minimum disruption during all phases of the works (other than the single blockade required to re-model Thornhill LNW Junction).
- This southerly alignment position effectively widens the existing cutting, thereby impacting the developable area of land allocated to Dewsbury Riverside. At the time of design development, this edge of the Dewsbury Riverside development was shown as a landscaped fringe, and therefore acquisition of a small strip of this land was judged as acceptable, given that the resultant cutting slope could be adopted within any future landscape proposals. It is critical to note that the vertical levels adopted through this location have a significant effect on land acquisition due to the steeply sloping nature of the ground. Therefore, there is a compromise to made in terms of lowering the grade separation (and therefore lowering the fast lines) versus the extent of land take on the southern boundary and volumes of earthworks materials to be excavated.
- The chosen alignment comes up against the boundary of the Veolia site and the vertical levels have been carefully co-ordinated to reduce impacts (this is the same compromise as noted above). The alignment does result in some temporary impacts to the business in providing access space to construct the grade separation earthworks, and to carry out utility diversions. The Scheme has accounted for these impacts by providing temporary land and facilities nearby to enable continued operation of the Veolia business.

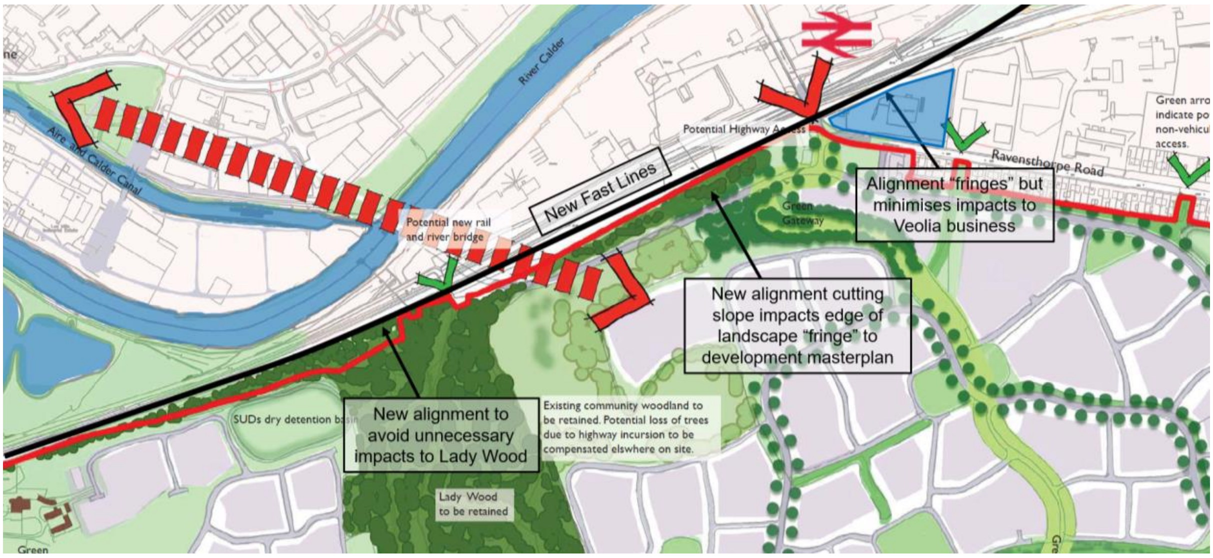


Figure 5: Extract from Dewsbury Riverside Masterplan (c.2017) with new fast line impacts

2.5 Fast Line Alignment Summary

2.5.1 In summary, the fast line alignment geometry has been positioned as far south as reasonably possible without unduly affecting land and property along its southern fringe (although there are some permanent and temporary effects). This enables off-line construction of the grade separation and works within the existing Ravensthorpe cutting. The chosen alignment ties back into the fixed geometry points to the east and west as described above. This optimised fast line plan alignment became a fixed parameter for the development of the Wakefield Lines grade separation and the associated Thornhill LNW Junction re-modelling.

2.5.2 As previously described, the chosen geometry to the south generates a best-fit horizontal curve through the Ravensthorpe Triangle, which can accommodate high line speeds. This curve allows 110mph running at an applied cant (crossfall) of 150mm (maximum allowable value for mixed services). This further enables the Scheme to maximise journey time improvements through the whole corridor by extending 110mph running from Westtown to Heaton Lodge. The Scheme arrangement for the fast lines and junction layout in the Ravensthorpe area also future proofs further capacity and/or small line speed increases that may be required for network enhancements beyond the current TRU remit. These enhancements may be enabled by future schemes to provide digital signalling or an extension of 4-tracking towards Dewsbury and Leeds.

3. SLOW LINE ALIGNMENT GEOMETRY

3.1 Introduction

3.1.1 This section includes the Scheme development of the Wakefield Line diversion, Thornhill LNW Junction re-modelling and the positioning of the re-constructed Ravensthorpe Station. Finding the optimal solution for this part of the design is again a complex problem and has involved many iterations to achieve a:

- Railway operational layout that performs safely within standards, is reliable and maintainable, cost effective, minimises disruption during construction and is acceptable to the wide range of railway industry stakeholders including passenger and freight train operating companies.
- Railway alignment geometry that echoes the above points, simplifies the infrastructure provided for Ravensthorpe Station and minimises undue impacts on adjacent land and property, whilst respecting local development plans.

