High Speed Rail in the Chilterns
Part 3: CRAG Proposal

June 2016

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 originally prepared by HS2 Ltd in May 2015 for internal use, and was subsequently published to allow Petitioners to better understand the Promoter's assessment of various tunnel options.

This document has been updated and republished in June 2016 to reflect changes to the Promoter's assessment of the original CRAG tunnel option and to enable comparison against the Promoters current Proposed Scheme.

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 3: CRAG Proposal

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List of acronyms

CLT	Chilterns long tunnel
CRAG	Chiltern Ridges Action Group
TBM	Tunnel Boring Machine
TSI	Technical Specification of Interoperability
PBA	Peter Brett Associates

References

Title	Reference
HS2 Project dictionary	HS2-HS2-PM-GDE-000-000002
Style guide	HS2-HS2-CO-GDE-000-000001
High Speed Rail in the Chilterns Part 1: General Long Tunnel Requirements	C222-ATK-TN-REP-020-000013

1 Executive summary

1.1.1 A number of options have been proposed by Petitioners to achieve a route that is substantially in bored tunnel for the full extent of the Chilterns AONB. In all cases, this tunnel option would be approx. 23.9 km long,would generally follow the Proposed Scheme horizontal alignment but would alter the Proposed Scheme vertical alignment to suit tunnelling requirements. This report describes the assessment of the CRAG T3i proposal, a long tunnel option proposed by the Chiltern Ridges Action Group (CRAG) with support from other Petitioners and which has been assessed by HS2 Ltd for compliance with high speed rail standards.

1.1.2 Other long tunnel options have been assessed in previous reports and are described briefly in Appendix D. Any comparison to the Proposed Scheme includes the provisions of AP4 within the Hybrid Bill.

1.1.3 The CRAG tunnel option was developed initially as the T2 option, and included an open to air intervention gap at Durham Farm to provide two separate tunnel lengths, each less than 20km in length, to meet requirements of the Technical Specification of Interoperability (TSI). This option was assessed by HS2 Ltd. and is referred to as the T2i option.

1.1.4 A subsequent option, the CRAG T3i option, was also assessed by HS2 Ltd. This provided a longer bored tunnel past Wendover on a lower vertical alignment providing a less complicated construction detail at this location.

1.1.5 The CRAG T3i option would terminate inside the AONB northern boundary to avoid impact to the adjacent Stoke Mandeville maintenance loop.

1.1.6 An intervention gap for this option would also be located in the vicinity of Durham Farm. This intervention gap has been assumed to consist of a combined open cut/retained structure and would need to be approximately 900m long.

1.1.7 The additional length of tunnel under this option would increase the heat build-up within the tunnels, requiring additional cooling and incurring added capital, energy and maintenance costs. The aerodynamic friction would also increase, resulting in additional traction power requirements.

1.1.8 The CRAG T3i option would have a similar programme to the Proposed Scheme as programme mitigation measures have been taken into account for both civil engineering and rail systems. TBMs would need to be launched from both the north and south portals. It would also be necessary that rail system installation be carried out from both ends of the tunnel as soon as possible after civil engineering construction activities are completed. The option would incur additional capital costs to construct the longer tunnels.

1.1.9 The CRAG T3i option is technically feasible and would provide some additional environmental benefits compared to the Proposed Scheme; however it would also create new/different impacts particularly associated with construction works and with the permanent impact of the intervention gap. The option would also incur greater cost and project risk due to an extended tunnel, and additionally it would increase operational maintenance requirements.

2 Abbreviations and descriptions

2.1.1 The abbreviations, descriptions and project terminology used within this document can be found in the project dictionary.

3 Introduction

3.1.1 The section of the Proposed Scheme immediately north of London passes through the area of the Chiltern Hills that is designated an Area of Outstanding Natural Beauty (AONB). The Proposed Scheme railway alignment within the AONB consists of twin-bored tunnels, a cut and cover tunnel, viaducts, cuttings and short lengths of embankments. Approximately 65% of the route within the AONB is in tunnel with less than 10% on embankment or viaduct. The presence of the above ground elements of infrastructure has led to submission of petitions concerned with the impact of the line on the environment. The Chiltern Ridges Action Group (CRAG) commissioned Peter Brett Associates (PBA) to develop tunnel options that extend through the full extent of the Chilterns AONB.

3.1.2 The CRAG T3i option seeks to achieve a route that is substantially in bored tunnel for the full extent of the Chilterns AONB. The CRAG T3i option would be approx. 23.9 km long and would follow the Proposed Scheme horizontal alignment and proposes an alteration to the Proposed Scheme vertical alignment to suit tunnelling requirements.

3.1.3 This report describes the particular requirements of the CRAG T3i Proposal with other previously assessed proposals summarised in Appendix D.

4 Review of CRAG T3i Proposal

4.1 General

4.1.1 CRAG's original proposals for a long tunnel through the AONB comprised two alternative schemes known as T1 and T2. These were published in a report by Peter Brett Associates (PBA) on 19th October 2012 and subsequently discussed with HS2 Ltd. Both tunnel proposals would have extended the Chiltern tunnel in the Proposed Scheme from Mantles Wood past Wendover, close to the northern boundary of the AONB. Both proposals included the provision of a gap structure to separate the tunnel length into two distinct tunnel lengths, each under 20km in length and compliant with fire safety in tunnels as set out in the European Technical Specification on Interoperability (TSI) as updated in 2014.

4.1.2 These tunnel options were discussed with HS2 Ltd with the CRAG T2 Option identified as the more preferable of these two options. CRAG subsequently produced a summary report for this proposed tunnel extension 'Proposal for a bored tunnel through the Chilterns AONB (T2 Option)', Draft 4 dated January 2015.

4.1.3 The CRAG T2i option would have extended the currently proposed Chiltern tunnel northwards to Wendover, including an intervention gap within the dry valley by Durham Farm. North of Ellesborough Road at Wendover the tunnel alignment became too shallow for a bored tunnel to be continued and the option includes a 1.35km long green tunnel to extend the tunnelled length to chainage 55+650, close to the AONB boundary.

4.1.4 The CRAG T3i option is a development of the previous CRAG submitted T2i option. This would have included a green tunnel past Wendover requiring some complicated engineering to effect the transition from a bored tunnel to a green tunnel cross-section. As CRAG preferred a longer fully bored tunnel to replace the green tunnel, a review of a longer bored tunnel alignment indicated that some alteration of the vertical alignment could be accommodated to facilitate an extension of the bored tunnel, with a tunnel portal at chainage 55+250. This would not extend the tunnelled length as far as the T2i option but would minimise impacts on the maintenance loop immediately up-chainage of the tunnel, which is considered by HS2 Ltd to be a constraining factor on any longer tunnel proposal. This longer bored tunnel option is referred to as the T3i option, which also includes the same need for an intervention gap at Durham Farm as the earlier T2i option.

4.1.5 In all options including an intervention gap, this is sized according to the TSI requirements. This specifies that the minimum gap length to be provided between successive sections of tunnel is set at the train length (approx. 400m for HS2) plus 100m. To this, two portal hood lengths, currently estimated at 200m each, must be added, giving a minimum 900m length of gap between the tunnel drives.

4.1.6 The rail alignment of the T3i option over the 500m gap length has been adjusted to achieve a maximum gradient of 0.2%. This is required for a train to be held stationary within the gap in the event of an emergency but also provides the minimum gradient for track drainage.

4.1.7 Other than the specific tunnel arrangements past Wendover the two options T2i and T3i are broadly similar. The T3i construction cost was assessed as less than the T2 option due to the simpler construction at Wendover and slightly shorter tunnel length proposed. The remainder of this report thus focusses on the T3i option for specific issues related to the CRAG tunnel.

Table 4.1 CRAG Option T3i Route Characteristics

Section	Chainage (m)		Length (m)	Type
	From	To		
South Portal to A413	31+363	43+000	11,637	Twin-bored tunnel
North side of A413	43+000	43+000	n/a	Vent shaft (TBM extraction)
A413 to Durham Farm	43+000	50+300	7,300	Twin-bored tunnel
Durham Farm	50+300	51+200	900	Intervention Gap
Durham Farm to B4009	51+200	55+250	4,050	Twin-bored tunnel
Option Length	**31,363**	**55,250**	**23,887**	

4.2 Assumptions

4.2.1 The following assumptions were included in the appraisal for the T3i option under consideration which are consistent with the Proposed Scheme:

- The maximum line speed would remain at 320kph through the bored tunnel
- Sufficient space would be available at the defined locations for the extraction of the TBMs (where required). Sufficient space would be available at the north portal and firefighting point (as required) for the construction of the 550m^2 hard standing rescue area and the associated portal buildings;
- The average drive rate for bored tunnel construction is taken at 80m/week;
- Length of porous portal hoods assumed at 200m; and
- It has been assumed that the ground cover to the bored tunnel structure would be a minimum of one diameter as there would otherwise be risks that would need to be considered in respect to design. For a list of general risks

associated with long tunnel options please refer to the Part 1 report C222-ATK-TN-REP-020-000013.

4.3 Ventilation-Intervention Shafts

4.3.1 The ventilation – Intervention shafts required for the additional tunnelled length are spaced with a maximum distance between the shafts slightly in excess of the general requirement of 3km (maximum 3.3km). It is assumed that this is acceptable for this study, however this would need to be confirmed at detailed design stage.

4.3.2 Shaft locations and depths are shown in Table 4.2:

Table 4.2 Shaft Locations and Depths.

Shafts	Chainage	Depth below existing GL (m)	
		Proposed Scheme	Option T3i
South Portal Chainage		**31+363m**	**31+363m**
S1	34+100m	65	65
S2	37+400m	35	35
S3	40+100m	47	47
S4	43+000m	36	35
S5	46+150m	42	42
S6	48+300m	-	28
S8	53+700m	-	27
North Portal Chainage		47+205m	55+250m
Note: Exact shaft chainage would need to be optimised during more detailed design in conjunction with the ventilation designer.			

4.4 Intervention Gap

4.4.1 The proposed layout for a gap structure at Durham Farm could be in the form of a cutting of approximate total depth ranging from 25m at the northern end of the intervention gap to 30m at the southern end. A single portal building and rescue area is similarly proposed but this could be located centrally on the west side of the route, as this is dictated by the trough from within the topography. An access route to facilitate parking and passage of emergency vehicles would be required alongside the western track and a permanent link road provided to the A413.

4.4.2 For current assessment purposes, it has been assumed that the headwall where the tunnel eye is located, would be constructed as a 75° and 20m high retained slope. To prevent eventual rock falls, soil nails, steel reinforced mesh and a sprayed concrete layer have been assumed.

4.4.3 The slopes of the cutting above the portal hoods are subdivided into several smaller retained heights supported by reinforced concrete anchored walls. At the present design stage the maximum retained height per retaining wall is adopted at approximately 10m. Where several retaining walls at different levels are needed to support the full height of the cutting a horizontal spacing of approximately 12m is adopted between each adjacent wall. The adopted geometry results in an overall slope of the cutting of approximately 35°, which is deemed conservative at the present design stage.

4.4.4 The existing topography has a natural trough towards the centre of the Intervention Gap Structure. Therefore the multiple retained walls are not required at the location of the portal buildings and access roads. Depending on the natural topography, the 10m retained sections will taper down and be reduced in number to the point where there will be only one retained wall or the slope will be cut back with no retained sections where the Portal buildings and the access roads are located.

4.4.5 Appendix B provides a developed indication of what the intervention gap could look like during the construction and operation phases, assuming construction as described above.

4.5 Construction & Spoil Removal

4.5.1 In order to complete the works within the existing programme it is proposed that the CRAG T3i tunnel would be built by launching four TBMs, two from the north portal and two from the south portal.

4.5.2 TBMs would be launched from compounds located at the north and south portals. It has been estimated that the plan size of the sites would be 100,000 to 150,000m^2, comprising a segment storage yard, temporary tunnel excavation storage, site offices, equipment storage and maintenance yards, parking facilities and access roads throughout the site. This would be extended by a further 30,000m^2 should a segment casting facility be required. In addition, further large drying/storage areas would be required for material storage and handling, which may double the size required for the segment casting facility depending on the amount of segments the contractor may cast before commencing tunnelling.

