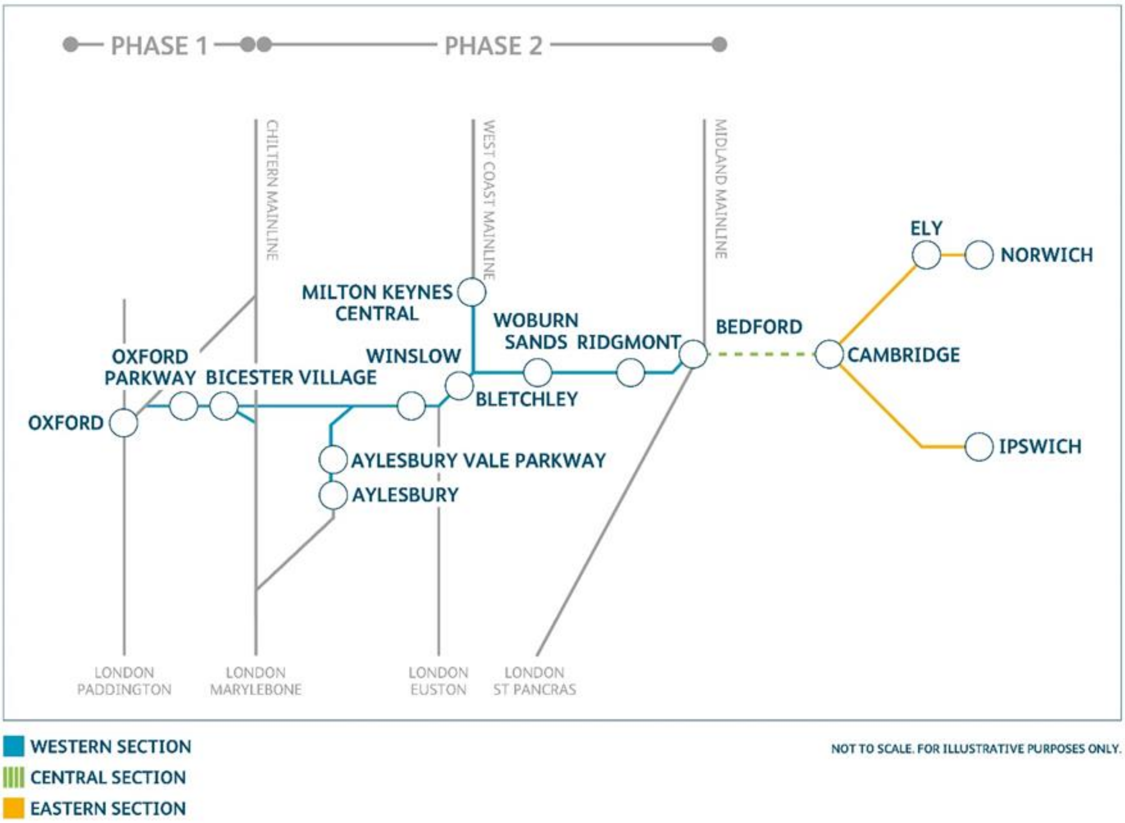
APPENDICES


PHASE 1
PHASE 2
CHILTERN MAINLINE
WEST COAST MAINLINE
MIDLAND MAINLINE
ELY
NORWICH
MILTON KEYNES CENTRAL
WOBURN SANDS
RIDGMONT
BEDFORD
CAMBRIDGE
OXFORD PARKWAY
BICESTER VILLAGE
WINSLOW
BLETCHLEY
OXFORD
AYLESBURY VALE PARKWAY
AYLESBURY
IPSWICH
LONDON PADDINGTON
LONDON MARYLEBONE
LONDON EUSTON
LONDON ST PANCRAS
WESTERN SECTION
CENTRAL SECTION
EASTERN SECTION
NOT TO SCALE. FOR ILLUSTRATIVE PURPOSES ONLY.

List of Abbreviations

ASNW	Ancient Semi-Natural Woodlands
BAP	Biodiversity Action Plan
C&D	Construction and Demolition
CICES	Common International Classification of Ecosystem Services
CO	Carbon Monoxide
CO2	Carbon dioxide
CPAWS	Conifers and Plantations on Ancient Woodland
CSR	Countryside Survey Report
CU	Cranfield University
dB	Decibel
DCLG	Department for Communities and Local Governement
DEFRA	Department for Environment, Food and Rural Affairs
EA	Environment Agency
ECML	East Coast Main Line
EFTEC	Economic for the Environment Consultancy
EU	European Union
EWR	East West Rail
EWRC	East West Rail Consortium
GHG	Greenhouse Gas
HLS	Higher Level Stewardship
HS2	High Speed 2
Km	Kilometre
LNP	Local Nature Partnership
LNR	Local Nature Reserve
m	Metre
m^3	Metres cubed
min	Minutes
MVL	Marston Vale Line
NCA	National Character Area
NH_3	Ammonia
NIC	National Infrastructure Commission
NMVOC	Non-Methane Volatile Organic Compounds
NO_x	Nitrogen Oxides
ORVal	Outdoor Recreation Valuation
PAWS	Plantation on Ancient Woodland Sites
PM	Particulate Matter
ppb	Parts Per Billion
RDF	Refuse Derived Fuel

RSPB	Royal Society for the Protection of Birds
RSSB	Rail Safety and Standards Board
SO_2	Sulphur dioxide
sqm	Square metre
SSSI	Site of Special Scientific Interest
TEEB	The Economics of Ecosystems & Biodiversity
UK	United Kingdom
UK-NEA	United Kingdom National Ecosystem Assessment
VAT	Value Added Tax
WAML	West Anglia Main Line

Appendix A Time, Distance and Areas

A.1 Railway Spacing

When rail infrastructure is developed, importance lies in evaluating the potential area impacted for estimating the possible consequences. For this project, Professor Paul Leinster provided the Cranfield project team with the following quotation relating to railway spacing, from a Network Rail employee:

“[Land spacing is] a surprisingly difficult question to answer which we’re having an ongoing debate about. Basically, ranges from about 30 m (at grade) but up to 150 m if it's in a cutting going in to a tunnel portal”.

The High Speed 2 (HS2) project specifications state a minimum corridor width of 22 m, reduced to 15 m in urban areas, if gaining more space is not viable (HS2 Ltd, 2012). On the map outputs, this difference was applied with urban (15 m) and non-urban (22 m) areas being attributed suitable widths. According to the Network Rail source quoted above, it was assumed by the project team that every building within 30 m should be bought back by the government in non-urban areas, where the travelling speed of trains is higher.

