Risk Assessment for Six Mile Bottom AHB Level Crossing

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REVISIONS

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APPROVAL

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CONTENTS

ACRONYMS AND ABBREVIATIONS

Acronym	Description	Comments
ABCL	Automatic Barrier Level Crossing, Locally-monitored	
AHB	Automatic Half-Barrier (level crossing)	
ALARP	As Low As Reasonably Practicable	
ALCRM	The All Level Crossing Risk Model	A tool for assessing the risk at particular level crossings.
AOCL	Automatic Open Level Crossing, Locally-monitored	
AOCL+B	Automatic Open Level Crossing, Locally-monitored with retrofitted half barriers	
BAP	Biodiversity Action Plan	
BOAT	Byway Open to All Traffic	
BPM	Barrier Protection Management	A solution for auto-lower crossings that delays barrier lowering should there be a road vehicle underneath a barrier.
CBA	Cost Benefit Analysis	A numerical comparison of the monetised advantages and disadvantages of undertaking a particular course of action.
CCU / LCU	Crossing Control Unit	
COD	Complementary Obstacle Detector	
CCTV	Closed Circuit Television	
DIA	Diversity Impact Assessment	
EA	Equality Act 2010	
ELR	Engineering Line Reference	
ERTMS	European Rail Traffic Management System	A system of train control that allows for automatic train protection and cab based signalling.
ETCS	European Train Control System	
FWI	Fatalities and Weighted Injuries	A measure of safety performance where the predicted rate of fatalities and minor and minor injuries are combined into an overall measure of risk.
HGV	Heavy Goods Vehicle	
LCM	Level Crossing Manager	
LED	Light Emitting Diode	

Acronym	Description	Comments
MCB-CCTV	Manually-Controlled Barrier Level Crossing with CCTV	
MCB-OD	Controlled Barrier Level Crossing with Obstacle Detection	
MCG	Manually-Controlled Gate Level Crossing	
NPV	Net Present Value	
ORCC	Operations Risk Control Coordinator	
ORR	Office of Rail and Road	
PHI	Priority Habitat Inventory	
POD	Primary Obstacle Detector	
PROW	Public Right of Way	
PSB	Power Signal Box	
RAM	Route Asset Manager	
ROC	Regional Operations Centre	
RLSE	Red light static enforcement cameras	
RSSB	Rail Safety and Standards Board	
RTL	Road Traffic Light	
SAC	Special Area of Conservation	
S&SRA	Suitable and Sufficient Risk Assessment	
SEU	Signalling Equivalent Unit	A measure of signalling cost
SLL	Stop, Look and Listen sign	Signage normally used for footpath or user-worked crossings that require pedestrians to check whether a train is approaching before deciding whether it is safe to cross
SMIS	Safety Management Information System	The database used by the UK rail industry for reporting accidents and near misses
SPAD	Signal Passed at Danger	
SRM	Safety Risk Model	The rail risk model managed on behalf of the industry by RSSB
SSSI	Sites of Special Scientific Interest	
TMOB	Trainman Operated Barrier crossing	

Acronym	Description	Comments
TOC	Train Operating Company	
TPV	Train Pedestrian Value	A measure of used based on pedestrian usage and train frequency
TTRO	Temporary Traffic Regulation Order	
TWAO	Transport & Works Act Order	
VAS	Vehicle Activated Sign	A sign that illuminates in the event of blocking back ahead, reminding drivers to keep the crossing clear
VpF	Value of Preventing a Fatality	A value used to express safety risk in financial terms
YN, YO, ZN, ZO	Denotes the corner of the crossing.	Y is closest to the Up line; Z the Down line; N is the nearside (for traffic); O the offside.

REFERENCE DOCUMENTS

The following documents have been used to support the production of this report:

Ref	Document Name	Number
1.	Level Crossings: A guide for managers, designers and operators (ORR)	Railway Safety Publication 7 December 2011
2.	Internal Guidance On Cost Benefit Analysis (CBA) IN Support Of Safety-related Investment Decisions	ORR, April 2015
3.	Network Rail Authority Paper (for LXEU and SEU costs)	V6.15 – 1st July 2015
4.	Census Report for Six Mile Bottom Level Crossing	Sky High-Count on Us 8801 Task 4 Site 26 – May 2013
5.	South Cambridgeshire Local Plan	Adopted September 2018
6.	Level Crossing Guidance Document: Applying Risk Reduction Bednefits in ALCRM When Modelling Safety Enhancements	LCG 14 March 2016
7.	Transforming Level Crossings: A vision-led long-term strategy to improve safety and level crossings on Great Britain's railways	NR17
8.	Manually Controlled Barriers Obstacle Detection: MCB-OD Selection and Risk Mitigation Guidance	Signalling Design Group NR/IP/SDG York/MCB-OD/02 August 2014 Version 3.1
9.	MCB-OD Pedestrian Risk Tool	AD Little V1
10.	AHB+ HAZID Report	AES/1739/R03, Issue 2, 09/07/19
11.	AHB+ System Definition	AES/1739/R01, Issue 1, 29/03/19
12.	AHB+ Option 2 Feasibility Analysis Extract	
13.	RSSB, Safety Risk Model	V8.5.0.2, March 2018

1 INTRODUCTION

1.1 Background

The renewal of level crossings on the UK network must be supported by appropriate and robust risk assessment. This level crossing risk assessment was originally produced in support of the Cambridge Area Interlocking Renewals (CAIR) project in 2013. The Cambridge – Dullingham – Bury Re-Signalling (CBD) Project started out being called Cambridge Inner Re-Signalling (CIRS) with a smaller geographical scope. A further scope of works Cambridge Outer Re-Control and Life Extension (CORCLE) was added to the CIRS scope partway through GRIP 1 in order to gain efficiencies. An update to this level crossing risk assessment is required in order to take into account the latest project information. As part of this process, Network Rail has tasked Sotera Risk Solutions to update the suitable and sufficient risk assessment of the closure and renewal options for Six Mile Bottom AHB level crossing.

1.2 Approach to risk assessment

In order to carry out the risk assessments, Sotera has:

- Reviewed available information pertinent to the level crossing (including, SMIS event data, and input data to the All Level Crossings Risk Model (ALCRM)).

- Analysed national level crossing risk information to compare the main level crossing type options.

- Undertaken a site visit to the crossing to assess its current operation, to determine the existing controls, identify local hazards, to measure distances key to the risk assessment and make a photographic record of any issues. If there was no census since 2013, the site visit included a half hour census, which could be used to assess the suitability of the old census.

- Specified and carried assessments of the crossing type options using the ALCRM, where available based upon an up-to-date traffic census otherwise making use of the Department of Transport's TEMPro v7.2 software, which allows users to view the National Trip End Model (NTEM) dataset and can be used to factor up '*old*' censuses to current levels of usage.

- Carried out an initial options assessment which considered the available crossing type options from a safety, cost and feasibility perspective

- Facilitated an options assessment workshop, which reviewed the initial options assessment, supplementing it with additional information and ideas as appropriate.

2 DESCRIPTION OF THE SITE AND THE EXISTING LEVEL CROSSINGS

2.1 Current level crossing detail

Six Mile Bottom is an AHB crossing, with two half-width barriers and four RTLs. The RTLs are not LED type; the RTLs are, however, fitted with extended hoods (*Figure 2*).

The crossing is monitored from Cambridge signal box.

The maximum line speed is 60 mph over this line. The line is not electrified.

Figure 1 shows the configuration of the crossing, viewed from the south. *Figure 3* provides the relevant extract from the sectional appendix covering the crossing. *Table 1* presents details of the location and operation of the crossing.

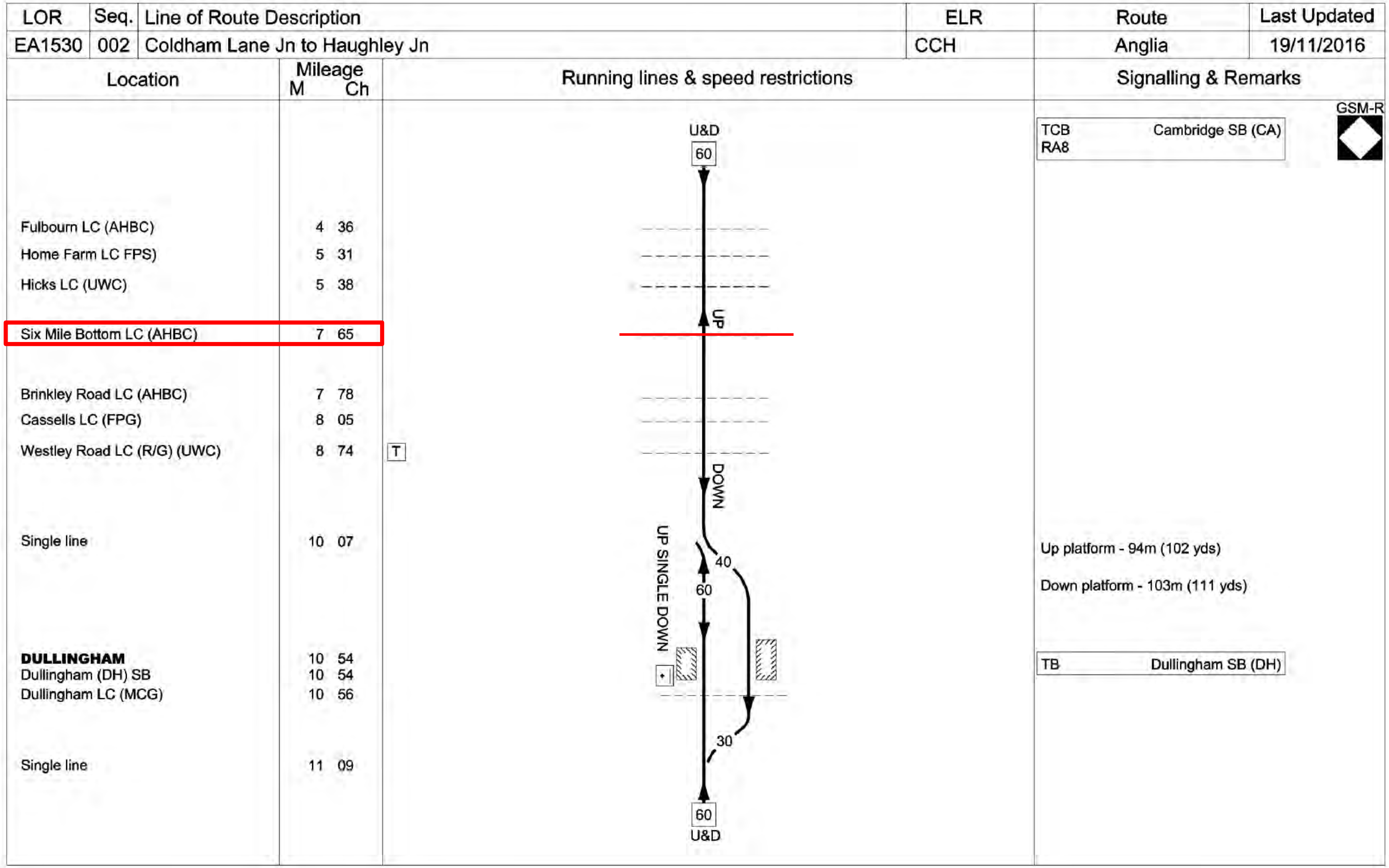
Figure 1 Current crossing equipment

Figure 2 Extended hoods

Table 1 Current Level Crossing Details

Level crossing names	Six Mile Bottom
Level crossing type	AHB
ELR and mileage	CCH 7m 65ch
Status	Public Road
Number of running lines	1
Permissible speed over crossing (Up)	60mph
Permissible speed over crossing (Down)	60mph
Postcode	CB8 0UJ
Local Authority	Cambridgeshire County Council
Supervising signal box	Cambridge PSB
Electrification and type	No

Figure 3 Extract from the sectional appendix



LOR	Seq.	Line of Route Description	ELR	Route	Last Updated
EA1530	002	Coldham Lane Jn to Haughley Jn	CCH	Anglia	19/11/2016

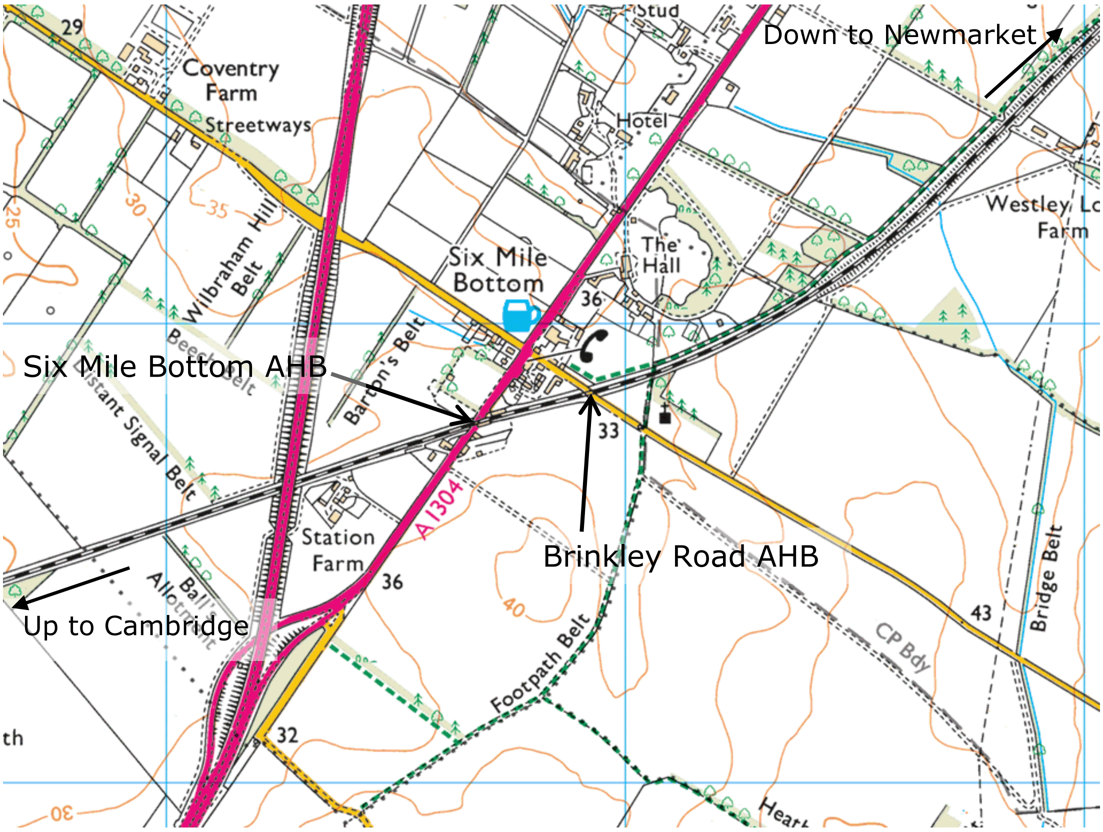
Location	Mileage M	Mileage Ch	Running lines & speed restrictions	Signalling & Remarks
				TCB RA8 Cambridge SB (CA) GSM-R
Fulbourn LC (AHBC)	4	36		
Home Farm LC FPS)	5	31		
Hicks LC (UWC)	5	38		
Six Mile Bottom LC (AHBC)	7	65		
Brinkley Road LC (AHBC)	7	78		
Cassells LC (FPG)	8	05		
Westley Road LC (R/G) (UWC)	8	74	T	
Single line	10	07		Up platform - 94m (102 yds)
				Down platform - 103m (111 yds)
DULLINGHAM	10	54		
Dullingham (DH) SB	10	54		TB Dullingham SB (DH)
Dullingham LC (MCG)	10	56		
Single line	11	09		

2.2 Environment

The crossing is located on the A1304 London Road in the village of Six Mile Bottom, in Cambridgeshire as shown in *Figure 4*. The crossing allows access to Newmarket and the villages of Six Mile Bottom and Brinkley from the A11. The crossing is in a rural village location, with residential properties and farmland nearby.

