High Speed Rail in the Chilterns
Part 2: Chiltern Long Tunnel Proposal

June 2015

Explanatory note

In response to a proposals by petitioners in the Chilterns, and in response to petitions against the High Speed Rail (London – West Midlands) Bill, a number of options for a tunnel or tunnel extension in the Chilterns have been evaluated by HS2 Ltd.

This document was prepared by HS2 Ltd in May 2015 for internal use, and has been published to allow petitioners to better understand the Promoter's assessment of various tunnel options.

General requirements for long tunnels are set out in Part 1, and the assessment of various options proposed by petitioners are set out in Part 2-4.

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London West Midlands

High Speed Rail in the Chilterns Part 2: Chiltern Long Tunnel Proposal

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List of acronyms

CDC Chiltern District Council
CLT Chilterns Long Tunnel
DNO Distribution Network Operator
PBA Peter Brett Associates
AONB Area of Outstanding Natural Beauty
TSI Technical Specification of Interoperability
FFP Fire Fighting Point

References

Title	Reference
HS2 Project dictionary	HS2-HS2-PM-GDE-000-000002
Style guide	HS2-HS2-CO-GDE-000-000001

1 Executive summary

1.1 Purpose of Engineering Review

1.1.1 The 'Chilterns Long Tunnel Route' is an alternative proposal developed by Peter Brett Associates (PBA) that is promoted by Chiltern District Council in association with Aylesbury Vale District Council. Buckinghamshire County Council and the Chilterns Conservations Board.

1.1.2 The 'Chilterns Long Tunnel' would consist of approximately 24.3km of tunnel between the current proposed West Hyde/M25 south portal and a new north portal south of Nash Lee Road at Wendover. Achieving a route that would be substantially in bored tunnel within the Chilterns Area of Outstanding Natural Beauty (AONB). It would comprise a realigned and extended tunnel between Amersham to just before the AONB northern boundary at Nash Lee Road, re-joining the Proposed Scheme alignment at the southern edge of Aylesbury.

1.1.3 The tunnels, as proposed would be constructed by concurrent twin tunnel drives from the north and south portals terminating at the Little Missenden vent shaft, where a Firefighting Point would be constructed.

1.1.4 Chiltern District Council has asked HS2 Ltd to consider this alternative proposal. This report provides a review of this proposal, based on the information in the PBA document 'High Speed Rail in the Chilterns: Feasibility Study of Alternative Tunnelling Options, Final Report Rev AC', dated February 2015.

1.2 Findings

1.2.1 A proposal for the Chiltern Long Tunnel (CLT), if viable, would reduce the surface impacts and disturbance through the Chiltern AONB from HS2 construction and operation compared to the HS2 Proposed Scheme. It would, however, incur additional cost, construction and operational risks and safety concerns compared to the HS2 Proposed Scheme.

1.2.2 The CLT would be a continuous tunnel, measuring approximately 24.3 km from the Proposed Scheme portal at West Hyde to a new northern portal near Nash Lee Road.

1.2.3 The firefighting point proposal by PBA, outlines an underground cavern between the two HS2 tunnel bores at Little Missenden Vent Shaft. This underground cavern option does not however fulfill the HS2 project requirements, where an open gap structure is required for such firefighting points. The project requires that for a tunnel greater than 20km in length an open gap structure is incorporated. There is not adequate space for a gap structure of this type at Little Missenden. A

potential location for this open box structure is at Durham Farm as suggested in High Speed Rail in the Chilterns Part 3: CRAG Proposal

1.2.4 The complex geometry and size of a Firefighting Point, in conjunction with potential groundwater, would create a number of technical and logistic challenges to ensure the structure can be constructed, serve as a firefighting point, and be properly maintained over the lifetime of the system. Further investigation would be required to capture the full impact of FFP, whether the PBA proposed FFP or a conforming open box FFP, on the local area and a better understanding of construction costs and programme, to determine viability of the structure.

1.2.5 The PBA proposal does not fully determine impacts of disposing of the excavated material arising from the northern tunnel drive of the CLT. A number of potential options were discussed in the PBA proposal and this report presents other methods. The cost, programme and environmental implications of all methods of disposal require further investigation.

1.2.6 The proposal only discusses the impacts during the construction phase. There is also the tunnel and rail fit out stage to consider. The Proposed Scheme provides rail heads and sidings, at the Calvert temporary railhead, to facilitate the transport of materials to the work sites. This arrangement allows reduced handling times of the materials onto the work trains working along the mainline and the sidings ensure that transport trains do not effect existing railway operations. The PBA proposal indicates that there would be no change to rail fit out from the Proposed Scheme. The logistics of installing the rail systems within the proposed tunnel, where there are no sidings requires investigation to determine programme impacts. It may also be necessary to commence rail fit out of the longer tunnel ahead of the rail-based fit out from Calvert to maintain programme. This would require a temporary rail systems compound introducing/extending road or rail based activities in this area.

1.2.7 The PBA proposal does not discuss railway maintenance impacts from the CLT during the life of the system. Underground structures with long distances between access points would increase duration and costs of maintenance tasks.

1.2.8 The proposal identifies the area of land required at the north end or the work site to service the northern drives. The area of land is similar to that previously identified by HS2 for this type of operation and the location, adjacent to the Chiltern Railway line is similar to a site previously identified by HS2 in its review of long tunnels proposals by the Chiltern Ridges Action Group. However, the area identified does not allow, spoil processing, storage and removal, including the provision of rail sidings.

1.2.9 The PBA proposal states that there would be no placement of excavations arisings within the AONB. However, there would be substantial arisings from the vent shafts and the Firefighting Point, which could be disposed locally within the AONB. Further investigation would be required to determine where and how these

excavation arisings would be disposed. Placing the north portal just outside the AONB theoretically removes the excavation arisings from the northern tunnel drives from the AONB. However, those arisings could have equal impacts on rural, tranquil localities just outside the AONB.

1.2.10 The cost comparison exercise undertaken by PBA is highly generalised and requires more refining if it is to be properly assessed. As part of the cost comparison, cost per km of tunnel and operational cost of the tunnel were referred to. The intent of these references are unclear as they do not directly compare the CLT to the Proposed Scheme.

1.2.11 As the PBA report discussed cost in only the broadest terms, a construction cost exercise was undertaken of the Chilterns Long Tunnel. This exercise determined that the Chilterns Long tunnel would cost approximately £485 million more than the Proposed Scheme. Appendix A contains a breakdown of this cost.

1.3 Issues and Concerns

1.3.1 There is not enough information presented in the PBA proposal to determine the complete environmental, cost and programme implications of the Chilterns Long Tunnel. There would need to be much more extensive studies and investigations to determine construction feasibility and risk; impacts on operational capacity, maintenance and safety. These studies would need to incorporate and focus on the following items:

a. Provide conceptual layouts of the proposed north portal work site locations, including location of material and segment storage, welfare stations, potential railheads and access routes to and from work site to determine full impact to local area.

b. Provide a compliant design for the horizontal alignment to the north of the proposed north portal, to determine the impact on the maintenance loops at Stoke Mandeville.

c. Determine if any passenger safety and comfort issues associated with the Chilterns Long Tunnel can be addressed so there is no reduction in the ability to provide appropriate safety and comfort for passengers.

d. Determine impacts to and from the rail fit out stage of HS2 construction, including: any revised construction methodology and revised construction times.

e. Determine all potential impacts to all adjacent water abstractions from tunnelling operations and associated construction.

f. Determine approximate quantities of excavated material arising from all excavations and impacts to local environment and infrastructure, inside and outside the AONB, of transporting and disposal of all excavated material.

g. Provide and investigate further layouts and locations of a Firefighting Point which complies with HS2 requirements, both for the construction phase and

final structure to fully capture impacts to the local area, construction cost, programme time and rail operations. Further investigate the engineering concept and construction costs of a deep structure of this scale in potentially water bearing ground.

h. Provide conceptual layout and locations of all worksites associated with the proposed new shaft locations.

i. Provide further justification for the proposed portal arrangement presented. As this portal is unique, it may not meet the HS2 requirements. Also, a standard portal layout should be shown to work with the PBA proposed alignment.

j. Provide a construction cost that only includes the capital costs of the Chiltern Long Tunnel in order to properly compare it to the same length of the Proposed Scheme.

2 Introduction

2.1 Background

2.1.1 The CLT is an extended tunnel proposal that is promoted by Chiltern District Council (CDC). This report provides an Engineering Review of this proposal, based on the information in the Peter Brett Associates (PBA) document 'High Speed Rail in the Chilterns: Feasibility Study of Alternative Tunnelling Options, Final Report Rev AC', dated February 2015.