A.2 Property Compensations

Developing rail infrastructure has several advantages for the population. However, both the population and the environment are negatively affected by rail lines. Noise and atmospheric pollution being key considerations amongst other impacts.

Although the proposed Bedford to Cambridge route, comprising of only two rail tracks, with a travelling speed of a passenger train (which is considerably less disturbing for local communities and the countryside than a freight train) cannot be directly related to the HS2 project, householders should still be compensated. Moreover, homeowners may even lose their home if their dwelling is on the proposed route. For this project, in non-urban areas, 30m from the line was chosen as a safeguarding area, where no building, except operational ones, should stand.

Although there are differences between HS2 and East-West Rail (EWR) there are also similarities. This has enabled the acquisition of costings and associated methods used for evaluating the impact of EWR on the surrounding landscape and environment. According to HS2, two compensation methods could be used, the “Homeowner Payment Scheme” as shown in Table A-1, financially assisting people living close to rail routes and the “Express Purchase Scheme”, to buy back properties of people living even closer, within the safeguarding area (>120 m for HS2), at 110% of their market value (up to £58,000) (GOV.UK, 2018).

Table A-1: HS2 Homeowner Payment Scheme.

Distance from line of the route	Amount (£)
Between 120m and 180m	22,500
Between 180m and 240m	15,000
Between 240m and 300m	7,500

Source: (GOV.UK, 2018)

The compensation amounts would be similar for the EWR with distances suiting the smaller scale of the Bedford to Cambridge rail line. The proportionality may be kept, starting at 30 m, reaching 75 m for this commuter route, whereas HS2 compensation went from 120 m to 300 m, this is shown in Table A-2.

Table A-2: Housing compensation scheme summary

	HS2 Distances (m)	EWR Distances (m)	Governmental Action	Compensation Amount
<	120	30	Buying Back	110%
<	180	45	Payment	£22,500
<	240	60	Payment	£15,000
<	300	75	Payment	£7,500

The Ministry of Housing, Communities and Local Governments, formerly the Department for Communities and Local Government (DCLG) has presented estimates of land value, which can be used in policy appraisal (DCLG, 2015). Agriculture land has been valued at £21,000/ha, whilst industrial land is valued at £482,000/ha (DCLG, 2015).

Different residential land value estimates are attributed based on demographics amongst other data sets, Bedford is valued at £2,135,000/ha whilst Cambridge is valued at £5,725,000/ha respectively.

This study was not able to identify the price of every house crossed by the proposed rail line. Consequently, the public land registry was used to give the closest possible average value. Hence, according to the Land Registry, the average price of houses in South Cambridgeshire in January 2018 was £389,042, whereas it was £447,879 in Cambridge, £285,413 in Bedford, £310,607 in Central Bedfordshire and £259,259 in Huntingdonshire (Land Registry, 2018).

An average property value of £328,354 was used based on the property values from Bedford, Central Bedfordshire and South Cambridgeshire.

A.3 Travelling Speed

With the existing transport infrastructure, driving from Bedford to Cambridge currently takes 51 minutes whereas commuting by train takes more than two hours, approximately 137 minutes (Atkins, 2017). Tables A-3 and A-4 summarise the current road and train travel duration between Cambridge and Luton Airport, highlighting Bedford along the route.

Table A-3: Current AM weekday highways journey times in East Midlands.

2016/17 Weekday AM Peak (mins)	Cambridge	Ely	King's Lynn	Newmarket	Thetford	Attleborough	Norwich	Cromer	Great Yarmouth	Bury St Edmunds	Diss	Lowestoft	Stowmarket	Sudbury	Ipswich	Felixstowe	Harwich	Sandy	Bedford	Milton Keynes	Bletchley	Bicester	Aylesbury	Oxford	Reading	Stevenage	Peterborough	Stansted Airport	Harlow	Luton/Luton Airport
Cambridge		34	75	28	47	58	83	118	98	42	69	113	54	67	69	82	96	40	50	65	67	98	89	123	120	52	50	44	54	67
Ely	37		45	23	42	53	77	97	93	37	64	107	48	62	64	77	91	53	34	79	80	111	102	137	134	68	50	56	66	84
King's Lynn	77	45		62	50	59	68	68	84	68	70	98	79	93	95	107	121	86	94	110	111	140	133	161	173	108	51	95	105	118
Newmarket	28	26	63		28	39	63	98	79	24	50	93	35	48	51	63	77	46	56	71	72	104	95	129	119	53	57	40	51	68
Thetford	49	45	51	27		19	44	78	59	24	25	73	34	49	49	62	76	67	47	92	94	125	116	150	140	74	78	61	72	90
Attleborough	60	55	59	37	18		27	62	43	40	23	57	47	65	63	75	90	77	58	103	104	135	126	161	150	84	88	72	82	100
Norwich	84	80	69	62	43	27		44	37	64	47	51	66	89	75	88	102	101	83	147	128	160	150	185	175	109	109	96	107	124
Cromer	117	97	70	95	76	60	44		57	98	80	73	103	123	112	125	139	135	145	160	161	193	184	218	208	142	111	129	140	158
Great Yarmouth	100	95	64	77	58	42	36	56		80	61	20	78	105	88	91	114	117	98	143	144	175	166	201	190	124	124	112	122	140
Bury St Edmunds	44	41	69	23	24	42	66	101	82		41	85	21	30	37	49	63	62	42	87	88	120	111	145	135	69	73	56	67	84
Diss	71	67	71	49	24	23	44	83	60	40		56	34	64	44	56	71	88	69	114	115	147	137	172	162	96	100	83	94	111
Lowestoft	114	110	99	92	72	56	50	73	22	85	56		74	108	74	75	103	131	142	157	158	183	180	215	205	139	139	126	137	154
Stowmarket	55	52	80	35	34	49	63	102	79	22	34	74		41	22	34	49	73	84	99	100	131	122	157	146	81	84	68	78	96
Sudbury	66	61	90	44	46	63	88	122	104	28	61	105	39		37	50	48	83	67	108	109	139	109	146	133	85	94	49	65	97
Ipswich	71	67	96	50	49	64	62	112	89	38	44	74	22	39		24	40	88	69	114	115	147	119	156	143	96	100	63	79	107
Felixstowe	85	81	110	64	63	78	86	126	95	51	58	76	36	55	25		49	102	113	128	129	160	130	167	154	110	114	74	90	118
Harwich	96	94	122	76	76	91	99	138	115	64	70	102	49	48	40	48		113	125	128	132	149	119	156	142	101	124	63	78	107
Sandy	41	52	86	48	67	78	102	137	118	62	89	132	73	87	89	101	113		22	36	37	68	59	94	92	24	41	60	51	39
Bedford	51	60	92	56	75	86	110	145	126	70	97	140	81	94	97	109	123	18		29	30	61	52	87	92	39	47	70	66	37
Milton Keynes	68	77	109	73	92	103	127	182	143	87	114	157	98	111	114	126	128	35	29		9	39	34	64	88	53	64	80	73	33
Bletchley	69	78	110	74	93	104	128	163	144	88	115	158	99	113	115	127	131	37	33	8		36	31	61	92	56	65	83	77	37
Bicester	100	110	141	105	124	135	160	194	176	119	146	189	131	135	146	159	146	68	98	39	36		30	28	62	83	96	98	92	68
Aylesbury	94	103	135	97	118	129	153	188	169	113	140	183	124	108	119	129	119	62	58	36	33	30		52	68	55	90	71	65	43
Oxford	125	134	160	130	149	160	184	219	200	144	171	214	155	142	154	163	153	92	123	64	60	27	51		54	90	115	105	99	78
Reading	116	134	171	117	137	148	173	207	189	132	160	202	144	128	140	150	139	91	94	85	89	60	67	57		76	126	92	85	64
Stevenage	50	67	107	54	74	85	109	144	125	69	96	139	81	83	96	109	99	24	42	51	55	83	53	90	77		62	46	32	27
Peterborough	52	49	52	59	78	89	110	111	126	73	100	139	84	97	100	112	124	42	50	66	67	97	89	117	129	63		72	82	74
Stansted Airport	45	59	97	43	63	73	98	133	114	58	85	127	69	47	64	73	63	61	73	80	84	101	71	108	94	50	73		27	59
Harlow	53	68	105	51	71	82	107	141	123	66	93	136	78	62	79	88	78	52	54	74	78	95	65	102	88	34	81	26		50
Luton/Luton Airport	65	82	118	69	89	100	125	159	140	84	111	154	96	94	106	115	105	39	42	33	37	68	41	79	66	28	73	57	51	