Brinkley Road AHB is 160m east of the crossing.

Figure 4 Map showing an overview of the location of the crossing

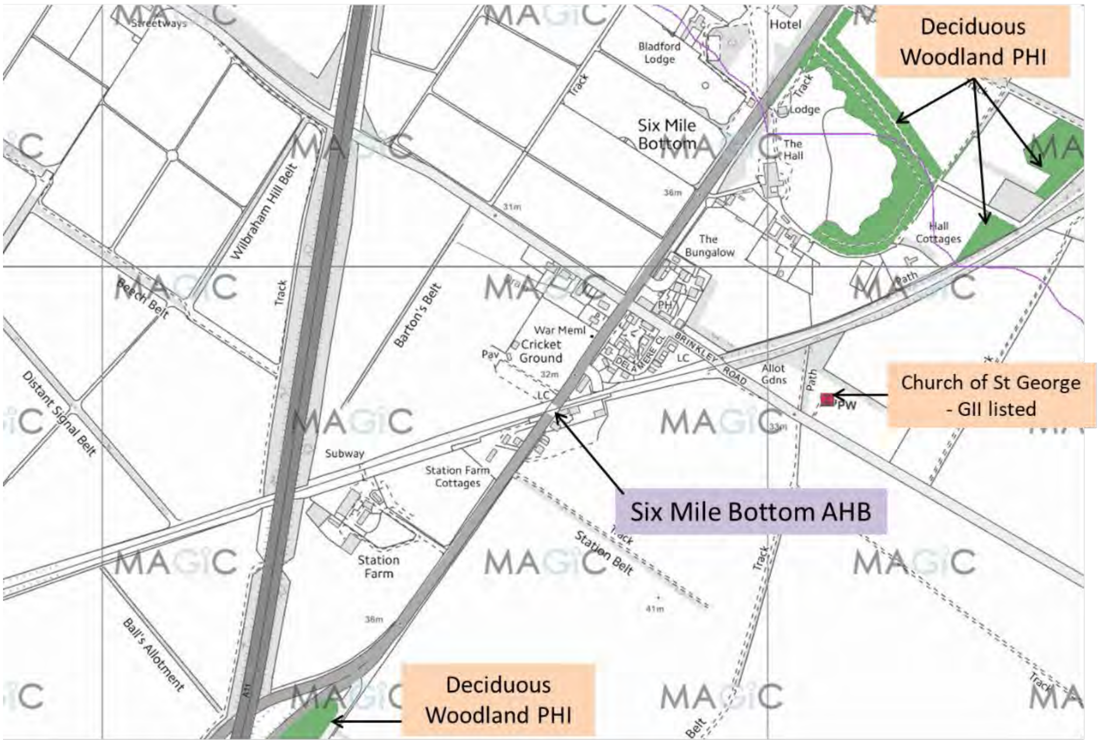


A satellite view of the location is shown in *Figure 5*.

Environmentally significant sites are shown in *Figure 6*. There are several Deciduous Woodland PHIs near to the crossing and the Church of St George, 400m east of the crossing, is Grade II Listed.

Figure 5 Satellite view showing the location of the crossing

Figure 6 Environmentally significant sites



2.3 Footpath approaches

There are footways on both sides of the crossing as seen in *Figure 1*. The footway on the west side (*Figure 7*) varies between 1.07m and 0.95m wide. The footway on the east side (*Figure 8*) varies between 1.06m and 0.72m wide as the footway is narrowed by the fence and grass at the ZN corner. There is moss growing over the south end of the west footway (*Figure 9*). There is uneven tarmac which presents a trip hazard at the south end of the east footway (*Figure 10*).

The west footway is 19m long, the east footway is 18m long.

Based upon ORR guidance [1], pedestrian footpaths over crossings are categorised into three classes based upon usage by pedestrians and the frequency of rail traffic. From the guidance, the volume of pedestrian and train flow is determined by the train pedestrian value (TPV). The TPV is the product of the maximum number of pedestrians and the number of trains passing over the crossing within a period of 15 minutes. The TPV at Six Mile Bottom, based upon a 9-day census, is 5. This places the crossing in the lowest usage category – category 'C' (the criteria for class C being a TPV of up to 150). In this class, the ORR recommends that the footpaths are 1.5m wide. The ORR also indicates that the footpath width can be reduced to 1.0m where the daily number of pedestrians is less than 25. The census indicates a weekday average pedestrian frequency of 15 and a weekly average of 11.

The west footway is therefore broadly in compliance with the minimum width of 1.0m specified in ORR guidance for a pedestrian category C crossing with fewer than 25 pedestrians per day (apart from a slight narrowing); however the east footway is not.

There are only small sections of pavement along the road near the crossing for the footways to join, apart from on the north east side where there is pavement along the road. On the south side there are driveways beyond the small sections of pavement on both sides of the road. On the northwest side there is a gate into a field beyond the small section of pavement. The gate does not appear to be regularly used.

There are no tactile thresholds on the footways.

1 ORR, Level Crossing: A guide for managers, designers and operators, Railway Safety Publication 7, December 2011.

Figure 7 Footway – West side

Figure 8 Footway – East side

Figure 9 Footway mossy – South west side

Figure 10 Footway trip hazard – South east side

2.4 Road approaches

Road approach to the crossing from the south

A 40mph speed limit applies on the road approach from the south from 120m south of the crossing. During the 9-day census the 85th percentile speed of approach was 56.8mph, this was however measured at the level crossing warning sign before the 40mph zone is reached.

The key features of the approach are:

1. The road has is straight on the approach.
2. The near side Level Crossing warning sign had been knocked down at the time of the site visit (*Figure 16*).
3. There is a driveway on the right, 67m south of the crossing (*Figure 17*).
4. There are driveways on the left 63m and 56m south of the crossing (*Figure 18*).
5. There is parking bay on the right, 26m south of the crossing (*Figure 19*).
6. There is a driveway on the right, 15m south of the crossing (*Figure 20*).
7. There is driveway and a rail access gate on the left, 6m south of the crossing (*Figure 21)*. This driveway has Keep Clear road markings, however they are very faded (*Figure 22*).
8. There is a driveway on the right, by the white line of the crossing (*Figure 23*). This driveway would be a very sharp turn for a vehicle approaching from the north, and therefore may be a cause of blocking back on occasion.
9. The RTLs are visible from beyond 150m on the approach.
10. The level crossing signage had good conspicuity at the time of the site visit.

The distant, intermediate and close road approaches from the east are shown in *Figure 12* to *Figure 15*. It can be seen in *Figure 12* that the crossing is visible from the distant signage.

A plan of the key features is shown in *Figure 11;* the numbers in the figure refer to the above numbered list of features.

Figure 11 Key features on the southern approach to the crossing

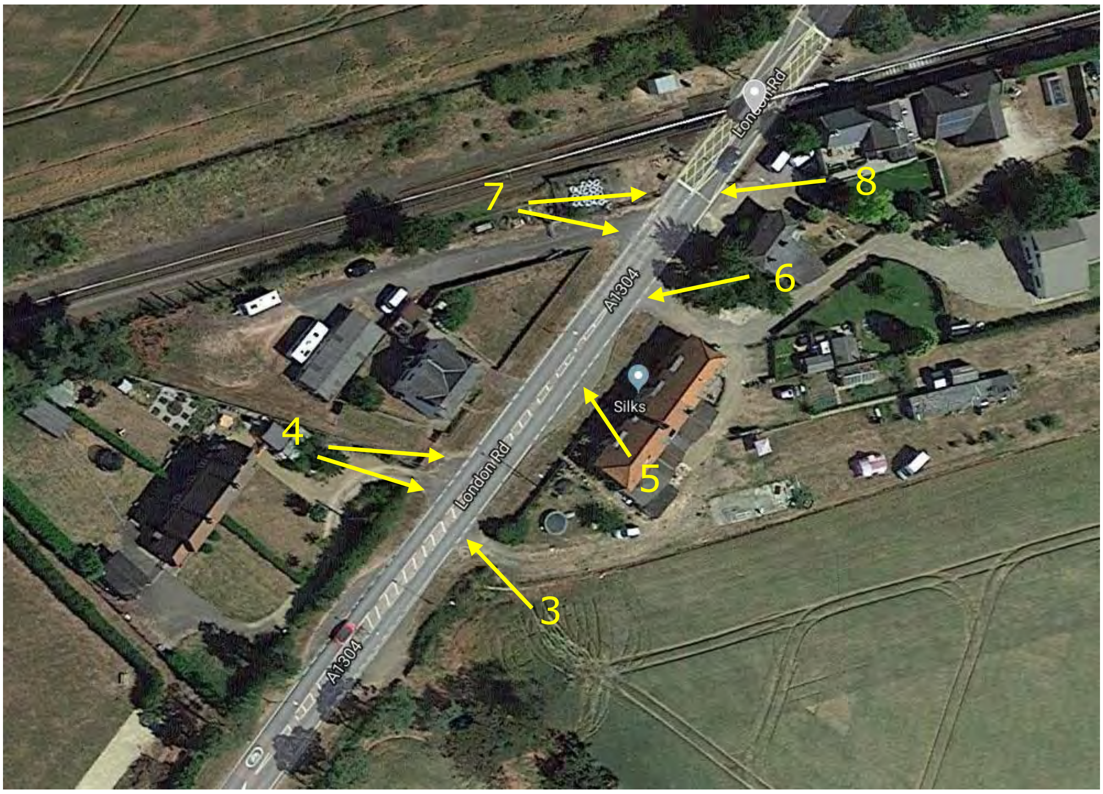


Figure 12 View approaching crossing from the south - distant

Figure 13 View approaching crossing from the south - intermediate

Figure 14 View approaching crossing from the south - intermediate

Figure 15 View approaching crossing from the south - near

Figure 16 Near side level crossing warning sign

Figure 17 Driveway on right

Figure 18 Driveways on left

Figure 19 Parking bay on right

Figure 20 Driveway on right

Figure 21 Driveway and rail access on left

Figure 22 Keep Clear faded

Figure 23 Driveway on right

Figure 24 View of crossing from driveway

Road approach to the crossing from the northwest

A 40mph speed limit applies on the road approach from the northwest. During the 9-day census the 85th percentile speed of approach was 38.3mph. The key features of the approach are:

1. The road is straight on the approach.
2. There is a crossroads with Brinkley/Wilbraham Road, 175m north of the crossing (*Figure 30*).
3. There is a shop car park on the left, 116m north of the crossing (*Figure 31*).
4. There is a gate into a playing field on the right, 116m north of the crossing (*Figure 32*).
5. There is junction with Ardross Court on the left, 60m north of the crossing (*Figure 33*).
6. There is gate on the right, 8m north of the crossing (*Figure 34*).
7. The RTLs are visible from over 170m on the approach.
8. The level crossing signage had good conspicuity at the time of the site visit.
9. The crossing has a skew of 35^{0}.

The distant, intermediate and close road approaches from the northwest are shown in *Figure 26* to *Figure 29*.

A plan of the key features is shown in *Figure 25;* the numbers in the figure refer to the above numbered list of features.

Figure 25 Key features on the northern approach to the crossing

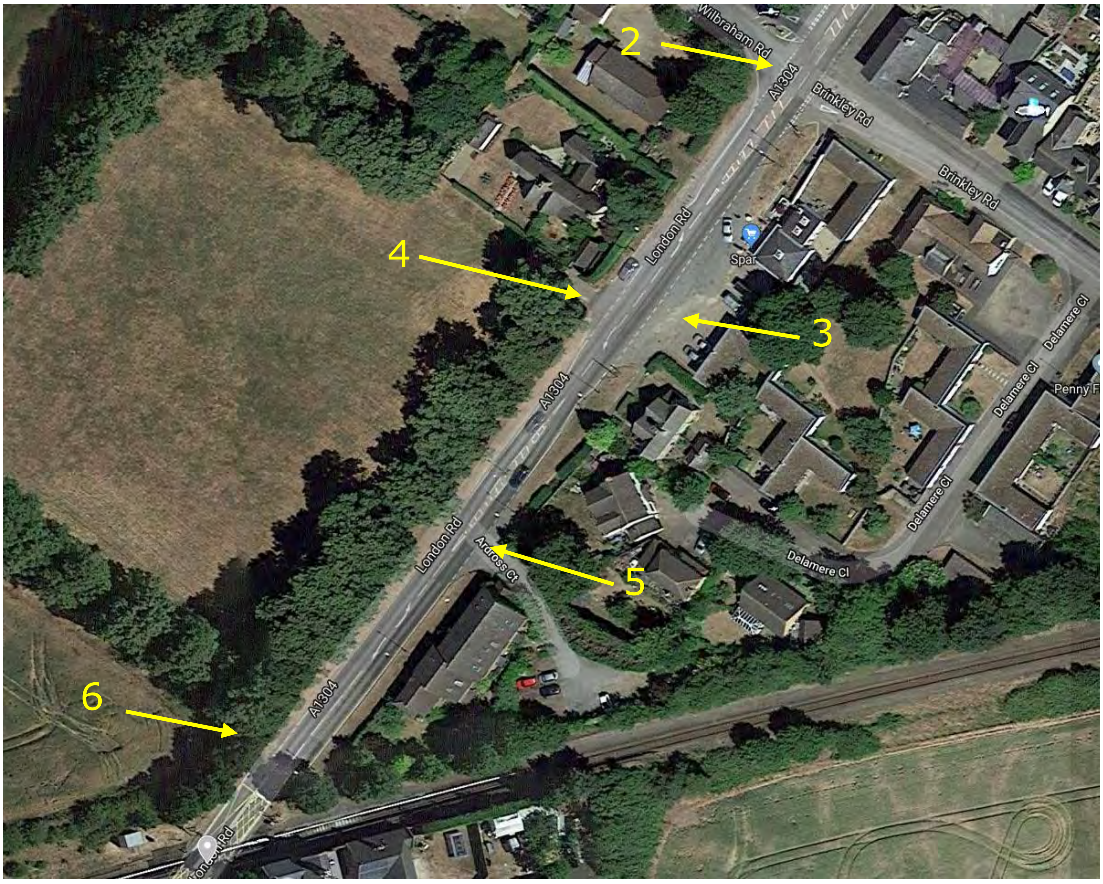


Figure 26 View approaching crossing from the north - distant

Figure 27 View approaching crossing from the north - intermediate

Figure 28 View approaching crossing from the north - intermediate

Figure 29 View approaching crossing from the north - near

Figure 30 Crossroads

Figure 31 Shop parking on left

Figure 32 Gate on right

Figure 33 Ardross Court on left

Figure 34 Gate on right

Figure 35 Crossing surface

Figure 36 Crossing skew 35^{0}

2.5 Impact of low sun on the crossing

Six Mile Bottom level crossing is a northeast-southwest facing crossing (for the road), therefore road users are potentially affected by sun glare.