4.5.3 The CRAG T3i option north portal construction compound would likely be in place for 6-7 years, covering compound establishment, receipt/handling of TBMs, tunnelling activities and subsequent rail systems fit out. Operations would be 24hrs/day, 7 days/week for tunnelling drives. Given the size of the compound and adjacent areas to store and manage tunnel spoil a location to the east of the Proposed Scheme, bounded by Stoke Mandeville and the Chiltern Main Line would likely be the most appropriate location for the compound.

4.5.4 Assuming an average TBM advance rate of 80m per week, there would be around 12,000m^3 of tunnel arising's that would need to be removed from the north portal worksite each week. This would generate a total of 1.7m m^3 requiring approximately 400,000 two way lorry trips for either partial re-use on site as mitigation earthworks or disposal off-site.

4.5.5 It has been assumed that all four TBMs would bore to shaft S4 at Little Missenden. This shaft would be enlarged compared to the Proposed Scheme in order to facilitate the TBM removal. As this ventilation-intervention shaft is immediately adjacent to the A413 and close to the proposed tunnel mid-point, retrieval of the TBMs could be facilitated at this location. Working sites located at the north and south tunnel portals would service both the parallel drives with segment supply, spoil removal and spoil treatment.

4.5.6 The TBMs launched from the southern portal would have a shorter run than that assumed for the Proposed Scheme, as they are extracted from Shaft S4 at Little Missenden. This would result in a shortage of material at the south portal which is needed to provide environmental mitigation in the Proposed Scheme. As a consequence additional material would have to be imported. Table 4.3 summarises additional volumes and associated lorry movements.

Table 4.3 Comparison of excavation/tunnel arisings between Proposed Scheme & CRAG T3i option.

Option	Tunnel Length (km)	South Portal	North Portal	Intervention Gap
		Spoil Generated		
Proposed Scheme	15.8	2.4Mm^3 ①	2.2Mm^3 ② [from South Heath cutting]	N/A
CRAG T3i Option	23.9	1.7Mm^3 ③	2.2Mm^3 ④	1.3Mm^{3}⑤

① 2.0Mm^3 used for environmental mitigation.
0.4Mm^3 for off-site disposal via M25.
② Excavation re-used along trace in Small Dean embankment (1.4Mm^3) and for Aylesbury mitigation earthworks (0.8Mm^3).
③ The CRAG T3i option would require an additional 0.3Mm^3 of material to be imported to form the environmental mitigation currently proposed at this location.
④ Assumed total volume is for off-site disposal (1.7Mm^3 tunnel arisings, 0.5Mm^3 north portal construction).
⑤ 0.8Mm3 to Aylesbury mitigation earthworks.
Possible use of 0.3Mm3 to south portal mitigation earthworks.
0.2Mm^3 re-used for local mitigation earthworks.

4.5.7 The spoil generated from the construction of a 900m long intervention gap at Durham Farm would be approximately 1.3m^3. It is assumed that surplus spoil arising from the construction of the intervention gap would be removed from site via the adjacent A413 and then other public roads. Approximately 200,000m^3 would be re-used locally for mitigation earthworks. Approximately 800,000m^3 would need to be taken northwards for use in the mitigation earthworks adjacent to Aylesbury, this would equate to approximately 190,000 two-way lorry movements. It is assumed the remaining 300,000m^3 could potentially be used to make good the shortfall of mitigation material at the southern portal or, alternatively, taken southwards to a suitable disposal site; this would equate to approximately 70,000 two-way lorry movements.

4.5.8 Approximately 500,000m3 of excavated material would be generated from the construction of the north portal. This material would need to be stored on site temporarily for treatment and removed off site via the public road network, equating to approximately 120,000 two-way lorry movements.

4.5.9 A suggested location for the proposed north portal site compound would be adjacent to the Marylebone to Aylesbury railway line. As an alternative solution, consideration could be given to constructing a temporary railway siding adjacent to the railway and site compound, removing the excavated material via the Chiltern Line. Temporary sidings for this purpose are typically around 400m in length, and would need to be located on the land adjacent to the site compound. However, this option would be dependent on the ability to provide sufficient train paths for material transport, along this section of the Chiltern Line, with typically 20 train paths/week required based on average tunnelling rates. It should also be noted that any temporary railway sidings need to be constructed on a level site, so additional earthworks would need to be undertaken to form the temporary sidings. The material generated from this construction could be stored on site for subsequent reinstatement.

4.6 Rail Systems

Tunnel Ventilation and Smoke Control

4.6.1 It is considered likely that smoke control could be achieved with similar capacity shafts as the others on the proposed 15.8km long Chiltern tunnel, but more shafts may be required to simultaneously operate, and to generate the required smoke control. This may increase maintenance demands to provide a sufficiently robust system, and also require a larger auxiliary power supply system.

4.6.2 Tunnel cooling would be required with temperatures near the exit portal otherwise approaching 42°C for the Durham Farm to West Hyde section. These might be provided in each of the last three shafts in the travelling direction, which would effectively result in every shaft being provided with a 1.5 MW cooling capacity installation serving 300mm diameter pipes carrying coolant fluid within the tunnels. A 10m x 8m building above ground space would potentially be required at each shaft. This would increase the capital, operating and maintenance costs of the proposal.

Operations

4.6.3 Assessment of journey time identifies that there would be a slight increase in journey time in the range of 10 to 15 seconds.

Power Requirement

4.6.4 The additional tunnel ventilation and more shafts potentially operating at the same time, as well as tunnel cooling, are likely to increase power requirement.

4.6.5 During construction an additional 11kV power supply would need to be routed from the national grid to run the TBM's from the north portal. It is likely that the route of the underground supply would be approximately 14km long in order to connect to an appropriately sized supply, and would follow the A4128 from Prestwood to Great Missenden then along the A413 to the north portal (refer to Figure 1 below). The anticipated lead-in time is three to five years. The information provided is indicative only at this stage.

4.6.6 There is likely to be engineering difficulty at railway crossings and major roads which have not been fully factored in to the costs of this power supply.

Figure 1 – Indicative route for 11kV power supply

Maintenance

4.6.7 From a maintenance perspective, the main changes of this proposal would be an increased length of slab-track (assuming that ballast is used outside tunnels), additional ventilation shafts, an intervention gap structure and a reduction in line side management (vegetation etc.).

4.6.8 The other item of concern would be the proximity of the new northern tunnel portal to the maintenance loop at chainage 56+000. The maintenance loop and associated crossover requires a minimum track spacing of 5m and a straight length of at least 850m between switches, constraining the location of the northern portal. The desired portal location at 56+200 at the border of the AONB could not be provided due to the requirement for the maintenance loop and associated crossover at 56+400 overlapping with the portal structure.

4.6.9 The bored tunnel section would emerge into open air at chainage 55+250, requiring an open cutting between chainage 55+250 and 56+200. To allow the maintenance loop to be located at its current position for CRAG T3i, the southern crossover would need to be positioned immediately south of the maintenance siding. In order to achieve the required track separation at the portal, the separation would need to be increased up to 29m on the curve to the south of the portal.

4.6.10 Consideration would need to be given to providing a scissors crossover at the intervention gap, to provide flexibility during perturbation and maintenance.

4.7 Tunnel Fit Out

4.7.1 The additional equipment required to support the longer length of tunnel may result in lower installation rates, due to additional work in the tunnels. This can be mitigated by providing additional resource, requiring greater access and logistics considerations at the access points.

4.7.2 In order to achieve the delivery programme for the CRAG T3i option, it is proposed that the installation of the rail systems would need to commence from both ends of the tunnels at the portals.

4.7.3 For the Proposed Scheme, tunnel fit out is carried out from both north and south portals. For the open sections north of the Chiltern tunnel north portal, fit out is carried out southwards from the rail system compound at Calvert. The CRAG T3i option would reduce the amount of systems installation that is possible from Calvert. There would be a reduction in the amount of materials delivered by train and an increase in construction traffic via road at the tunnelled section access points, unless new railway sidings were introduced at the Stoke Mandeville compound to assist in reducing road traffic.

4.8 Programme

4.8.1 The civil engineering programme for the CRAG T3i option would be expected to be broadly the same as the Proposed Scheme programme as the TBMs are launched from both directions and maximum tunnel drives are less than the 15.8km drive required by the Proposed Scheme.

4.8.2 To avoid programme delay, construction of the rail systems would need to commence from both the southern and northern portals; this would ensure that the construction programme is likely to be of similar duration to the Proposed Scheme.

4.8.3 The ventilation shafts are not on the critical path of the project, so the number required should not impact the overall project programme. The intervention gap would need to be constructed ahead of the bored tunnelling reaching this point but it is envisaged that this programme could be met and thus will not impact the overall project programme.

4.9 Cost

4.9.1 Comparative construction cost estimates include for:

- Civils works: earthworks, structures (including viaducts and bridges), road and PRoW diversions, utility diversions, landscaping;
- Tunnels: bored tunnel, green tunnels, vent shafts, tunnel portals, facilities and portal hoods; and
- Rail systems: track (including catenaries), power and ATS stations, ventilation equipment, smoke control equipment.

4.9.2 Although not estimated, the increase in plant/equipment as a consequence of the tunnel extensions is likely to have a significant impact on the HS2 operating cost over and above the Proposed Scheme.

4.9.3 New land areas are needed for the larger northern tunnel construction site and for the additional ventilation shafts and intervention gap.

4.9.4 Relative costs comparing the Proposed Scheme and the CRAG T3i option are provided in Appendix C. It should be noted that these figures specifically exclude the following:

- Risk provision;
- Allowance for optimum bias;
- Contingency;
- Disruption costs; and
- Compensation payments

5 Conclusion

5.1.1 The CRAG T3i option is technically feasible and would provide some additional environmental benefits compared to the Proposed Scheme; however it would also create new/different impacts particularly associated with construction works and with the permanent impact of the intervention gap. The option would also incur greater cost and project risk due to an extended tunnel, and additionally it would increase operational maintenance requirements.

5.1.2 The intervention gap would create a more onerous aerodynamic consideration than the Proposed Scheme.

5.1.3 The CRAG T3i civil engineering programme would be expected to be broadly the same as the Proposed Scheme. With rail system installation from both ends of the tunnels, and with the systems installation from the northern portal commencing ahead of the rail based fit-out from Calvert (as utilised for the Proposed Scheme), the rail systems programme would also be likely to be of similar duration to the Proposed Scheme.

5.1.4 Based on the present assessment of this option it is clear there could be extensive additional requirements for ventilation, cooling and traction power. These factors escalate the capital and operational cost against the Proposed Scheme.