Source: (Atkins, 2017)

Table A-4: Current AM weekday rail journey times in East Midlands.

AM peak mins, Uncrowded IVT + (Waiting Time - First Wait Time)	Cambridge	Ely	King's Lynn	Newmarket	Thetford / Attleborough	Norwich	Cromer	Great Yarmouth	Bury St Edmunds	Diss	Lowestoft	Stowmarket	Sudbury	Ipswich	Felixstowe	Harwich	Sandy	Bedford	Milton Keynes	Bletchley	Bicester	Aylesbury	Oxford	Reading	Stevenage	Peterborough	Stansted Airport	Harlow	Luton/Luton Airport
Cambridge	-	16	62	22	65	103	214	182	40	114	204	59	219	77	77	180	82	130	127	138	166	159	147	124	44	78	38	41	39
Ely	14	-	31	101	26	64	175	143	119	101	165	125	240	136	136	193	108	154	147	158	188	180	169	146	73	41	71	67	67
King's Lynn	40	30	-	133	87	124	235	203	151	161	225	170	268	186	186	249	140	181	171	183	212	205	193	171	102	101	106	99	96
Newmarket	30	63	122	-	113	120	231	200	18	85	220	37	184	55	55	128	127	198	187	198	228	221	209	187	89	122	85	82	103
Thetford / Attleboroug	48	25	101	132	-	38	149	117	160	75	139	87	213	98	98	163	138	196	186	198	227	220	208	185	107	83	104	100	101
Norwich	79	57	133	132	32	-	51	34	111	17	41	29	155	43	43	105	170	192	185	197	222	215	203	180	149	115	135	128	127
Cromer	163	141	217	200	116	48	-	127	179	85	149	97	223	109	109	173	253	258	251	263	288	282	269	247	214	199	219	189	193
Great Yarmouth	149	127	203	185	101	34	145	-	165	71	135	83	209	92	92	159	238	242	234	246	272	265	253	230	200	184	205	173	175
Bury St Edmunds	50	83	143	20	145	91	202	171	-	71	190	23	170	41	41	102	149	202	194	206	233	226	214	191	111	144	105	111	123
Diss	141	113	189	115	88	20	131	99	94	-	121	12	138	25	25	88	186	174	167	179	205	198	186	163	147	173	179	141	154
Lowestoft	160	138	214	198	113	45	156	124	178	82	-	100	220	102	102	169	253	255	248	259	285	279	266	244	214	196	223	196	199
Stowmarket	73	117	187	43	100	32	143	111	22	12	154	-	126	14	14	73	169	163	155	167	193	186	174	151	131	170	150	130	136
Sudbury	186	206	253	199	211	143	254	222	179	123	209	114	-	84	84	105	183	172	165	177	203	196	183	161	144	177	175	135	154
Ipswich	123	131	202	93	110	43	154	122	72	22	133	13	113	-	-	60	163	150	143	154	180	173	161	138	124	158	148	118	131
Felixstowe	123	131	202	93	110	43	154	122	72	22	133	13	113	-	-	60	163	150	143	154	180	173	161	138	124	158	148	118	131
Harwich	162	175	236	136	156	88	199	167	116	68	182	55	127	35	35	-	185	175	168	180	205	199	186	164	147	180	174	140	158
Sandy	83	110	179	165	154	191	302	270	183	205	287	201	224	174	174	207	-	128	122	133	161	153	142	119	21	37	119	95	34
Bedford	137	163	206	219	215	213	324	293	237	193	297	188	215	164	164	198	136	-	66	40	158	152	140	117	98	131	145	110	10
Milton Keynes	131	157	200	213	209	215	326	294	231	195	298	190	216	166	166	199	135	99	-	4	153	149	141	111	92	125	136	103	81
Bletchley	142	168	211	224	220	226	337	305	242	206	310	201	227	177	177	210	146	35	7	-	170	159	149	120	103	136	147	114	73
Bicester	144	170	213	226	222	225	336	305	244	205	309	200	227	176	176	210	144	133	125	137	-	89	62	97	105	138	155	118	115
Aylesbury	152	178	221	234	230	233	344	312	252	213	316	208	234	183	183	217	151	141	132	144	58	-	115	110	113	146	162	126	122
Oxford	158	184	227	240	236	240	351	320	258	220	324	216	242	191	191	225	157	147	133	145	50	142	-	20	119	152	163	127	128
Reading	136	162	205	218	214	219	330	298	236	199	303	194	220	170	170	203	136	125	112	123	92	125	21	-	97	130	142	106	107
Stevenage	44	90	137	126	134	171	282	250	144	174	271	162	192	142	142	175	19	96	89	101	129	121	110	87	-	37	97	72	6
Peterborough	60	39	115	144	79	115	226	194	162	152	216	160	223	172	172	209	31	128	123	135	159	152	141	118	52	-	115	108	68
Stansted Airport	59	92	151	141	140	177	288	257	159	176	270	165	198	148	148	181	124	122	113	124	158	152	139	117	90	126	-	10	92
Harlow	58	90	150	140	139	167	278	246	158	161	259	155	182	131	131	164	104	106	95	107	138	133	120	98	69	111	23	-	76
Luton/Luton Airport	60	87	133	142	138	155	266	235	160	167	256	153	195	145	145	178	35	13	99	80	135	129	117	94	6	59	100	79	-