Below, is the output from the SunCalc application, which has been used to identify the line of the sun at sunrise and sunset at times of year when low sun would align with the road approaches. The shortest and longest day are shown in *Figure 37*.

The thin orange curve is the current sun trajectory, and the yellow area around is the variation of sun trajectories during the year. The closer a point is to the centre, the higher is the sun above the horizon.

The yellow line shows the direction of sunrise; the dark orange line the direction of sunset and the mid orange line the direction at a selected time of day (shown by the orange circle above the satellite image).

Figure 37 Suncalc diagrams

Shortest Day

Longest Day

Northbound approach

There is one potential issue with low sun when approaching the crossing northbound:

1. In the winter, the setting sun would shine towards the RTLs, potentially washing them out. The vehicle approach speed is quite high however there are trees and buildings south of the crossing to reduce the impact of this and there is no gradient. Whilst the crossing is not currently provided with LED type RTLs, it has extended hoods to mitigate the impact of this problem.

Southbound approach

There is one potential issue with low sun when approaching the crossing southbound:

1. In the winter, the setting sun would be straight behind the crossing, potentially causing glare. The vehicle approach speed is quite high however there are trees and buildings south of the crossing to reduce the impact of this and there is no gradient. The crossing has an anti-slip/anti-glare road surface; this has, however, worn off.

3 CROSSING USAGE

This section of the risk assessment discusses the current usage of the crossing and its history of accidents and incidents. It then considers proposed and potential future changes to the usage and assesses the safety impact.

3.1 Traffic census

A nine-day, 18-hour traffic census by continuous recording was carried out at the crossing between 20th and 28th April 2013. The following provides a summary of the results obtained of this census.

Train frequency	**Weekday**	36
	Saturday	34
	Sunday	1
Road closure (min:secs)	**Average**	00:39
	Maximum	01:21
Road vehicle frequency	**Busiest day**	8,635
	Average weekday	8,442
Blocking Back Observations		None
85th percentile speed (free flowing cars only)	**Northbound**	56.8
	Southbound	38.3
Pedestrian and cyclist frequency	**Busiest day**	55
	Average week day	28
Train Pedestrian Value (TPV)		5
Pedestrian Category		C (with fewer than 25 pedestrians per day)

The observed train, vehicle and pedestrian usage is presented in *Table 2,* and the results of a 30 minute census in 2019 are shown in *Table 3*; a comparison to a 30 minute census in 2019 is shown graphically for vehicles in *Figure 38,* and for pedestrians in *Figure 39*.

It is concluded from the 30-minute 'quick' census that there has not been a major change in usage since 2013.

The notable observations recorded in the report were:

- No Blocking back was observed.

Table 2 Traffic survey observed usage 2013

Census Site 26 - Six Mile Bottom Level Crossing			Totals per day										
			Vehicles							Non-vehicles			
Day		No. trains per day	Cars	Vans / small lorries	HGVs	Buses	Tractors	Motor cycles	Total	Pedal cycles	Herded animals and horses	Pedestrians	Total
Saturday	20-Apr-13	1	4,813	323	148	14	5	164	5,467	20	0	16	36
Sunday	21-Apr-13	0	4,023	193	66	26	2	177	4,487	49	0	6	55
Monday	22-Apr-13	34	6,508	936	338	17	7	55	7,861	11	0	13	24
Tuesday	23-Apr-13	34	7,184	997	306	17	7	85	8,596	21	0	15	36
Wednesday	24-Apr-13	34	7,236	952	330	25	13	68	8,624	9	0	17	26
Thursday	25-Apr-13	33	7,322	930	294	23	5	61	8,635	17	0	16	33
Friday	26-Apr-13	36	7,185	907	331	20	8	45	8,496	6	0	13	19
Saturday	27-Apr-13	34	4,949	335	142	11	4	96	5,537	19	0	2	21
Sunday	28-Apr-13	1	4,134	143	68	13	0	43	4,401	39	2	0	41
Highest		36	7,322	997	338	26	13	177	8,635	49	2	17	55
7 day average		24	6,360	743	258	18	6	65	7,450	17	0	11	29
Weekday average		34	7,087	944	320	20	8	63	8,442	13	0	15	28

Table 3 Traffic survey observed usage 30 minute census 2019

Metric	2013 census	Manual 30 min census	% Change	Conclusion
Total Pedestrians	0	0	N/A	Within expected range
Total vehicles	179	205	14.5%	Within expected range

Figure 38 Comparison to 2019 30 minute census - vehicles

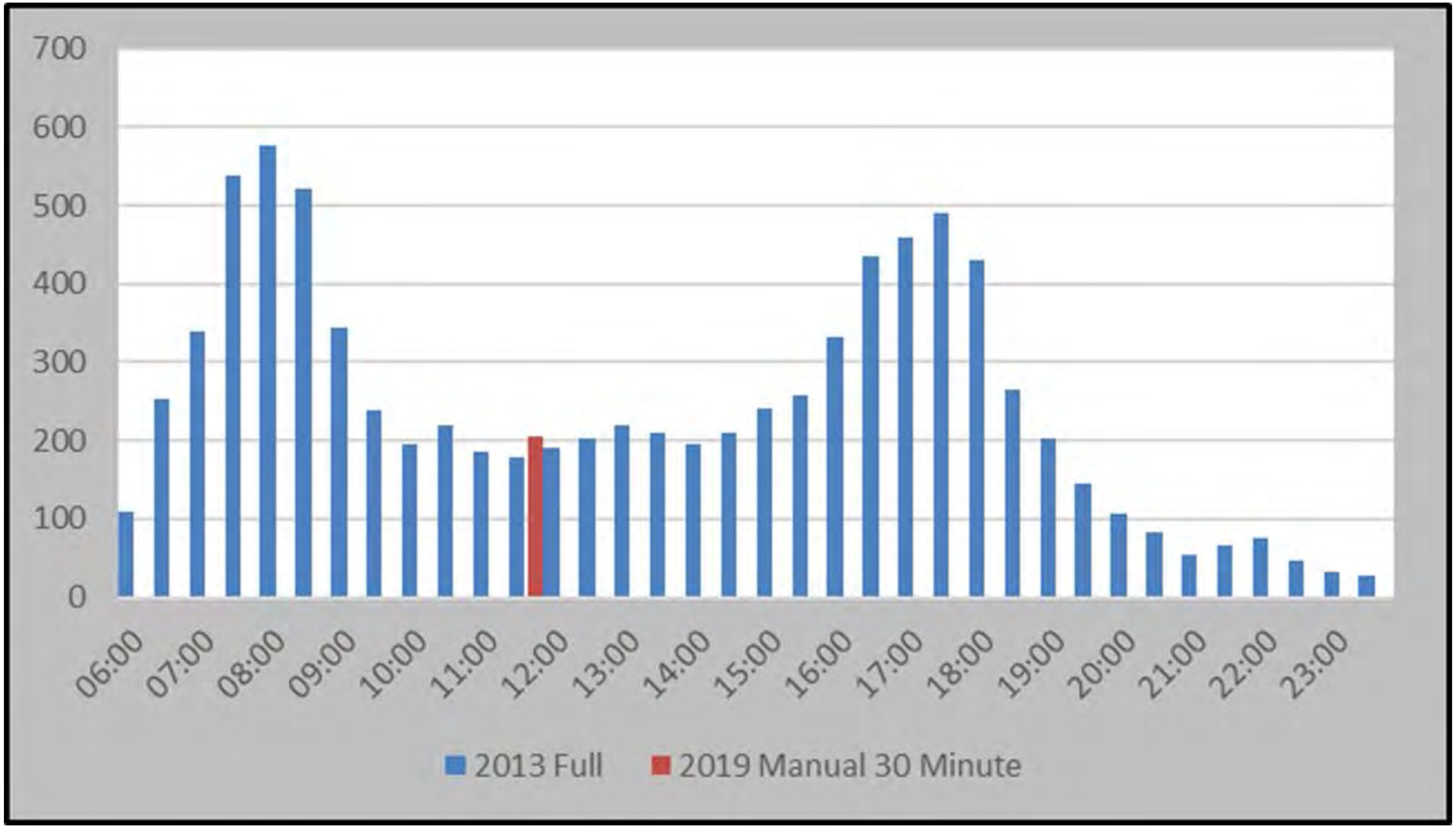
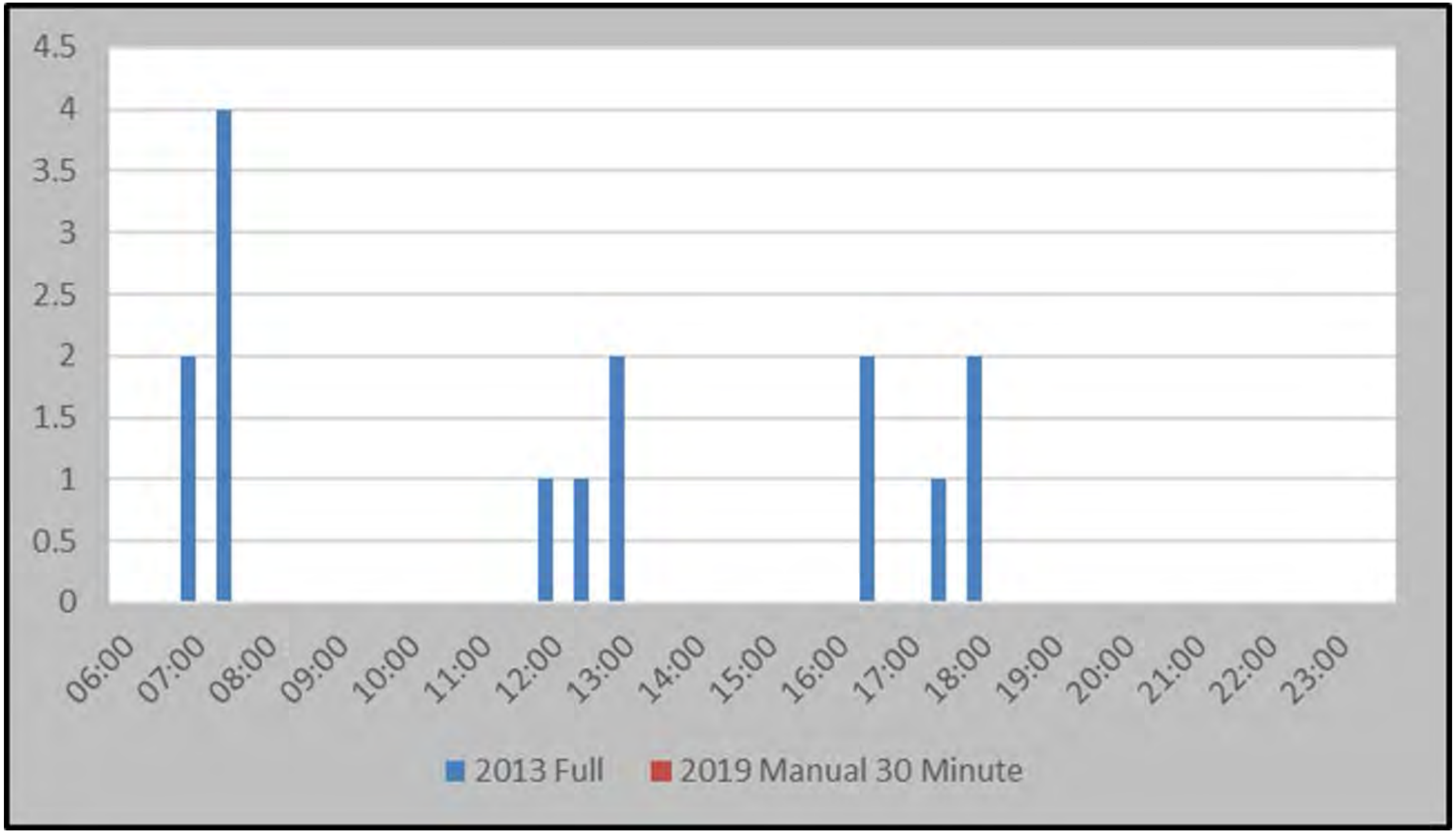


Figure 39 Comparison to 2019 30 minute census - pedestrians



3.2 Rail approach and usage

The crossing is located between Coldham Lane Junction and Haughley Junction. There is single track at the crossing, and it is not electrified. It is a moderately utilised stretch of line with a weekday average of 35 trains. There are approximately 34 passenger trains and one freight train in each direction. The line speed is 60mph along this stretch of track.

The rail approach to the crossing from the west

Trains travelling east are travelling in the Down direction towards Newmarket. The view from the crossing looking west is shown in *Figure 40*. The track is slightly curved on this approach.

For trains travelling in the Up direction, in the unlikely event of a derailment following hitting a vehicle on the crossing, the curve and disused platform may exacerbate the potential derailment consequences.

Figure 40 View of Down rail approach (looking towards Cambridge)

The rail approach to the crossing from the east

Trains travelling west are travelling in the Up direction towards Cambridge.

The view from the crossing looking east is shown in *Figure 41*. The track is slightly curved on this approach.

For trains travelling in the Down direction, in the unlikely event of a derailment following hitting a vehicle on the crossing, the curve and disused platform may exacerbate the potential derailment consequences.

Figure 41 View of Up rail approach (looking towards Newmarket)

3.3 Incident/near miss history

Ten years of Incident data have been analysed for the crossing, which was provided by RSSB (the data period ends in August 2016). A summary by incident type is listed in *Table 4*.

The crossing has a lower than average number of near miss/misuse incidents for the crossing type.

It is recognised that not all incidents are reported into RSSB's SMIS database.

Table 4 Summary of Incidents

SMIS classification	Incidents in data set	Average for LC type	Ratio to average for LC type
Train - striking road vehicle or gate at LC	0	0.10	0.00
Train - striking or being struck	0	0.15	0.00
Non-rail vehicles (incl. vehicle on line)	1	1.55	0.65
Person - personal accident	0	0.28	0.00
Level Crossing/LC equipment - misuse/near misses	4	5.36	0.75
Near miss - train with person (not at LC)	0	0.01	0.00
Train - striking animal	0	0.07	0.00
Animals - on the line	0	0.11	0.00
Person - trespass	0	0.12	0.00
Person - vandalism	0	0.25	0.00
Train - signal passed at danger	0	0.05	0.00
Train - running over LC (when unauthorised)	0	0.02	0.00
Irregular working (pre 25/11/2006)	0	0.05	0.00
Irregular Working	0	0.24	0.00
Level crossing - equipment failure	1	9.38	0.11
Signalling system - failure	0	0.11	0.00
Permanent way or works - failure	0	0.03	0.00
All incidents	6	18.10	**0.33**

Note, the data in this table is not normalised, therefore a crossing with high use would generally be expected to have higher ratios.

The following incidents are noteworthy at the crossing:

- One reported incident of a '*near miss*' with a road vehicle;
- One reported incident of a road vehicle zig-zagging the barriers;

- Two reported incidents of a road vehicle striking a barrier (in one incident the vehicle crossed whilst the red light was flashing); and

- One reported incident of a barrier lowering between the cab and trailer of a road vehicle. Vehicle was close to but not on the track.

More recent SMIS data, for one year to 13th March 2019, shows one reported incident in which a road vehicle jumped the red lights, and struck and removed the Up side barrier.

3.4 Future demand and use of the level crossing

Any decision to install a level crossing needs to account for both the current use and any reasonably foreseeable increase in future demand that may affect the risk to passengers and the public.