5.1.5 The construction cost of the CRAG T3i proposal would be approximately £340M more than the Proposed Scheme.

Appendix A CRAG T3i Plan & Profile Drawings

C222-ATK-TN-DGA-020-000270-RST00000571

C222-ATK-TN-DGA-020-000271-RST00000571

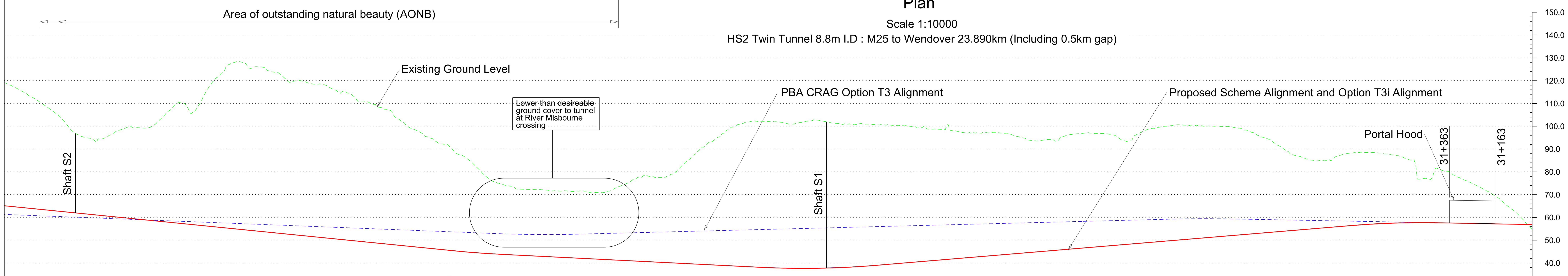
C222-ATK-TN-DGA-020-000272-RST00000571

C222-ATK-TN-DGA-020-000273-RST00000571

Plan

Scale 1:10000

HS2 Twin Tunnel 8.8m I.D : M25 to Wendover 23.890km (Including 0.5km gap)



Chainage	Existing Level	Proposed Level	Cut and Fill
37+700	126.9	68.0	-58.9
37+600	125.6	68.1	-57.5
37+500	119.3	68.0	-51.3
37+400	115.3	67.6	-47.7
37+300	123.5	66.9	-56.6
37+200	121.9	66.0	-55.9
37+100	118.6	65.0	-53.6
37+000	113.0	64.0	-49.0
36+900	106.6	63.0	-43.6
36+800	96.9	62.0	-34.9
36+700	94.4	61.0	-33.4
36+600	98.5	60.0	-38.5
36+500	99.2	59.0	-40.2
36+400	105.9	58.0	-47.9
36+300	106.1	57.0	-49.1
36+200	119.2	56.0	-63.2
36+100	128.0	55.0	-73.0
36+000	126.0	54.0	-72.0
35+900	122.6	53.0	-69.6
35+800	119.8	52.0	-67.8
35+700	117.9	51.0	-66.9
35+600	114.5	50.0	-64.5
35+500	109.9	49.0	-60.9
35+400	104.3	48.0	-56.3
35+300	98.0	47.0	-51.0
35+200	92.5	46.0	-46.5
35+100	87.1	45.0	-42.1
35+000	78.3	44.2	-34.1
34+900	73.8	43.7	-30.1
34+800	72.2	43.2	-29.0
34+700	71.6	42.7	-28.9
34+600	71.7	42.2	-29.5
34+500	70.9	41.7	-29.2
34+400	74.0	41.2	-32.8
34+300	78.4	40.7	-37.7
34+200	78.2	40.2	-38.0
34+100	85.6	39.7	-45.9
34+000	93.4	39.2	-54.2
33+900	100.2	38.7	-61.5
33+800	102.1	38.2	-63.9
33+700	101.8	37.8	-64.0
33+600	101.8	37.6	-64.2
33+500	101.9	37.8	-64.1
33+400	101.0	38.2	-62.8
33+300	100.8	38.8	-62.0
33+200	100.3	39.7	-60.6
33+100	99.7	40.5	-59.2
33+000	98.6	41.3	-57.3
32+900	97.2	42.2	-55.0
32+800	97.3	43.0	-54.3
32+700	96.6	43.8	-52.8
32+600	93.7	44.7	-49.0
32+500	93.7	45.5	-48.2
32+400	96.7	46.3	-50.4
32+300	96.8	47.2	-49.6
32+200	93.8	48.0	-45.8
32+100	98.2	48.9	-49.3
32+000	100.1	49.7	-50.4
31+900	100.4	50.5	-49.9
31+800	99.9	51.4	-48.5
31+700	99.3	52.2	-47.1
31+600	95.5	53.0	-42.5
31+500	91.0	53.9	-37.1
31+400	85.9	54.7	-31.2
31+300	85.0	55.5	-29.5
31+200	88.2	56.4	-31.8
31+100	88.4	57.1	-31.3
31+000	87.2	57.5	-29.7

Horizontal Alignment: R=5400.0 L=1264.2; L=375.0; Ch. 35737.073 TP. 45.354; Ch. 35537.091 TP. 43.854; L=2938.1; Ch. 34404.079 TP. 38.189; Ch. 33879.095 TP. 39.083; L=375.0; R=-5400.0 L=1188.9; L=375.0; L=375.0

Vertical Alignment: L=562.5 R=37500.0; L=2086.2 G=1.000%; L=200.0 R=-40000.0; L=1149.7 G=0.500%; L=500.6 R=-37500.0; L=2089.5 G=-0.835%; L=2089.5 G=-0.835%; L=38 R=375

Maximum Speed: 320km/h; 320 km/h

Vertical Alignment

Scale H 1:10000 V 1:1000

Work-in-progress

METRES @ 1:10000 — 0, 100, 200, 500, 1000

Rev	Description	Drawn	Checked	Con App	HS2 App
P03	Updated Proposed Scheme to reflect AP4 and revised CRAG T3i details	HM 14/06/16			

Legends/Notes:

1. Proposed Scheme Alignment as at February 2016.
2. Option T3i is an amended version of PBA CRAG Option T3 to meet current HS2 standards.
3. A 500m open to air firefighting point (gap) is provided (at Durham Farm) to provide appropriate safety and intervention access.

Registered in England
Registration No. 06791686
Registered office:
One Canada Square,
London, E14 5AB

Creator/Originator: Atkins

Zone: Country South
Project/Contract: Country South Design
Design Stage: DESIGN-FOR-PETITION
Discipline/Function: Tunnels
Drawing Title: Proposal by CRAG — Chiltern Tunnel Option T3i — Sheet 1 of 4
Drawn: IE | Checked: | Approved:
Date: 06/05/2016 | Scale: AS SHOWN | Size: A1
Drawing No.: C222-ATK-TN-DGA-020-000270-RST00000571 | Rev.: P03

Plan

Scale 1:10000

HS2 Twin Tunnel 8.8m I.D : M25 to Wendover 23.890km (Including 0.5km gap)

Horizontal Alignment: L=8845.9; L=375.0; R=5400.0 L=1264.2; R=5400.0 L=1264.2

Vertical Alignment: .0; L=2390.1 G=1.700%; L=2390.1 G=1.700%; L=449.9 R=-37500.0; L=1982.4 G=0.500%; L=375.0 R=-37500.0; L=1481.8 G=-0.500%; L=1481.8 G=-0.500%; L=562.5 R=37500.0

Maximum Speed: 320km/h

Chainage	Existing Level	Proposed Level	Cut and Fill
44+500	168.1	116.3	-51.8
44+400	163.3	114.6	-48.7
44+300	154.3	112.9	-41.4
44+200	139.7	111.2	-28.5
44+100	148.6	109.5	-39.1
44+000	162.1	107.8	-54.3
43+900	166.5	106.1	-60.4
43+800	166.2	104.4	-61.8
43+700	163.4	102.7	-60.7
43+600	158.6	101.0	-57.6
43+500	156.4	99.3	-57.1
43+400	153.8	97.6	-56.2
43+300	150.0	95.9	-54.1
43+200	145.7	94.2	-51.5
43+100	141.3	92.5	-48.8
43+000	130.3	90.8	-39.5
42+900	117.3	89.1	-28.2
42+800	123.3	87.4	-35.9
42+700	129.8	85.7	-44.1
42+600	129.5	84.0	-45.5
42+500	125.1	82.3	-42.8
42+400	118.4	80.6	-37.8
42+300	112.2	78.9	-33.3
42+200	112.7	77.2	-35.5
42+100	112.6	75.5	-37.1
42+000	106.4	73.9	-32.5
41+900	102.0	72.5	-29.5
41+800	99.6	71.4	-28.2
41+700	99.5	70.6	-28.9
41+600	99.7	70.0	-29.7
41+500	99.7	69.5	-30.2
41+400	100.6	69.0	-31.6
41+300	104.0	68.5	-35.5
41+200	107.8	68.0	-39.8
41+100	111.6	67.5	-44.1
41+000	114.1	67.0	-47.1
40+900	114.2	66.5	-47.7
40+800	107.2	66.0	-41.2
40+700	102.5	65.5	-37.0
40+600	108.4	65.0	-43.4
40+500	125.3	64.5	-60.8
40+400	138.4	64.0	-74.4
40+300	140.7	63.5	-77.2
40+200	141.6	63.0	-78.6
40+100	142.4	62.5	-79.9
40+000	142.3	62.0	-80.3
39+900	140.2	61.5	-78.7
39+800	136.0	61.0	-75.0
39+700	129.5	60.5	-69.0
39+600	118.7	60.0	-58.8
39+500	105.3	59.8	-45.5
39+400	100.8	59.8	-41.0
39+300	120.8	60.1	-60.7
39+200	134.9	60.6	-74.3
39+100	131.9	61.1	-70.8
39+000	130.4	61.6	-68.8
38+900	140.9	62.1	-78.8
38+800	149.8	62.6	-87.2
38+700	161.6	63.1	-98.5
38+600	163.7	63.6	-100.1
38+500	160.0	64.1	-95.9
38+400	153.4	64.6	-88.8
38+300	156.3	65.1	-91.2
38+200	153.4	65.6	-87.8
38+100	149.0	66.1	-82.9
38+000	140.1	66.6	-73.5
37+900	129.6	67.1	-62.5
37+800	125.9	67.6	-58.3
37+700	126.9	68.0	-58.9
37+600	125.6	68.1	-57.5
37+500	119.3	68.0	-51.3
37+400	115.3	67.6	-47.7
37+300	123.5	66.9	-56.6
37+200	121.9	66.0	-55.9
37+100	118.6	65.0	-53.6

Vertical Alignment

Scale H 1:10000 V 1:1000

Work-in-progress

METRES @ 1:10000 — 0, 100, 200, 500, 1000

Rev	Description	Drawn	Checked	Con App	HS2 App
P03	Updated Proposed Scheme to reflect AP4 and revised CRAG T3i details	HM 14/06/16			

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Scale with caution as distortion can occur.

Legends/Notes:

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3. A 500m open to air firefighting point (gap) is provided (at Durham Farm) to provide appropriate safety and intervention access.

hs2

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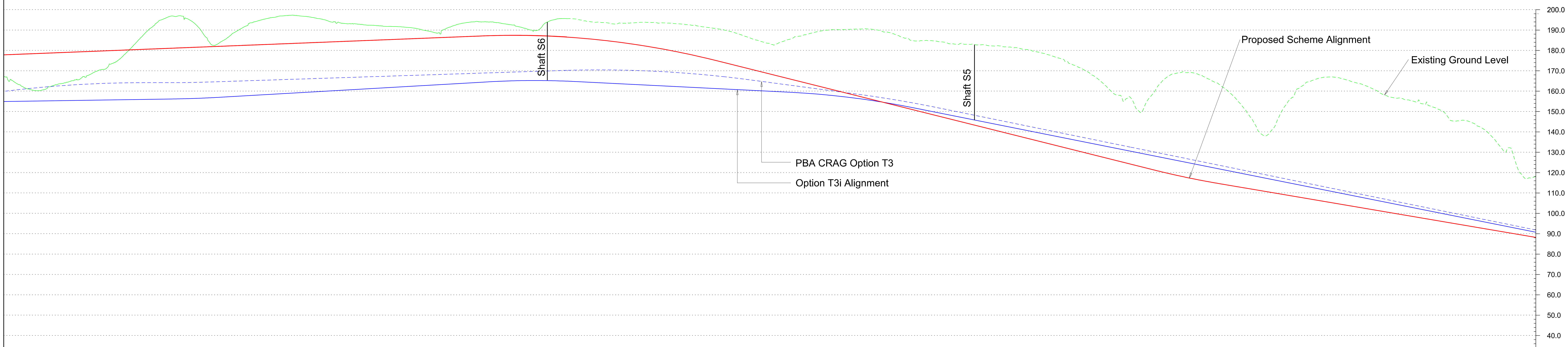
Creator/Originator: Atkins

Zone	Country South
Project/Contract	Country South Design
Design Stage	DESIGN-FOR-PETITION
Discipline/Function	Tunnels
Drawing Title	Proposal by CRAG Chiltern Tunnel Option T3i Sheet 2 of 4
Drawn	IE
Checked	
Approved	
Date	06/05/2016
Scale	AS SHOWN
Size	A1
Drawing No.	C222-ATK-TN-DGA-020-000271-RST00000571
Rev.	P03