Source: (Atkins, 2017)

Appendix B Construction Costs

B.1 Price of Railways per Kilometre

The European high-speed railways are built at a cost varying between £15m/km and £24m/km. Whereas, according to existing UK figures for high-speed railways the UK high speed railways cost approximately £27m/km (Infrastructure UK, 2012). However, American figures are very different, presenting a cost not exceeding $2m/km for building a double track on a new stone bed (Compass, 2017).

The rail route created by the East West Rail Consortium (EWRC) will not be suitable for the use of high-speed rail due to the limited distance likely to be traversed. Therefore, a simplified calculation was undertaken with figures obtained from the 'East-West Rail Strategic Options Report' produced by Jacobs, for representing financial values in the decision-making process undertaken in this study (Jacobs, 2016). Many criteria including cubic meters of cutting or filling were not considered, however, the numbers of bridges and tunnels were calculated along with an approximation of the railway engineering costs relating to length. The Jacobs report proposes many corridor options for the area. Consequently, in order to estimate the price that the proposed routes could have, the average value, arising from the four corridors in the C1-1, C1-8, C1-9 and C2-2, with their different costs and lengths, gave a mean value nearing £24m/km (Jacobs, 2016).

B.2 Tunnels and Bridges

The elevation values of the study area were from 1.2 m to 136.6 m above sea level. Consequently, tunnel construction was considered for each one of the three suggested routes with the purpose of reducing natural capital impact and avoiding elevation constraints.

The track gradient is the distance travelled horizontally for a rise of one unit. The 'Normal Limiting Design' value stipulated for the track gradient in the UK is 1:40, and as an 'Exceptional Design' value 1:25 is permissible. That means that usually, a track cannot run on an elevation exceeding 1.25%.

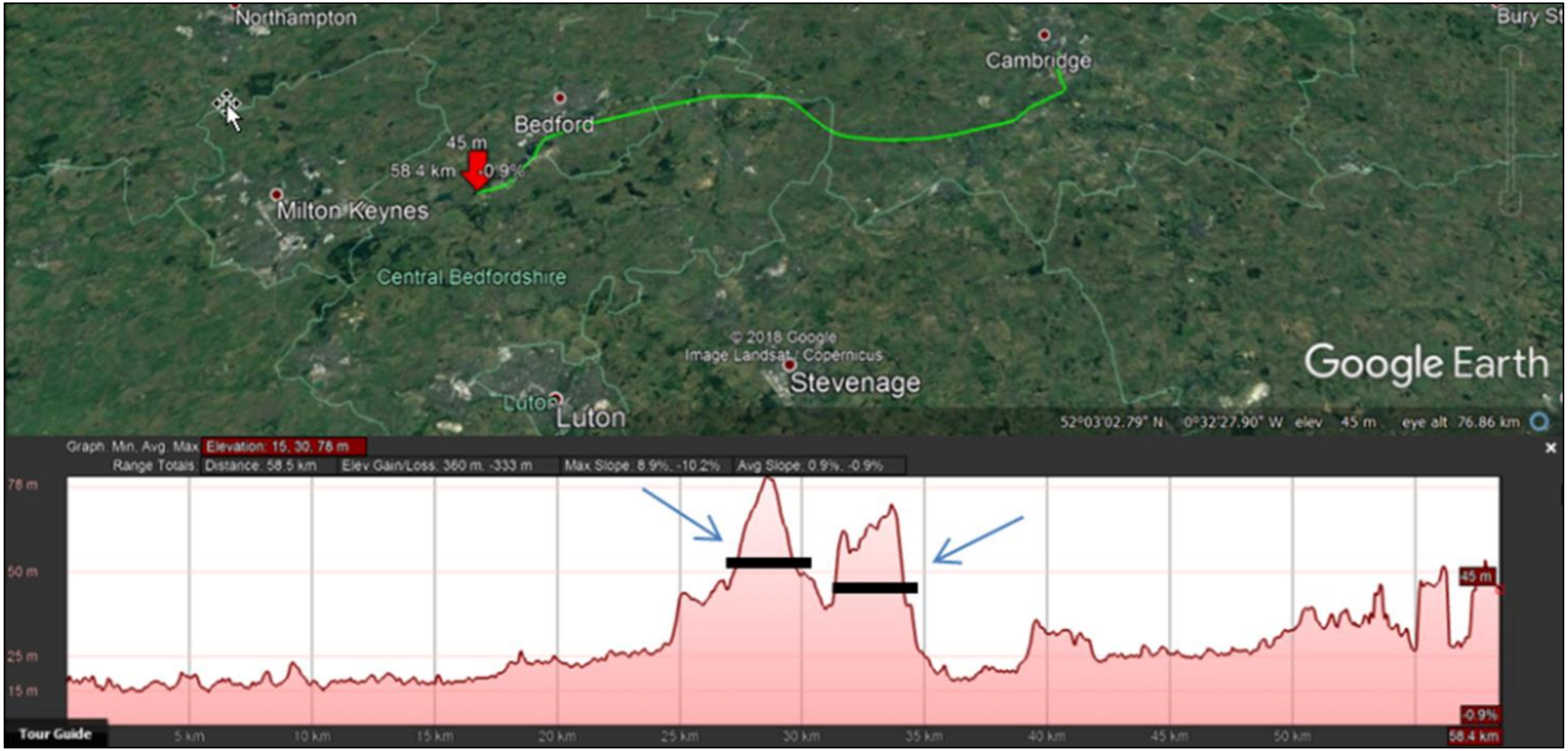
Moreover, in order to avoid problems with available tractive effort, it is considered good practice that the design value for track gradient for freight traffic should not be steeper than 1:100 (1%) (Railway Group Standards, 2010).