2.1.2 This review is limited to the area where the CLT proposal varies from the proposed scheme. However, cost comparisons are taken over the full length of the CLT proposal from the southern portal at West Hyde and the northern tie-in to the proposed scheme.

2.1.3 This tunnel alignment would follow the Proposed Scheme alignment to Little Missenden, where it would deviate horizontally and vertically before rising to a portal just south of Nash Lee Road and running northwards in cutting to re-join the Proposed Scheme alignment near the Princes Risborough railway line south of Aylesbury.

2.1.4 The proposed Chilterns Long Tunnel would be constructed by tunnelling with two TBMs from both the north and south and meeting at the Little Missenden Vent Shaft where all four TBMs would be removed. The PBA proposal further postulates that a Fire Fighting Point (FFP) would be placed at the Little Missenden shaft which would require underground access roads connected to a central bore between the tunnels. This arrangement would facilitate the removal of passengers and provide emergency equipment access in case of a fire or similar emergency.

2.1.5 The 'Chiltern Long Tunnel' is promoted as a better alternative to the Proposed Scheme. This long tunnel petition is submitted on the basis that only a full tunnel through the AONB would provide adequate environmental mitigation.

2.2 Chilterns Long Tunnel

2.2.1 The southern half of the PBA proposed CLT would be driven from the site of the Proposed Scheme south portal for the Chiltern Tunnel at West Hyde. The northern half would be driven from a new portal location just south of Nash Lee Road at approximate chainage 55+600. All TBMs would be removed at the location for the Little Missenden Vent Shaft.

2.2.2 The PBA proposal also includes the provision for a Fire Fighting Point (FFP) at the Little Missenden Vent Shaft. This FFP would include above ground and

underground access roads to allow emergency services and vehicles access to track level. This FFP is non-conforming with HS2 requirements.

2.2.3 Three additional ventilation shafts would be required compared to the Proposed Scheme. One each, approximately at chainages 46+600, 49+600 and 52+600.

2.2.4 The Chiltern Borough Council is promoting the CLT as an alternative that would reduce the impact to the local area when compared to the Proposed Scheme, which includes a mixture of cuttings, embankments, green tunnels and viaducts. The Engineering Review of the PBA proposal is based on the following areas:

- Engineering feasibility
- Construction feasibility
- Conformance with HS2 requirements
- Environmental impacts
- Construction impacts on adjacent sections
- Alignment
- Excavated Material Management
- Railway Systems Construction
- Tunnel Ventilation and Smoke Control
- Railway Operations
- Traction Power and Overhead Contact System
- Train Control and Telecoms
- Non Traction Power
- Railway Maintenance
- Construction Costs
- Programme Impact

3 Engineering Review

3.1 Introduction

3.1.1 The Engineering Review evaluated the Chilterns Long Tunnel proposal against the assessment criteria outlined below.

3.2 Engineering Feasibility

3.2.1 In general, the design of the CLT could be feasible. However, there are a number of elements that would require further investigation and refining to be able to fully assess its feasibility. The proposal for an underground firefighting point does not fulfil the HS2 project requirements. An open gap structure provides the safest form of firefighting point and should be incorporated for tunnels longer than 20km in length. Despite the underground FFP not adhering to the HS2 project requirements, a commentary has still been provided within this report from section 3.2.3 – 3.2.14.

3.2.2 To conform with HS2 requirements, the CLT proposal would need to replace the proposed FFP with an open box structure (900m long). As there is not adequate space for a 900m long open gap structure at Little Missenden, a potential position of this structure would be at Durham Farm as suggested in High Speed Rail in The Chilterns Part 3: CRAG Proposal.

3.2.3 The viability of the proposed CLT is dependent on the feasibility of the FFP at the Little Missenden Shaft. The proposal envisages access roads capable of providing emergency vehicles access to rail level. These roads would be a combination of surface and underground roads that would slope down to the rail level approximately 40 to 50m below ground surface. See figures below.

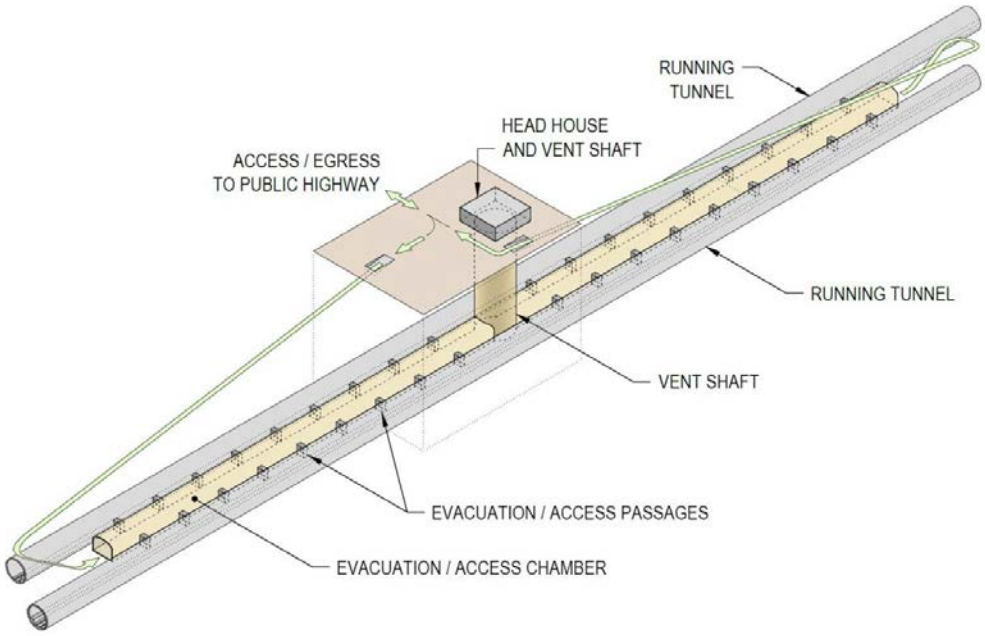

Figure 3.1 Extracted from PBA Report

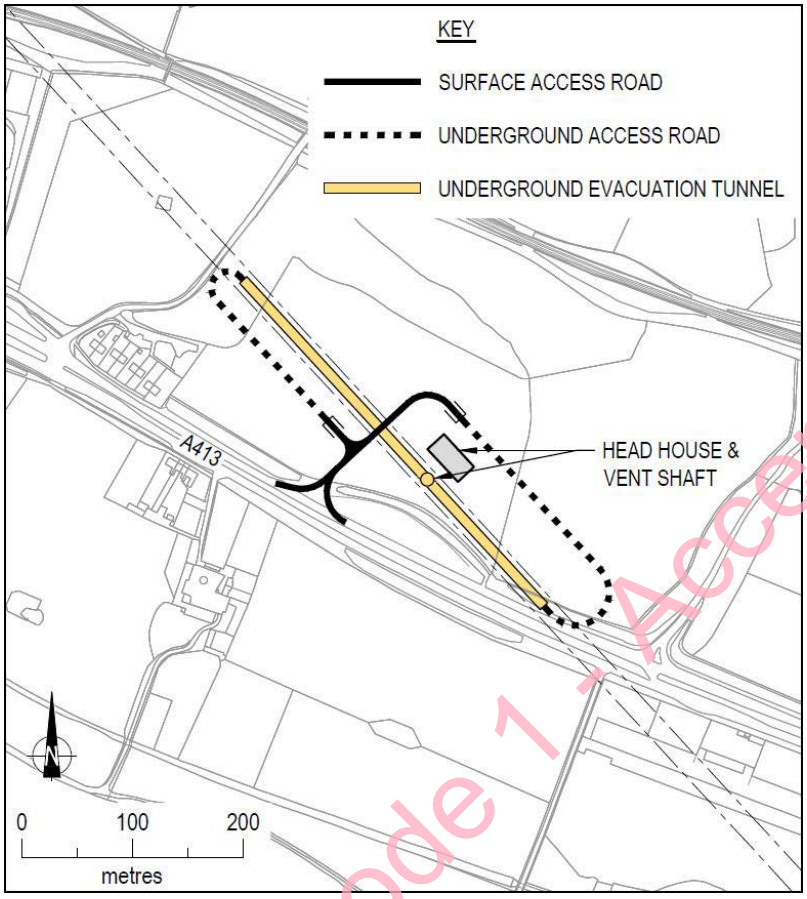

Figure 3.2 Extracted from PBA Report

3.2.4 The PBA proposal indicates a ramp/access road that turns back on itself and crosses over the tunnel. Assuming a maximum gradient of 1:8 the length of ramp to track surface would be approximately 400m. A typical turning radius for firefighting equipment, a pumping appliance, is generally 16.8 m and a swept circle of approximately 20m. Another geometric constraint, when considering the feasibility of the ramp from ground surface, is that the ramp would have to pass over the tunnel by at least a diameter or risk impacts requiring further measures to mitigate.