Key factors that can affect the future use are:

- Planned increases to train services or train speeds;

- Local developments (e.g. opening schools, retail outlets, factories);

- Closure of adjacent level crossings, meaning that the road and pedestrian traffic of any closed crossings now use the one subject to assessment.

Under the South Cambridgeshire Local Plan[5] (Adopted Sept 2018), Six Mile Bottom is identified as an '*Infill Village*'. Residential development and redevelopment within the development frameworks of these villages will be restricted to scheme sizes of not more than 2 dwellings. In very exceptional circumstances, a slightly larger development (not more than about 8 dwellings) may be permitted where this would lead to the sustainable recycling of a brownfield site bringing positive overall benefit to the village.

Current approved planning applications in the vicinity of the crossing include:

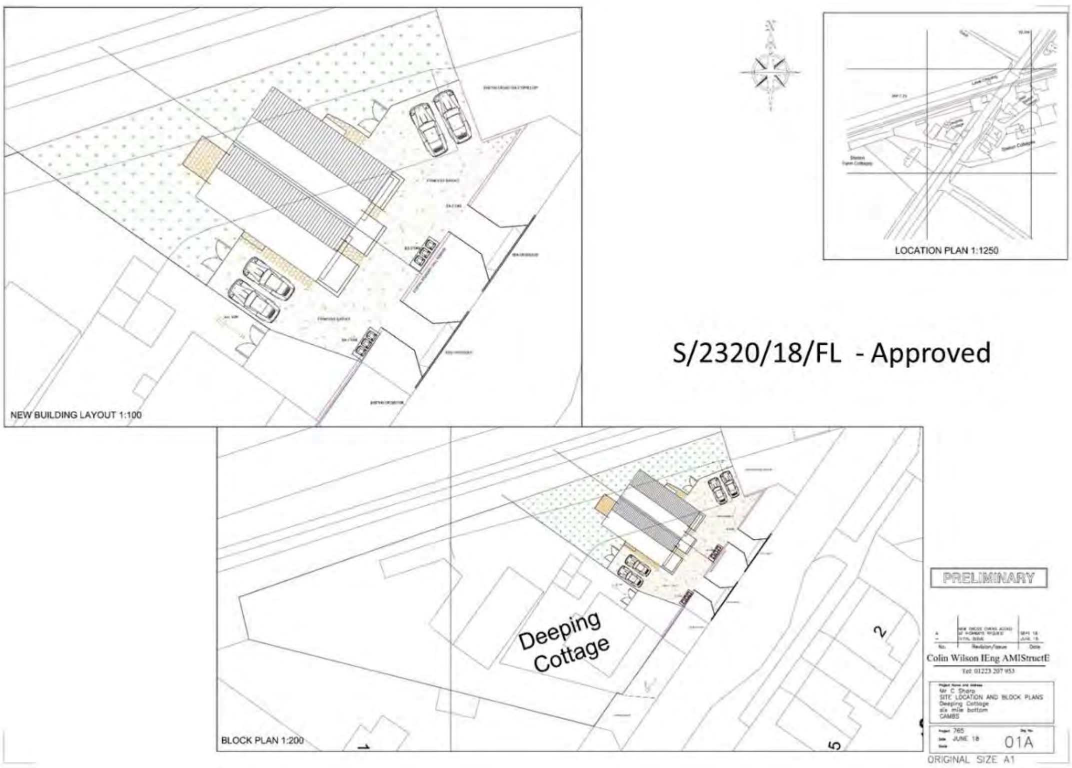
S/2400/18/FL - No. 4 and 5 Station Cottages, London Road, Six Mile Bottom. The construction of 1no. five bedroom chalet bungalow and 1no. two bedroom end of terrace dwelling. Removal of an existing single storey extension to no.5 Station Cottages and general renovation works to no.5 and no.4 Station Road.

S/2320/18/FL - Deeping Cottage Six Mile Bottom. Two new semi detached houses with parking and amenity.

These developments could result in slightly increased pedestrian use of the crossing.

Figure 42 Station Cottages

Figure 43 Deeping Cottage



It is important, as for all level crossings, that Network Rail ensures it is consulted about any change of use for the businesses and area adjoining the crossing and seeks compensation for further upgrade should anything be proposed which would significantly increase the usage of the crossing.

There are no proposals for increasing the line speed or providing new signalling infrastructure apart from that required to support any level crossing renewals. Train frequency increases are unlikely on this single line, unless a project to redouble the line to extend East – West rail services to Newmarket goes ahead; this project is currently at a very early stage.

Road closure time predictions

Road closure time is an important parameter that impacts level crossing risk as well as utility. This is because a high road closure time can cause aggravation and frustration for users which can lead to increased misuse.

Sotera has used a fairly simple model to estimate the potential impact of any upgrade to an MCB-type fall barrier crossing (MCB-OD or MCB-CCTV). For Six Mile Bottom this suggests that the busiest hour road closure time would increase from about 2% now to about 9% as shown in *Figure 44*. The average daytime road closure time is shown in *Figure 45*.

Figure 44 Road closure time in the busiest hour

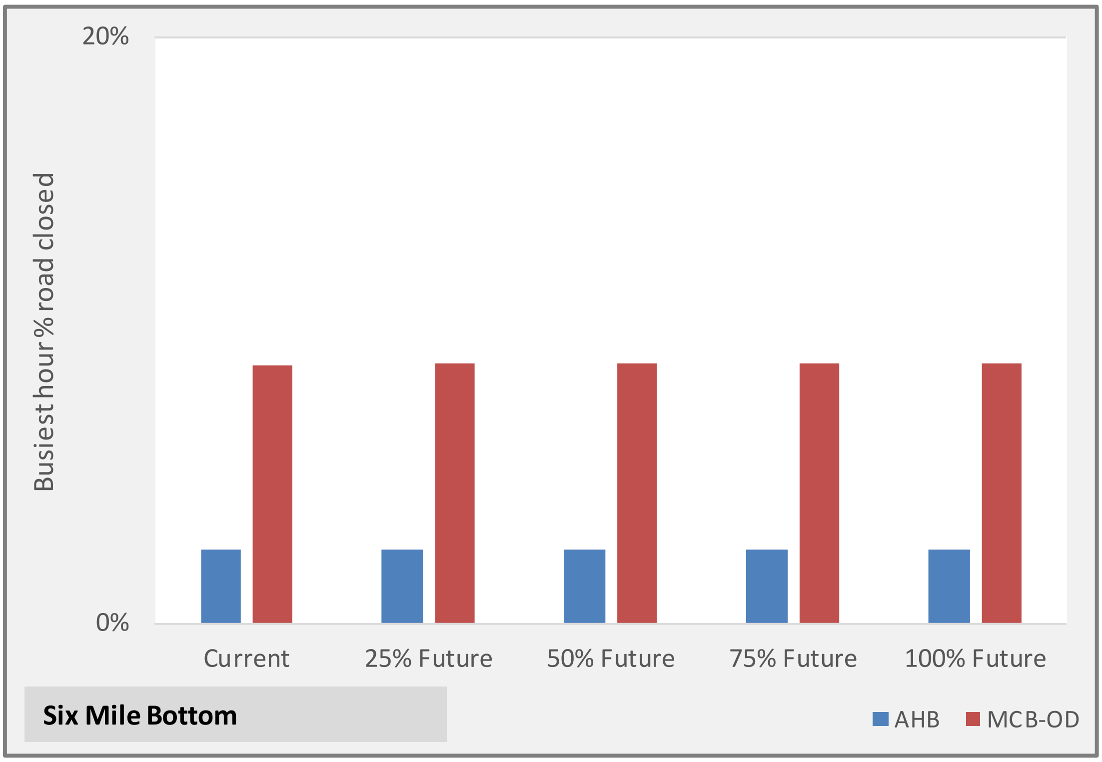
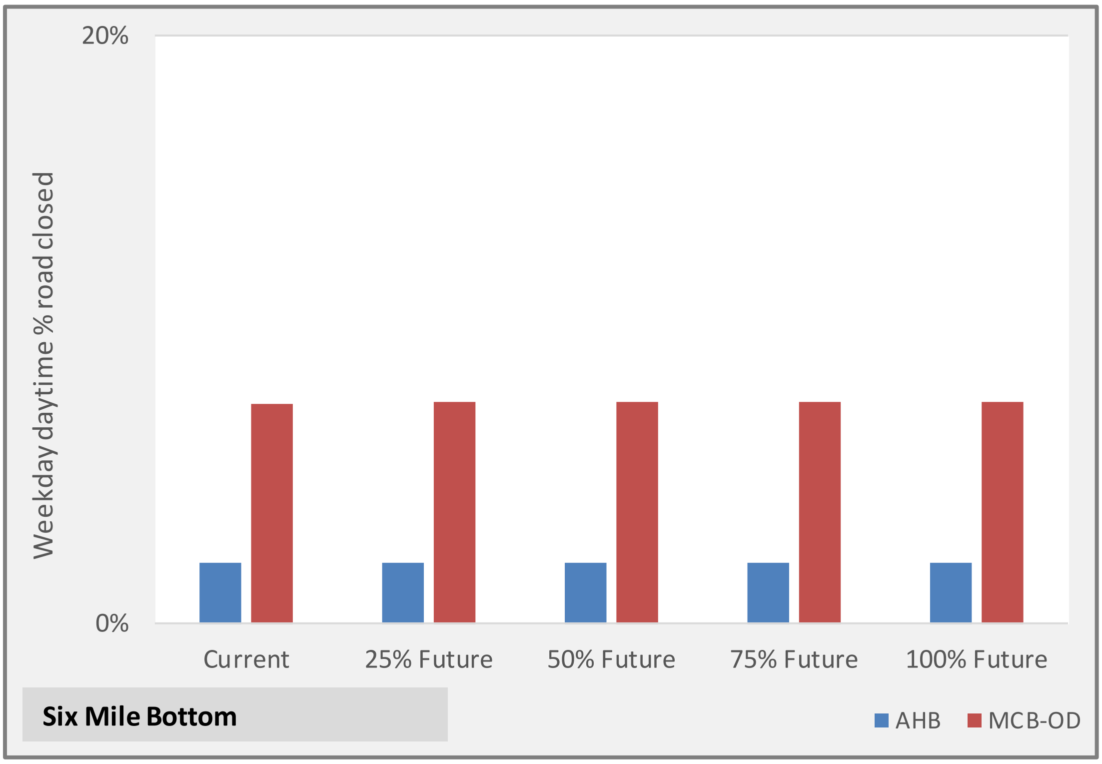


Figure 45 Average daytime road closure time



4 OPTIONS ASSESSMENT

Sotera carried out an initial assessment of options for the crossing, which was then reviewed and updated in workshops with Network Rail staff. The results of the assessment are described in this section.

4.1 Options assessment workshops

The attendees of the initial workshop at One Stratford Place on 8th April 2019 were as follows.

Present	Role
David Swift	Project Engineer Signalling
Bode Asabi	Project Manager
Ray Spence	Senior Delivery Manager
Charles Muriu	Asset Engineer
Nathan Garratt	DPE
Brendan Lister	LCM
Ben Chipman	Level Crossing Designer
Chris Chapman	Sotera, Workshop Chair
David Harris	Sotera, Workshop Secretary

Following this initial workshop, The Safety Review Panel commented that a more robust consideration should be made of a new type of full barrier level crossing (AHB+), which is being developed by Network Rail. The basic premise of this type of level crossing is envisaged to be an adaptation of the existing AHB crossing type, adding exit barriers whilst retaining the AHB's train approach initiated method of operation. Road closure times would be comparable with those of existing AHB level crossings. The lowering function of the exit barriers would be controlled by obstacle detection technology.

As such two further workshops were held:

i) To understand better the functionality of AHB+ level crossings and the progress of the AHB+ development project;

ii) To assess the potential benefits of AHB+ at crossings at the specific crossings that were proposed for upgrade as part of the Cambridge resignalling and recontrol project.

The attendees at the first AHB+ workshop on 9th September 2019 were:

Present	Role
Bode Asabi	Project Manager
Nathan Garratt	DPE
Brendan Lister	LCM
Chris Chapman	Sotera, Workshop Chair
Ben Chipman	Level Crossing Designer
Gavin Scott	RAM Signals Anglia
Sam Rose	Graduate
Paul Fletcher	Signaller / Project Operations Interface Specialist
Paige Skinner	Scheme Project Manager
Darren Witts	STE Principal Engineer
Will Cavill	Principal Designer

The attendees at the second AHB+ workshop on 25th October 2019 were:

Present	Role
Bode Asabi	Project Manager
Nathan Garratt	DPE
Brendan Lister	LCM
Chris Chapman	Sotera, Workshop Chair
Ben Chipman	Level Crossing Designer
Gavin Scott	RAM Signals Anglia
Sam Rose	Graduate Engineer
Paul Fletcher	Signaller / Project Operations Interface Specialist
Paige Skinner	Scheme Project Manager
Darren Witts	STE Principal Engineer
John Prest	Route Level Crossing Manager
Charles Muriu	Asset Engineer
Gabrielle Hodlaun	Delivery Manager
Harry Newgas	Graduate Engineer
Isaac Dozen-Anane	Assistant Project Engineer
Rebecca Wiecigroch	Asset Engineer - Signalling

4.2 Assessment of AHB+

Overall risk benefit

Currently the All Level Crossing Risk Model (ALCRM) does not include an assessment of AHB+ and does not include a breakdown of AHB hazards to enable such an assessment to be made. In order to make an assessment of potential benefits of AHB+, RSSB's Safety Risk Model (SRM) v8.5.0.2 [(13)] can be used. The risk at an AHB level crossing is broken down into 66 contributory events in *Table B1* of the SRM. The most significant contributors to risk at an AHB crossing are shown in *Table 6*. It can be seen that not all risk contributors are expected to be affected by fitment of AHB+ e.g. '*RV struck by train - on AHB - RV stranded/failed on LC*' is not expected to be affected by the fitment of the additional barrier as there are no protecting signals with which to stop a train. One of the highest contributors to risk at an AHB level crossing is, however, '*MOP (non-trespasser) pedestrian or cyclist struck/crushed by train on AHB - ignores lights/barriers*' and it is reasonable to assume that an AHB+ type crossing, which would have an offside barrier lowering as the same time as the entrance barrier, would provide a greater deterrent to level crossing users who might use the open off side to traverse the railway with the lights on and barriers down. In this instance, a 75% reduction in risk from this source is estimated.

Of the 66 AHB contributors identified in the SRM, the following change in risk was estimated for AHB+:

- 10 were considered to be reduce
- 3 were considered to increase (additional barriers likely to result in more strikes on people)
- 53 were considered to be similar (no change in risk estimated).

The risk contributors for which change is predicted is shown in *Table 7*. It was noted in the first workshop that if the off-side barrier was not fully lowered, the train driver would report it as a '*failure*'. As such, it is expected that AHB+ level crossings will only be installed in locations where the off-side OD controlled barriers very rarely fail to lower i.e. AHB+ will only be fitted to crossings that do not have high peak pedestrian/cyclist use, not at a busy station or where there is pedestrians are not going to be able to traverse the crossing in time due to a long traverse distance or slow/vulnerable users. As such, the benefits of AHB+ is assessed on this basis.