The appropriate site for each tunnel was selected through site visits, examining the elevation profile of each route and analysing the slope percentage values derived from the elevation model data.

The 5th Studio proposed rail route was designed based on new housing development likely to occur between Bedford and Cambridge. This rail route is neither the shortest nor the fastest route. However, the proposal is based on putting new housing developments near Bassingbourn and Foxton. For this specific route, the construction of two tunnels (2.7km and 2.2km) is essential for enabling the route to be feasible. The tunnels are located north of Potton village. Figure B-2 shows the area and the elevation of this route.

The EWR Route is the fastest and shortest route (43.6km). Based on the initial proposal, a tunnel of 2.8 km near Gamlingay is essential to be within the maximum values for gradient percentages. In some instances, cuttings are easier and less expensive, although tunnelling offers higher biodiversity production values and less noise pollution. This route shows slopes near Everton village and a small tunnel would be beneficial at this location for maintaining a level rail line. Figure B-3 shows the area and the cross section of this route.

The Northern Route is slightly different from the other ones because it takes a more northerly route. A small tunnel could be required near Little Barford due to the difference in elevation values as Figure B-4 shows. However, this possibility was rejected from the project due to construction reasons.



Source: (Google Earth, KML file)

Figure B-1: 5th Studio Report Route – Elevation Profile and tunnel placement.

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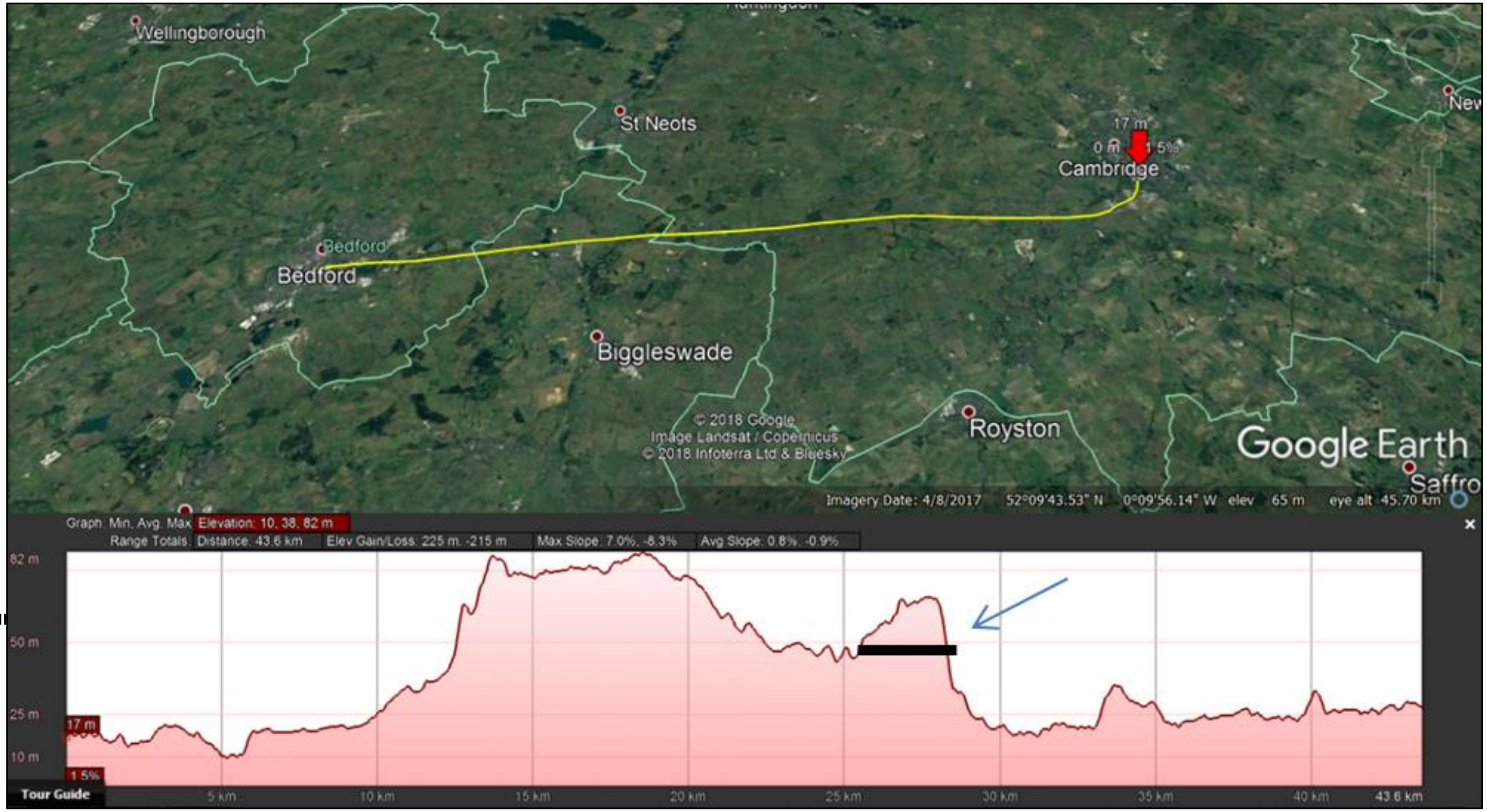
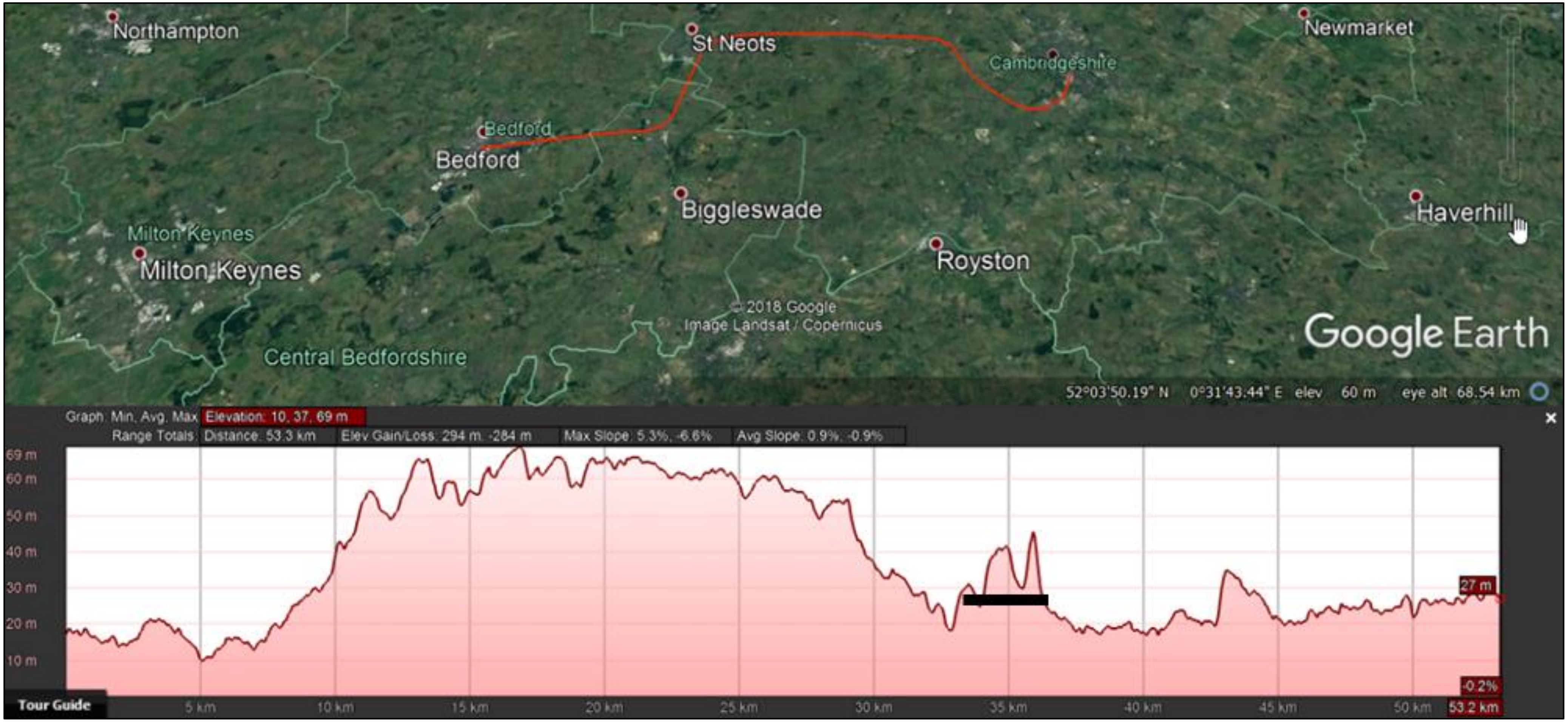