Plan

Scale 1:10000

HS2 Twin Tunnel 8.8m I.D : M25 to Wendover 23.890km (Including 0.5km gap)



Chainage	Existing Level	Proposed Level	Cut and Fill
50+900	172.7	172.7	
50+800	178.2	173.8	-4.4
50+700	181.2	174.9	-6.3
50+600	180.9	176.0	-4.9
50+500	177.6	177.0	-0.6
50+400	169.9	177.6	+7.7
50+300	164.2	178.1	+13.9
50+200	160.5	178.5	+18.0
50+100	163.6	178.9	+15.3
50+000	166.1	179.2	+13.1
49+900	170.8	179.6	+8.8
49+800	176.4	180.0	+3.6
49+700	186.2	180.4	-5.8
49+600	195.4	180.8	-14.6
49+500	197.6	181.2	-16.4
49+400	190.7	181.6	-9.1
49+300	185.3	182.0	-3.3
49+200	191.2	182.4	-8.8
49+100	195.5	182.8	-12.7
49+000	197.3	183.2	-14.1
48+900	197.1	183.6	-13.5
48+800	195.5	184.0	-11.5
48+700	193.6	184.4	-9.2
48+600	193.0	184.8	-8.2
48+500	192.2	185.2	-7.0
48+400	191.8	185.6	-6.2
48+300	190.2	186.0	-4.2
48+200	190.6	186.4	-4.2
48+100	193.6	186.8	-6.8
48+000	194.1	187.1	-7.0
47+900	193.1	187.3	-5.8
47+800	190.8	187.2	-3.6
47+700	193.7	186.9	-6.8
47+600	195.6	186.3	-9.3
47+500	194.3	185.5	-8.8
47+400	193.5	184.4	-9.1
47+300	193.6	183.1	-10.5
47+200	193.8	181.5	-12.3
47+100	193.4	179.7	-13.7
47+000	192.6	177.6	-15.0
46+900	191.2	175.3	-15.9
46+800	189.3	172.8	-16.5
46+700	186.0	170.3	-15.7
46+600	183.2	167.8	-15.4
46+500	185.7	165.3	-20.4
46+400	188.5	162.8	-25.7
46+300	190.2	160.3	-29.9
46+200	190.4	157.8	-32.6
46+100	190.3	155.3	-35.0
46+000	188.2	152.8	-35.4
45+900	184.7	150.3	-34.4
45+800	184.6	147.8	-36.8
45+700	183.1	145.3	-37.8
45+600	182.8	142.8	-40.0
45+500	182.1	140.3	-41.8
45+400	181.4	137.8	-43.6
45+300	179.5	135.3	-44.2
45+200	176.7	132.8	-43.9
45+100	172.2	130.3	-41.9
45+000	166.4	127.8	-38.6
44+900	158.0	125.3	-32.7
44+800	150.8	122.8	-28.0
44+700	162.5	120.4	-42.1
44+600	169.0	118.2	-50.8
44+500	168.1	116.3	-51.8
44+400	163.3	114.6	-48.7
44+300	154.3	112.9	-41.4
44+200	139.7	111.2	-28.5
44+100	148.6	109.5	-39.1
44+000	162.1	107.8	-54.3
43+900	166.5	106.1	-60.4
43+800	166.2	104.4	-61.8
43+700	163.4	102.7	-60.7
43+600	158.6	101.0	-57.6
43+500	156.4	99.3	-57.1

Horizontal Alignment: L=1673.4; L=1738.5; L=320.0; R=8100.0 L=1546.4; L=320.0; L=8845.9

Vertical Alignment: L=282.0 R=40000.0; L=282.0 R=40000.0; L=2302.3 G=-0.395%; L=1157.7 R=40000.0; L=2095.7 G=2.500%; L=319.8 R=-40000.0; L=2390.1 G=1.700%

Maximum Speed: 400km/h; 360km/h; 320 km/h; 320km/h

Vertical Alignment

Scale H 1:10000 V 1:1000

Work-in-progress

METRES @ 1:10000 — 0 100 200 500 1000

Rev	Description	Drawn	Checked	Con App	HS2 App
P03	Updated Proposed Scheme to reflect AP4 and revised CRAG T3i details	HM 14/06/16			

Legends/Notes:

1. Proposed Scheme Alignment as at February 2016.
2. Option T3i is an amended version of PBA CRAG Option T3 to meet current HS2 standards.
3. A 500m open to air firefighting point (gap) is provided (at Durham Farm) to provide appropriate safety and intervention access.

Registered in England Registration No. 06791686 Registered office: One Canada Square, London, E14 5AB

Creator/Originator: Atkins

Zone: Country South

Design Stage: DESIGN-FOR-PETITION

Drawing Title: Proposal by CRAG — Chiltern Tunnel Option T3i — Sheet 3 of 4

Project/Contract: Country South Design

Discipline/Function: Tunnels

Drawn: IE | Checked: | Approved:

Date: 06/05/2016 | Scale: AS SHOWN | Size: A1

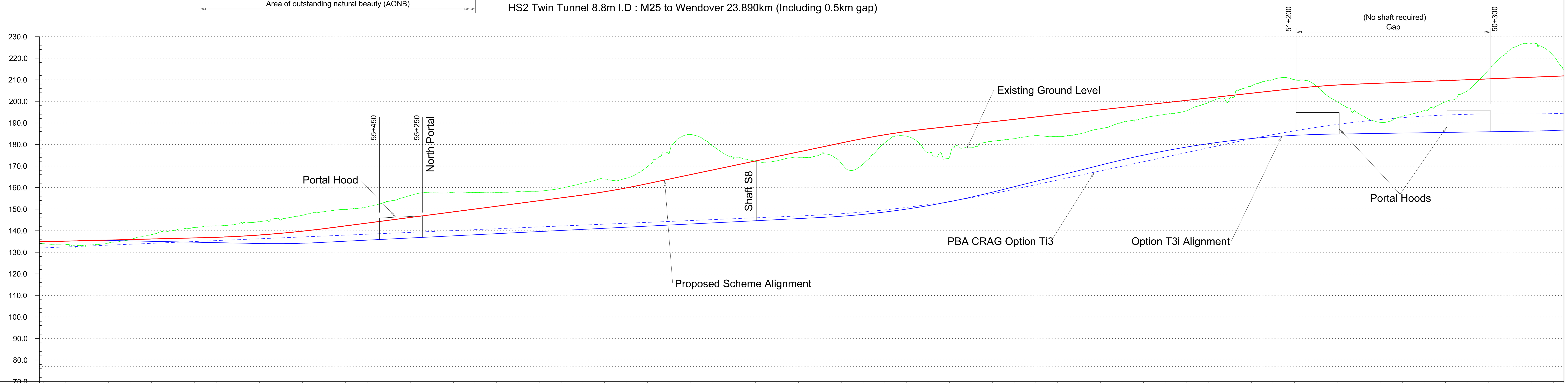
Drawing No.: C222-ATK-TN-DGA-020-000272-RST00000571 | Rev.: P03

Plan
Scale 1:10000

HS2 Twin Tunnel 8.8m I.D : M25 to Wendover 23.890km (Including 0.5km gap)

Tunnel portal within AONB due to horizontal alignment constraints

Area of outstanding natural beauty (AONB)



Horizontal Alignment: L=2780.0; L=300.0; R=-10000.0 L=75.0; L=208.5; R=-8250.0; L=3391.5; L=75.0 R=-10000.0; L=208.5; L=300.0; L=1673.4; L=

Vertical Alignment: L=1519.4 G=-0.250%; L=587.9 R=-56000.0; L=1138.1 G=-1.300%; L=319.9 R=-40000.0; L=926.1 G=-2.100%; L=399.8 R=40000.0; L=1672.3 G=-1.100%; L=282.0 R=40000.0; L=282.0 R=40000.0

Chainage	Existing Level	Proposed Level	Cut and Fill
57+000	98.4	103.4	+5.0
56+900	98.8	103.7	+4.9
56+800	99.9	103.9	+4.0
56+700	99.7	104.2	+4.5
56+600	103.5	104.4	+0.9
56+500	103.8	104.7	+0.9
56+400	104.0	104.9	+0.9
56+300	103.7	105.2	+1.5
56+200	103.4	105.4	+2.0
56+100	104.4	105.7	+1.3
56+000	106.0	105.9	-0.1
55+900	108.2	106.2	-2.0
55+800	110.1	106.4	-3.7
55+700	111.5	106.7	-4.8
55+600	112.3	107.0	-5.3
55+500	113.1	107.4	-5.7
55+400	114.2	108.1	-6.1
55+300	115.5	108.9	-6.6
55+200	117.2	109.9	-7.3
55+100	119.0	111.0	-8.0
55+000	119.9	112.3	-7.6
54+900	121.2	113.6	-7.6
54+800	123.8	114.9	-8.9
54+700	126.6	116.2	-10.4
54+600	127.6	117.5	-10.1
54+500	127.9	118.8	-9.1
54+400	127.8	120.1	-7.7
54+300	127.7	121.4	-6.3
54+200	128.3	122.7	-5.6
54+100	128.6	124.0	-4.6
54+000	129.9	125.3	-4.6
53+900	132.3	126.7	-5.6
53+800	134.1	128.2	-5.9
53+700	134.4	129.9	-4.5
53+600	140.8	132.0	-8.8
53+500	148.1	134.1	-14.0
53+400	154.8	136.2	-18.6
53+300	149.3	138.3	-11.0
53+200	144.1	140.4	-3.7
53+100	142.3	142.5	+0.2
53+000	142.7	144.6	+1.9
52+900	144.2	146.7	+2.5
52+800	145.5	148.8	+3.3
52+700	140.6	150.9	+10.3
52+600	141.5	152.9	+11.4
52+500	151.3	154.6	+3.3
52+400	153.8	156.1	+2.3
52+300	146.1	157.3	+11.2
52+200	145.2	158.4	+13.2
52+100	148.5	159.5	+11.0
52+000	151.6	160.6	+9.0
51+900	152.7	161.7	+9.0
51+800	154.2	162.8	+8.6
51+700	153.6	163.9	+10.3
51+600	155.1	165.0	+9.9
51+500	157.5	166.1	+8.6
51+400	160.6	167.2	+6.6
51+300	162.5	168.3	+5.8
51+200	164.4	169.4	+5.0
51+100	166.1	170.5	+4.4
51+000	170.1	171.6	+1.5
50+900	172.7	172.7	
50+800	178.2	173.8	-4.4
50+700	181.2	174.9	-6.3
50+600	180.9	176.0	-4.9
50+500	177.6	177.0	-0.6
50+400	169.9	177.6	+7.7
50+300	164.2	178.1	+13.9
50+200	160.5	178.5	+18.0
50+100	163.6	178.9	+15.3
50+000	166.1	179.2	+13.1

Maximum Speed: 400km/h; 400km/h; 320km/h; 360km/h; 400km/h; 40

Vertical Alignment
Scale H 1:10000 V 1:1000

Work-in-progress

METRES @ 1:10000 0 100 200 500 1000

Rev	Description	Drawn	Checked	Con App	HS2 App
P03	Updated Proposed Scheme to reflect AP4 and revised CRAG T3i details	HM 14/06/16			

Legends/Notes:

1. Proposed Scheme Alignment as at February 2016.
2. Option T3i is an amended version of PBA CRAG Option T3 to meet current HS2 standards.
3. A 500m open to air firefighting point (gap) is provided (at Durham Farm) to provide appropriate safety and intervention access.