Generally, the following factors are taken into account:

- The '*second train coming*' benefits are taken to be greater than for first train as the likelihood that the off-side barriers have lowered is greater;
- Whilst an AHB+ is not considered suitable for a busy station environment, the benefits at a station would be considered lower

as there is an incentive to cross to catch a train on the opposite platform;

- Road vehicles generally get a higher level of benefit than pedestrians/cyclists as it will be more of a violation to drive through a barrier than to duck under or climb the barrier;
- A minor benefit is taken for users that have failed to observe the level crossing, which is likely to be associated with those that approach from the off side; and
- A disbenefit is predicted for users being potentially struck by barriers.

It should be noted that existing AHB precursors from the SRM have been modified; there may be new error mechanisms such as users going onto the crossing while the barriers are held up incorrectly believing that the crossing is safe. Such potential precursors have not been assessed.

Taking these benefits into consideration, the risk at all current AHB level crossings and total benefit if all these crossings were upgraded to AHB+ is shown in *Table 5*. It can be seen that overall, upgrade to AHB+ is expected to approximately halve the risk compared to an AHB.

Table 5 Overall risk benefit if all AHB level crossings were upgraded to AHB+.

Parameter	SRMv8.5 Risk (FWI/yr)
AHB	1.62
AHB+	0.84
AHB+ Benefit	0.78
% AHB+ Benefit	48%

Table 6 Most significant contributors to risk at an AHB level crossing

Hazardous Event Code	Precursor code	Cause precursor description	Risk cont. (FWI/year)	% of Total	Assessment of AHB reduction in risk	Comment
HEM-27E	KAHB-WALKH	MOP (non-trespasser) pedestrian or cyclist struck/crushed by train on AHB - ignores lights/barriers	0.627	39%	75%	AHB+ barriers will be down in vast majority of instances such that a pedestrian would have to climb over or under barrier, rather than walk around the barrier.
HET-10E	VAHB-DELTH	RV struck by train - on AHB - zigzags barriers	0.245	15%	85%	AHB+ barriers would be lowered in vast majority of instances to prevent a zig zagging car being struck by the approaching train. There may be some unreliability of OD and small objects may prevent barrier lowering. Note that there is no 'fail safe' for OD system – if there is an OD system failure, the exit barrier will not lower.
HET-10E	VAHB-STRTE	RV struck by train - on AHB - RV stranded/failed on LC	0.090	6%		
HET-10E	VAHB-EBLTE	RV struck by train - on AHB - RV incorrectly on LC due to environmental factors/driver error: user brakes too late	0.068	4%		
HEM-27E	KAHB-2TRAH	MOP (non-trespasser) pedestrian or cyclist struck/crushed by train on AHB - second train coming	0.063	4%	85%	AHB+ barrier will be down in vast majority of instances by the time a second train arrives so pedestrian would have to climb over or under a barrier.
HET-10E	VAHB-ASETH	RV struck by train - on AHB - fails to observe level crossing	0.050	3%	2%	Additional barrier would give a small increase in visibility if approaching from the off-side
HET-10E	VAHB-VANTE	RV struck by train - on AHB - RV deliberately placed on level crossing	0.043	3%		
HET-10E	VAHB-ESNTE	RV struck by train - on AHB - RV incorrectly on LC due to environmental factors: sunlight obscures crossing/lights	0.043	3%		
HET-10E	VAHBRTA-TE	RV struck by train - on AHB - RV incorrectly on LC due to RTA	0.036	2%		
HEM-27E	KAHB-SLOWH	MOP (non-trespasser) pedestrian or cyclist struck/crushed by train on AHB - slow moving/short warning	0.035	2%		

Table 7 Changes in Risk with AHB +

Hazardous Event Code	Precursor code	Cause precursor description	Risk cont. (FWI/year)	% of Total	Assessment of AHB+ reduction in risk	Comment
HET-10E	VAHB-ASTTH	RV struck by passenger train - on AHB - second train coming	1.15E-03	0.1%	90%	AHB+ barrier will be down in vast majority of instances by the time a second train arrives so vehicle would have to drive through barrier. There may be some unreliability of OD and small objects may prevent barrier lowering.
HET-11E	VAHB-ASTTH	RV struck by freight train - on AHB - second train coming	1.36E-04	0.0%	90%	AHB+ barrier will be down in vast majority of instances by the time a second train arrives so vehicle would have to drive through barrier. There may be some unreliability of OD and small objects may prevent barrier lowering.
HEM-27E	KAHB-2TRAH	MOP (non-trespasser) pedestrian or cyclist struck/crushed by train on AHB - second train coming	0.063	3.9%	85%	AHB+ barrier will be down in vast majority of instances by the time a second train arrives so pedestrian would have to climb over or under a barrier.
HET-10E	VAHB-DELTH	RV struck by passenger train - on AHB - zigzags barriers	0.245	15.1%	85%	AHB+ barrier will be down in vast majority of instances by the time a zig zagging car that would be hit by a train arrives. Unreliability of OD and small object being detected. There may be some unreliability of OD and small objects may prevent barrier lowering. Note that there is no 'fail safe' for OD system – if there is an OD system failure, the exit barrier will not lower.
HET-11E	VAHB-DELTH	RV struck by freight train - on AHB - zigzags barriers	0.029	1.8%	85%	AHB+ barriers would be lowered in vast majority of instances to prevent a zig zagging car being struck by the approaching train.
HEM-11E	PAHB-2TRAH	Passenger struck/crushed by train on AHB adjacent to station - second train coming	0.030	1.9%	75%	AHB+ barrier will be down in vast majority of instances by the time a second train arrives so pedestrian would have to climb over or under a barrier. There is an Incentive to cross at a station to join the arriving train.

Hazardous Event Code	Precursor code	Cause precursor description	Risk cont. (FWI/year)	% of Total	Assessment of AHB+ reduction in risk	Comment
HEM-27E	KAHB-WALKH	MOP (non-trespasser) pedestrian or cyclist struck/crushed by train on AHB - ignores lights/barriers	0.627	38.7%	75%	AHB+ barriers will be down in vast majority of instances such that a pedestrian would have to climb over or under barrier, rather than walk around the barrier.
HEM-11E	PAHB-WALKH	Passenger struck/crushed by train on AHB adjacent to station - ignores lights/barriers	5.41E-03	0.3%	50%	AHB+ barriers will be down in vast majority of instances such that a pedestrian would have to climb over or under barrier, rather than walk around the barrier. There is an incentive to cross at a station as the passenger may attempt to join the arriving train.
HET-10E	VAHB-ASETH	RV struck by train - on AHB - fails to observe level crossing	0.050	3.1%	2%	Additional barrier would give a small increase in visibility if approaching from the off side
HET-11E	VAHB-ASETH	RV struck by train - on AHB - fails to observe level crossing	5.90E-03	0.4%	2%	Additional barrier would give a small increase in visibility if approaching from the off side
HEN-44E	KEQUAHB-1H	MOP (non-trespasser) pedestrian or cyclist/motorcyclist struck/trapped by level crossing equipment on AHB - user error	9.38E-04	0.1%	-50%	Assumed that near side barriers are a threat to those entering of leaving the crossing while the off side barriers are a threat only to those entering the crossing
HEN-44E	KEQUAHB-3H	MOP (non-trespasser) pedestrian or cyclist/motorcyclist struck/trapped by level crossing equipment on AHB - other	9.38E-04	0.1%	-50%	
HEN-44E	KEQUAHB-2H	MOP (non-trespasser) pedestrian or cyclist/motorcyclist struck/trapped by level crossing equipment on AHB - incorrect use	4.69E-04	0.0%	-50%	

Level crossing specific risk benefit

The risk reduction at a particular crossing will be dependent at the risk contributors at that crossing. The following scaling factors were taken to apply:

Pedestrian/cyclist hazards were taken to scale with:

- The number of pedestrian/cyclists relative to the average at AHB level crossings;
- The number of trains relative to the average at AHB level crossings.

Vehicular hazards were taken to scale with:

- The number of pedestrian/cyclists relative to the average at AHB level crossings;
- The number of trains relative to the average at AHB level crossings.

Second train coming hazards were taken to scale with the square of the number of trains relative to the average at AHB level crossings unless there was a single track, in which case, the factor was set to zero.

Road approach speed was used to generate the scaling factors for the *brakes too late* hazard. The methodology used is summarised in *Table 8*. The value for each level crossing is the average of the factors for the two approaching directions.

Table 8 Road approach speed factor

85% tile Speed (mph)	Road approach speed factor
<20	0.1
20-30	0.2
30-40	0.5
40-50	2
50-60	6
>60	10
>60 long straight	15

The level crossing usage from the 2018 census and scaling factors for the Cambridge level crossings are shown in *Table 9*. The risk benefit from upgrading to AHB+ can then be calculated and the benefit to cost ratio for renewing as an AHB+ level crossing as compared with renewing as an AHB can also be calculated assuming the renewal costs are as follows:

- AHB renewal cost £1.46m
- AHB+ renewal cost £2.007m

These costs are based on the CP6 unit rates for level crossings and, in particular, the AHB+ cost was based on the cost of an MCB-OD level crossing without lower LIDAR.

A benefit to cost ratio greater than 1 in *Table 10* does not indicate that AHB+ is the preferred upgrade. Indeed, at very high risk level crossings, it is likely that the preference will be to upgrade to a protected full barrier crossing (MCB-OD or MCB-CCTV), as this will give a higher level of safety benefit. The risk for each crossing as an AHB, AHB+ and as an MCB-OD is shown in *Figure 46*.

The cost benefit analysis for upgrading to an MCB-OD type crossing relative to upgrading to an AHB+ type level crossing is shown in *Table 11*. The second to last column in this table compares the safety benefits and costs for upgrading to an MCB-OD type with upgrading to AHB+. A higher value indicates that and MCB-OD type crossing is justified from a safety perspective and a value less than 1 indicates that investing in and MCB-OD is disproportionate to the safety benefit. However, whether cost is grossly disproportionate also needs to be considered, and as such, other factors such as a road closure time and modifying signal locations are likely to be factors.

Brinkley Road and Six Mile Bottom are only 250m apart and therefore need to be considered together. Six Mile Bottom is the higher risk crossing and is the primary concern for an upgrade. From *Table 11,* it can be seen that the cost of installing MCB-OD at Six Mile Bottom is not justified based on safety benefits alone due to the significant signalling costs. As such, upgrade to AHB+ may be considered a cost-effective upgrade path. If an upgrade to MCB-OD is preferred, there may be concerns that there will be two types of level crossing (MCB-OD at Six Mile Bottom and AHB at Brinkley Road), which is a potential source of signaller/driver error if the train has to talked past the protecting signal.

Table 9 Scaling factors for individual AHB level crossings

Level crossing	Daily usage 2018			Factors 2018					
	Vehicles	Pedestrians/ cyclists	Trains	Vehicles	Pedestrians/ cyclists	Trains	Trains[2] (Second train coming)	Station	Road approach speed
Milton Fen	77	366	178	0.05	4.0	2.4	5.5	0	0.1
Waterbeach	4,880	889	178	3.0	9.7	2.4	5.5	Yes	0.4
Dimmocks Cote	6,330	133	178	3.8	1.4	2.4	5.5	0	6.0
Six Mile Bottom	7,826	99	35	4.7	1.1	0.5	0.0	0	3.3
Brinkley Road	1,626	60	35	1.0	0.6	0.5	0.0	0	4.0
Black Bank	1,378	59	127	0.8	0.6	1.7	2.8	0	4.0
Croxton	4,466	15	67	2.7	0.2	0.9	0.8	0	10.5
Meldreth Road	1,455	124	194	0.9	1.4	2.6	6.6	0	1.3

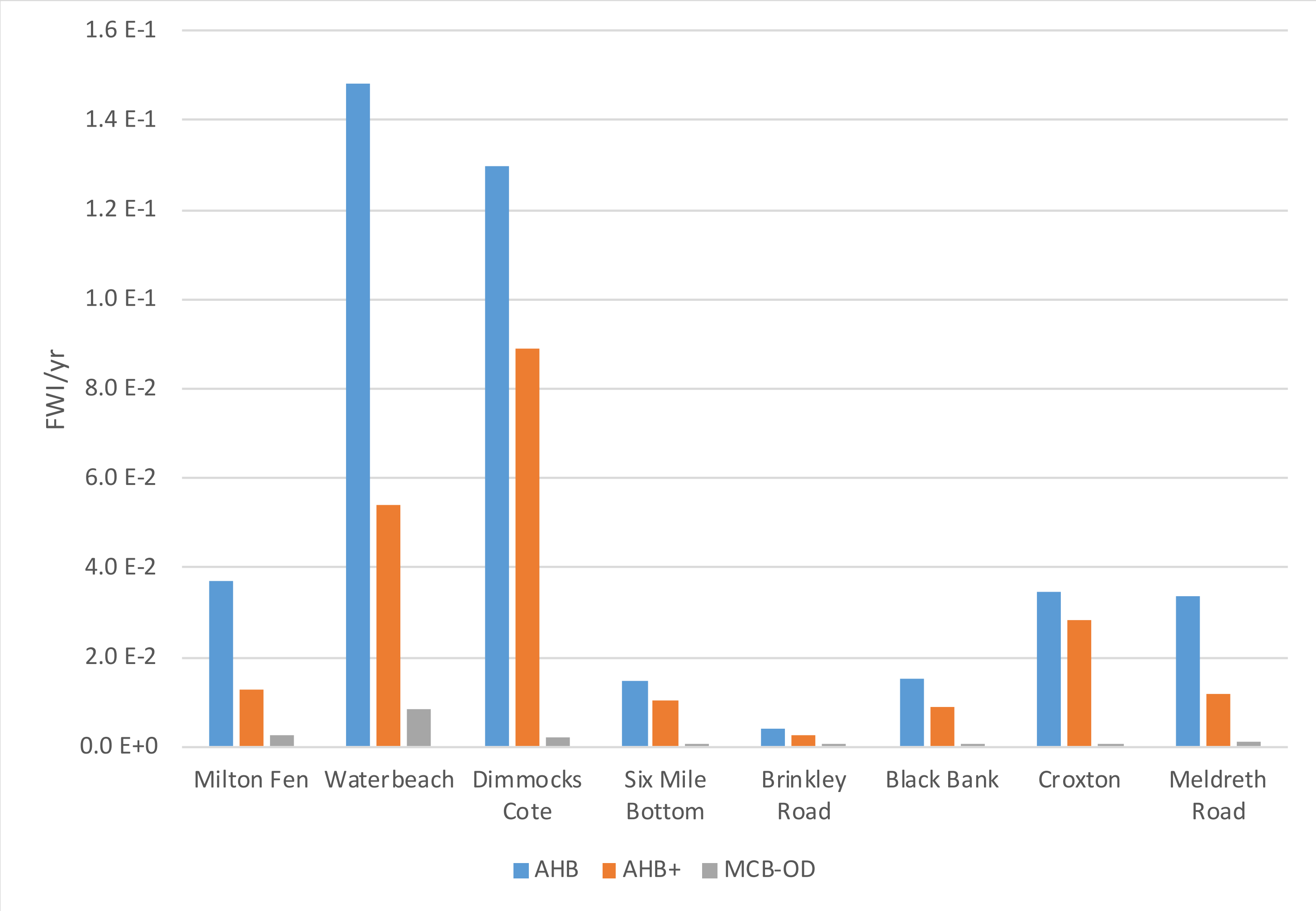
Table 10 Risk benefit and cost benefit analysis for renewing as AHB+ relative to AHB