Source: (Google Earth, KML file analysis)

Figure B-2: EWR Studio Report Route – Elevation Profile and tunnel placement



Source: (Google Earth, KML file analysis)

Figure B-3: Northern Route – Elevation Profile and tunnel placement.

Early rail lines in the United Kingdom were laid out with gentle gradients, such as 0.05% (1:2000), because the early locomotives (and their brakes) were not felt to be effective (Railway Group Standards, 2010).

An indicative cost of tunnel building may be taken from the HS2 example. A single bore tunnel with a diameter of 12m would cost approximately £66m/km (HS2, 2012). In the same report, a 2-track single span rail bridge, rising from 0 to 10 meters high would cost £2,346/m^2 (HS2, 2012).

Other works and investment may be realised on the infrastructure, such as signalling, embankments, cuttings and overhead equipment.

Caution notice: *The Jacobs report already presented prices with associated investments (cuttings, fillings, tunnels, over and under bridge). This accumulation of small investments around the rail route is accounted into the £24m/km value.*

Appendix C Noise Barriers

Noise barriers are designed to provide attenuation through numerous processes. These processes include: adsorption (Yang *et al.*, 2010; GreenBlue Urban, 2016), deflection (Dobson and Ryan, 2000; GreenBlue Urban, 2016), refraction (Yang *et al.*, 2010; GreenBlue Urban, 2016), interference (Yang *et al.*, 2010), dispersion (Bucur, 2006; GreenBlue Urban, 2016), reflection (Bucur, 2006; Yang *et al.*, 2010) and diffraction (Yang *et al.*, 2010). The diagram in Figure C-1 illustrates the various methods of attenuating noise propagation.

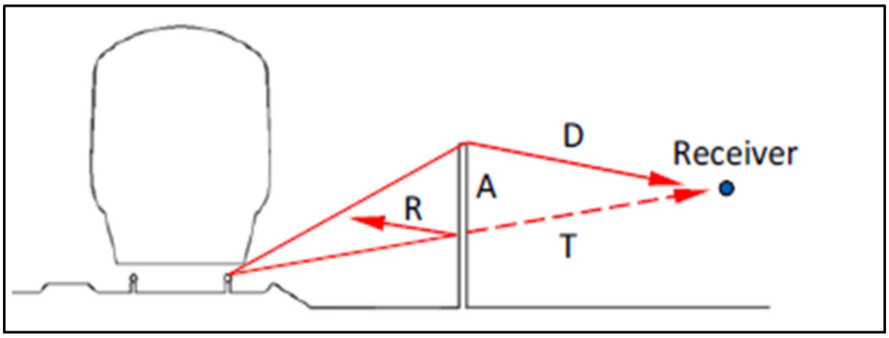


Figure C-1: Noise barrier methods of attenuation (reflection, adsorption, diffraction and transition).

The functionality of the barriers will ultimately depend on their material composition and height. Various materials can be fabricated into different shapes and styles making noise barriers adaptable and highly versatile. The focus of this study is from an environmental perspective and it may be assumed that a renewable resource would be the most beneficial in relation to sustainability and whole life environmental impact when compared to a material such as aluminium or acrylic, which is likely to have a far greater environmental cost.