3.2.5 Taking into account these geometric constraints, the emergency access ramp would have to rise from between the two tunnels about 150m before turning back on itself over a 17m radius curve and rising the remaining way to the surface over another 250m and there would be earthworks associated with this ramp as it descended from ground level into the service adit. This ramp would begin from the end of a proposed emergency access tunnel located between the two running tunnels. PBA indicate that this emergency access tunnel would be at least 400m long to ensure that all passengers could disembark quickly and safely off the trains to an area of safe refuge. It is required by the TSI that an additional 100m is provided to the emergency access structure. Applying all the above dimensions to the FFP concept in the PBA proposal could considerably expand the land area required to fully encompass the FFP than is shown in the sketch in the PBA report.

3.2.6 All the above assumed dimensions, along with the minimum dimension of the ramp itself, would have to be verified by the latest standards and the dimensions of the potential equipment that would be used in emergency situations. Also, it should be noted that there would not be available space to turn typical firefighting equipment around between the running tunnels.

3.2.7 The PBA proposal does not provide any specific dimensions that would be required for the emergency access tunnels. Using the dimensions of a typical firefighting pumping appliance of 2.3m wide by 3.3m high and assuming that two vehicles may have to pass each other or be side by side, a minimum interior width of 7m is assumed for the emergency access tunnel. Also, “crosscuts” are suggested that would provide access from the running tunnels to the emergency tunnel. These crosscuts, according to the PBA proposal, would have a double ventilation door system. Incorporating the two doors, as proposed, would require a minimum of 6m to allow a reasonable space between the doors for smoke control. Adding the crosscut dimension from both tunnels to emergency access tunnel minimum width indicates that a total of 19 metres would be required between the running tunnels. The existing space between running tunnels in the Proposed Scheme is approximately 12m. These assumed dimensions do not take into account the probable requirement for people to congregate safely within the emergency access tunnel, which could further increase the required width between the running tunnels.

3.2.8 Based on the above assumptions, the alignment of the running tunnels would have to be potentially widened by a minimum of 7m to allow enough space to construct the PBA proposed emergency access tunnel and first part of the ramp to the surface. To allow no reduction in train running speeds the horizontal alignment would need to be varied gradually over a considerable distance. The PBA proposal does not discuss any alignment changes associated with the FFP.

3.2.9 The precast segments of the main running tunnel at this location would be designed to withstand the additional stress of excavating the emergency access tunnel and the ramp passing over the tunnels to the surface. Also, the spacing of openings in the tunnel required to disembark the passenger, distance between the doors of the train, is significantly shorter than the cross passage spacing and would probably require a different design from the cross passage openings.

3.2.10 A number of specific elements would be required to be incorporated into the vent shaft to ensure that the PBA proposal could be constructed. The PBA proposal indicates a circular shaft at the Little Missenden location. It also shows the TBM bored tunnels partially intersecting this circular shaft, which is an unstable configuration and would be difficult to provide a design that can be constructed. Therefore, the PBA proposal is being reviewed with the assumption that the vent shafts would need to be rectangular.

3.2.11 To achieve the required air flow and have space for the ventilation equipment, the shafts at present in the Proposed Scheme are rectangular structures that extend beyond the limits of the tunnels. The temporary propping of these shafts would have to be designed to be located where they would not interfere with removal of the TBMs.

3.2.12 As the rectangular shaft walls are already being intersected by the tunnel bores, any further substantial openings could reduce the supporting sections of the shaft walls to a point where the shaft would be difficult to construct. Direct pedestrian or vehicular access should not be created from the emergency access tunnel to the vent shaft as that would create openings that could compromise the integrity of the shaft walls, considering the existing openings for the running tunnels. As passengers would be exiting via the emergency access ramp to the surface, access to the vent shaft should not be required.

3.2.13 The shaft size would require widening to incorporate the wider spacing between the running tunnels to accommodate the emergency access tunnels. Using the assumptions from paragraph 3.2.5, the minimum interior width would be approximately 40m to account for the two running tunnels and emergency access tunnel between them.

3.2.14 This probable geometry of the PBA proposed FFP would require careful design to ensure it would remain stable during construction and over the lifetime of the system. The proposed sequence of construction could affect the design requirements. Regardless of method of construction, an underground structure of

this magnitude and complex geometry would require significant cost and time to implement and could affect programme.

3.2.15 The above commentary was provided, along with further comments on the PBA proposed FFP, to indicate the PBA proposal was completely reviewed. For the PBA proposal to be taken forward, a FFP would be required to conform to HS2 requirements.

3.3 Construction Feasibility

3.3.1 The CLT would comprise two 8.8m ID tunnels bored through various types of chalk.

3.3.2 The slurry machine in the PBA proposal is well suited for the chalk layers anticipated to be encountered in the extended section of the CLT

3.3.3 Launching the southern TBMs from the West Hyde/M25 location would provide an adequate works area and good access to major highway routes as with the Proposed Scheme.

3.3.4 The proposed north portal location would have substantial impact to the local area and road network. The associated work site would have to provide enough area for a welfare station, segment storage, excavations arising, equipment storage and slurry plant. Approximate area for work site could range between 100,000-150,000m^2. If segments were to be cast on site, an additional area of approximately 30,000m^2 would be required at this location. The PBA proposal is in agreement with this. However, an additional area would be required to treat and stock pile the spoil, prior to it being removed from site. This does not appear to be taken into account within the area identified, especially if settlement ponds are required. The CLT report references activities and the possible pumping of slurry, and/or the removal of material by rail. It is not clear from the indicative sketch, included within the report, what the area labelled 'additional area required for Chiltern Long Tunnel' is required for. It is assumed that the space required for rail sidings has not be taken into account in the area indicated for the worksite.

3.3.5 A review of the slurry pumping provision for CEMEX has indicated that an area of 14,000m^2 would be required to support a slurry pumping operation. The operation at Kenworth for CEMEX occupies approximately 18,500m^2.

3.3.6 The PBA report does not discuss how access is provided to the northern work site area. Provision would be required for highway access, this could be taken from the A413 Wendover Road. This would require a temporary bridge and approach embankments over the Chiltern mainline.

3.3.7 As the TBMs are electrically driven, a reliable and substantial electric supply is required to operate the TBMs and provide electricity for the work site and all ancillary works. This supply would likely come directly from the National Grid. Further investigation would be required to determine if an adequate location for

connecting the power supply could be provided for the north portal site. It is likely that this could be supplied from the National Grid network adjacent to Wendover.

3.3.8 If segments are not cast on site, to maintain 2 TBMs at an average advance rate of 80 m/week would require approximately 40 two-way lorry trips/day to deliver segments over the 3 year course of the tunnel construction. It should be noted that 80m/week is an average advance rate with peak rates that could substantially exceed that, probably increasing the required lorries/day and/or required storage for segments.

3.3.9 The segments could be cast on site which, would reduce but not eliminate the lorry trips required for the segments, as materials for casting the segments would need to be delivered.

3.3.10 The construction activities proposed at the Little Missenden Shaft, or at a site where a compliant FFP could be constructed, including removal of four TBMs, would require a substantial work site. The area of Little Missenden is on a slope, substantial re-grading would be required to provide enough level area to support all the envisaged construction activities and the final vent shaft/FFP layout.

3.3.11 The proposed works area for the FFP is bounded to the south by the A413, a dual carriageway, to the north by a railway line and east and west by two minor roads. Total approximate area of this space is 138,000 m^2. However, the area that can be utilised is limited by a number of cottages located at the southwest corner and having to slope the back of the works area to provide adequate support to the existing Chiltern rail line. These constraints prevent an open box FFP from being located in this area. The following commentary applies to the PBA proposed non-compliant FFP.

3.3.12 There is up to a 20m difference between the rail elevation and the elevation of the A413. As HGVs would need to exit and enter the site, the work site would probably be excavated to the level of the A413, creating a steep embankment at the back of the worksite which would support the railway. The embankment could require reinforcing to ensure that the railway is properly supported.

3.3.13 The influence of water during construction and operation of the FFP could be a significant constraint depending upon local rock mass permeability and flow characteristics. The upper portions of the proposed sloped ramp to the track level could be most affected as weathering of the chalk may have increased rock permeability. The area around the FFP could require dewatering or grouting to provide groundwater control during construction. Both these methods of controlling groundwater could adversely affect the water abstraction point located at Little Missenden, considering the depth of construction.