Level crossing	ALCRM Risk as AHB	%Risk Benefit for AHB+ from SRM	Comments	Risk as AHB+	AHB+ Risk Benefit	NPV of safety benefit over 30 years (AHB+)	Benefit to cost ratio for renewing as AHB+ relative to AHB)
Milton Fen	3.7 E-2	65%	High pedestrian and rail use	1.3 E-2	2.4 E-2	£1,145,935	2.09
Waterbeach	1.5 E-1	64%	High level of benefit for AHB+ but currently at a station and so probably would not be suitable for fitment as AHB+	5.4 E-2	9.4 E-2	£4,466,196	8.16
Dimmocks Cote	1.3 E-1	31%	Does not address late braking	8.9 E-2	4.1 E-2	£1,929,555	3.53
Six Mile Bottom	1.5 E-2	31%	No second train coming benefit (single track)	1.0 E-2	4.6 E-3	£217,390	0.40
Brinkley Road	4.0 E-3	36%	No second train coming benefit (single track)	2.6 E-3	1.5 E-3	£68,963	0.13
Black Bank	1.5 E-2	40%	Does not address late braking e.g. southwest bound traffic. Vehicles do slow down for crossing.	9.0 E-3	6.1 E-3	£288,859	0.53
Croxton	3.4 E-2	17%	Does not address late braking etc.	2.8 E-2	6.0 E-3	£285,008	0.52
Meldreth Road	3.4 E-2	65%	Addresses second train coming; relatively high pedestrian use	1.2 E-2	2.2 E-2	£1,047,676	1.91

Table 11 Cost benefit analysis for renewing as AHB+ relative to renewing as MCB-OD

Level crossing	NPV of safety benefit over 30 years (MCB-OD)	%Risk Benefit (AHB to MCB-OD)	Cost of providing MCB-OD or MCB-CCTV	MCB-OD Cost justification	Benefit to cost ratio (AHB to MCB-OD)	Benefit to cost ratio (Difference between upgrading MCB-OD and AHB+)	Comments
Milton Fen	£1,627,290	93%	£2,482,532	1 SEU	0.66	1.01	Some concern about vulnerable users with AHB+ (4 uses by wheelchair user and 1 scooter in 9 days)
Waterbeach	£6,610,690	94%	£2,932,532	2 SEUs	2.25	2.32	AHB + at a station not likely to be preferred. May be suitable if station is moved
Dimmocks Cote	£6,059,183	98%	£4,732,532	Six additional signals 6 SEUs	1.28	1.52	Much higher benefit for full barrier level crossing
Six Mile Bottom	£691,693	98%	£3,832,532	4 SEUs	0.18	0.26	To be considered in conjunction with Brinkley Road
Brinkley Road	£184,971	97%	£2,032,532	0SEUs - assume signals already in place for Six Mile Bottom	0.09	4.58	Brinkley Road would not cost significantly more to renew as MCB-OD if the signals have already been put in place for Six Mile Bottom. Mix of crossing types for protecting signal if not upgraded.
Black Bank	£694,912	97%	£3,157,532	2 new signals and 2 signal reheads (2.5 SEUs)	0.22	0.35	If signals installed at Black Bank, a train stopped at the signal would stand over adjacent AHB level crossings introducing a new hazard at those AHB level crossings
Croxton	£1,617,385	99%	£3,832,532	4 SEUs	0.42	0.73	Only a full barrier crossing with signal protection addresses the main hazards at Croxton level crossing and facilitates the removal of the TSR. Skew crossing and so any pedestrians may hold up exit barrier.
Meldreth Road	£1,543,040	96%	£2,032,532	0SEUs	0.76	19.54	The only benefit of AHB+ relative to a full barrier crossing is the shorter road closure time

Figure 46 Chart showing risk as AHB, AHB+ and MCB-OD



4.3 Options for closure or alternate level crossing designs

Options Assessment

The following options were considered:

- Crossing closure (via diversions);
- Crossing closure with a pedestrian bridge only provided;
- Crossing closure with an underpass for road vehicles and pedestrians;
- Crossing closure with a full road bridge provided;
- Crossing closure with a full road bridge provided in a scheme also enabling closure of Brinkley Road AHB;
- Retain 'As-Is' as AHB type;
- Renew as ABCL;
- Renew as an automatic full barrier (AHB+);
- Upgrade to an MCB-CCTV or MCB-OD, which provide the highest level of protection as a level crossing.

Table 12 provides a summary of the results of the workshop. The main arguments are then discussed below.

In the table the residual safety risk of each option has been converted into monetised safety cost in Net Present Value (NPV) terms over the life of the crossing. This is based on the VpF for 2018 published by RSSB and a safety discount rate of 1.5%. It represents the total financial value of safety for accidents at the crossing over a life of 30 years should that option be pursued. It includes minor (injury) accidents such as slips, trips and falls as well as more serious accidents involving vehicles or pedestrians being struck by trains.

Table 12 Closure / level crossing type assessment

Option/ Crossing type	ALCRM			Feasibility	Cost		Justification for cost estimate
	2019 usage						
	FWI	Score	NPV (30)		Capital	Annual	
Current crossing type (AHB)	1.5E-02	E2	£708,421	Current level crossing is assessed to present a high level of risk, it is contrary to NR strategy to renew such a high risk crossing as AHB. Doing resignalling work in this area may not be able to retain as is considering the high risk. LCM never witnessed blocking back, maybe could occur on Newmarket race days when much busier. Housing development might give a small increase in the number of pedestrians	£1,460,010	£16,933	Standard cost, if renewal is required. Renewal 2018 / SICA 2029.
Closure	0		£0	Six Mile Bottom is on a busy 'A' road (A1034) which links Newmarket and the M11 (via the A11), therefore closure without providing an alternative means of access is not viable.			
Closure + pedestrian bridge	0		£0	Main use is road vehicles so would not enable closure.			
Closure + road bridge	0		£0	A bridge is not likely to feasible either on-line or off-line at this location due to the number of properties in close vicinity to the crossing and the lack of an available off-line route.	£10m+	£2,746	Standard £7m + additional compensation and building work for local properties. Also skew increases length of bridge and hence cost. Assume £10m+.
Closure + underpass	0		£0	See above - as bridge.			

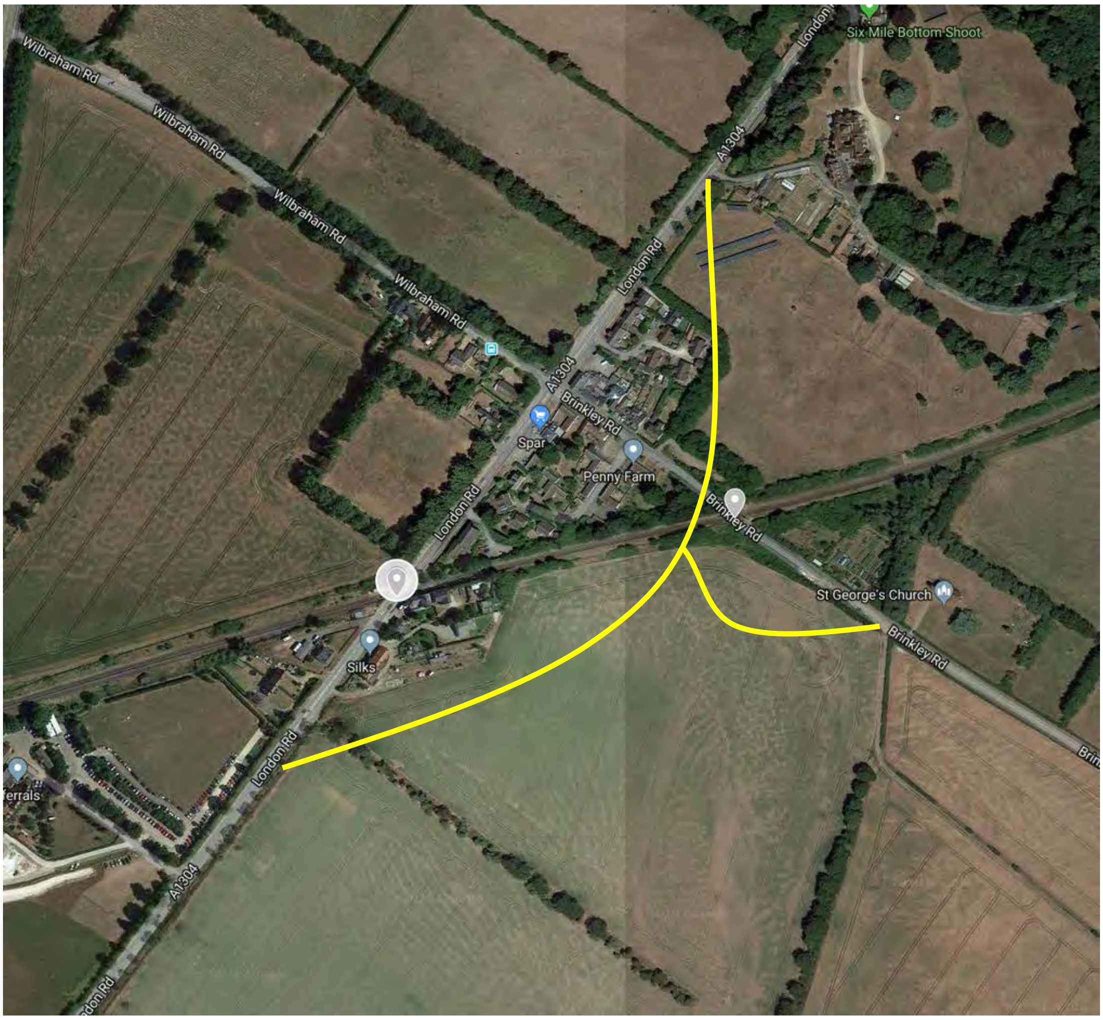
Option/ Crossing type	ALCRM 2019 usage FWI	Score	NPV (30)	Feasibility	Cost Capital	Annual	Justification for cost estimate
Closure + link road also enabling closure of Brinkley Rd	0		£0	2013 scheme bypassed Six Mile Bottom with a link road bridging at Brinkley Road and re-joining A1304 north of the Brinkley Road junction Spur bridge to meet Brinkley Road Likely need at least one ramped bridge as well	£15m		Broad estimate: £10m bridge, £2.1m ramped footbridge plus link roads, junctions and land purchase
ABCL	-	-	-	Not a viable option due to the restriction in linespeed that would be necessitated (would require at least a 5mph line speed reduction)	£1,336,708	£16,933	
AHB+	1.0E-02		£491,030	May be a viable option at this crossing which is predominantly a vehicular crossing. From *Table 11*, it can be seen that the cost of installing MCB-OD at Six Mile Bottom is not fully justified by the safety benefits due to the significant signalling costs. As such, upgrade to AHB+ may be considered a cost-effective upgrade path although it would not offer the same level of safety benefit as MCB-CCTV/OD and given high risk as AHB. It is understood that the AHB+ project is in development with a trial site expected to be installed in 2020. It is understood that there is potential for further trial sites. The project risk of utilising a number of trial sites on this project due to the uncertainty of when AHB+ will be available to install as a renewal is a significant concern.	£2,007,185	£20,154	CP6 standard renewal costs for MCB-OD without lower LIDAR and no signalling costs
MCB-CCTV	3.5E-04	K6	£16,728	Feasible, although there is a need for additional protecting signals in both directions. Likely need to control this crossing together with Six Mile Bottom so if both CCTV or MCB-OD then may be 2 SEUs in total. Road closure time is unlikely to be problematic as single line limits the extent of any train frequency increase. Signaller workload impact tends to favour MCB-OD. If an upgrade to MCB-CCTV is preferred, there may be concerns that	£3,664,316	£54,265	CP6 standard renewal costs, 4 x SEUs required

Option/ Crossing type	ALCRM 2019 usage FWI	Score	NPV (30)	Feasibility	Cost Capital	Annual	Justification for cost estimate
				there will be two types of level crossing in the same signalling section (MCB-CCTV at Six Mile Bottom and AHB at Brinkley Road), which is a potential source of signaller/driver error if the train has to talked past the protecting signal.			
MCB-OD	3.53E-04	K6	£16,728	Feasible, although there is a need for additional protecting signals in both directions. Likely need to control this crossing together with Six Mile Bottom so if both CCTV or MCB-OD then may be 4 SEUs in total. Relatively level profile, although long distance due to skew may necessitate additional LIDAR. Within 20km Cambridge radio telescope planning zone. Road closure time is unlikely to be problematic as single line limits the extent of any train frequency increase. Concrete slab situated beneath ballast, issues tamping etc. If renew as MCB-OD may need UTX and concrete slab may be a problem. If an upgrade to MCB-OD is preferred, there may be concerns that there will be two types of level crossing in the same signalling section (MCB-OD at Six Mile Bottom and AHB at Brinkley Road), which is a potential source of signaller/driver error if the train has to talked past the protecting signal.	£3,832,532	£20,154	CP6 standard renewal costs, 4 x SEUs required

4.4 Conclusions regarding closure of the crossing

The first priority should be to close the crossing where possible. The only option identified that could be feasible is a major scheme to close Six Mile Bottom and Brinkley Road crossings via a bridge and new link roads (*Figure 47*).

Figure 47 Scheme to close Six Mile Bottom and Brinkley Road crossings



Since this scheme would likely cost £15m or more, the cost would be grossly disproportionate to the safety benefit compared with the alternative of renewing Six Mile Bottom as MCB-OD with a cost of about £3.8m and a moderate residual risk as can be seen from *Table 13*.

Table 13 ALCRM Risk at Six Mile Bottom and Brinkley Road crossings

		Current type			MCB-CCTV or MCB-OD		
Crossing	Type	FWI	Score	NPV_{30}	FWI	Score	NPV_{30}
Six Mile Bottom	AHB	1.5 E-2	E2	£708,421	3.5 E-4	K6	£16,728
Brinkley Road	AHB	4.0 E-3	E4	£190,959	1.3 E-4	J6	£5,988
Total		1.9 E-2		£899,380	4.8 E-4		£22,716
Six Mile Bottom MCB-OD / Brinkley Road AHB					4.4 E-3		£207,687

Significant train frequency increases are not expected at this location and a road closure time of about 9% in the busiest hour for an MCB-CCTV or MCB-OD type crossing would be sustainable.

It is therefore concluded that whilst closure of the crossing could be feasible, crossing renewal provides a more viable and cost-effective option.

4.5 Conclusion about crossing type

Retaining an AHB crossing would not be the preferred option as it presents a high level of 1.5 x 10^{-2} FWI per year. It is also exposed to hazards associated with a fast road approach. Renewal of a crossing with an ALCRM score of E2 as an AHB would also be contrary to Network Rail's strategy of upgrading high risk AHB crossings when renewal is required.

AHB+ may be a viable option at this crossing which is predominantly a vehicular crossing. Comparing the costs and benefits of upgrading Six Mile Bottom to MCB-OD or AHB+ in *Table 12*, it can be seen that the cost of installing MCB-OD at Six Mile Bottom is not fully justified by the safety benefits due to the significant signalling costs, although there would be potential to utilise the additional signals for an upgrade to nearby Brinkley Road crossing. As such, upgrade to AHB+ may be considered a cost-effective upgrade path although it would not offer the same level of safety benefit as MCB-CCTV/OD.

The AHB+ project is in development with a trial site expected to be installed in 2020; there may be potential for further trial sites. The project risk of utilising a number of trial sites on this project due to the uncertainty of when AHB+ will be available to install as a renewal is, however, a significant concern.