Noise reduction capabilities that barriers can provide are based on a report by the European Commission (European Commission, 2017). The report suggests that a reduction of 10 dB (A) is achievable from a barrier of 2m in height and that a reduction of 15 dB (A) is achievable from barriers that are 3-4 m high. From a cost based perspective, installation of a more robust barrier may be more economically feasible in comparison to a biodegradable material, which may after 20 years, need replacing due to deterioration (Morgan and Peeling, 2012).

Noise barriers have a small physical footprint in comparison to green belts and can reduce the costs of land acquisition when constructing rail lines, making them an attractive choice for developers. Mitigation utilising noise barriers is well proven in softening the effects of railways, particularly in urban environments.

C.1 Green Sound Barriers

Green sound barriers comprise of artificial and living materials. When used in conjunction with solid barriers, vegetation provides an effective means of noise attenuation. The additional benefit vegetation provides, through the ability to reflect and adsorb sound (Dobson and Ryan, 2000; Bucur, 2006; Kalansuriya, Pannila and Sonnadara, 2009), complements the greater effectiveness attributed to artificial barriers. Green infrastructure, in particular trees, provides an attractive alternative to artificial noise abatement structures such as aluminium or concrete walls. The addition of vegetation brings with it the rustling of leaves, movement of branches and attraction of wildlife. All of these features help to mask the effect of noise and improve the presence of roads (Bucur, 2006). Such plantations can provide habitat to invertebrates, birds and mammals, provide sources of pollen and a means for carbon sequestration.

C.1.1 Green Belt Opportunity

There is the opportunity with the development of East-West Rail, to install green sound barriers and belts at various points along its corridor. Reference is made by Kalansuriya, Pannila and Sonnadara (2009) to the lack of opportunities available when constructing roads, due to the number of dwellings already apparent. Based on the points raised by Kalansuriya, Pannila and Sonnadara, (2009), it can be proposed, that due to the possibility of acquiring undeveloped land, there presents an opportunity to mitigate the rail route development. This mitigation could occur through tailoring of the land, to implement, manage and gain from ecosystems goods and services (European Environment Agency, 2018).

C.1.2 Green Belt Ecosystem Goods and Services

Green belts consisting of mixed vegetation are versatile features, whereby their components can be easily modified to suit the needs of a developer. Numerous ecosystem good and services can be provided by green belts with some being more applicable to the EWR construction than others. The following list has been compiled by the project team in order to accentuate the versatility, importance and relevance of 'Green Belts' to infrastructure development:

- Cultivation of plants for energy, timber and fibre
- Hydrological cycle and water flow regulation
- Buffering and attenuation of mass movement
- Control of erosion rates
- Wind protection
- Pollination
- Seed dispersal
- Maintaining nursery population and habitats
- Preservation of genetic material
- Weathering processes (regulating soil quality)
- Decomposition and fixing processes (regulating soil quality)
- Regulation of chemical composition of atmosphere
- Regulation of transpiration
- Mediation of wastes and nuisances of anthropogenic origin

C.1.3 Species Selection

Medium-sized (<25m) broadleaved (deciduous and evergreen) and coniferous trees provide a heterogeneous mix and maximum canopy cover whilst also providing leaf litter, berries and sources of nectar for insects. They must be within close enough proximity of one another, and the source, to provide effective screening and abatement.

Canopies provide different scattering cross sections. A crowded evergreen canopy containing numerous branches, stems twigs and foliage will be more effective at scattering sound waves in comparison to a sparse canopy (Bucur, 2006; GreenBlue Urban, 2016). Deciduous species can be used, providing they have dense frameworks to aid with attenuation rather than reflection of noise. Further, Bendtsen (2010), eludes to the point that in some instances, deciduous species provide an advantage over evergreens due to the tendency for road dust to accumulate on the surface of leaves.

C.1.4 Morphological Features

Yang *et al.* (2010) refer to the effectiveness of leaves in relation to their width and weight, likewise Dobson and Ryan (2000) have stated it is the bark of trees which is most efficient for noise attenuation. Additionally, Huddart (1990), refers to other morphological features including plant root systems as well as leaf litter for attenuation of low frequencies (between 250 and 500 Hz) through adsorption (Huddart, 1990).

C.1.5 The Understorey

The amount of foliage in the shrub layer must be considered. Reference is made by Yang *et al.* (2010), who mentioned the importance of foliage for reducing sound transmission, with specific reference to higher frequencies and the ability for foliage to scatter this transmission (Yang *et al.*, 2010).

Grasses and herbaceous plants provide suitable ground cover. The results from green barriers (other than the willow) will not be apparent during the first few years of establishment. Nevertheless, benefits are likely to be observed within 5 years (Dobson and Ryan, 2000). It is believed that the use of vegetation aids the mitigation of noise, if the source cannot be seen then people tend to be less conscious of the noise.

Whilst plants provide many ecosystems goods and services, in relation to mitigating noise emissions, their ability only extends to a height of 12 meters, after which attenuation decreases due to the opening of canopies (Dobson and Ryan, 2000). This stresses the importance of species selection.

When deciding species, the following criteria benefit from consideration;

- Majority medium sized tree species (12m)
- Some taller sized tree species (>25m)
- Rooting system
- Longevity of species
- Time to reach maturation
- Maintenance frequency/intensity
- Canopy structure
- Provenance
- Soil requirements
- Suitability to adapt to climate change
- Disease resistance / susceptibility (*Xylella fastidiosa* in particular)

Some of the aforementioned characteristics may be suitable in certain situations. For example, tall species would camouflage a viaduct or screen a rail line from raised structures such as apartments, or perhaps a certain type of Oak (*Quercus*) provides habitat to an endangered invertebrate. Therefore, not all species should be neglected. To further complicate species selection, a variety of other factors come into play (Bucur, 2006). These include;

- Underlying geology
- Topography
- Known meteorological conditions
- Land use
- Depth and fertility of soil

The project team suggests that a planting plan would be most beneficial if it was tailored to specific areas rather than as a generic plan. This would present the option to incorporate species of local provenance and take into account preference through qualitative community surveying. Habitat creation could lead to development of specific habitats aimed at encouraging and establishing highly specific organisms such as; bryophytes and lichens in calaminarian grassland, reptiles in lowland heathland and watervoles in lowland meadows or even the use of agroforestry systems such as; silvipasture, agrosilviculture, agrosilvipasture (Deeks, 2017).