3.3.14 The location of the proposed surface access of the emergency access ramps, as shown in the PBA proposal, would have to be adjusted to match the geometric constraints discussed in 3.2.2 and 3.2.3. Taking into account these adjustments,

one of the surface access points could be located within the limits of the A413 and the other could be close to western limit of the construction site, making it difficult to provide access for emergency vehicles. Also the exact length of the emergency access tunnel at track surface in the PBA proposal should be clarified to determine any final geometry layouts of the FFP and if the conceptual layout in the PBA proposal would fit within the area bounded by the A413 and the rail line.

3.3.15 As discussed previously, the emergency access tunnel could be constructed either prior to or after the bored tunnels have been completed and the TBMs removed from the Little Missenden Shaft. Either option could have impacts on programme. Excavating the access ramp and emergency access ramp prior to the bored tunnels reaching Little Missenden should not affect the construction programme, however, because the tunnels would be bored in close proximity to the emergency access tunnel, advance rates may be reduced to avoid adversely impacting the emergency access tunnel.

3.3.16 Boring the tunnels first could affect the overall HS2 programme, depending on the specific elements of critical path. The upper sections of the access ramp could be excavated prior to the TBMs being removed from the shaft, but programme time would have to be added to finish the lower sections above and between the tunnels. Regardless of the sequence of construction at the FFP, additional programme time would be required to construct the multiple crosscuts between the running tunnels and emergency access tunnels after both are completed.

3.3.17 As part of the PBA proposal, there are a number of additional shafts that would be constructed to provide adequate ventilation and emergency access to the tunnels. These shaft locations are approximately located in the PBA proposal, but no specific site location are indicated. The potential shaft locations and associated work site impact needs further investigating to determine the minimum area to store excavation arisings, construction materials and welfare site along with the area for the shaft, permanent buildings and vehicle parking.

3.4 Conformance with HS2 Requirements

3.4.1 The Chilterns Long Tunnel proposal extends approximately 24km with an intervening Fire Fighting Point at approximately mid-point. The revised alignment would require review to ensure the tunnel length with FFP would maintain a safe environment for passengers and be in conformance the safety and ventilations guideline presently adopted in the HS2 Proposed Scheme.

3.4.2 The arrangement at the FFP is not currently conforming to the HS2 project requirements. An underground cavern FFP would need to be appropriately investigated to determine if emergency crew operations would be able to use the

FFP in conformance to HS2 safety requirements. For conformance to HS2 requirements, an open box structure, 900m long, would be required for the FFP.

3.4.3 A unique arrangement is proposed for the north portal final structure. Further justification would be required to ensure that this arrangement is in conformance with HS2 requirements.

3.5 Environmental Impacts

3.5.1 The construction of the Chiltern Long tunnel would mitigate a number of the adverse environmental impacts within the Chiltern AONB that would be caused by the implementation of the Proposed Scheme. However, the PBA proposal, relocates some of the environmental impacts out of the AONB to substantially impact equally rural areas just outside the boundaries of the AONB. The Chiltern Long tunnel also creates localised environmental impacts that would require more assessment.

3.5.2 The tunnel alignment runs immediately adjacent to a Thames Water public water supply abstraction just north of Wendover. The PBA proposal does not refer to this abstraction. The local geology and exact distance of the abstraction from the PBA proposed alignment would need to be thoroughly investigated to determine potential impacts to the abstraction.

3.5.3 The water abstraction at Little Missenden may be affected by the dewatering operations associated with the construction of the vent shaft/FFP. Potential impacts to this abstraction would require to be investigated.

3.5.4 The increased volume of HGV traffic would have a significant impact to the local area around the north portal, with an anticipated number of two way lorry trips to and from the work site up to 300/day. Even with the excavated arisings being taken off site by train or pipeline, there would still be significant daily lorry traffic to handle segment and other ancillary equipment and materials required for the TBM drives. This would increase the construction traffic using the local highway network compared to the Proposed Scheme.

3.5.5 The construction of the Fire Fighting Point and the several additional vent shafts would have local impacts, including increased noise, land take, and significant HGV traffic. As the FFP is a fairly extensive final structure and also the location where the TBMs are to be removed, it would have the largest impacts.

3.6 Construction Impacts on Adjacent Sections of the Proposed Scheme

3.6.1 The PBA proposal indicates that the Chiltern North Tunnel portal is immediately adjacent to the location of the Proposed Scheme's maintenance loop. As the space

requirements for a north portal work site are extensive, it may impact the construction schedule for installing the maintenance loop.

3.6.2 The PBA alignment has located a horizontal curve in the location where the Switch and Crossing would be located for the maintenance sidings. This would not be acceptable and either the horizontal alignment would have to be designed to avoid this or the maintenance loops re-positioned to avoid this. The latter would require a new horizontal alignment, which may impact the Proposed Scheme up chainage from the proposed north portal location.

3.6.3 The length of the southern switch and crossing would need to be increased. The track separation immediately outside the tunnel portal would be greater than the track separation of 5m for the Proposed Scheme. This will result in the position of the maintenance loops moving further north

3.7 Alignment

3.7.1 The review of the alignment has been undertaken based on the assumption that the design speed throughout the CLT would be 320 kph.

3.7.2 It is noted that a number of vertical curves and horizontal curves are coexistent which is non-compliant with the first preference for vertical and horizontal alignment combinations. However, these combinations also occur in the Proposed Scheme, but the new combinations in the PBA proposal would need to be checked against the detailed alignment models and cant values/deficiency to determine if they comply with the second or third preferences within the standard.

3.7.3 The gradient of two sections are also noted a being within the Limiting Values of 0.2% for drainage but outside the Desirable Values of 0.5%.

3.8 Excavated Material Management

3.8.1 Approximately 12,000m^3 per week of material would be excavated by two TBMs advancing at long term average rate of 80m/week. To remove that amount of material would require over 400 two-way lorry trips/day, making the total number of over 440 two-way lorry trips/day over a three year period to remove material and deliver segments. This does not include additional lorries delivering machinery, segment accessories and any other worksite related equipment and material. The PBA proposal provides an approximate number of 300 two way lorry journeys/day. However, the PBA proposal states that all trucks could be operated during the day, avoiding night time impacts to local area. If this scenario could be implemented, and assuming a 10 hour day, there would be truck movement to or from the site every minute for 10 hours. The logistics of that movement would have to be carefully analysed for feasibility.

3.8.2 The PBA proposal also suggests removing the slurry by pipeline along the trace of the proposed HS2 line north of the CLT. While this would remove the lorries locally,

it may just move them to another locality where the impacts could be just as significant. The pipeline would have its own environmental impacts and costs. The suggested location along the trace north of the CLT could interfere with parallel construction, detrimentally impacting the overall programme. If there are any issues with the pipeline that would require it to be shut down for any time, there would be significant impacts to TBM progress as the slurry could no longer be removed. A backup system of removal would have to be in place, further increasing the cost of disposal.

3.8.3 Another potential method of reducing the quantity of tunnel spoil arisings being transported from site, by road, would be to move material up the trace northward, to be used in landscape/mitigation proposals around Aylesbury, where approximately 800,000m^3 of material is required. This would reduce the amount of two-way lorry trips on the local roads however, there would still 1.1M m^3 of excess tunnel spoil that would need to be transported off site.

3.8.4 As mentioned in the PBA proposal, another method of removing the excavated material is by rail through a short access road to the existing rail line through Aylesbury. A rail head would have to be constructed to facilitate loading and unloading the trains carrying the excavated material. The availability of train paths, to serve this construction compound and the destination for disposal of this material would need to be reviewed further before this could be considered a viable option. Removing the material by train would reduce the impact to the local road network but would increase the local land take and environmental impact.

3.8.5 The above paragraphs briefly discuss potential methods of disposing/using the excavation arisings from the north tunnel drives. Full environmental impacts of all potential methods of disposal/mitigation would need to be investigated to determine if a northern tunnel drive of the CLT would be feasible.

3.8.6 The PBA proposal, in making the assumption that all excavated material disposal would be commercially reused is optimistic. Commercial reuse requires a specific type and quality of chalk and only a small percentage of the excavation arisings could probably be reused. Considering the quantity of material arising from the CLT northern drive there may be difficulty in finding appropriate disposal locations for all the excavation arisings from this tunnel drive, thus probably increasing the cost of disposal.