3.2 Background and Initial Studies

Track and station platform standards

3.2.1 I have previously discussed some of the railway standards in my PoE section 3.1 (points 3.1.25 to 3.136), which have governed design development in this area. I would also like to highlight the importance of Rail Industry Standard RIS-7016-INS, “Interface between Station Platforms, Track, Trains and Buffer Stops” which sets out important requirements and good practice for the provision of station platforms. This includes the following:

- Platforms shall not be located on horizontal curves with radii less than 1000m
- Platforms shall not be located on gradients steeper than 1 in 400.

Signalling Considerations

3.2.2 There are many constraints and operational requirements that need to be considered to provide a safe and acceptable layout when positioning signals relative to junctions and other major infrastructure elements including stations and viaducts. Some of the key considerations and associated signalling terminology are set out in the table below.

Table 1: Signalling Definitions

Signalling Term	Definition
Safe Overrun Distance	The safety margin a train has between a stop signal and encountering another train.
Signal Sighting Distance	The ability for the driver to see and interpret the aspects that the signal is displaying.
Driveability	The tasks and the time between tasks that the driver must perform in addition to driving the train.
Operational Standage	The distance a signal is required from a junction to ensure a train standing at a signal does not block a junction to the rear. For a 70mph junction on straight, level track, this is circa 200m.
Headway/Junction Clearance	The time a train is occupying the junction from the protecting signal.
The Braking Distance	The time a train is occupying the junction from the protecting signal.
The Braking Distance	The required distance between the first caution to the stop signal.
Technical Positioning	Minimum distances from Neutral Sections, switches and crossings and platform stand back which preclude the system from function if too near.

Existing Railway Operation around Ravensthorpe Station

3.2.3 To achieve the capacity, reliability and journey time required, the Scheme must ensure that the proposed railway system does not inherit any of the very restrictive features of the existing operational layout.

3.2.4 In the current layout, the proximity of Ravensthorpe Station to Thornhill LNW junction results in low capacity and poor resilience of the operational railway. The figure below shows the current station and junction layouts.

Figure 6: Ravensthorpe Station, Current Operational Model

3.2.5 Trains using route A to travel towards Wakefield pass in front of Ravensthorpe Station as they transit Thornhill LNW Junction. Whilst a train is undertaking this manoeuvre, trains from Dewsbury cannot enter the station at normal speed, therefore passing through the signalling section very slowly. Trains entering this signal section are restricted to 15mph due to the proximity of the protecting signal to the junction and very short overlap distance (if a train overruns the signal). This in turn slows the following train services from the Dewsbury/Leeds direction and reduces the overall capacity of the route.

3.2.6 In the example shown above, Train C will be travelling at 15mph or less when Train A is moving. If Train A is a freight train (as is commonly the case on the Wakefield route), its longer length and reduced speed increases the time it takes to clear the Thornhill LNW and Mirfield east Junctions, which are nearly 1 mile apart. Conversely, if Train B proceeds before Train A passes through the junction, services from the Mirfield/Huddersfield direction are slowed in a similar manner.

Initial Alignment, Junction & Signalling Studies

Grade Separation Plan Location

3.2.7 Placing the grade separation as far east as possible was the initial starting point to develop the grade separation design. This was the focus of early geometrical studies, which included a very substantial diversion of the Wakefield lines into the Ravensthorpe Triangle.

3.2.8 This initial arrangement resulted in the intersection angle of the Wakefield Lines with the linking chord lines being very shallow at the common convergence point on approach to the Ravensthorpe cutting. In this arrangement it is not possible to quickly junction the Up-slow chord with the Wakefield lines due to adverse cant and cant transitions on the tight horizontal curves. The resultant geometry inhibits the simple formation of a 70mph junction between these lines. At a high level, this presented three broad concepts with respect to junction location, platform layout and station location.

- **Station West of existing location:** A long opened out ladder junction (circa 300m in length) extending beyond Calder Road bridge. This would push the station platforms towards the western extremity of the Ravensthorpe Cutting resulting in a very undesirable station location, remote from highway and population centres, and within a deep cutting.
- **Station East of existing location:** Conversely the station could be located to the east. The first opportunity to site the station on suitable railway geometry (curves and gradients) and to suit signalling constraints (operational standage to Thornhill Junction, see my earlier point), is in the vicinity of the new Baker Viaduct. In a similar way to the option above, the station is in an undesirable location, remote from highway and population centres and formed at height.
- **Station near existing location**: This situated Ravensthorpe Station on the chord lines just to the east of Calder Road Bridge (as illustrated below and as referenced in my PoE's Appendix 2 drawing from July 2017). This required the re-modelled Thornhill LNW Junction to be located to the west of the station within the Ravensthorpe cutting.

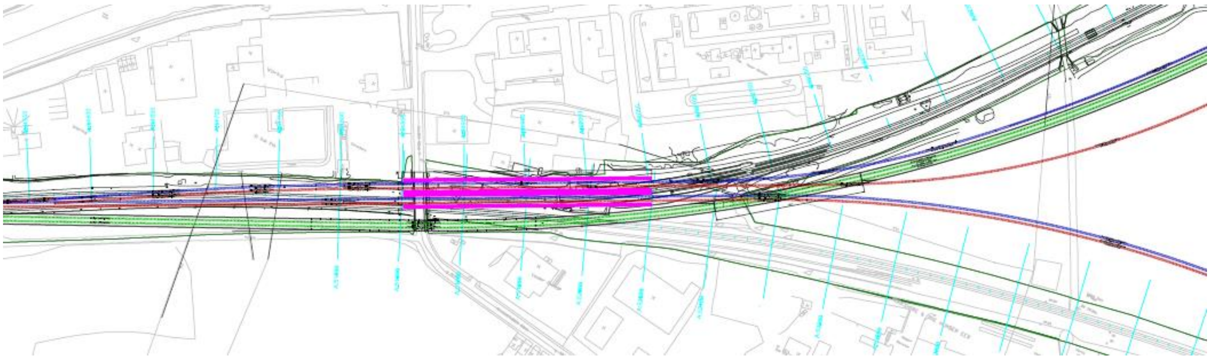


Figure 7: Early GRIP3 Junction and Station Layout (developed from July 2017 GA)