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Creator/Originator: Atkins

Zone: Country South	Project/Contract: Country South Design	
Design Stage: DESIGN-FOR-PETITION	Discipline/Function: Tunnels	
Drawing Title: Proposal by CRAG Chiltern Tunnel Option T3i Sheet 4 of 4	Drawn: IE	Checked: / Approved:
	Date: 06/05/2016	Scale: AS SHOWN / Size: A1
	Drawing No.: C222-ATK-TN-DGA-020-000273-RST00000571	Rev.: P03

Appendix B CRAG T3i CT-05/06 Drawings

C222-ATK-EV-DPL-020-751006-RST00000571

C222-ATK-EV-DPL-020-751008-RST00000571

C222-ATK-EV-DPL-020-751010-RST00000571

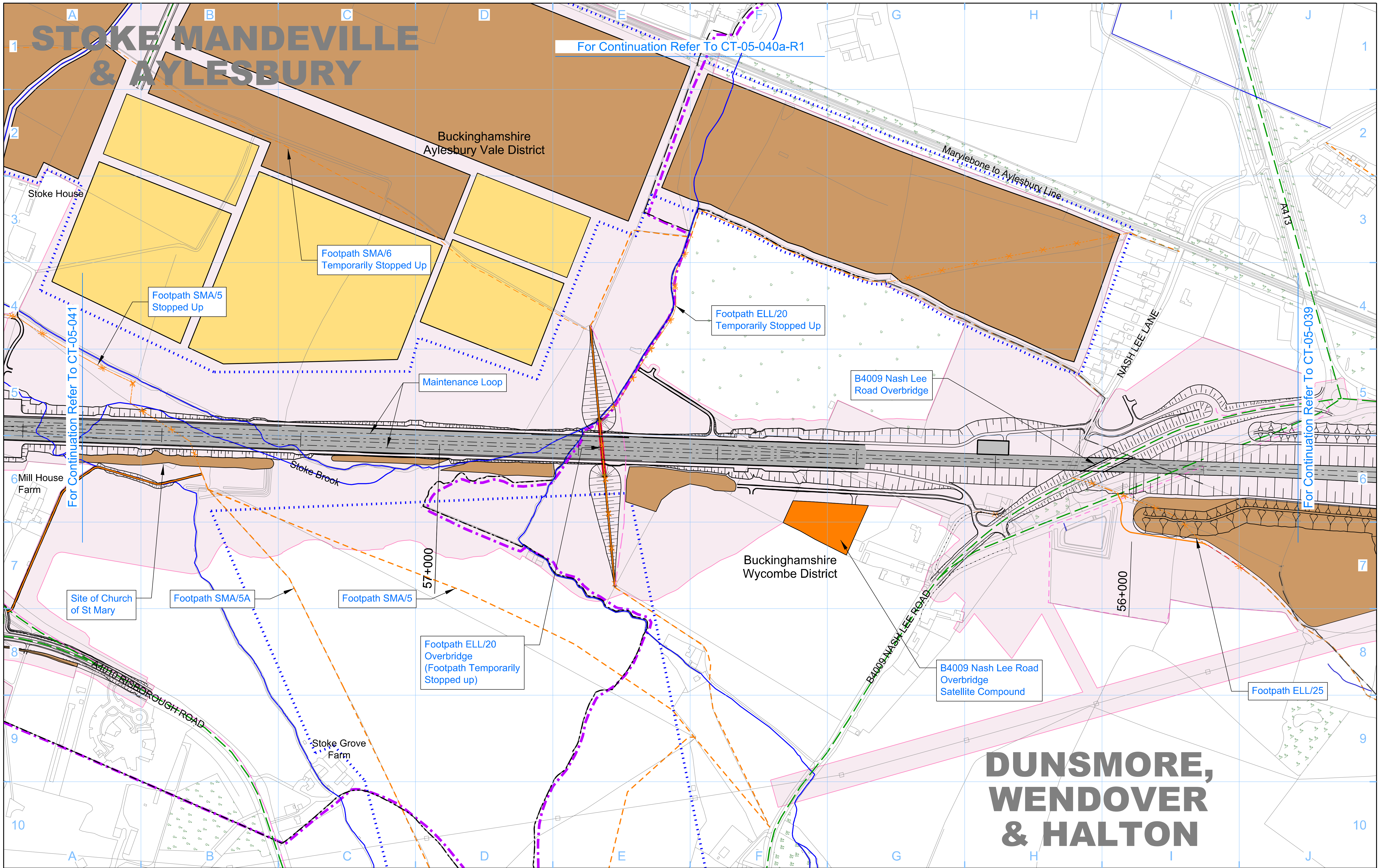
C222-ATK-EV-DPL-020-751901-RST00000571

C222-ATK-EV-DPL-020-761006-RST00000571

C222-ATK-EV-DPL-020-761008-RST00000571

C222-ATK-EV-DPL-020-761010-RST00000571

C222-ATK-EV-DPL-020-761901-RST00000571



Legend

- Depot, station, headhouse or portal building
- Tunnel portal
- Main construction compound
- Satellite construction compound
- Temporary material stockpile
- Rail alignment formation
- Landscape earthworks
- Engineering earthworks
- County boundary
- Borough / District boundary
- Land potentially required during construction
- Temporary replacement community facility
- Community forum boundary
- Existing watercourse
- Tunnels external extent
- Construction traffic route
- Existing public right of way (PRoW)
- New, diverted or realigned PRoW
- Stopped-up PRoW
- Temporary PRoW diversion / realignment
- Temporary highway diversion / realignment
- UT Main utility works
- 10+000 Chainage (e.g. 10+000)
- Rail alignment

Map Number

CT-05-040a

Map Name

Construction Features
CRAG - T3i North Portal
Construction Compound (Sheet 1)

Community Forum Area

CFA10
Dunsmore, Wendover and Halton

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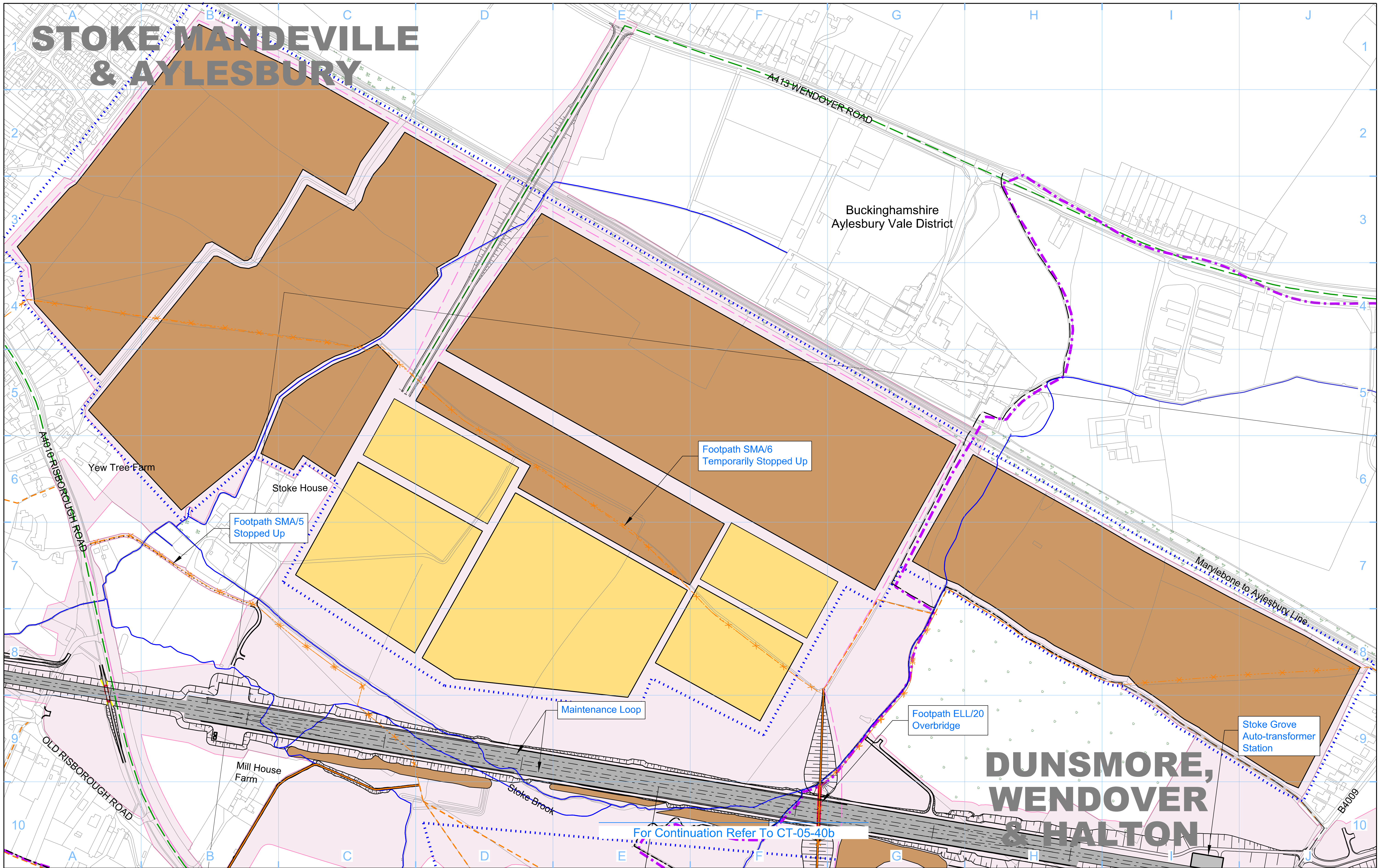
Scale at A3: 1:5,000

0 50 100 150 200 250
Metres

Doc Number: C222-ATK-EV-DPL-020-751006-RST00000571 P00.1 **Date:**



Legend

- Depot, station, headhouse or portal building
- Tunnel portal
- Main construction compound
- Satellite construction compound
- Temporary material stockpile
- Rail alignment formation
- Landscape earthworks
- Engineering earthworks
- County boundary
- Borough / District boundary
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- Community forum boundary
- Existing watercourse
- Tunnels external extent
- Construction traffic route
- Existing public right of way (PRoW)
- New, diverted or realigned PRoW
- Stopped-up PRoW
- Temporary PRoW diversion / realignment
- Temporary highway diversion / realignment
- UT Main utility works
- 10+000 Chainage (e.g. 10+000)
- Rail alignment

Map Number
CT-05-040a-R1

Map Name
Construction Features
CRAG - T3i North Portal
Construction Compound (Sheet 2)