4 Rail Systems Construction

4.1.1 The CLT option only discusses the impacts during the construction phase. There is a further four years plus, when the rail fit out is performed. The Proposed Scheme provides rail heads and sidings to facilitate the transport of materials to the work sites. This arrangement allows reduced handling times of the materials onto the work trains along the mainline. The sidings ensure that transport trains do not effect existing railway operations. The PBA report does not describe the logistics of installing the rail systems within the proposed tunnel.

4.1.2 The key construction issue with the PBA proposal is the restrictive access to the trace, increasing the logistical constraints compared to the Proposed Scheme.

4.1.3 The assessment by HS2 Ltd. Indicated that rail systems fit-out would need to be undertaken from both the south, working northwards to the Little Missenden vent shaft; and from the new northern portal, fitting out southwards. This southern fit out would need to commence as soon as tunnel civil work were complete and would require rail systems equipment to be supplied to this portal area.

4.2 Tunnel Ventilation and Smoke Control

4.2.1 The shaft spacing proposed for the hybrid bill adopts features that are both in accordance with the TSI and found to be acceptable to the regulators on similar projects in the UK. Key factors in this are the ability to provide intervention points for fire fighters and to limit the number of trains between ventilation shafts to one. The maximum shaft spacing on HS2 is currently 3.3 km. If the shaft spacing becomes longer then there are risks that the fire authorities may not find this acceptable (3.3 km is the longest shaft spacing on any UK project).

4.2.2 It is a mandatory requirement of the TSI to provide a firefighting point at up to 20 km. It has become common practice in Europe, in tunnels longer than 20km, to provide an intermediate rescue facility with an enhanced level of evacuation facilities and tunnel ventilation. Providing a level of safety closer to that which might prevail if the train stopped outside the tunnel. These facilities have been found to offer an acceptable level of safety on other similar systems. It is recommended that such an installation is considered for HS2. However, such a facility to be compliant with HS2 requirements must be constructed as an open box structure.

4.2.3 At such rescue facilities it has become common practice to provide a cross passage door for each train carriage. The door would typically lead to a separate evacuation gallery connected to ground level, but it might otherwise lead to the

non-incident bore. In either case there would be significantly more cross passage doors within the tunnel requiring maintenance.

4.2.4 It has also become common practice to provide transverse ventilation at such facilities. A longitudinal ventilation system, as employed for the shorter tunnels, may still expose some passengers downstream of the fire to smoke. For the longer tunnels there is a higher likelihood of the train stopping within the tunnel and hence improved tenability is sought. A transverse ventilation system extracts smoke along the length of the train and tangibly reduces the probability of passengers being exposed to smoke during any evacuation and intervention. The nature of these systems has been developed and optimised in other European long tunnels. It has become typical to provide a large duct connected to each bore in at least five locations to provide a reasonable distribution of airflows and control of smoke.

4.2.5 The required airflow capacity at the shaft is considered likely to be within the current proposed capacity of the HS2 shafts. At rescue stations it has become common practice to supply air to the non-incident bore and exhaust air from the incident bore at the same shaft at the same time. The current above ground shaft arrangements cannot achieve this. Either a larger above ground shaft arrangement would be required, or potentially some of the shafts either side might be used for supply air.

4.2.6 Such below ground rescue stations become the target stopping location for a train on fire. However, by enclosing these facilities below ground there is a greater probability of damage to the structural components and ventilation system equipment. This means that post incident recovery can become extended and the operational consequences and loss of revenue to HS2 may be much higher than compared to an open to air facility. Such losses of revenue, and also of public confidence, have been tangible for the Channel Tunnel, albeit the fire hazard is higher on the Channel Tunnel considering the types of vehicles using that infrastructure. There may be opportunities to include fire suppression systems at these locations to minimise infrastructure damage and such facilities have been retrospectively added to the Channel Tunnel. This potentially negative impact of the below ground rescue stations should be acknowledged and accounted for in the decision making process.

4.2.7 If the rescue stations are located entirely below ground common practice is for the tunnel bore, at the point of the rescue station, to be similar to the main tunnel bore. This limits the potential for micro pressure wave generation as well as construction costs. There is also an effect on the amount of tunnel cooling required for below ground facilities. Individual tunnels up to 20 km are predicted to require approximately 13 MW of cooling. Therefore, two such tunnels in succession separated by an open to air facility might require around 26 MW of cooling. One much longer tunnel without an opening, and associated natural

cooling, might require about 36 MW of cooling, meaning more equipment and running cost.

4.2.8 A key consideration relates to crossovers at or near the rescue facilities. It may be desirable and necessary to include a crossover at the rescue location for both emergency and tunnel maintenance scenarios. If the rescue station is below ground the crossover potentially needs to be located in a cavern or discrete tunnel bores. In either case it makes it challenging to provide a place of relative safety in a non-incident part of the tunnel, since there is no non incident cavern at this location. If the entire cavern were to be made tenable this may be highly challenging given the potential for any smoke to be affected by the high speed airflows that take some time to decay in the non-incident bores. Potentially the evacuation routes may need to be constructed separately on the outside edges of the crossover. There may also be micro pressure wave issues caused by the sudden change in tunnel cross sectional area at the cavern. There is a risk that any such arrangement would not be able to be developed with a satisfactory outcome. It may therefore be necessary to develop any below ground crossover before or after the rescue facility, as has been the case on other long rail tunnels. Such crossovers would be provided with doors to allow the tunnel airflows to be isolated from each other. The doors are large and comparatively expensive and demand maintenance. There may still be some micro pressure wave issues at the HS2 train speeds.

4.2.9 If crossovers are required it may be highly desirable to provide these at open to air rescue facilities. Any smoke from a fire would rise upwards and passengers might evacuate via a side platform to a protected refuge area. Tunnel cooling would be minimised, infrastructure damage after a fire minimised, and the need for crossover doors eliminated and potentially improved construction access gained. There may still be a need for porous portals on the approach to the crossover/rescue facility, but there may be options to duct such periodic vents to above ground allowing much of the porous portal to be back filled. Further work is required to understand the optimum outcome considering the operational and maintenance demands versus the construction costs and impacts.

4.2.10 The principle cause of heating in the Chilterns tunnel is aerodynamic drag and also the traction package inefficiencies in converting energy into motion. The PBA report mentions that the drag is about 10% greater in tunnels than open air. This estimate is inaccurate and tunnel modelling predictions using differing software and prediction methods and specific to HS2 13.3 km tunnels indicate that the drag in the longer tunnels may increase by about 50% compared to outside. Warming of longer tunnels is therefore an important consideration.

4.2.11 The tunnels have a maximum temperature criterion of 35°C. This is to allow the train cooling system to be able to keep the insides of the trains cool enough when running through tunnels. Allowing temperatures to be controlled with a practicably sized tunnel ventilation system if the trains stopped in the tunnels. Providing reasonable conditions for maintenance and evacuation within the

tunnel and to limit the probability of tunnel based equipment prematurely failing due to hot conditions. For the HS2 13.3 km baseline case, the Chilterns tunnel was predicted to exceed this condition after about 10 km, rising to about 38°C by the time the air left the portal. This was judged to be a small enough exceedance to be acceptable over a short length of tunnel and a short duration of exposure.

4.2.12 Tunnel cooling would very likely be required with temperatures near the exit portal otherwise approaching 46°C. These might be provided in each of the last five shafts in the travelling direction which would effectively result in all seven shafts being provided with an average 2.2 MW cooling capacity installations serving 300 mm diameter pipes within the tunnels. A 10 m x 8 m above ground space would potentially be required at each shaft. This would increase the capital, operating and maintenance costs of the proposal.

4.2.13 If the trains stop in tunnels during normal operations the tunnel ventilation fans would likely be required to operate to manage tunnel air temperatures. The increase in length of tunnels theoretically increases the probability of a train stopping in the tunnel during congestion. This potentially increases the usage and wear and tear on the fans and associated equipment and also the probability of an uncomfortable event occurring if the ventilation system at any shaft were not available.

4.2.14 It is assumed that the ventilation facilities could be operated to manage the emissions from a diesel powered rail grinding train, albeit that the final technology of the rail grinding train and other heavy maintenance vehicles remains under review. With longer tunnels, the ventilation system would need to operate more frequently in support of such rail grinding activities meaning more maintenance and cleaning of the airways.