3.2.9 The above arrangement had obvious disbenefits including:

- A 6-track formation would be required through the Calder Road area, comprising of 2-tracks for the fast lines, 2-tracks forming the slow Transpennine lines (linking chords to the east), and 2-slow lines serving the Wakefield route.
- The volume of work required to reconstruct Thornhill LNW Junction would be extensive as this extended 4-track section plus most of the junction S&C units would need to be constructed during blockade conditions, increasing the length of such a blockade.
- The Wakefield line diversion would require substantial works including a total of 1.3km of 2-track railway and a new bridge over the Calder & Hebble Navigation.
- The Wakefield Line diversion would also require ground stabilisation works to mitigate settlement effects over a recent land fill cell and potential for additional mine remediation.

- Provision of station facilities for this platform layout would require third party land to the north and sever the existing access road.
- Additional platform faces would be required to future-proof platforming of passenger services on the Wakefield Route.

Junction, platform and signalling studies

3.2.10 Multiple design options were studied with respect to the platform and Thornhill LNW junction layouts and associated signalling approach. The optioneering was undertaken in a systematic way to identify the different operational concepts as shown in the figure below. Table 2 below shows some of the layouts studied.

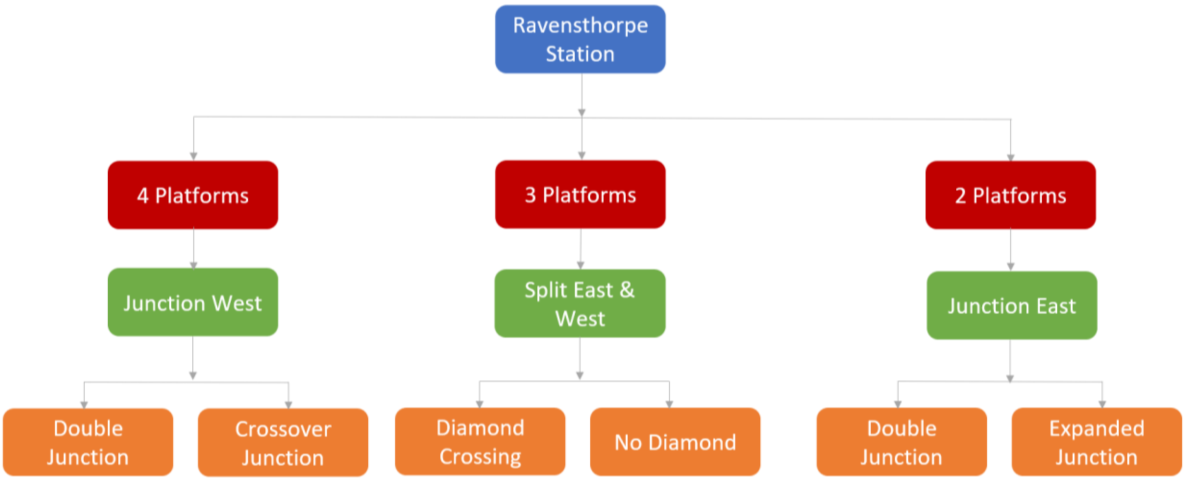
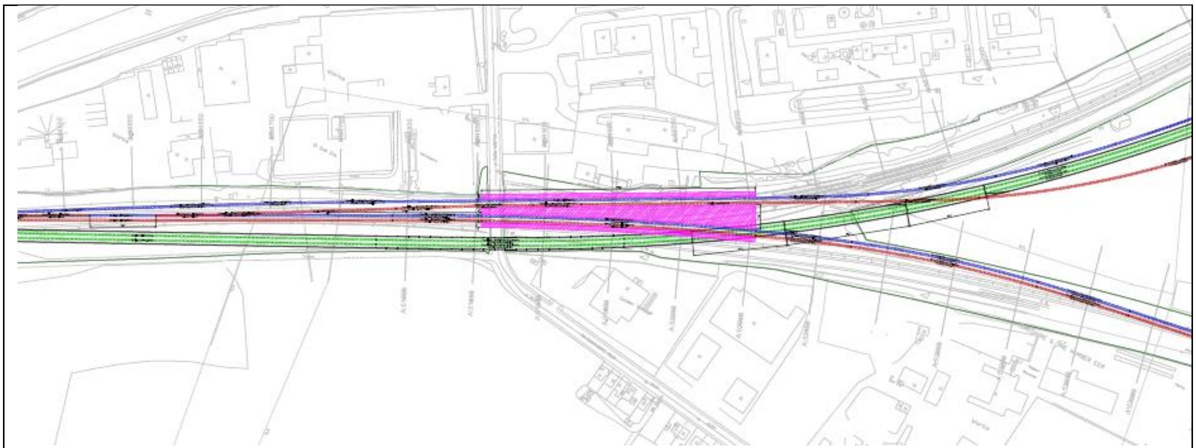