The preferred option is, therefore, to renew the crossing as MCB-CCTV or MCB-OD; both of these crossing types would offer significant risk reduction compared with AHB from 1.5 x 10^{-2} to 3.5 x 10^{-4} FWI per year.

Normally MCB-OD would be preferred over MCB-CCTV for workload reasons. The crossing is within the 20km Cambridge MERLIN radio telescope planning zone so precautions against interfering with this would need to be taken should MCB-OD Mk. 1 be provided; it is understood, however, that the project intends to use Mk2 radar and so proximity to the MERLIN telescope should not be an issue.

The choice between MCB-OD and MCB-CCTV is therefore likely to be made on the basis of feasibility and cost.

New protecting signals will be required for this crossing whichever option is taken. The Up direction protecting signal should be positioned on the approach to Brinkley Road crossing in a compliant location to facilitate any renewal of that crossing as MCB-CCTV or MCB-OD and to prevent trains being caused to stand over Brinkley Road crossing. There could be operational issues associated with having two crossings sharing the same protecting signals that need to be resolved; the operations team should be consulted about this.

Renewal of Six Mile Bottom was not previously included within the project scope. Whilst it is recommended that renewal is added to the scope of the project, if funding is not available for this then as a minimum the project should provide new protecting signals in a compliant location for Six Mile Bottom and Brinkley Road.

4.6 Options for additional controls

The key level crossing hazards at the crossing have been considered to determine what additional controls should be provided upon renewal (see *Table 14*).

The additional controls identified for consideration include:

- The road approaches to the crossing are fast and straight, giving an elevated risk of misuse, late braking and barrier strikes. Additional controls to consider include an anti-reflective and anti-slip road surface (or renewal of the existing anti-slip surface) and VASs (which may be preferred). RLSE cameras could also be considered to help mitigate the risk from misuse, especially if the crossing is retained as AHB. If the crossing is renewed as MCB-CCTV or MCB-OD then it may not be a high priority crossing for RLSE cameras.
- Low sun is potentially an issue for road approach sighting, particularly around sunset in winter, however there are trees and buildings which block the sun and provide background shielding for the RTLs. The crossing already has extended hoods to mitigate this, but not LED RTLs; these would be provided as standard upon renewal but should be considered prior to renewal. With LED RTLs it may not be necessary to retain the extended hoods.
- The crossing is significantly skewed (the road is 35° to the rail) and whilst the census did not show significant cyclist use this may have increased since 2013. Consideration should be given to this when selecting the deck type; velostrail could be a consideration despite the lack of incidents of cyclist falls at the crossing in the past. Cyclist dismount signs could be considered if velostrail is not provided, but this is not likely to be particularly effective.
- Retro-reflective edge markings could be provided to manage the risk of a vehicle turning down the railway which is slightly elevated at this crossing due to the skew. It might, however, be a risk to cyclists.
- The audible warnings seemed to be set to a reasonable level at the time of the site visit; with houses close to the crossing and an increased crossing area due to the skew it might, however, be worthwhile to provide audible warnings at all four corners of the crossing; this would enable a suitable volume to be retained whilst reducing the disturbance to neighbouring properties.
- The current footway widths are not sufficient to meet ORR guidance, especially in areas where they narrow towards the ends.

At least one 1.5m footway is recommended, on the east side, where it is closest to properties; this allows for pedestrian growth arising from the nearby housing developments. The edge markings should also be improved.

- The Up direction protecting signal should be positioned on the approach to Brinkley Road crossing in a compliant location to facilitate any renewal of that crossing as MCB-CCTV or MCB-OD and to prevent trains being caused to stand over Brinkley Road crossing. There could be operational issues around degraded working associated with having two crossings sharing the same protecting signals that need to be resolved; the operations team should be consulted about this.
- The crossing design will need to ensure that the barrier machine in the YO corner does not obstruct sighting of traffic for people exiting the property close to the crossing.

Table 14 Assessment of additional controls

Hazard	Comment	Standard/existing controls	Potential additional controls	Feasibility	Cost (£)	Recommend
High road speed on straight approach from south	Northbound 85th% speed was 56.8mph in census. Good RTL visibility. SMIS incidents of vehicles striking barriers.	Full barriers Obstacle detection system to ensure crossing is clear	Anti-slip road surface	Yes subject to Highway Authority agreement	Significant maintenance cost to Highway Authority	Has high friction road surface but has worn off Prefer VAS
			VAS			Consider, rejected on optioneering in 2017
			RLSE			Yes for existing crossing. Has been approved and is proposed but not currently in the plan due to lack of available RLSE installation capacity. Not required if crossing is upgraded to MCB-OD
Skew	Skew is 35° to the rail. Moderate cyclist use, may have increased since 2013.		Velostrail deck	Yes - OK at this line speed		Consider. Holdfast should not be used on high skew crossings; Strail preferred over Holdfast. No incident history. Maintenance to be consulted about this.
			Cyclist dismount signage	Yes		Consider if do not provide Velostrail
			Eliminate skew	No - nearby houses prevent this		No
	Slightly elevated turn onto railway risk (no		Retro-reflective edge markers	Yes	Low	Consider Maybe a risk to cyclists

Hazard	Comment	Standard/existing controls	Potential additional controls	Feasibility	Cost (£)	Recommend
	nearby junctions, but there are driveways)		Sacrificial RADAR reflectors	Yes		No as single track
Audible warning volume	Set to a reasonably audible level above high road noise	Audible warnings on two corners	Provide audible warning alarms at all 4 corners	Yes	Low	Yes, potential to reduce disturbance to local properties
Narrow footways	Footway widths are not sufficient to meet ORR guidance, especially in areas where they narrow towards the ends. Road width is 7m.		New footways that meet ORR guidance width along entire length (1.5m)	Yes	Low upon renewal	Yes. May only need 1 footway, 1.5m width as pedestrian use may increase with housing developments. Could provide 1m on the other side.
Footways	Edge markings are poor, grass and mossy growing on west footway, there is a slight trip hazard at the edge of the deck on the east footway		Improved pedestrian footways and maintenance	Yes	Low	Yes
Low sun	Low sun is potentially an issue for road approach sighting – particularly around sunset in winter, however there are trees and buildings which block the sun and provide background shielding for the RTLs. Has	Extended hoods	LED RTLs	Yes	Low	Yes - Would be provided upon renewal Currently planned CP6

Hazard	Comment	Standard/existing controls	Potential additional controls	Feasibility	Cost (£)	Recommend
	extended hoods; does not have LED RTLs.					
			Extended hoods	Yes	Low	Consider retaining on renewal but may not need with LED RTLs
Protecting signal placement	Crossing in close proximity to Brinkley Road crossing No signals currently in suitable locations for protecting signals		Place protecting signal on Up side of Brinley Road crossing	Yes	N/A	Yes - avoid train standing over Brinkley Road, place signal in a suitable location on approach to Brinkley Road
	There are operational issues in failure scenarios with two crossings sharing the same protecting signals. Different issues potentially apply whether the crossings are of like type or different types.		Consult operations about management of failure scenarios with two crossings sharing the same protecting signal			Yes
Barrier machine in YO corner might obstruct sighting of traffic for people exiting the property close to the crossing	This is based on the CAIR ground plan. There is a solid white line at the road edge so residents should not turn right; it is a hazard for turning left also.		Care in barrier machine placement / Mirror			Consider this hazard during design phase

4.7 Assessment of the costs and benefits of Lower LIDAR

Network Rail has developed an assessment tool (9) to calculate the benefits of the provision of Lower LIDAR at MCB-OD level crossings. The rationale for undertaking the assessment is that the Lower LIDAR, whilst providing some additional safety benefit, reduces the overall reliability of the crossing with a knock-on impact for delaying trains. The system also has associated capital and maintenance costs. The capital cost can be very high for some crossings due to the stringent demands it places on the flatness of the road profile.

The project currently anticipates that it will use the Mk. 2 version of MCB-OD, although this currently does not have type approval. It is expected that the Mk. 2 system will not require LIDAR as the RADAR would be configured to provide equivalent functionality. An assessment of lower LIDAR is however made in case the Mk. 2 system is not available or does not obviate the need for LIDAR.

The Costs of Lower LIDAR

Based upon accepted Network Rail HQ costs and adjustments [8], the costs for providing Lower LIDAR are taken to be as shown in *Table 15*.

Table 15 Assumed Lower LIDAR costs

Type of cost	Costs	
	Low Level LIDAR Child vulnerable user group (175mm beam height)	Low Level LIDAR Adult (elderly) vulnerable user group (280m m beam height)
Materials	£17,141	£17,141
Installation and set up	£8,206	£8,206
Civils work	£site specific, may be zero	£site specific, may be zero
Maintenance costs - attending failure (over 30 year asset life)	£17,987	£17,987
Faulting / local control over (30 years asset life)	£17,987	£8,993
Total cost associated with Lower LIDAR	£61,321 + Civils work	£52,327 + Civils work

No civil engineering or train delay cost estimate for Lower LIDAR is available currently; therefore, in order to provide an onerous assessment case these have been assumed to be zero.

The benefits of Lower LIDAR

The key inputs to and outputs from the numerical assessment are as follows:

Inputs		
Recommended height setting		Adult
Train frequency per day		35
Pedestrians per day		11
Cycles per day		18
Motorcycles per day		69
Other road vehicles per day		7,826
Crossing is at a station		N
If at a station, the number of stopping trains per day		N/A
Is line speed at the crossing 20mph or less?		N
Outputs		
Safety benefit	**FWI per year**	0.000045
	NPV_{30}	£1,803
Cost	**NPV_{30}**	£52,327
Safety benefit to cost ratio over 30 years		0.03

From these inputs, the current safety benefit of the Lower LIDAR is 4.5×10^{-5} FWI per year. This is equivalent to a monetised benefit over 30 years of £1,803.

Lower LIDAR – comparing costs and benefits

The estimated cost of Lower LIDAR at this crossing is at least £52,327 over the life of the asset. It is considered that the crossing is likely to have very low usage by unaccompanied children, so it is assumed not to require the lower height setting; the safety benefit is approximately £1,803. The benefit to cost ratio for providing Lower LIDAR is just 0.03, subject to there not being significant civils cost, which suggests that the cost of providing Lower LIDAR is grossly disproportionate to the safety benefit according to the guidance [8] that *"If above 0.5 Lower LIDAR should be considered. Lower LIDAR may be considered if below 0.5 where there are significant hazards unmitigated"*.

Lower LIDAR risk factors

The tool [9] for the assessment of the benefits to pedestrian slip, trip or fall risk from Lower LIDAR identifies a range of potential local hazards related to the causation of users slipping, tripping or falling on the crossing. This set of hazards has been reviewed and supplemented by Sotera and is considered to represent a fairly comprehensive set of pedestrian slip, trip or fall hazards (some however appear to have only limited relevance to pedestrian slip, trip or fall) but one, relating to equestrian use has been added. Each hazard has been considered in relation to the crossing based upon the site visit and traffic census to determine the potential significance of each hazard based upon the crossing features; it was then discussed in the risk workshop and additional controls considered. Each hazard has been rated as to its significance based upon the tool's three-point rating scale of 'Major', 'Minor' or 'No'.

In assessing whether additional control measures are required, both the rating and the overall level of risk have been considered. Where mitigation is suggested, the post-mitigation risk rating is also provided.

The full list of hazards, ratings and crossing specific comments are presented in *Table 17*. This assumes that the crossing is maintained in good condition over its full life.

The following additional controls are recommended for consideration:

- Improved maintenance to remove vegetation from footway ends and ensure the white edge lines are visible and in appropriate locations.
- At least one new footway that meets ORR guidance width along entire length. A width of 1.5m is preferred for the east footway to allow for a growth in pedestrian use of this footway due to nearby housing developments.
- Velostrail deck to reduce the likelihood that cyclists fall at the crossing.

Table 16 summarises the number of hazards afforded each rating before and after the proposed additional controls.

Table 16 Number of Pedestrian slip, trip or fall hazards

Hazard rating	Number of hazards afforded stated rating	
	Number before additional mitigation	Number after proposed additional mitigation
Major	2	0
Minor	6	6

Conclusion about Lower LIDAR

Lower LIDAR is not required at this crossing as the safety benefit to cost ratio is less than 0.5 and there are no '*Major*' ranked hazards that cannot be mitigated. If Velostrail is not provided to mitigate the cyclist hazard, then lower LIDAR might be a consideration however.

Table 17 Lower LIDAR Hazards

Ref:	Topic	Hazards	Site comments	Possible additional controls	Rating pre-mitigation	Rating post-mitigation
Topographic/physical features						
1	Surface	Slippery surface	Footways outside of decked area have become mossy and grassy due to lack of use. This affects the west side more than the east side which is more likely to be used by pedestrians.	Improved pedestrian footways and maintenance	Minor	Minor
2	Surface	Uneven surface, differential height of slabs, gaps between panels, holes in asphalt, subsided surface	There is one minor trip hazard at the edge of the deck on the east footway	Improved pedestrian footways and maintenance	Minor	No
3	Surface - loose material	Mud in rural areas, gravel	Footways outside of decked area have become mossy and grassy due to lack of use and footways have some loose material. This affects the west side more than the east side which is more likely to be used by pedestrians.	Improved pedestrian footways and maintenance	Major	Minor
4	Surface – drainage	Pooling of water following rain	There are no identified areas where water pooling is likely		No	No
5	Surface - flange gap	Degradation of flange gap - bicycle wheels trapped, trip hazard for pedestrians	To standards		No	No
6	Layout – bend	Level crossing on bend	Crossing is on a straight road		No	No
7	Layout - skew	Direction of users traverse not orthogonal to tracks. Increased traverse time	Skew about 35 degrees which presents a hazard to cyclists. The census suggests that the crossing has moderate levels of cyclist use, although	Velostrail deck	Major	Minor

Ref:	Topic	Hazards	Site comments	Possible additional controls	Rating pre-mitigation	Rating post-mitigation
		where skew is significant.	this might have grown since 2013.			
8	Layout / environment / conspicuity	Extraneous light and noise sources, short approach, no audible alarm (or hard to hear), poor conspicuity	Good street lighting, no background noise, good RTL visibility. Some very slight potential for distractions on the Up side where vehicles manoeuvre into and out of parking areas and driveways.		Minor	Minor
9	Gradient / profile	Crossing on a raised profile (gradient up or down to crossing). Crossing itself on a gradient	The road profile is level over the crossing and immediate approaches		No	No
10	Footpath width and road width	Narrow footpath, or narrow roadway meaning less space for pedestrians	Narrow, poorly marked footway, road used by HGVs at speed. Road is quite wide however (7m).	New footway(s) that meet ORR guidance width along entire length (1.5m allowing for pedestrian usage growth)	Minor	No
11	Pedestrian walkway - edging	Poor marking of edge of crossing / railway	Poorly marked footway edges, especially on the west footway	Improve maintenance of edge markings	Minor	Minor
12	Pedestrian walkway - obstacles	Posts, fencing, etc protrudes into walkway	Fence at ZO corner narrows the east footway to 0.72m	New footway(s) that meet ORR guidance width along entire length (1.5m allowing for pedestrian usage growth)	Minor	Minor
13	Lighting	Low levels of lighting in hours of darkness	Good street lighting		No	No
Pedestrian vulnerability factors						
14	Vulnerable -	Used by large numbers of	There are no specific environs that would encourage a particular user		No	No

Ref:	Topic	Hazards	Site comments	Possible additional controls	Rating pre-mitigation	Rating post-mitigation
	elderly	elderly people	group.			
15	Encumbered – push chairs, luggage / baggage	Used by large numbers of adults with push chairs, and/ or lots of travellers	There are no specific environs that would encourage a particular user group.		No	No
16	Encumbered - dogs	Used by high proportion of dog walkers	There are no specific environs that would encourage a particular user group.		No	No
17	Vulnerable – cognitive impairment	Large proportion of users with reduced cognitive capability	There are no specific environs that would encourage a particular user group.		No	No
18	Vulnerable – other mobility impaired	Large proportion of users with impaired mobility including wheelchair users	There are no specific environs that would encourage a particular user group.		No	No
19	Vulnerable – unaccompanied children	Used by large numbers of school children who are not accompanied by adults	The census did not record any use by children, whether accompanied or unaccompanied. There are no specific environs that would encourage a particular user group.		No	No
20	Impaired users	Users under the influence of alcohol	There are no specific environs that would encourage a usage by impaired users.		No	No
N/A	Equestrian use	Person thrown from horse	The census identified some low level of use by this group despite the busy road but the railway is not electrified.		Minor	Minor

Ref:	Topic	Hazards	Site comments	Possible additional controls	Rating pre-mitigation	Rating post-mitigation
Operational factors						
21	Event hazard	Local event promotes high temporary use of the crossing	Racing events at Newmarket may give higher than normal levels of use by vehicles, but not likely for other user groups		No	No
22	Seasonal hazard	Weather - icy road	Rural location likely subject to occasional icing. On a priority gritting route.		Minor	Minor

4.8 MCB-OD Configuration factors

There are a number of design parameters for the MCB-OD system that can be modified to help manage particular hazards at a crossing. Sotera has considered these and they were further assessed in the workshop. This process is documented in *Table 18*.