4.2.15 The longer tunnels may affect air quality in the rolling stock. It may be necessary to shut off the outside (fresh) air to the rolling stock when in tunnels to prevent pressure waves affecting the pressure comfort of passengers. This loss of ventilation would cause carbon dioxide (CO2) levels to rise. Whilst the TSIs require a long-term safety exposure limit of 5,000 ppm, there are uncertainties in relation to general air quality at levels above 2,000ppm. Operational practice in aircraft usually results in 1,500ppm of CO2. Levels of around 2,000 ppm might be acceptable in rolling stock based on anecdotal evidence from other long tunnels. Levels between 2,000 and 5,000ppm present a risk in terms of general air quality. If the CO2 level could be controlled to 500 to 600ppm when leaving the stations (outside air is about 400 ppm), the in-car CO2 content may rise to around 2,000ppm at the end of a 20 km tunnel and higher for the 24 km options. For a crowded car this would increase further and for slower train operations this could increase again.

4.2.16 To achieve even 2,000ppm at the end of the tunnel potentially a supplementary rolling stock ventilation system would be required at the stations to provide a high capacity purge of the carbon dioxide down to a lower starting condition before the

journey into the tunnels. It is known that some countries are considering actively controlled pressure ventilation for rolling stock that may allow some ventilation in tunnel when pressure waves were not near the train. This would require a detailed review for HS2. Other countries are understood to have developed a specialised air supply system, possibly from a pressurised reservoir.

4.2.17 Further work would be required to develop mitigation for HS2, but at this time it is recommended to assume that some form of special measure would be required for the rolling stock. Such a special measure might only be achievable on the rolling stock purchased specifically for HS2. Potentially affecting the ability for other rolling stock to inter operate in the longer tunnel without risks associated with pressure discomfort or poor air quality.

4.2.18 It could not be ascertained with clarity whether the southern crossover associated with the maintenance loop at 56km would be located within the tunnelled section. The ventilation system design and ability to control smoke is strongly affected by the tunnel cross sectional area. It is assumed in this report that the tunnel descriptions and dimensions are as stated in the various reports and that there are no enlargements for crossovers. If the southern crossover could not be relocated outside the tunnelled section then doors would be required to allow the tunnel airflows to be isolated from each other (as discussed above) which increased construction complexity, maintenance requirements and costs as well as increased capital cost.

4.2.19 The PBA proposal includes for a rescue facility due to the length of the tunnel. Only one example in Spain can be found for such a long tunnel being proposed without such a facility. Whilst omission of such a facility might be justified by later risk analysis, such risk analysis for tunnel fires can be highly subjective in relation to accurately understanding the fire frequency. Therefore, based on the acceptance being based on other similar systems, it is recommended that the rescue facility is accounted for with enhanced ventilation and egress. Similar to other tunnel configurations being considered, such a facility might be located at Little Missenden subject to a review of the vertical alignment to maximise the chance of the train reaching and stopping at this location in an emergency. It should be noted that the facility would have to be an open box structure to be in conformance with HS2 standards.

4.2.20 The PBA report cites underground crossovers, although it is not clear whether this is an option or a proposal. Such a crossover has a significant impact on the tunnel fire and ventilation arrangements. For the Channel Tunnel, and also the longer European tunnels where crossovers are provided special doors are used to allow the crossover to be isolated to provide the required airflows to manage smoke. If crossovers are provided detailed analysis will be needed to develop a satisfactory tunnel and systems configuration, but it is considered likely that these will have a

negative impact on tunnel costs and maintenance demands and might result in a reduced level of fire safety.

4.2.21 It is also proposed to provide three new intervention shafts at chainage 45+985, 48+785 and 51+675. This would result in four ventilation zones of length 3.0 km, 2.8 km, 2.9 km and 3.8 km. It is considered likely that smoke control could be achieved with similar capacity shafts as the others on the existing Chilterns tunnels. More shafts may be required to coincidentally operate which may increase maintenance demands to provide a sufficiently available system.

4.2.22 The current proposal would make distance between intervention points longer than the longest 3.3 km proposed anywhere else on HS2. Further discussion with the authorities would be required, but it would be prudent to assume that an additional shaft would need to be provided closer to the portal.

4.3 Railway Operations

4.3.1 An assessment has been undertaken to determine the implications of journey time, technical headway and mechanical traction energy between the Proposed Scheme and the alternative CLT proposal.

4.3.2 The following table summarises these differences, with the values extracted from Parsons Brinkerhoff's report on Extended Chiltern Tunnel Proposals. It should be noted that:

a. The Proposed Scheme is taken as the baseline against which the PBA proposal has been compared.

b. The Up direction refers to trains running towards London and Down refers to trains running towards Birmingham.

c. Journey Time refers to the total journey between London and Birmingham.

d. Technical Headway is the taken as the time between two consecutive trains running in the same direction. A shorter technical headway implies a more frequent service is possible.

e. The Mechanical Energy refers to the energy required to move the train from London to Birmingham.

Option	Journey Time	Difference from Baseline	Technical Headway (OOC-INT)	Technical Headway (OOC-56km)	Difference in Technical Headway	Summated Journey Mech Energy (kWHr)	Difference in Mech Energy from Baseline
Baseline Down	00:44:54	00:00:00	00:00:00 00:01:55	00:00:00 00:01:40	00:00:00 00:00:00	5532.536	0
Baseline Up	00:45:03	00:00:00	00:00:00 00:02:10	00:00:00 00:02:10	00:00:00 00:00:00	5154.232	0
PBA Down	00:44:57	00:00:03	00:00:00 00:01:55	00:00:00 00:01:50	00:00:00 00:00:10	5524.351	-8.185
PBA Up	00:45:13	00:00:10	00:00:00 00:02:15	00:00:00 00:02:15	00:00:00 00:00:05	4963.317	-190.915

4.3.3 It is noted that further work would be required to confirm if these small changes to journey time and headway would impact sectional running times and route capacity respectively, which means there remains a risk that the timetable could be affected. The journey time changes would typically be higher for the increased tunnel lengths for speed limit and resistance, but these are offset by the improved flatter vertical alignments.

4.3.4 The summated Mechanical Energy figures show an energy saving over the Baseline due to the tunnel alignment providing a flatter profile than the Proposed Scheme. Tunnel resistance is of less impact than gradient in this case. The impact of the mechanical energy figures is discussed in the traction power section.

4.4 Traction Power and Overhead Contact System

4.4.1 In overall terms, based on comparative single train performance simulation runs for a 400m long train that have been undertaken, total train mechanical energies are predicted to be slightly lower for the proposed CLT option. However there is predicted to be an appreciable redistribution (and transfer) of average traction power loading (electrical) from Quainton ATFS to Ickenham ATFS electrical feeding area of the order up to an estimated 2.5MW (Phase One 10tph train service) and 5.5MW (Phase Two 18tph train service). This is due to the change in operating

profile for trains in the Up direction in particular relating to relocation of the point at which braking from surface to tunnel maximum line speed occurs.

4.4.2 The adequacy of the currently proposed Traction Power (Electrification Distribution) System Design (for both Phase One and Phase Two operational scenarios), particularly in respect of the capability of Ickenham ATFS and its electrical feeding area to support this increase in loading whilst continuing to be TSI compliant in respect of (minimum mean useful and instantaneous) train voltages, requires further assessment employing multi-train traction power simulation modelling and represents a risk. A possible mitigation to compensate for this would be to relocate South Heath Mid Point Auto-transformer Station (MPATS), currently at 47.4km, to be at Little Missenden, at 43.0km, so as to reduce the extent of electrical feeding area for Ickenham and increase that for Quainton ATFS respectively. This would also be compatible with relocating the neutral sections for the MPATS to be at the tunnel rescue facility.

4.4.3 Notwithstanding these traction power system capability aspects, a particular issue is that South Heath MPATS, currently at surface level at 47.4km, is located adjacent to a new tunnelled section for all proposal options. This has an associated 400m long type neutral section (physically 800m long) on each track with numerous 25kV cable connections spanning across the neutral section connected at each end by overhead line disconnectors. The accommodation of these cables and disconnectors within the tunnel space envelope is potentially problematic (the latter possibly requiring additional tunnel adits). In addition, there are potential constraints between signalling block sections (within and adjacent to tunnels) and neutral sections that are yet to be investigated. Furthermore, the MPATS itself needs to be co-located with a ventilation shaft or open air rescue station/rescue facility in order that transformer equipment can combined with a headhouse or similar surface level provision and 25kV cable connections have a routed to reach between switchgear/transformers and track level , none of which is present at 47.4km.

4.4.4 Wendover ATS, currently at surface level at 51.8km, is also located adjacent to a new tunnelled section and is not necessarily coincident with a ventilation shaft or rescue station/facility.