Figure 7: Ravensthorpe operational concepts

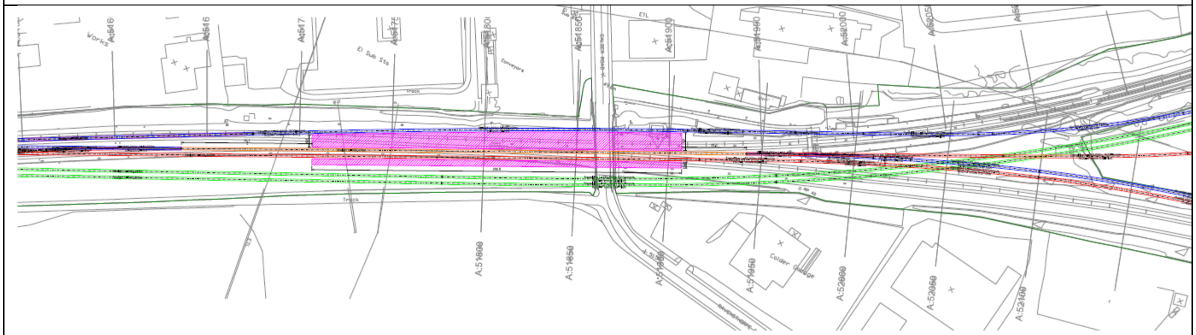
Table 2: Junction, platform and signalling studies

Layouts studied

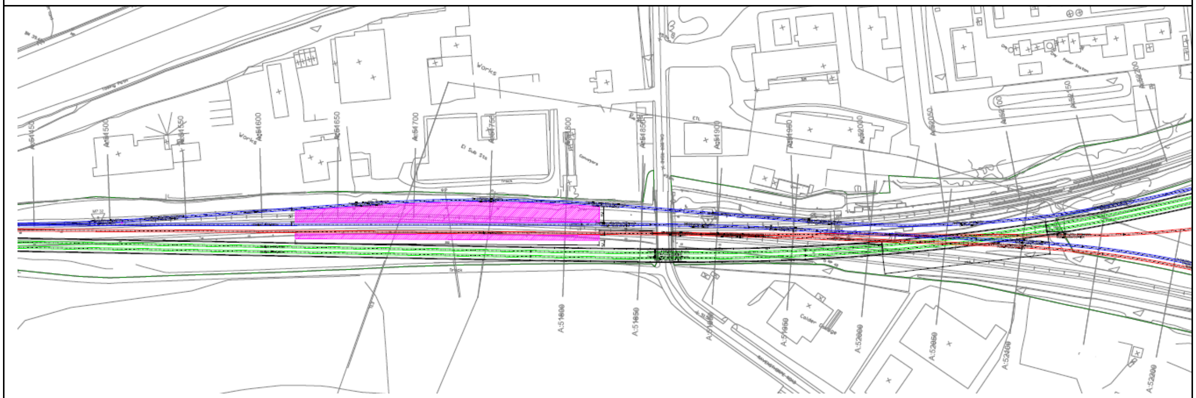
Horizontal alignment with junction west of the station (straight platform edges)



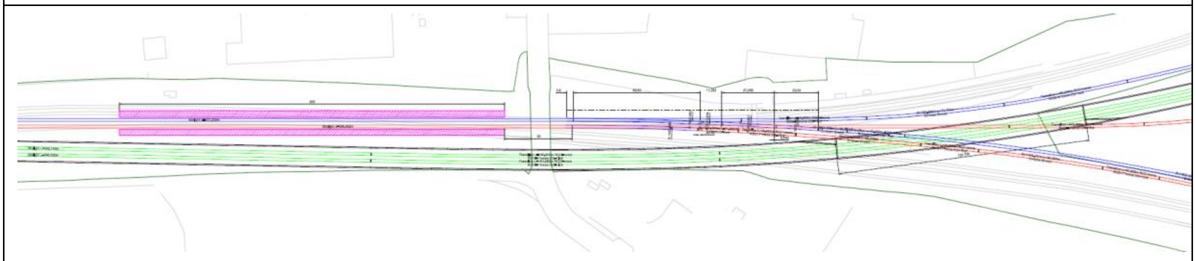
Horizontal alignment with junction to west of the station (no diamond)



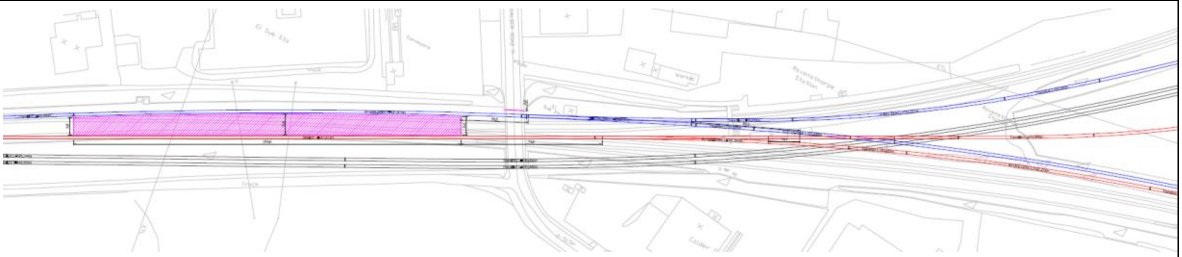
Horizontal alignment with junction either side of the station (with diamond crossing)



Horizontal alignment with junction either side of the station (with diamond crossing)



Horizontal alignment with junction to the east of the station (double junction)



Horizontal alignment with junction to the east of the station (opened out double junction)

3.3 Single Option Selection

3.3.1 After detailed evaluation, the preferred single option for track, signals, junction geometry and station platforming arrangements are as shown in the figures below. This layout progressed through Network Rail assurance processes to the GRIP3 Stage Gate held in December 2019.