Community Forum Area
CFA10
Dunsmore, Wendover and Halton

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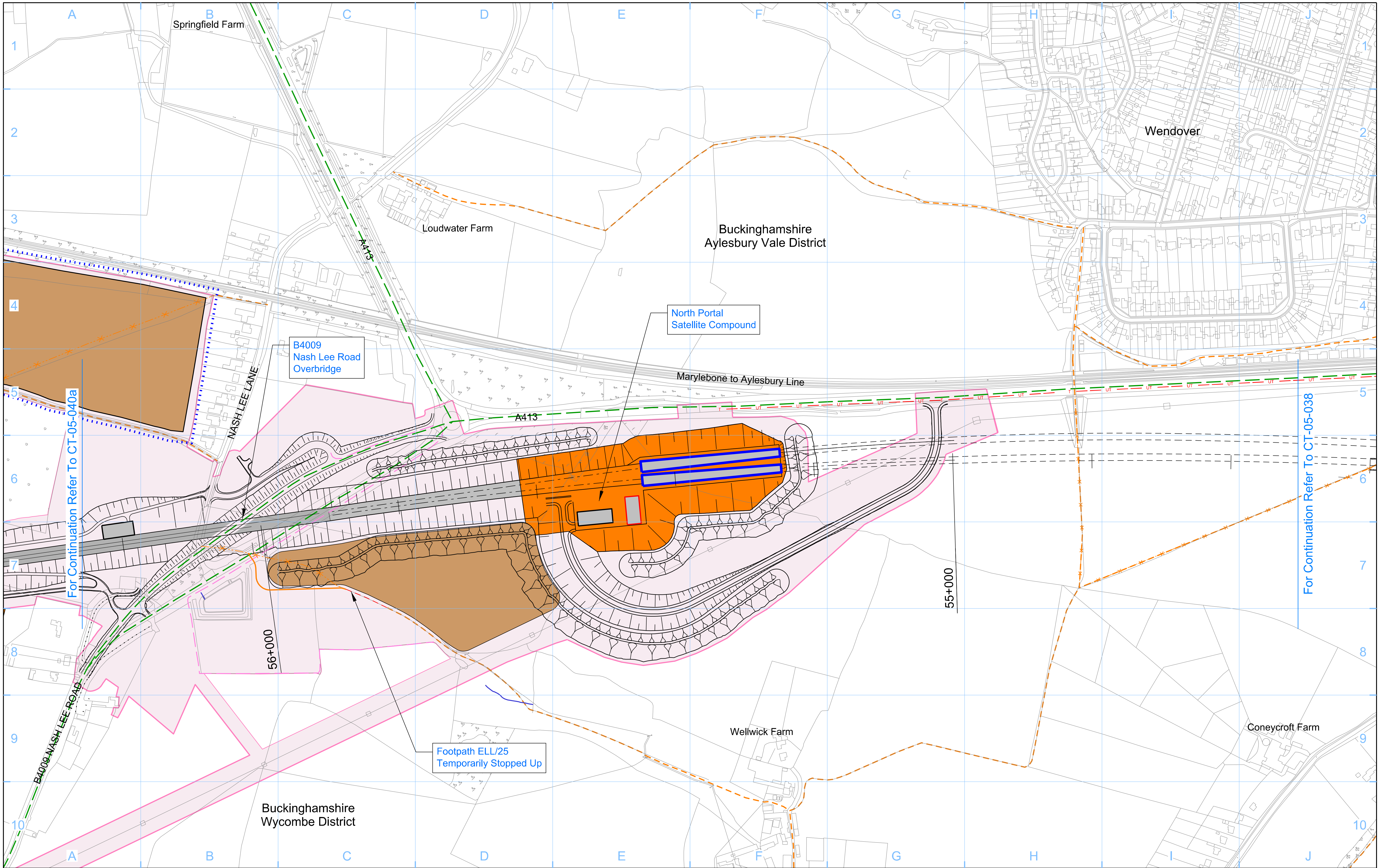
Scale at A3: 1:5,000
0 50 100 150 200 250
Metres

Doc Number: C222-ATK-EV-DPL-020-751008-RST00000571 P00.1 **Date:**



Legend

- Depot, station, headhouse or portal building
- Tunnel portal
- Main construction compound
- Satellite construction compound
- Temporary material stockpile
- Rail alignment formation
- Landscape earthworks
- Engineering earthworks
- County boundary
- Borough / District boundary
- Land potentially required during construction
- Temporary replacement community facility
- Community forum boundary
- Existing watercourse
- Tunnels external extent
- Construction traffic route
- Existing public right of way (PRoW)
- New, diverted or realigned PRoW
- Stopped-up PRoW
- Temporary PRoW diversion / realignment
- Temporary highway diversion / realignment
- UT Main utility works
- 10+000 Chainage (e.g. 10+000)
- Rail alignment

Map Number

CT-05-039

Map Name

Construction Features
CRAG - T3i
North Portal - Indicative Layout

Community Forum Area

CFA10
Dunsmore, Wendover and Halton

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Registered office: One Canada Square,
London, E14 5AB

Scale at A3: 1:5,000

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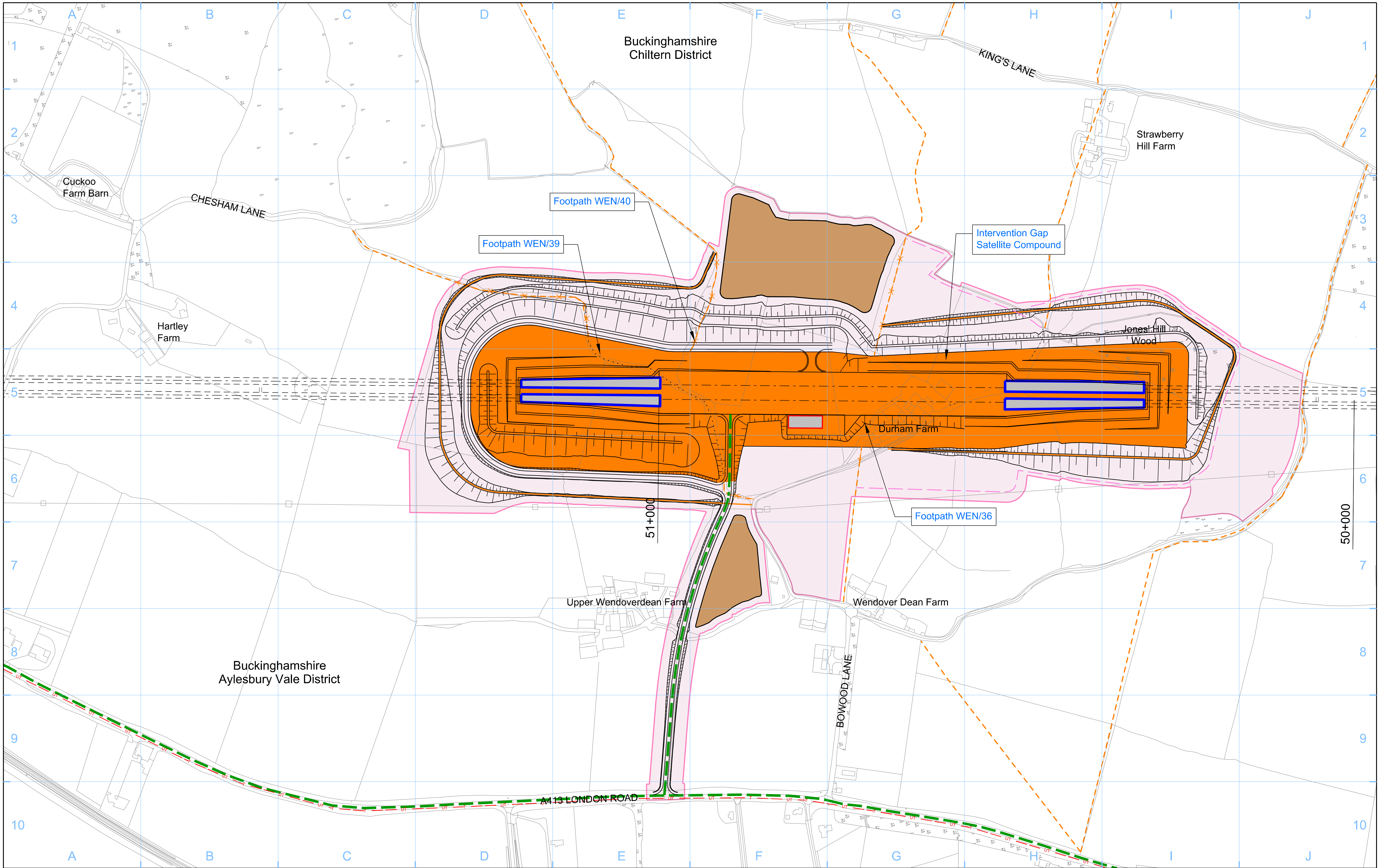
Metres

Doc Number: C222-ATK-EV-DPL-020-751010-RST00000571 P00.1 **Date:**



Legend

- Depot, station, headhouse or portal building
- Tunnel portal
- Main construction compound
- Satellite construction compound
- Temporary material stockpile
- Rail alignment formation
- Landscape earthworks
- Engineering earthworks
- County boundary
- Borough / District boundary
- Land potentially required during construction
- Temporary replacement community facility
- Community forum boundary
- Existing watercourse
- Tunnels external extent
- Construction traffic route
- Existing public right of way (PRoW)
- New, diverted or realigned PRoW
- Stopped-up PRoW
- Temporary PRoW diversion / realignment
- Temporary highway diversion / realignment
- UT Main utility works
- 10+000 Chainage (e.g. 10+000)
- Rail alignment

Map Number: CT-05-036

Map Name: Construction Features CRAG - T3i Intervention Gap - Indicative Layout

Community Forum Area: CFA09 Central Chilterns

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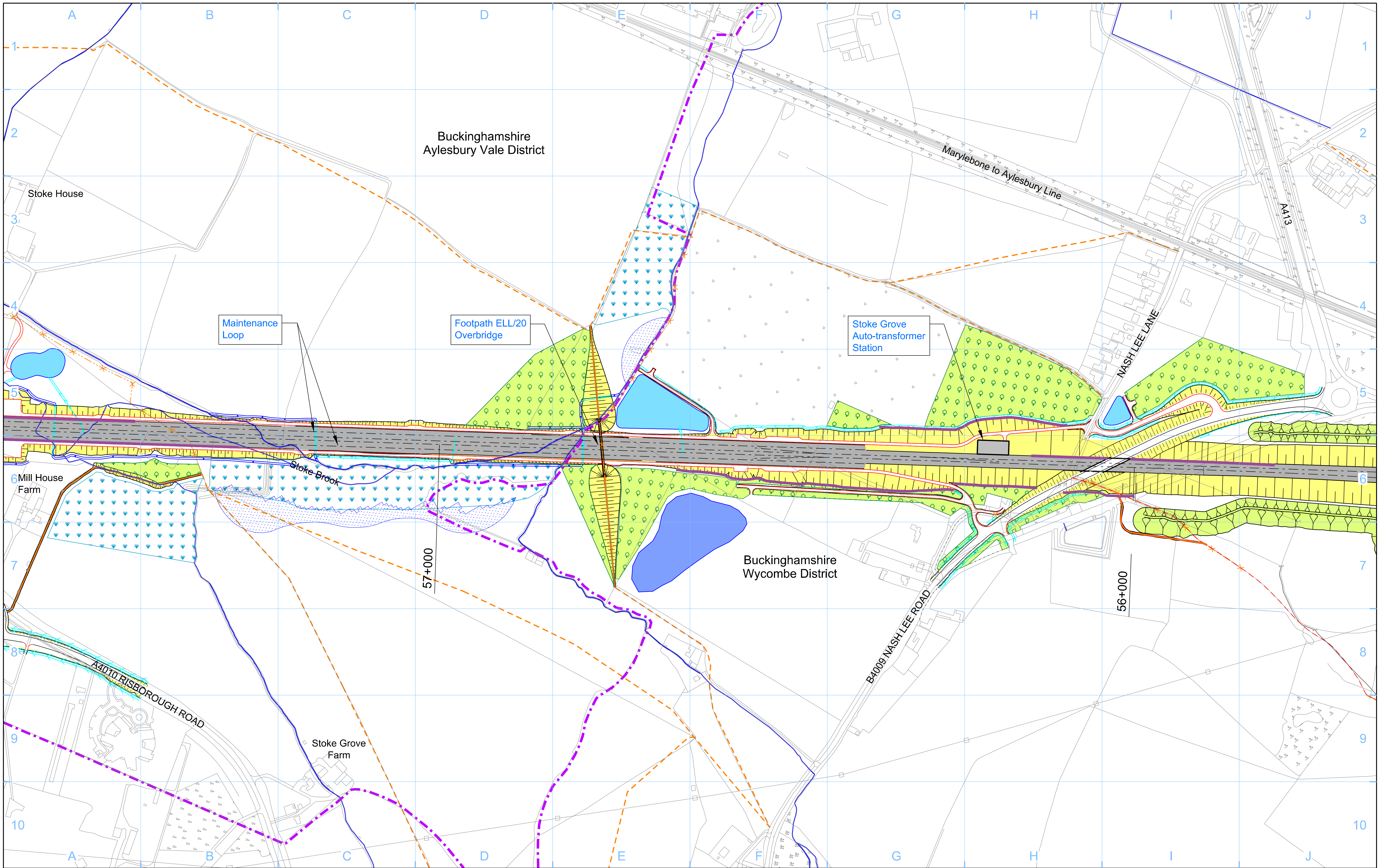