4.4.5 For the PBA proposal it is likely that South Heath MPATS would be relocated to be at Little Missenden rescue facility at 43.0km or at a location where a conforming rescue station could be located. This would provide additional space to accommodate some of the 25kV cabling and disconnectors associated with the neutral sections and would also provide mitigation for the transfer in traction power loading from Quainton to Ickenham ATFS described above. A new ATS (effectively substituting for Little Missenden, but further north) would be required at either the 45+985 or 48+785m ventilation shaft. This may need to be supplemented by some along track 25kV feeder cabling to reach an overhead contact system connection point that achieves a reasonably equal spacing

between adjacent ATS sites. In addition Wendover ATS would be relocated slightly to 51+675m under PBA proposal.

4.4.6 The 25kV switchgear at these relocated MPATS and ATS sites will need to be of the indoor type and co-located within ventilation shafts/rescue facility buildings, with transformers combined with headhouse or similar surface level provision. The size of ventilation shafts and similar provisions will need to be sufficient to accommodate 25kV traction power cable routing between MPATS/ATS switchgear and track level.

4.5 Train Control and Telecoms

4.5.1 The high level review has not identified any significant technical issues with the alternative proposal with respect to train control or telecoms.

4.5.2 From a train control perspective further investigation would be required to understand the potential constraints between signalling block sections (within and adjacent to tunnels) and neutral sections.

4.5.3 The presence of the maintenance loop immediately outside the tunnel portal in the PBA proposal is far from ideal and may further extend the block sections in the up direction impacting operations which needs to be further investigated.

4.6 Non-Traction Power Supplies

4.6.1 The proposal for non-traction power supplies for the Proposed Scheme includes a bulk intake at the Chiltern tunnel south portal. Supplying a HV ring network extending, in the Country direction, towards South Heath Cut and Cover substation at chainage 47+300. From this point onwards, non-interconnected DNO HV intakes are proposed at discrete locations.

4.6.2 Any extension to the present tunnel limits will require amendment of these arrangements and required supply. The additional tunnel ventilation and more shafts potentially operating at the same time, as well as tunnel cooling, are likely to have an impact on the HV power supply, cable sizing and number of connections to the DNO supplies. A detailed review of this would be required.

4.6.3 The following requires further investigation:

a. Achievable supply options for a new substation at the revised northern portal location

b. Practicalities of extending the HV ring network further north (including additional cabling costs for both the extension, and overall cabling size for the associated total loads and losses).

c. Implications on the ability of the Chiltern Tunnel South Portal bulk intake to accommodate the additional load demands, inclusive of any tunnel cooling necessary.

4.6.4 Based on the initial analysis of the performance of tunnel cooling pipes, it is estimated all seven shafts would require cooling, with an electrical demand of approximately 1.1MW per shaft.

4.7 Railway Maintenance

4.7.1 The PBA proposal states that constructing the Chilterns Long Tunnel would create a more economical maintenance strategy. Inspecting and maintaining tunnels can only be done at very limited times when the trains are not running. Surface features, such as viaducts and bridges can be inspected in part during normal operations.

4.7.2 Considering the length of the proposed tunnels, a significant amount of the time available for maintenance and inspection could be taken up travelling to the site.

4.7.3 Inspections and maintenance tasks for the CLT would take substantially longer with than for the HS2 Proposed Scheme and cost more over the life of the system. Specific issues are noted below:

a. There will be an increase in the plant and equipment due to the increase tunnel length and vent shafts. In addition, cooling equipment is required for the PBA proposal which is not required for the Hybrid Bill scheme.

b. The length of the tunnel rescue areas required an increased number of cross passage doors and other life safety equipment that needs to be maintained.

c. Although the ventilation shafts can be safely visited during the day, inspection and maintenance of items such as the cross-passages and the rescue areas will need to be undertaken during the night-time "maintenance windows". The opportunities to work within these maintenance windows is limited due to the quantum of other works that must be undertaken and the number of maintenance trains that will be travelling between the IMD and their worksites every night.

4.7.4 The proximity of the new northern tunnel portal to the maintenance loop at 56km is a concern as there may be difficulty in retaining the maintenance loop. To retain the loop would require a non-standard layout which would make it difficult to maintain the required ride quality and have a reduced asset life. The transition from slab track to ballasted track in this region would also need to be carefully considered.

4.7.5 This maintenance loop will still be required even though there is no ballasted track to maintain in the CLT. Without this loop the time taken for any maintenance vehicle to transit from the IMD to a worksite at the south end of the route would severely constrict the time allowable for maintenance. As the route is in tunnel,

the only means of transporting materials and plant to site is either via the shafts or by rail. Items transported via the shafts will be size constrained.

4.7.6 The current working assumption for the use of Engineering Trains in the Proposed Scheme is that all engineering trains and on-track plant would be diesel powered as the overheads would need to be isolated to undertake maintenance work. The impact of the extra length of the tunnel on the ventilation and heat requirements would need further consideration to understand any implications.

4.7.7 Several assumptions are made in the PBA proposal which should be considered:

a. It indicates that putting the OHLE in a tunnel will reduce the number of dewirements due to cross-winds. The system will be designed to mitigate this risk regardless.

b. It states that the maintenance of OHLE in tunnels will be reduced as there will be no need for stanchions. It could be argued that the space constraints will make it more difficult to manoeuvre the elevated platforms and reduce productivity, although this not necessarily significant.

c. It assumes that the 850m length of a maintenance loop is dictated by the length of the high-output track renewal trains for ballasted track. The length was determined by the need for a 400m service train to be able to push a 400m failed service train into the loop.

5 Construction Costs

5.1.1 The PBA proposal specifically states that a detailed cost estimate was not performed but instead a number of assumptions were made to provide an approximate cost differential between the Proposed Scheme and the Chilterns Long Tunnel. Therefore a review of the costs could not be adequately performed but the general assumptions used to provide the cost comparison were evaluated.

5.1.2 The PBA proposal indicates that as a tunnel becomes longer the capital cost/kilometre is reduced. In general that is correct as surface structures costs and capital costs for the TBM can be spread over the length of the tunnel. However, in the case of tunnels required for HS2, a shaft would be located every 3 kilometres, with its associated capital costs, regardless of length. Therefore, after 3 kilometres the capital cost/kilometres decreases at a much slower rate to include singular structures as the FFP and individual capital costs as a TBM

5.1.3 Land acquisition costs would be reduced as indicated in the PBA proposal, but the cost of environmental mitigation may increase from the cost of removing and disposing of the excavations arising. The PBA proposal indicates that environmental mitigation cost would be lower than the Proposed Scheme.

5.1.4 Rail systems costs probably would increase because of more complicated logistics and equipment that is installed in a tunnel compared to surface works, contrary to the assumption stated in the PBA proposal.

5.1.5 As stated in section 4.4 traction power for this length of tunnel and its associated cost has not been fully assessed. What is fully understood is that the increased power is required, from increased air friction, to operate the trains in the tunnel. The increased cost of that power along with the cost of getting that power from the surface to track level would indicate that traction power would be more expensive for the CLT than the Proposed Scheme.

5.1.6 The cost of the “loss of the environment” is cited as part of comparison of construction costs. While it can be agreed that loss of environment is a negative impact from the Proposed Scheme, it is an intangible regarding cost and should not be included in the cost comparison.

5.1.7 The PBA proposal mentions that the cross passage and ventilation shaft spacing could be increased. It is not clear if that assumption was used in determining their approximate comparative costs. However, vent shaft spacing and cross passage

provision would need to be consistent with current Proposed Scheme tunnel fire and safety strategy at this present stage of the feasibility assessment.

5.1.8 To determine a more definitive cost comparison, HS2 has prepared a construction cost of the CLT. This cost comparison has determined that the PBA proposed CLT will cost approximately £485 million more than the Proposed Scheme.

5.2 Rail Systems Costs

5.2.1 A high level rail systems (including tunnel ventilation) construction cost estimate indicates that the incremental cost of the PBA proposal over and above the HS2 Proposed Scheme would be approximately £64.5 million, (included in the above overall cost comparison).

5.2.2 Further costs would be incurred for any additional equipment for tunnel cooling as further work would be required to identify the extent of the issue and a feasible solution.

6 Programme Impacts

Civil Works

6.1.1 Having two tunnel drives, from the north and the south, of approximately the same length as the Proposed Scheme should not adversely affect the programme. However, there may be programme implications, as discussed in section 3.3.15-16, from the construction of the Fire Fighting Point as the Chiltern Tunnels are on the critical path for the overall HS2 programme

Rail Systems

6.1.2 The key construction issue with the PBA proposal is the restrictive access to the trace increasing the logistical constraints compared to the HS2 Proposed Scheme. This will increase risk to the overall rail systems installation. Hence complex logistics planning and access are key to the delivery and would require risk mitigation to ensure delivery.