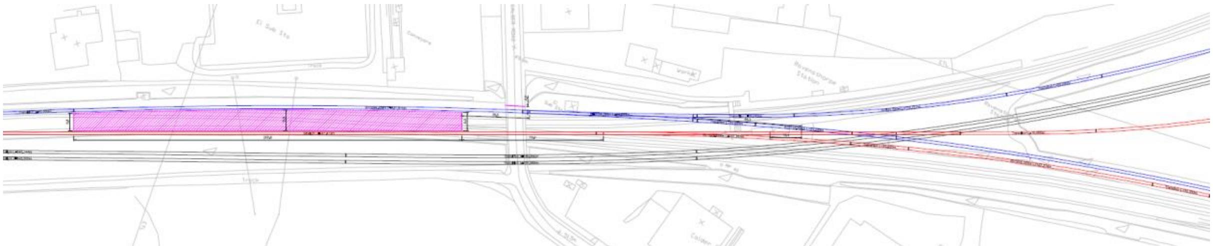


Figure 8: Ravensthorpe Station and Thornhill LNW junction, preferred scheme layout (c. June 2019)

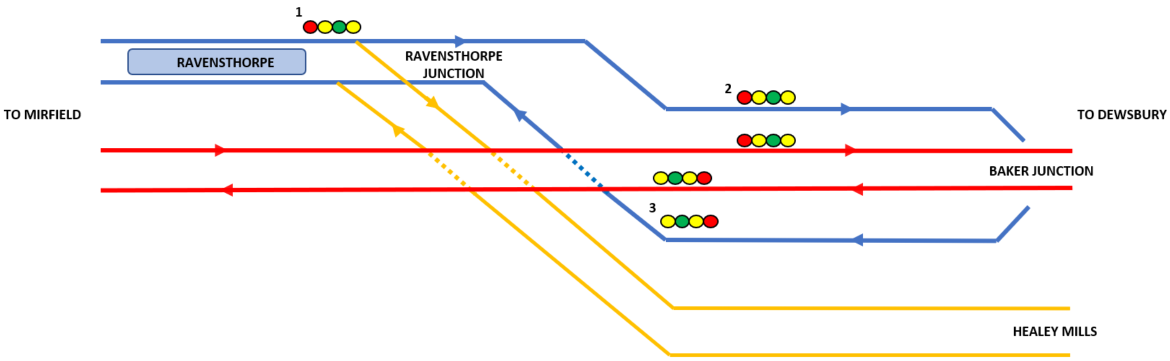


Figure 9: Ravensthorpe Station and Thornhill junction, preferred signalling scheme layout

3.3.2 This arrangement was selected as it provided the following clear benefits in comparison to the other options:

- The diversion of the Wakefield Lines is very much reduced, keeping them close to their existing formation (out of the landfill site) thereby eliminating additional ground stabilisation and associated risks, minimising any other infrastructure works including a new bridge in the Wakefield direction.

- The geometry of all through routes is optimised with no sudden directional changes or features that would create excessive track wear on components at the desired line speeds (70mph in all directions).
- The geometry developed for the junction allows the "opening out" of all the S&C units so they can be lifted and maintained separately. They all also use standard componentry (including the diamond crossing angle), which is similar to other S&C units in the area. This dramatically improves the maintainability of this junction and therefore reliability of the train services. As this will become a critical location on the network, this is a very important feature of the Scheme.
- The construction of the grade separation structure, embankments and associated works is maintained off-line, and the volume of work required during the single planned blockade period is vastly reduced due to the smaller footprint through the Calder Road area and volume of track works. This then reduces the blockade period required (currently forecast at 23 days) and associated extensive disruption to the North of England rail services.
- Ravensthorpe station becomes a simple island platform from the outset which is easy to access from the higher ground above (only a single lift and stairs required) and naturally forms a very useful interchange station facility with the ability to service all directions towards Leeds, Huddersfield, and Wakefield. In my opinion, in combination with large scale residential development, this will potentially transform future patronage figures as well as encouraging a modal shift from car transport.

Ravensthorpe Station Further Development

3.3.3 The preferred junction arrangement, as described above, presents an opportunity to locate an island platform between the Up Slow and Down Slow lines. The western extent of the platform is defined by the distance to the junction and protecting junction signal, as shown in the figure below.

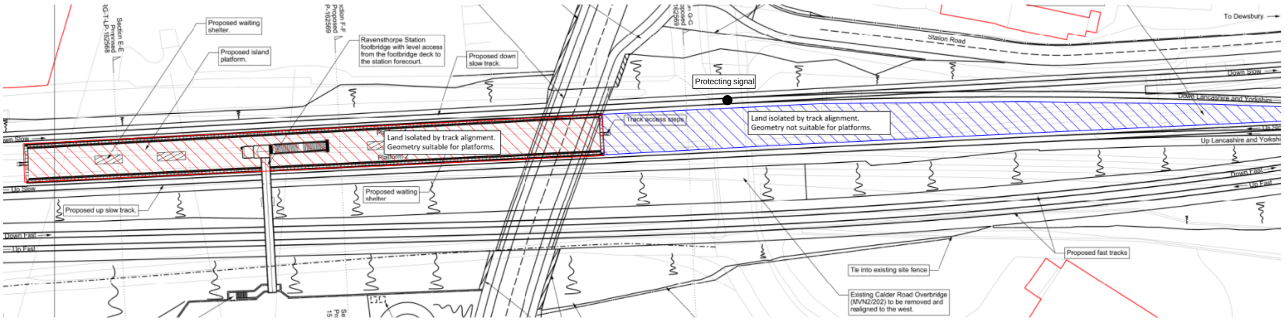


Figure 10: Space made available by the preferred junction arrangement (area suitable for platforms shown in red / area not suitable for platforms shown in blue).