Legend

Depot, station, headhouse or portal building	Replacement floodplain storage
Tunnel portal	Woodland habitat creation
Electricity substation	Wetland habitat creation
Land drainage area	Grassland habitat creation
Ecological mitigation pond	Landscape mitigation planting (scrub / woodland)
Balancing pond	Grassed areas
	Sustainable placement

- Public realm/Replacement community facility
- Engineering earthworks
- Landscape earthworks
- Rail alignment formation
- Returned to suitable development use
- County boundary
- Borough / District boundary
- Community forum boundary
- Watercourse diversion
- Existing watercourse
- Ditches - new
- Hedgerow habitat creation
- UT Main utility works
- Existing public right of way (PRoW)
- New, diverted or realigned PRoW
- Stopped-up PRoW
- Tunnels external extent
- Rail alignment
- HS2 Access road
- Noise fence barrier
- 10+000 Chainage (e.g. 10+000)

Map Number
CT-06-040a

Map Name
Permanent Features
CRAG - T3i North Portal
Construction Compound (Sheet 1)

Community Forum Area
CFA10
Dunsmore, Wendover and Halton

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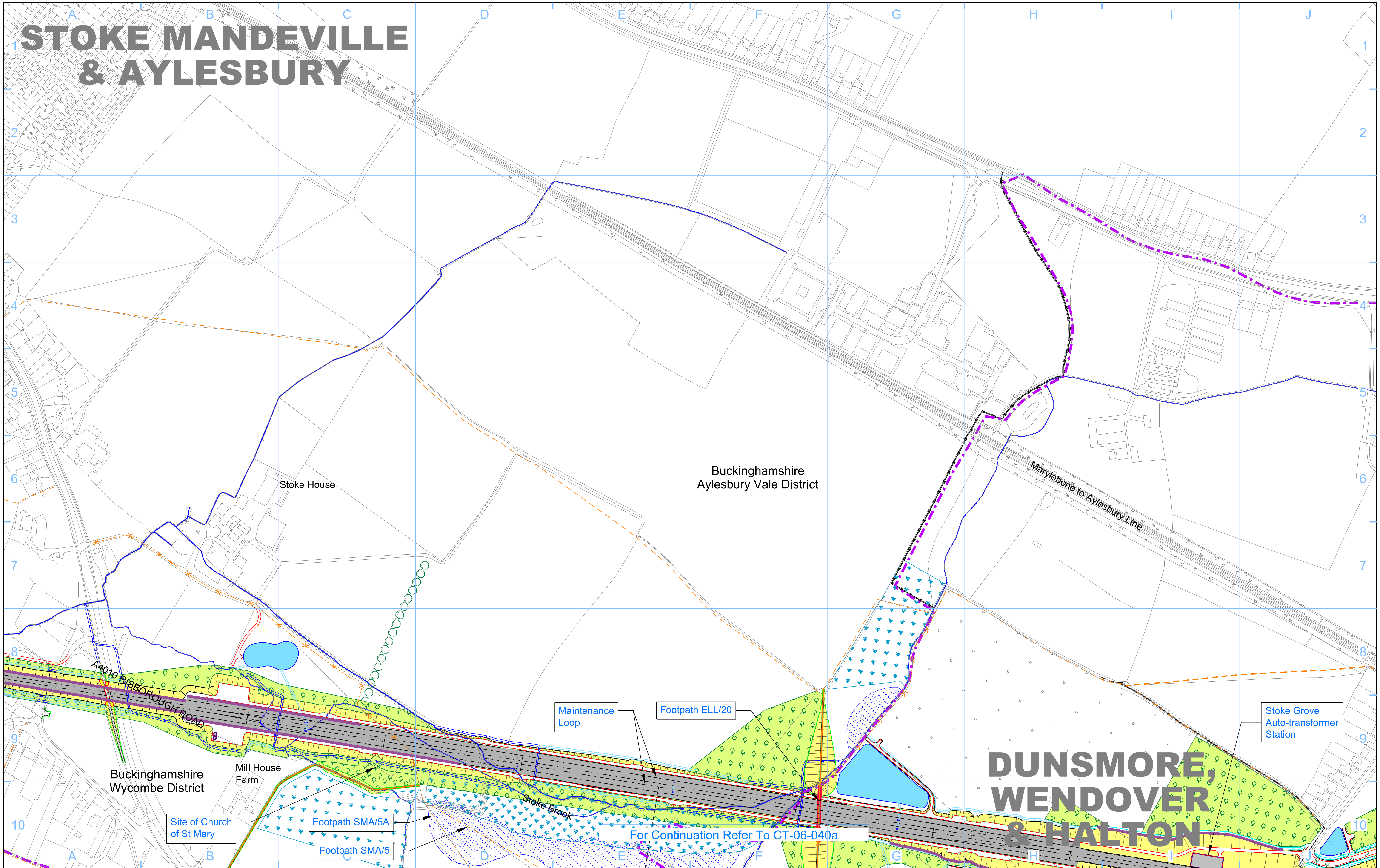
Doc Number: C222-ATK-EV-DPL-020-761006-RST00000571 P00.1 **Date:**



Legend

- Depot, station, headhouse or portal building
- Tunnel portal
- Electricity substation
- Land drainage area
- Ecological mitigation pond
- Balancing pond
- Replacement floodplain storage
- Woodland habitat creation
- Wetland habitat creation
- Grassland habitat creation
- Landscape mitigation planting (scrub / woodland)
- Grassed areas
- Sustainable placement
- Public realm/Replacement community facility
- Engineering earthworks
- Landscape earthworks
- Rail alignment formation
- Returned to suitable development use
- County boundary
- Borough / District boundary
- Community forum boundary
- Watercourse diversion
- Existing watercourse
- Ditches - new
- Hedgerow habitat creation
- UT Main utility works
- Existing public right of way (PRoW)
- New, diverted or realigned PRoW
- Stopped-up PRoW
- Tunnels external extent
- Rail alignment
- HS2 Access road
- Noise fence barrier
- 10+000 Chainage (e.g. 10+000)

Map Number: CT-06-040a-R1

Map Name: Permanent Features CRAG - T3i North Portal Construction Compound (Sheet 2)

Community Forum Area: CFA10 Dunsmore, Wendover and Halton

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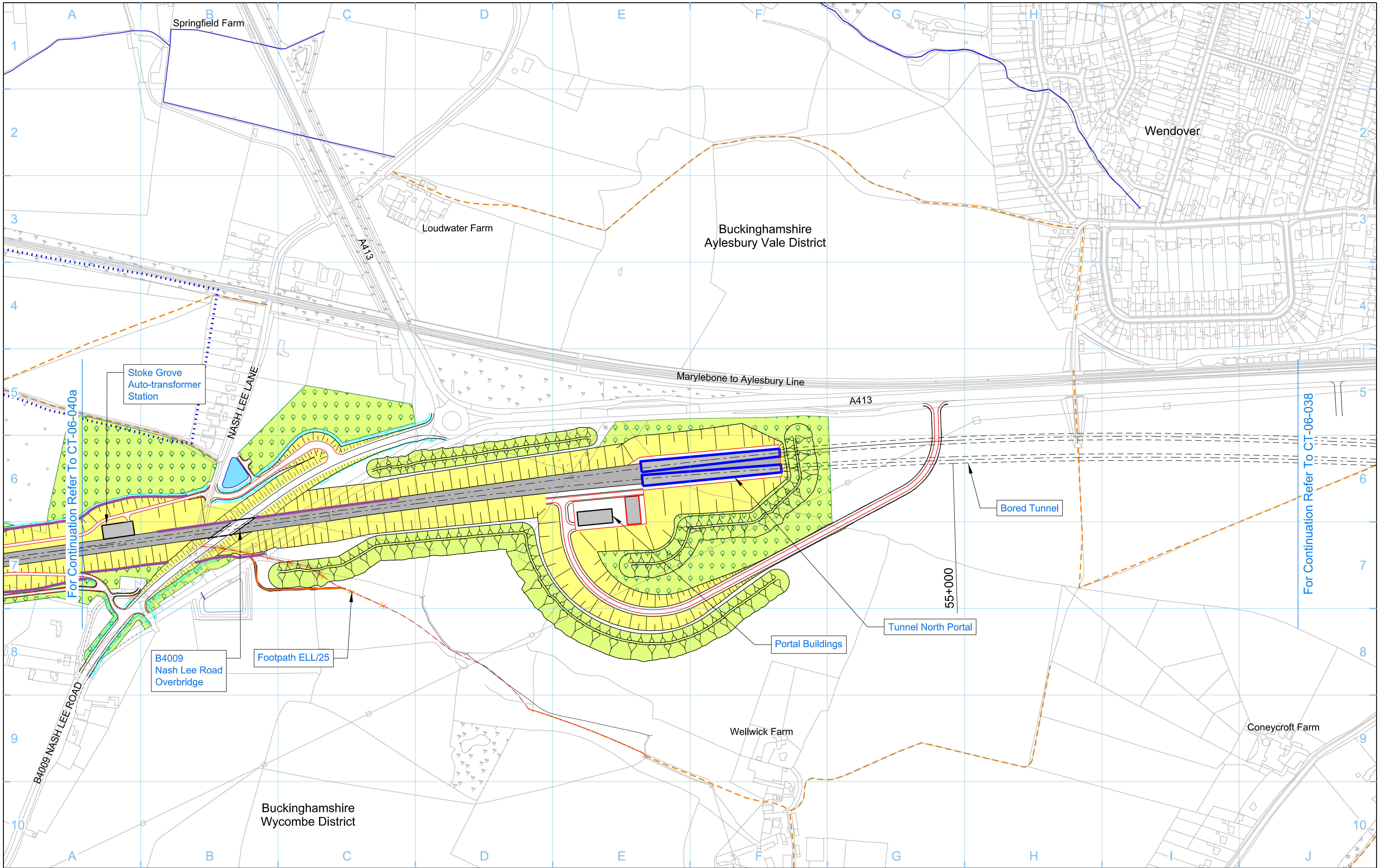
Doc Number: C222-ATK-EV-DPL-020-761008-RST00000571 P00.1 Date:



Legend

- Depot, station, headhouse or portal building
- Tunnel portal
- Electricity substation
- Land drainage area
- Ecological mitigation pond
- Balancing pond
- Replacement floodplain storage
- Woodland habitat creation
- Wetland habitat creation
- Grassland habitat creation
- Landscape mitigation planting (scrub / woodland)
- Grassed areas
- Sustainable placement
- Public realm/Replacement community facility
- Engineering earthworks
- Landscape earthworks
- Rail alignment formation
- Returned to suitable development use
- County boundary
- Borough / District boundary
- Community forum boundary
- Watercourse diversion
- Existing watercourse
- Ditches - new
- Hedgerow habitat creation
- UT Main utility works
- Existing public right of way (PRoW)
- New, diverted or realigned PRoW
- Stopped-up PRoW
- Tunnels external extent
- Rail alignment
- HS2 Access road
- Noise fence barrier
- 10+000 Chainage (e.g. 10+000)