6.1.3 Programme considerations have been based on the same construction rates as per the Hybrid Bill, which are as follows:

a. Track rate of 1.08km per month (average)

b. All other railway systems 0.72km per month (average)

6.1.4 Ventilation shafts are stand alone on the programme so the number affects the potential resources required for delivery. The actual duration may extend depending on the additional equipment that might be required from the additional systems requirements. This will affect their independent installation durations, but should not impact on overall delivery programme if managed well.

6.1.5 The firefighting points are new so have no current programme base. At this stage of development they can be likened to the ventilation shafts and viewed as standalone items. As such they should not be critical but will require additional construction compounds at the surface and will have more of an interface with installation in the tunnel. They would need to be factored into the testing and commissioning strategy, to determine what additional time and other factors they add to the overall programme.

6.1.6 Where increased temperatures are possible, then some of the core installation logic / sequence may need to be addressed and revised to allow for more of the installation of the permanent cooling systems and ventilation. This would allow and support early operation to assist in reducing the local tunnel temperatures during construction. This may affect the average installation rates as the number of workfronts / worksites within the tunnel operating at the same time may need to be reduced, or other considerations about durations of shifts and cycling of labour may be required, for health and safety reasons.

6.1.7 A key consideration is that the additional infrastructure/equipment required to support these longer tunnels may result in lower average installation rates due to the additional works in the tunnel. The potential mitigation for this is to increase the resourcing to mitigate the reduced installation rates. This leads to greater access and logistics considerations and potential space required at the access points.

6.1.8 For the PBA proposal the rail systems installation from Calvert is not feasible, in order to maintain programme requirements. The longer tunnel option reduces the amount of rail based systems installation that is possible from Calvert. Rail systems installation would need to commence from the northern tunnel portal as soon as civil works are complete. This would allow fit out of rail systems southwards to the Little Missenden vent shaft, however all equipment would need to be brought in by road to the portal site compound (assuming no railhead was available). This would significantly increase and extend local traffic impacts associated with this compound.

6.1.9 The PBA proposal of a 24.3 km bored tunnel with no gap structure would require a change in the construction delivery strategy to achieve the programme. The new strategy would involve construction commencing from both ends of the tunnel at the portals. Therefore the construction programme is likely to be similar in duration to the hybrid bill scheme, however the resources and worksites would have to be doubled to achieve this. Replacing the FFP with a conforming open box FFP could reduce the resources required for the longer tunnel to be completed on programme.

7 Conclusions

7.1.1 It is clear that a Chiltern Long Tunnel would provide overall environmental benefits compared to the HS2 Proposed Scheme during operation and construction. However, certain elements would remain similar, with the continual need for land take for the north portal and ventilation shafts. Also some of the environmental impacts, associated with construction, have just been relocated outside the AONB to equally undisturbed rural areas and would have significant impact there.

7.1.2 The proposed underground firefighting point is not conforming to the HS2 project requirements. The project requires that a FFP must be an open gap structure as this provides a safer form of egress and passenger holding during an emergency event. It also provides and improved solution for ventilation, both for railway operations and during a fire event.

7.1.3 The PBA proposed construction works would be mainly focused on the West Hyde Portal construction site, the Fire Fighting Point at Little Missenden, the north portal construction site and other associated tunnel construction activities, all of which would require extensive work areas over extended periods and which would require land for earthwork handling. There would also be construction sites required for the additional vent shafts.

7.1.4 The PBA proposal for a tunnel focuses on the engineering requirements and presents them in detail. However, the Engineering review of the PBA proposal concludes that it does not adequately investigate a number of issues, including:

- Impacts required to the infrastructure to the north of the proposed Northern Portal as a result of the relocation of the maintenance sidings;
- Impacts to rail operations, including tunnel ventilation, traction power, maintenance, travel times and passenger comfort;
- Impacts from the movement and disposal of approximately 2 million tonnes of excavated material from the north portal;
- Environmental impacts, particularly at water abstraction sites;
- Complete costs of underground civil works;
- Impacts on rail fit out construction costs and programme;
- Programme impact to overall HS2 system construction;
- The complete surface impacts of the proposed Chilterns Long Tunnel.

7.1.5 The technical, logistic and operational issues regarding the Fire Fighting Point at Little Missenden or a conforming open box FFP in another location have not been explored in enough detail to determine engineering feasibility. These issues include but are not limited to: access from to the highway network, long term

logistics associated with maintenance of the system, impact to train operations, adequate space for construction works, long term and short term impact to local area.

7.1.6 Potential disturbance to Thames Water abstraction sites adjacent to the CLT near Wendover and the Little Missenden vent shaft have not been fully explored to the point where the impact from the tunnel construction is reasonably understood.

7.1.7 In general, a more detailed analysis of the Chilterns Long Tunnel proposal would be required to evaluate all potential impacts at the new vent shaft locations and the North Portal and to capture all potential operational, maintenance, construction costs, risks and programme impacts to the overall HS2 system, from beginning of construction to rail fit out through the life of the system.

7.1.8 The estimated cost of the PBA proposal is only provided in very general comparative terms and is not directly related to the individual components of their proposal. HS2 has undertaken a more detailed cost comparison of the PBA proposal against the Proposed Scheme. This indicates a potential cost difference of approximately £485 million.

7.1.9 Based on the present assessment of the PBA proposal, it is clear that there could be additional cost and risk to the construction programme. There could be further costs relating to additional measures required after completion of construction and during operations, some of which would be difficult to implement effectively. Including:

- Increased ventilation to maintain tunnel temperatures and fire safety;
- Installation of additional ventilation equipment;
- Increased traction power requirements from air resistance;
- Increased distances to place traction power cables;
- Rail fit out.

7.1.10 These would all further escalate the already substantial cost difference of the Chiltern Long Tunnel proposal over the HS2 Proposed Scheme.

Appendix A

A.1 Cost Breakdown

Chiltern Long Tunnel option - cost comparison vs HS2 Proposed Scheme

		CHILTERN LONG TUNNEL (PBA OPTION)	COMMENTARY
		£	
1.00	LAND AND PROPERTY	-47.10	Excludes any allowance for re-sale of returned or unused land/property
2.00	TUNNELS	614.46	
	Bored Tunnels	540.70	
	Fire Fighting Cavern	105.50	Underground fire fighting point as defined in CLT report
	Green Tunnels	-114.40	Saving on existing South Heath & Wendover green tunnels
	Portals	-0.36	
	Portals at "Gap"		
	Shafts	73.62	Increased depth of shafts and additional shafts for longer tunnel
	Additional disposal costs	9.40	Off-site disposal of surplus tunnel spoil
3.00	CIVIL ENGINEERING	-185.09	
	CUTTINGS	-38.14	
	Cuttings	-38.14	
	Cuttings at "Gap"		
	EMBANKMENTS	-21.43	
	EARTHWORKS	-9.35	
	Landfill & Contaminated Remediation Measures		
	Landscaping	-9.35	
	ENVIRONMENTAL MITIGATION WORKS	-9.57	
	Planting	-7.15	
	School protection works		
	Enhanced Planting		
	Noise Barriers	-2.42	
	RETAINING WALLS	-1.46	
	BRIDGES	-16.26	
	Overbridge	-13.67	
	Underbridge	-2.59	
	VIADUCTS	-41.32	
	HIGHWAYS	-17.39	
	OTHER	-30.18	
	Culverts	-0.65	
	Utilities Diversions	-27.22	
	Utilities Connections	-2.31	
	EXTENDED PRELIMINARIES	0.00	No extension of construction programme assumed.
5.00	DEPOT AND SIDINGS	0.00	
	Sidings		
	Other Facilities		
	IMD Depot		
	Temporary Railhead		No costs included for potential temporary railhead at northern portal
6.00	RAILWAY SYSTEMS	64.50	Includes £17.5m for tunnel cooling, not required in Proposed Scheme.
8.00	INDIRECT COSTS	89.74	
		536.50	
	Less ECP/VE	-51.50	
	Net total	485.0	

NOTES

1 Costs are point estimates, based at second quarter 2011 levels and therefore exclude contingency and escalation
2 Land and property costs are figures provided by CBRE
3 Construction costs are based on PSC figures reviewed and adjusted by the HS2 costs team
4 Railway systems costs are figures provided by Parsons Brinkerhoff
5 Indirect costs figures have been provided by the HS2 costs team
6 Savings from the Efficiency Challenge Programme and Value Engineering have been provided by the HS2 costs team