3.3.4 In accordance with British Standard BS8300-1:2018, “Design of an Accessible and Inclusive Built Environment” and the DfT’s ‘Design Standards for Accessible Railway Stations’, a station forecourt (including its accessible parking) must be less than 50m from the station entrance, taken here (due to the unstaffed nature of the station) as the entry point to the station footbridge.

3.3.5 This requires the station forecourt and highway connection to be within third-party land to the north or south of the railway corridor to the west of Calder Road. The most appropriate position for this infrastructure is to the south of the railway on land on the fringe of the Dewsbury Riverside development site. Locating the station forecourt to the south minimises the permanent impact on neighbouring operational industrial sites. It reasonably maintains the existing walking distances from Ravensthorpe town centre to the north and reduces walking distances from the south.

3.3.6 Side platforms in this location were also considered. The island platform arrangement is located where the track radii are >1000m and where the width of the 6-Foot allows for the provision of two platform faces (3.35m) and a lift shaft (3m), a total width of approximately 10m, Figure 11. If side platforms were utilised in this location, the additional width required at the stairs and lift would result in the platforms being located outside of the current rail corridor, Figure 12.

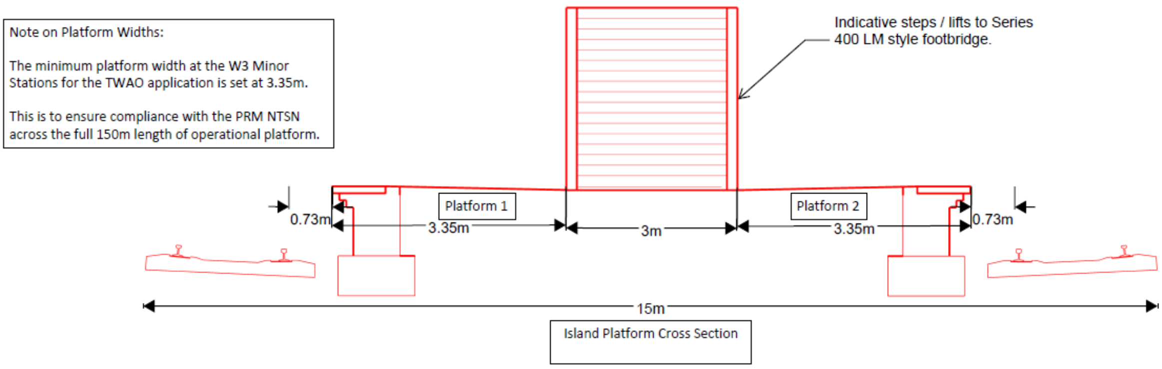


Figure 11 - Typical Island Platform Cross Section

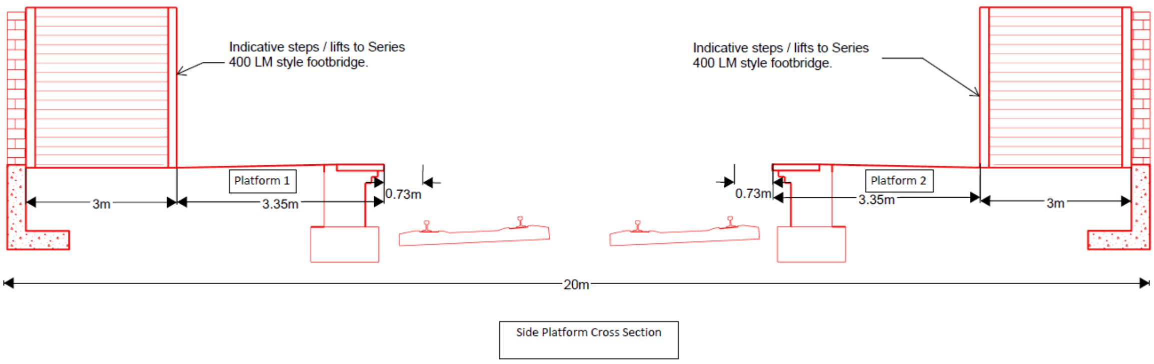


Figure 12 - Typical Side Platform Cross Section

3.3.7 In summary, by consolidating the platform infrastructure within the proposed railway corridor and providing an island platform arrangement accessed from the south, the following advantages are achieved:

- A single-entry point to both platforms, improving wayfinding and passenger interchange between services.
- One lift and set of steps to serve both platforms, reducing the overall cost of the station intervention, reducing the construction complexity, and minimising ongoing maintenance costs.
- Connectivity to both Ravensthorpe Town Centre, the existing communities to the south of the railway and possible future connection to proposed residential development.
- Platforming the Wakefield Lines at no additional cost.