Map Number

CT-06-039

Map Name

Permanent Features
CRAG - T3i
North Portal - Indicative Layout

Community Forum Area

CFA10
Dunsmore, Wendover and Halton

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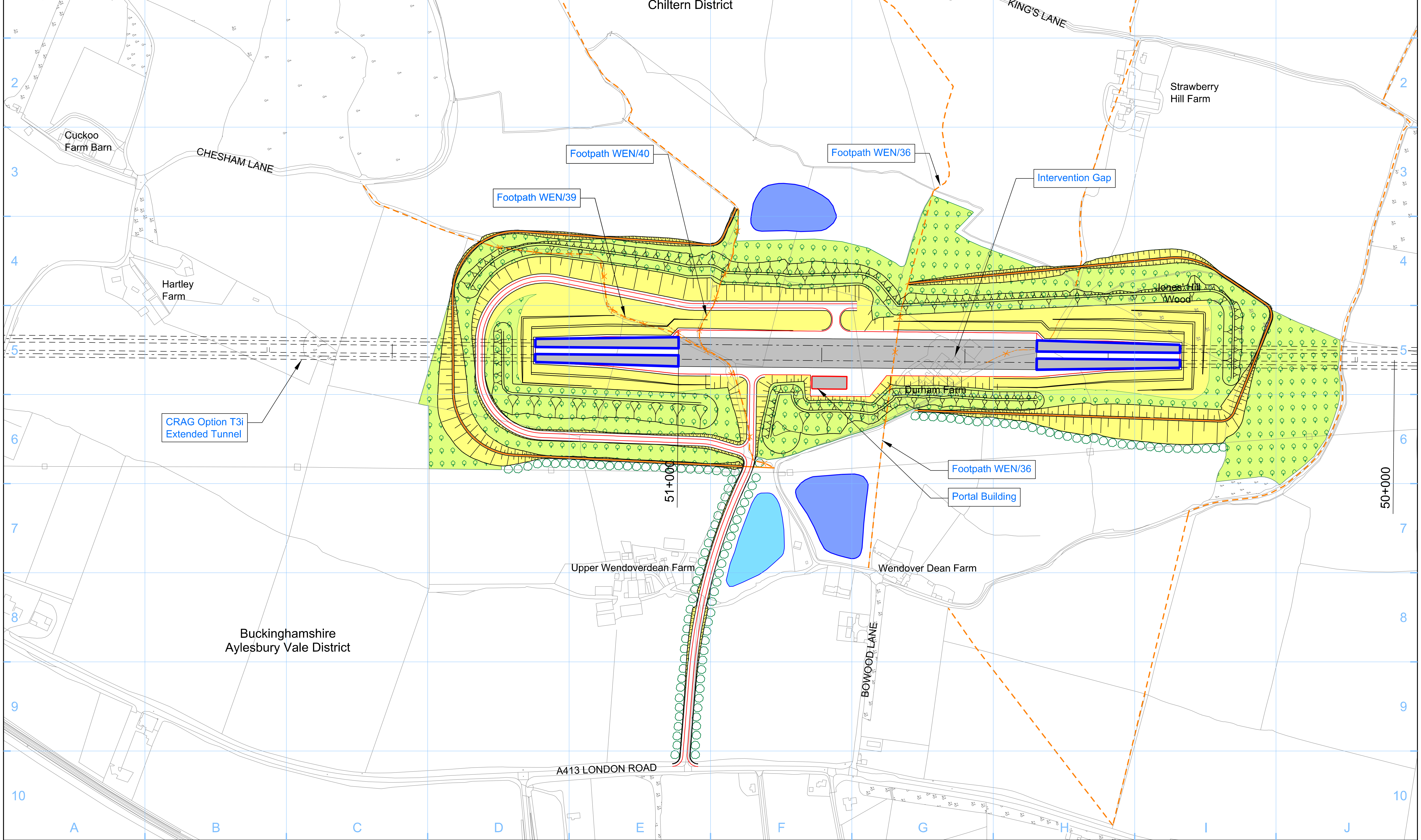
OPERATION (CRAG T3i)



Legend

- Depot, station, headhouse or portal building
- Tunnel portal
- Electricity substation
- Land drainage area
- Ecological mitigation pond
- Balancing pond
- Replacement floodplain storage
- Woodland habitat creation
- Wetland habitat creation
- Grassland habitat creation
- Landscape mitigation planting (scrub / woodland)
- Grassed areas
- Sustainable placement
- Public realm/Replacement community facility
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- Rail alignment formation
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- County boundary
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- Watercourse diversion
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- Ditches - new
- Hedgerow habitat creation
- UT Main utility works
- Existing public right of way (PRoW)
- New, diverted or realigned PRoW
- Stopped-up PRoW
- Tunnels external extent
- Rail alignment
- HS2 Access road
- Noise fence barrier
- 10+000 Chainage (e.g. 10+000)

Map Number
CT-06-036

Map Name
Permanent Features
CRAG - T3i
Intervention Gap - Indicative Layout

Community Forum Area
CFA10
Dunsmore, Wendover and Halton

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Metres

Doc Number: C222-ATK-EV-DPL-020-761901-RST00000571 P00.1 **Date:**

Appendix C Cost Details

CRAG T3i assessed tunnel option - cost comparison vs HS2 Proposed Scheme

	Proposed Scheme (including extended Chiltern Tunnel)	CRAG Option T3i	Difference	Comments
	£m	£m	£m	
LAND AND PROPERTY	32.43	4.35	-28.08	Mantles Wood to Nash Lee Road
TUNNELS	957.90	1,409.75	451.85	
Bored Tunnels	771.91	1,176.70	404.78	Proposed Scheme Chiltern tunnel 15.8km exc portal hoods CRAG tunnel 23.9km including Intervention Gap but exc portal hoods
Green Tunnels	63.29	0.00	-63.29	
Tunnel Portals	52.60	44.79	-7.81	Proposed Scheme includes Chiltern tunnel portals and Wendover green tunnel portals CRAG includes M25 south portal and Wendover north portal Excavation for portals included with cuttings
Portals at Intervention Gap	0.00	42.42	42.42	Excavation for portals included in Intervention Gap costs
Shafts	66.27	96.16	29.89	
Additional disposal costs	3.82	22.00	18.18	Extra transport allowance only - Landfill tax would be at additional cost
Intervention Gap	0.00	27.68	27.68	Excavation and construction of 900m long retained cut structure.
CIVIL ENGINEERING	215.48	88.42	-127.06	
CUTTINGS	38.09	19.56	-18.52	
Cuttings	38.09	19.56	-18.52	
EMBANKMENTS	15.03	0.00	-15.03	
EARTHWORKS	22.88	17.95	-4.93	
Landfill & Contaminated Remediation Measures	0.00	0.00	0.00	
Landscaping	22.88	17.95	-4.93	
ENVIRONMENTAL MITIGATION WORKS	12.01	6.63	-5.38	
Planting	7.38	6.26	-1.13	
School protection works	0.00	0.00	0.00	
Enhanced Planting	0.00	0.00	0.00	
Noise Barriers	4.63	0.37	-4.25	
RETAINING WALLS	1.46	0.00	-1.46	
BRIDGES	13.95	4.40	-9.55	CRAG includes for B4009 Nash Lee Lane Overbridge
Overbridge	11.36	4.40	-6.96	
Underbridge	2.59	0.00	-2.59	
VIADUCTS	41.32	0.00	-41.32	
HIGHWAYS	30.18	23.20	-6.97	CRAG includes for vent shaft and Intervention Gap accesses
OTHER	40.57	16.67	-23.91	
Culverts	0.14	0.00	-0.14	
Utilities Diversions	37.74	14.02	-23.73	
Utilities Connections	2.69	2.65	-0.04	
EXTENDED PRELIMINARIES	0.00	0.00	0.00	
DEPOT AND SIDINGS	0.00	0.00	0.00	
RAILWAY SYSTEMS	176.15	201.80	25.66	
INDIRECT COSTS	245.21	308.89	63.68	
	1,627.17	2,013.21	386.05	
Less ECP/VE	-153.08	-192.83	-39.75	
OTHER ASSURANCES PROVIDED	6.00	0.00	-6.00	Assurances for AONB design panel, St Mary's church, Wendover School and other local assurances under the Proposed Scheme
Net total	1,480.09	1,820.39	340.30	

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 Efficiency Challenge Programme and Value Engineering have been provided by the HS2 costs team

Appendix D Previously Assessed Options

D.1 General

D.1.1 This appendix summarises the other long tunnel options put forward by Petitioners:

- Chiltern Long Tunnel (CLT) proposal
- Tunnel Bored One-way (T-BOW)

D.2 Chiltern Long Tunnel Proposal

D.2.1 The Chiltern Long Tunnel (CLT) was an alternative proposal developed by Peter Brett Associates (PBA) that was promoted by Chiltern District Council in association with Aylesbury Vale District Council, Buckinghamshire County Council and the Chilterns Conservations Board. A more detailed review of this study can be found in a separate report: "High Speed Rail in the Chilterns Part 2: Chiltern Long Tunnel Proposal" (C222-ATK-TN-REP-020-000012).

D.2.2 The CLT would be a continuous tunnel measuring 24.3km, 0.4 km longer than the CRAG T3i option. The tunnel would extend from the current proposed West Hyde/M25 south portal to 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.

D.2.3 The CLT alignment would follow the Proposed Scheme alignment from West Hyde to Little Missenden. It then deviates horizontally and vertically before rising to a portal just south of Nash Lee Road. It then runs northwards in a cutting to re-join the Proposed Scheme alignment at approximate chainage 57+200, part way along the proposed maintenance loop. The CRAG T3i alignment would follow the horizontal alignment of the Proposed Scheme and would tie-into the vertical alignment before reaching the maintenance loop.

D.2.4 Two additional ventilation shafts are indicated in the CLT proposal at approximate chainages 48+800 and 51+500. The CRAG T3i option identifies two additional shafts at chainages 48+300 and 53+700 with a 900m intervention gap at chainage 50+700m.

D.2.5 The CLT tunnels 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.

D.2.6 The firefighting point in the CLT proposal comprises an underground cavern between the two tunnel bores at Little Missenden vent Shaft. The TBMs would be removed at this location. This differs from the CRAG T3i proposal of an open intervention gap at Durham Farm.

D.2.7 HS2 Ltd review of the CLT proposal indicated concerns regarding cost, viability and environmental impacts including some of the following (for further details, refer to "High Speed Rail in the Chilterns Part 2: Chiltern Long Tunnel Proposal"):

- The 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 need to 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.

- The proposed underground firefighting point would be non-conforming to the HS2 project requirements which would look to provide an open gap structure for the firefighting point on such a long tunnel, as this provides a safer form of egress and passenger holding during an emergency event.

D.2.8 The engineering review of the CLT proposal concluded 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;

- Complete costs of underground civil works;

- Impacts on rail fit out construction costs and programme; and

- Programme impact to overall HS2 system construction.

D.2.9 The technical, logistical and operational issues regarding the firefighting point at Little Missenden or a conforming open intervention gap in another location have not been explored in enough detail to determine engineering feasibility. These issues include, but are not limited to, access from the highway network, long term logistics associated with maintenance, impact to train operations, adequate space for construction works and long term and short term impacts on the local area.

D.2.10 The review of the CLT proposal clearly indicated that there could be additional costs and risks 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. These include:

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

D.3 Tunnel Bored One Way (T-BOW)

D.3.1 The option of constructing a long tunnel through the AONB, similar to the CRAG T3i tunnel, but by boring in one direction from the West Hyde/M25 south portal was proposed by the Potter Row Neighbourhood Watch Scheme, referred to as the T-BOW option.

D.3.2 The T-BOW option was reviewed by HS2 Ltd. and while this would mitigate the environmental impact by significantly reducing the size of the north portal construction compound at Wendover it would have a major impact on the construction programme, cost and the movement of excavated material from the south portal.

D.3.3 The review of this option considered the use of an Earth Pressure Balance Machine (EPBM). Maintaining the EPBM advance rate of 80m/week added 23 months to the programme. Increasing the average EPBM advance rate to 120m/week would be required to construct the tunnel within the present programme. This is considered unrealistic taking into account potential difficulties in tunnelling that could be encountered and considering the probable maintenance and face interventions required.

D.3.4 The estimated increase in cost compared to the original hybrid Bill was approximately £412M. This cost did not include additional temporary works and specialised equipment for rail systems fit out or a revised intervention gap to comply with HS2 operational requirements.

D.3.5 The volume of excavated material at the south portal would be approximately 3.4Mm^3. Approximately 2Mm^3 would be used to form the environmental mitigation earthworks currently proposed at this location and approximately 1.4Mm^3 would need to be transported, by public highway, to a suitable disposal site.

D.3.6 The volume of excavated material from the intervention gap would be approximately 1.3Mm3. Approximately 0.8Mm^3 would be transported northwards, by public highway, for use in mitigation earthworks at Aylesbury. Approximately 0.2Mm^3 would be re-used to form local environmental mitigation earthworks and approximately 0.3Mm3 would be transported, by public highway, to a suitable disposal site.