No firm recommendations are made as the designer would prefer flexibility to make the design decisions to manage the hazards in the most appropriate way, however key considerations for this crossing are listed as follows:

- *Blocking back.* Whist there is no known issue with blocking back currently, there are features of the road layout that could provide possible sources of blocking back. The crossing has a history of barrier strikes some of which BPM might be able to mitigate; in particular a reported incident of a barrier lowering between the cab and trailer of a road vehicle. Other barrier strikes in SMIS appear to be vehicles striking barriers; these would not be mitigated by BPM. BPM could therefore be a consideration to manage this although the normal BPM criteria are not met. It should be noted that there will a higher level of congestion at the crossing after the crossing has been upgraded to a full barrier crossing with longer road closure times.

- *Lower LIDAR.* See *Section 4.7*. Consider providing if the skew hazard to cyclists is not mitigated e.g. by Velostrail.

- *Anti-trapping delay in lowering and pausing of the exit barriers.* There is a fairly long traverse distance between the white lines so extending the anti-trapping delay slightly should be considered.

- *Enhanced OD Control of Barriers Lowering.* This provides an alternative mitigation to increasing the anti-trapping delay. This might particularly be a consideration should BPM also be provided as it utilises the same circuitry, although it can lead to increased misuse.

- *Amber phase duration.* The crossing is used by a large number of HGVs and the road approach speed by cars is high; both of these factors contribute to an elevated likelihood of vehicles failing to stop sufficiently quickly and consequently of vehicle strikes on barriers. Methods of managing this should be considered and a consideration would be to extend the amber phase of the crossing sequence beyond the default of 3s. The Down side of this would be a slightly increased road closure time; this is not, however, likely to be particularly problematic at this crossing.

- *Sacrificial RADAR reflectors.* These could be provided to manage the risk of a vehicle turning down the railway which is slightly elevated at this crossing due to the skew. There may however not be space on the single line crossing for these, and it is not clear that they would be a design option with the Mk. 2 type MCB-OD.

- *Provide audible warning at all four wig-wags.* The crossing has a fairly large area and the audible warning is currently set quite low; there is also background noise from the road traffic; therefore, consideration should be given to providing audible warnings at all four RTLs.

- *Response time and number of available attendants for CCU operation should it be necessary.* A crossing attendant is likely to come from Cambridge depot. The CCU is currently in the YN corner and given that the attendant could approach from either direction no particular preference for the location is identified at this stage.

Table 18 Review of MCB-OD configuration factors

MCB-OD configuration factor	Hazards	Consideration at level crossing	Recommended
Minimum Road Open time (MROT) Default of 10 seconds from when the barriers are fully raised until the amber light coming on for a new closure	**Lower MROT**: May cause entrapment - large queues of pedestrians not having time to cross, eg, at a station. **Higher MROT**: Increasing closure time, higher chance of second train coming - may lead to frustration and misuse.	Single line crossing so not applicable	N
Fitting of BPM at exit barriers or at the exit and entrance barriers. Default is fitment but can be removed based on blocking back survey and assessment of likely hazards to the barrier.	**Provision of BPM:** Manages blocking back risk	The local layout, with driveways close to the crossing, suggests there could be some short duration blocking back but this would not be expected to be of significant duration. Blocking back was not observed in the 2013 traffic census. Would fail BPM criteria. Barrier strikes in incident history so designer could consider BPM	Designer to consider
Default time at which time barriers lower (30 secs). Exit barriers at 4 barrier crossing.	Blocking back for extended durations	See above - not recommended.	N
Fitting of lower LIDAR. Default is fitment but can be removed based on risk assessment. LIDAR height – adult or child	Person (pedestrian, cyclist, motorcyclist) incapacitated on crossing.	See separate lower LIDAR risk assessment Consider providing if skew hazard not mitigated e.g. by providing velostrail	Consider
Minimise distance between barriers	Long traverse at skew crossing giving rise to entrapment risk.	There is a significant skew however the distance between the barriers at	N

MCB-OD configuration factor	Hazards	Consideration at level crossing	Recommended
		the existing AHB crossing has already been minimised. It is recommended that this principle is retained for the upgraded crossing.	
Anti-trapping delay in lowering and pausing of the exit barriers (default is up to 10 seconds)	Long traverse distance Slow, encumbered or vulnerable users	Fairly long traverse length between white lines. Consider this as would allow time for ped to walk around the lowered entrance barrier - does however encourage peds to walk into road. Issue with not providing this is ped panic.	Consider
Enhanced OD Control of Barriers Lowering. There is an option to also require the OD system (i.e. POD and COD) to be clear in order to allow the lowering of any barrier pair (similar to BPM).	Long traverse distance (> 39m, or where BPM also provided) Entrapment	Consider as an alternative to the above. Problem is significant delays if someone on the crossing. Unlikely to have a ped on the crossing here so could be a good idea, however vehicle misuse could be encouraged by this.	Consider
Hurry call systems integrating with highway traffic lights	Traffic congestion caused by nearby highway traffic lights.	Not recommended, there are no nearby highway traffic lights.	N
Lengthen the amber phase. Default is 3 seconds	Amber sequence provides inadequate warning - high road approach speeds, difficulty braking, high use by large vehicles.	Northbound 85th% speed was 56.8mph in census although this is at the advance signage. Good RTL visibility. SMIS incidents of vehicles striking barriers. A slight increase is therefore recommended.	Recommend

MCB-OD configuration factor	Hazards	Consideration at level crossing	Recommended
Sacrificial RADAR reflectors	Road vehicles accidentally driven down the railway, e.g. high skew or Sat. Nav. errors with nearby junctions.	High skew means that this could be a consideration. No nearby junctions, but there are several driveways. May not be space on single line crossing.	Consider
Provide audible warning at all four wig-wags	Large crossing area, local background noise or high likelihood that would be set to low volume due to nearby properties meaning that audible warning cannot be heard.	Recomemended due to nearby houses	Y
Standing red man indication	High pedestrian use Poorly sited RTLs for pedestrians	Low pedestrian misuse and a good view of the RTLs, therefore not recommended.	N
Response time and number of available attendants for CCU operation should it be necessary	Crossing spends a long duration in a failed state, delaying trains.	Can approach from either direction (from Cambridge). LCU currently in YN corner.	Designer to consider location

5 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are made from the analysis:

Strategic options

1. The only feasible closure option identified is a major scheme to close Six Mile Bottom and Brinkley Road crossings via a bridge and new link roads. Since this scheme would likely cost £15m or more and the cost would be grossly disproportionate to the safety benefit compared with the alternative of renewing Six Mile Bottom as MCB-OD at a cost of about £3.8m and a moderate residual risk.

2. It is, therefore, concluded that whilst closure of the crossing could be feasible, crossing renewal provides a more viable and cost-effective option.

3. Retaining an AHB crossing would not be the preferred option as it presents a high level of 1.5×10^{-2} FWI per year. Renewal of a crossing with an ALCRM score of E2 as an AHB would also be contrary to Network Rail's strategy of upgrading high risk AHB crossings when renewal is required.

4. AHB+ may be a viable option at this crossing which is predominantly a vehicular crossing. Comparing the costs and benefits of upgrading Six Mile Bottom to MCB-OD or AHB+ in *Table 12*, it can be seen that the cost of installing MCB-OD at Six Mile Bottom is not fully justified by the safety benefits due to the significant signalling costs, although there would be potential to utilise the additional signals for an upgrade to nearby Brinkley Road crossing. As such, upgrade to AHB+ may be considered a cost-effective upgrade path although it would not offer the same level of safety benefit as MCB-CCTV/OD. The AHB+ project is in development with a trial site expected to be installed in 2020. There may be potential for further trial sites. The project risk of utilising a number of trial sites on this project due to the uncertainty of when AHB+ will be available to install as a renewal is, however, a significant concern.

5. The preferred option is, therefore, to renew the crossing as MCB-CCTV or MCB-OD; both of these crossing types would offer significant risk reduction compared with AHB from 1.5×10^{-2} to 3.5×10^{-4} FWI per year.

    - Normally MCB-OD would be preferred over MCB-CCTV for signaller workload reasons. The crossing is within the 20km Cambridge MERLIN radio telescope planning zone so precautions against interfering with this would need to be taken should MCB-OD Mk. 1 be provided; it is understood, however, that the project intends to use Mk2 radar and so proximity to the MERLIN telescope should not be an issue.

- The choice between MCB-OD and MCB-CCTV is therefore likely to be made on the basis of feasibility and cost.

Consideration of local hazards and MCB-OD configuration parameters

2. The additional controls identified for consideration include:

    - The road approaches to the crossing are fast and straight, giving an elevated risk of misuse, late braking and barrier strikes. Additional controls to consider include an anti-reflective and anti-slip road surface (or renewal of the existing anti-slip surface) and VASs (which may be preferred). RLSE cameras could also be considered to help mitigate the risk from misuse, especially if the crossing is retained as AHB. If the crossing is renewed as MCB-CCTV or MCB-OD then it may not be a high priority crossing for RLSE cameras.

    - Low sun is potentially an issue for road approach sighting, particularly around sunset in winter, however there are trees and buildings which block the sun and provide background shielding for the RTLs. The crossing already has extended hoods to mitigate this, but not LED RTLs; these would be provided as standard upon renewal but should be considered prior to renewal. With LED RTLs it may not be necessary to retain the extended hoods.

    - The crossing is significantly skewed (the road is 35° to the rail) and whilst the census did not show significant cyclist use this may have increased since 2013. Consideration should be given to this when selecting the deck type; velostrail could be a consideration despite the lack of incidents of cyclist falls at the crossing in the past. Cyclist dismount signs could be considered if velostrail is not provided, but this is not likely to be particularly effective.

    - Retro-reflective edge markings could be provided to manage the risk of a vehicle turning down the railway which is slightly elevated at this crossing due to the skew. It might, however, be a risk to cyclists.

    - The audible warnings seemed to be set to a reasonable level at the time of the site visit; with houses close to the crossing and an increased crossing area due to the skew it might, however, be worthwhile to provide audible warnings at all four corners of the crossing; this would enable a suitable volume to be retained whilst reducing the disturbance to neighbouring properties.

    - The current footway widths are not sufficient to meet ORR guidance, especially in areas where they narrow towards the ends. At least one 1.5m footway is recommended, on the east side, where it is closest to properties; this allows for pedestrian growth arising from the nearby housing developments. The edge markings should also be improved.

- The Up direction protecting signal should be positioned on the approach to Brinkley Road crossing in a compliant location to facilitate any renewal of that crossing as MCB-CCTV or MCB-OD and to prevent trains being caused to stand over Brinkley Road crossing. There could be operational issues around degraded working associated with having two crossings sharing the same protecting signals that need to be resolved; the operations team should be consulted about this.

- The crossing design will need to ensure that the barrier machine in the YO corner does not obstruct sighting of traffic for people exiting the property close to the crossing.

3. Lower LIDAR may not be required for the Mk. 2 MCB-OD units. If lower LIDAR is a consideration, then it is not likely to be required at this crossing as the safety benefit to cost ratio is less than 0.5 and there are no Major ranked hazards that cannot be mitigated. If Velostrail is not provided to mitigate the cyclist hazard however, then lower LIDAR might be a consideration.

4. MCB-OD design parameters that should be considered to manage the risk for this crossing are listed as follows:

   - *Blocking back.* Whist there is no known issue with blocking back currently, there are features of the road layout that could provide possible sources of blocking back. The crossing has a history of barrier strikes some of which BPM might be able to mitigate; in particular a reported incident of a barrier lowering between the cab and trailer of a road vehicle. Other barrier strikes in SMIS appear to be vehicles striking barriers; these would not be mitigated by BPM. BPM could therefore be a consideration to manage this although the normal BPM criteria are not met. It should be noted that there will a higher level of congestion at the crossing after the crossing has been upgraded to a full barrier crossing with longer road closure times.

   - *Lower LIDAR.* See *Section 4.7*. Consider providing if the skew hazard to cyclists is not mitigated e.g. by Velostrail.

   - *Anti-trapping delay in lowering and pausing of the exit barriers.* There is a fairly long traverse distance between the white lines so extending the anti-trapping delay slightly should be considered.

   - *Enhanced OD Control of Barriers Lowering.* This provides an alternative mitigation to increasing the anti-trapping delay. This might particularly be a consideration should BPM also be provided as it utilises the same circuitry, although it can lead to increased misuse.

- *Amber phase duration.* The crossing is used by a large number of HGVs and the road approach speed by cars is high; both of these factors contribute to an elevated likelihood of vehicles failing to stop sufficiently quickly and consequently of vehicle strikes on barriers. Methods of managing this should be considered and a consideration would be to extend the amber phase of the crossing sequence beyond the default of 3s. The Down side of this would be a slightly increased road closure time; this is not, however, likely to be particularly problematic at this crossing.

- *Sacrificial RADAR reflectors.* These could be provided to manage the risk of a vehicle turning down the railway which is slightly elevated at this crossing due to the skew. There may however not be space on the single line crossing for these, and it is not clear that they would be a design option with the Mk. 2 type MCB-OD.

- *Provide audible warning at all four wig-wags.* The crossing has a fairly large area and the audible warning is currently set quite low; there is also background noise from the road traffic; therefore, consideration should be given to providing audible warnings at all four RTLs.

- *Response time and number of available attendants for CCU operation should it be necessary.* A crossing attendant is likely to come from Cambridge depot. The CCU is currently in the YN corner and given that the attendant could approach from either direction no particular preference for the location is identified at this stage.