3.3.8 I have demonstrated above that the location of Ravensthorpe station has been carefully evaluated in full consideration of all the driving factors including the geometric development of the grade separation and the associated re-modelling and signalling of Thornhill LNW Junction. As with other parts of the Scheme development, some compromises have had to be made to arrive at a balanced decision which responds to the needs of the railway, the travelling public, stakeholders, and adjacent land and property.

3.4 Slow Line Alignment Summary

3.4.1 Early design studies investigated placing the grade separated junction as far to the east as reasonably possible. This was achieved by a very substantial diversion of the existing Wakefield railway lines. However, these early layouts had significant drawbacks, which I have summarised above.

3.4.2 The preferred Scheme has developed an at-grade railway junction and grade separation layout by much more judicious means. By positioning the station to the west of the re-modelled Thornhill junction and splitting the lines around an island platform, this has generated a junction geometry, which positions the grade separation very near to the most eastward point previously studied. This solution had significant benefits over other layouts studied including:

- Reduced amount of track and associated civil engineering works
- An efficient and easily maintainable operational layout
- A layout that can be built largely off-line which minimises, the amount of work undertaken during line closures (blockades).
- Reduced blockade works minimises disruption to this section of railway, which is critical to rail services in the North of England.
- Ravensthorpe station becomes as simple island platform which can service all route directions.

4. VERTICAL GEOMETRY DEVELOPMENT

4.1 Introduction

4.1.1 The design of the horizontal and vertical alignments on the fast lines, slow lines and Wakefield lines has been an iterative process. In this section I provide further clarity with respect to the vertical alignment design decisions within the principles established in previous sections describing the development of the horizontal alignments.

4.1.2 The principal attributes which govern the vertical alignment are track geometry standards, signal standards and operation, OLE clearance, and existing physical constraints. In the figure and paragraphs below, I have set out the various constraints, design inputs and resulting geometry.

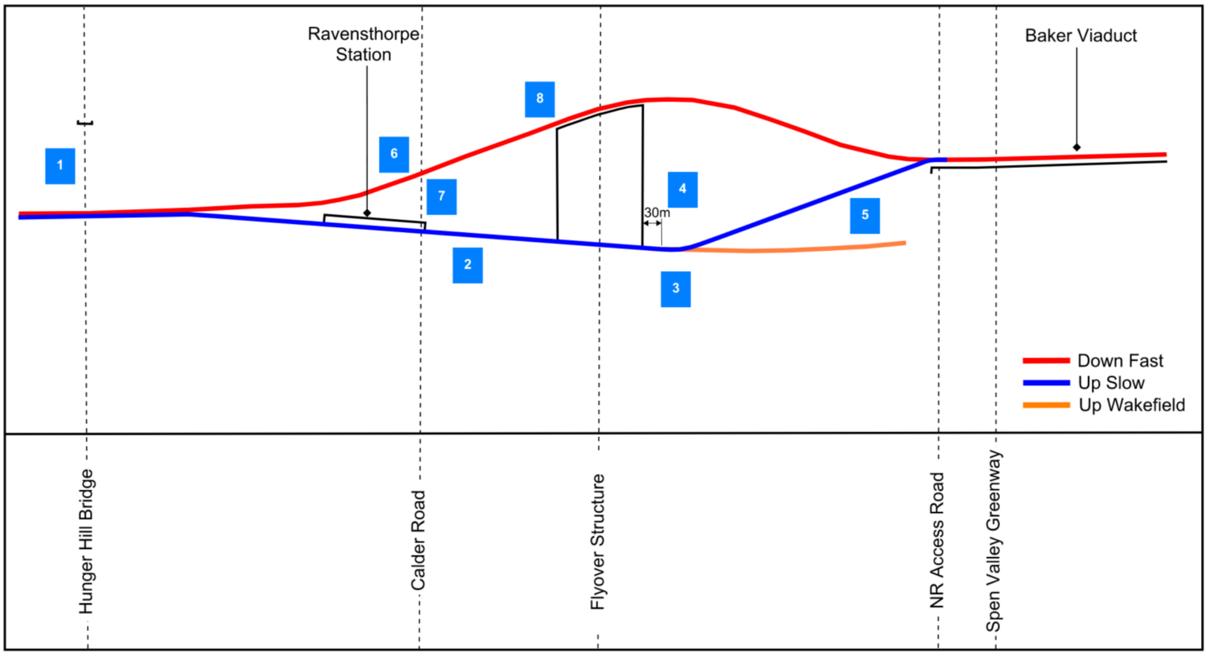


Figure 13: Vertical Alignment

4.1.3 Hunger Hill bridge (1 on the above figure) has been taken as a fixed constraint both vertically and horizontally, as discussed in the fast line geometry section. Therefore, the track level has been defined by the minimum vertical clearance required under the existing structure, which has been minimised as far as reasonably possible.

4.1.4 The slow lines diverge vertically from the fast lines to the east of Hunger Hill bridge (2 on the above figure). As described in the proceeding sections, the preferred plan geometry has located the station to the west of the Thornhill LNW Junction. A gradient of 1 in 400 has been applied as this is good practice and in line with NTSNs for the construction of new platforms. This continuous gradient allows the junction to be placed as close as possible to the station. A change (or steeping of this gradient) would introduce an additional vertical curve pushing the junction further east. By maintaining a constant gradient, the junction can be placed in a position which minimises signalling headways and improves capacity.

4.1.5 The lowest proposed vertical level is to the east of the intersection structure (3 on the above figure). The depth at this point has been developed such that it can be drained by gravity, eliminating the whole life cost and reliability issues of a pumped drainage system. The scheme has also sought to limit disruptive works to the Wakefield lines through limiting the change in vertical levels to the east. The selected alignment for the Wakefield Line diversion ties back into the existing railway before the Calder and Hebble Canal crossing.

4.1.6 A minimum of 30m is recommended by standards between the end of the Flyover structure and the start of the vertical curve (4 in the above figure). This enables Network Rail to maintain the vertical track geometry tolerances during lifting and tamping. The vertical curve used is the maximum ‘normal’ radius permitted such to minimise its horizontal length.

4.1.7 The Up Slow Line then rises on a 1 in 80 gradient (5 in the above figure). This is the maximum ‘normal’ gradient permitted and has been subject to significant consultation with the TOCs and FOCs. This vertical element could move slightly further east, such that the vertical tie-in between the fast and slow lines occurs on the western spans of the Baker Viaduct, however care must be taken with respect to the vertical clearances over the Network Rail maintenance access track and the Spen Valley Greenway.

4.1.8 Considering the fast line alignment (6 in the above figure), the track rises at the maximum ‘normal’ gradient of 1 in 80 on the Down Fast (uphill in direction of travel) and exceeds this on the Up Fast (downhill). The minimum vertical dimension is defined by the required OLE clearance at Calder Road and the Flyover structure (7 and 8 respectively in the figure above). The Order scheme has minimised these clearances through the challenging of OLE standards and efficient structural solutions.

4.2 Calder Road Re-Alignment

4.2.1 The initial geometry studies showed the vertical re-alignment of Calder Road Bridge could be achieved by an off-line diversion of the highway to the west with the new fast lines passing immediately behind the existing southern abutment of Calder Road. This enabled a construction strategy which could be sequenced with the major utility diversions required and earthworks operations.

4.2.2 The vertical alignment of Calder Road was also guided by efforts to minimise the earthwork cut into the steeply sloping hillside, to reduce the scale and cost of the Scheme, and to ensure the highway tied back into Calder Road to the southwest. Considering these topographical constraints, to minimise earthworks and third-party land requirements, it followed that the reconstruction of Calder Road at a higher level than existing gave benefits in reducing the overall footprint and associated works required for the TRU scheme as shown in the diagram below.

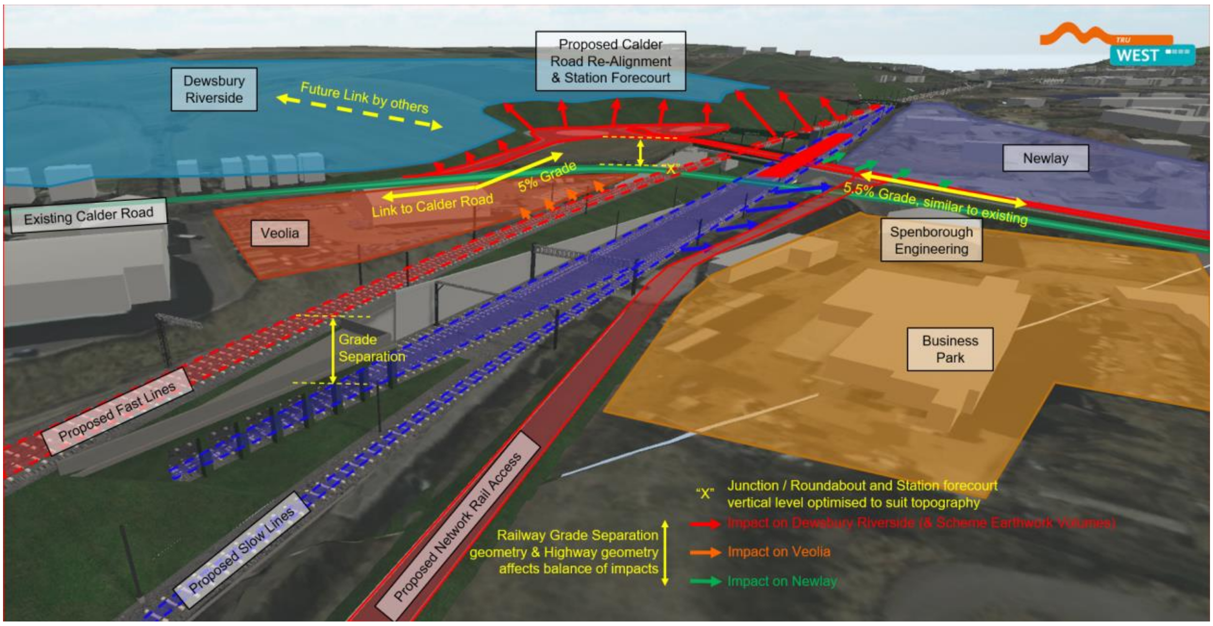


Figure 14: Grade Separation, Topography and Land Impacts around Calder Road

4.3 Vertical Alignment Summary

4.3.1 In summary, the vertical geometry has been designed to provide an alignment which responds to the requirements of the preferred operational layout. To minimise vertical level constraints and balance boundary impacts throughout the Ravensthorpe area, the scheme has utilised the maximum gradients and curves allowed by the standards, challenged recommended values for track geometry and OLE clearances, and implemented efficient structural solutions.

4.3.2 The plan geometry of the Calder Road diversion as shown in the Order represents the necessary extent of the lateral position based on the level of design confidence at the time of Order preparation. Network Rail has defined Limits of Deviation to allow the design of the Order Scheme to be refined with a view to achieving some further reduction in the geometric offset of Calder Road into the Hargreaves site.