C.1.6 Planting Distances

Planting distances would be specific depending on the chosen species and their eventual height and spread. Greenblue Urban, (2016), have recommended planting in multiple rows of a meter to two meters deep. This contradicts the work of Yang *et al.* (2010), who clearly state the benefits that a cross planting arrangement has in comparison to planting in rows. A reason for planting at this depth maybe to create a dense network of tree stands rather than using multiple understorey layers. However, further studies would be needed to support this theory.

C.1.7 Costings

Woven inert willow barriers are available from Cheviot Trees priced at £150 - £175/m^2 (excluding VAT). Living Willow acoustic barriers are also available starting from £170/m^2 (excluding VAT). Both styles of barrier are available in heights of 1.5 and 2.5 m (Cheviot Trees, 2015). Although willow barriers are cheaper than artificial barriers their longevity is compromised due to deterioration. Brampton Willows have estimated that degeneration begins after six years with a total lifetime expectancy of 10 – 15 years (Brampton Willows, 2017).

Information within the railway noise mitigation factsheet by Morgan and Peeling, (2012a), provides reference to the International Union of Railways height-based barrier costings. The following figures are from 2008 and do not take into account inflation;

- 2m = €1000/m
- 3m = €1,350/m
- 4m = €1,700/m

In reference to the cost of artificial barriers, the cost value provided above is for the purpose of illustrating the range of different costs. It is noteworthy that such costs are variable through different suppliers. The cost value provided is on a general scale and is reported by the Union Internationale des Chemins de Fer (UIC). Prices vary mainly according to the different height, ground condition, design. Table C-1 shows many styles of artificial barriers based on shapes and different materials.

Table C-1: Barrier categories

Shapes	***Material***	***Sound Absorption***	
		type of absorption	*type of absorptive material*
a. plane, vertical b. plane, inclined c. plane, curved d. plane, bent e. embankment	A. metal B. concrete C. brick or ceramic D. wood or board E. transparent glass or plastic F. earth	1. no absorption 2. integrated absorption 3. additional absorption	a. rock or mineral wool b. glass wool c. chip wood d. clay grains or other ceramic granulate e. plastic or rubber foam.

Source: (Royal HaskoningDHV, 2013).

Among these materials, barriers made of timber have the lowest cost. However, as aforementioned it is not cost effective to use timber for it may not be robust enough to serve for 20-30 years. Concrete barriers cost twice as much timber ones.

One of the disadvantages of concrete or metal (aluminium) barriers is aesthetic problems and the blocking of scenery for rail travellers. One solution is to plant climbing vegetation, similar to green sound barriers, although frequent maintenance is required.

Barriers made of transparent acrylic material are considered the costliest, approximately three times more expensive than timber barriers (Morgan and Peeling, 2012). This type of barrier is beneficial both in urban and rural environments because it will not block the residents' view and allow travellers to be able to see the landscape. Additionally, it can reduce the visual effect of a noise barrier. Although there is no detailed evaluation, it is reported that humans tend to be more sensitive to noise when the source of noise is unseen (Morgan and Peeling, 2012a). Thus, transparent barriers might be more functional in noise attenuation, to some degree, than other material types.

C.1.8 Barrier Placement

In reference to placing of the noise barriers along the proposed railway routes, three major factors have been taken into account: settlement populations, important areas, and noise transmission. The aim of constructing noise barriers is to protect residents from rail noise and vibration. First of all, in order to achieve this purpose, the populations of towns passed by the proposed routes were statistically estimated according to UK Service Data (2017).

Secondly, the Department for Environment, Food and Rural Affairs (DEFRA) has developed the Noise Action Plan. This report specifies 'important areas' through strategic noise mapping (DEFRA, 2013). The use of shape files of the 'important areas' published by DEFRA has been included in the noise barriers proposal.

Thirdly, considering the distance of noise transmission, it will not be a problem when residents live 0.53 – 0.84 km from the track.

In the Northern Route proposal, establishment of barriers will not be proposed when the distance between towns and the track is over 1 kilometre. However, spot investigations and assessments of noise emissions are necessarily suggested before construction. Noteworthy, is the use of existing rail lines by 5th Studio and the Northern Route. Utilisation of existing rail lines, particularly the stretch between Sandy and St Neots, will be exempt from proposed noise barrier locations, due to pre-existing disturbance. Thus, noise barriers are not required for existing rails. Additionally, they are not required for areas undergoing tunnel proposals.

Table C-2: Study area town and village populations.

EWR Route						
Towns/Villages	Marston Moretaine	Wotton	Kempston	Shortstown	Moggerhanger	
Population	4560	4230	19440	2631	620	
Towns/Villages	Sandy	Potton	Gamlingay	Trumpington		
Population	11657	7789	4900	8034		
5th Studio Route						
Towns/Villages	Marston Moretaine	Houghton Conquest	Wilstead	Shortstown	Cople	Moggerhanger
Population	4560	1514	3270	2631	722	620
Towns/Villages	Sandy	Potton	Gamlingay	Wrestlingworth	Whaddon	Meldreth
Population	11657	7789	4900	850	489	1783
Towns/Villages	Shepreth	Barrington	Foxton	Harston	Hauxton	Little Shelford
Population	768	993	1260	1729	673	840
Towns/Villages	Great Shelford	Trumpington				
Population	4233	8034				
Northern Route						
Towns/Villages	Marston Moretaine	Wotton	Kempston	Shortstown	Moggerhanger	Blunham
Population	4560	4230	19440	2631	620	946
Towns/Villages	Sandy	Tempsford	St Neots	Cambourne	Hardwick	Coton
Population	11657	590	10477	8186	2670	910

Source: (UK Service Data, 2017)

C.1.9 Alternative Solutions

Novel engineering solutions are available to alleviate constraints related to construction of infrastructure. Slope stabilisation, acoustic solutions and erosion prevention are likely to be relevant to the construction of EWR line. Maccaferri, (2018) can provide suitable engineering solutions for overcoming construction constraints. One solution offered is the Duna system. Duna systems are reinforced earthen bunds that combine a variety of specialised geogrid and modular facia systems to create highly engineered solutions (Maccaferri, 2018). Geogrids and meshes provide an array of solutions, such as lessening soil erosion, improving soil consolidation, aiding with drainage and establishing vegetation (Maccaferri, 2018).

C.1.10 Conclusion

Whilst infrastructure is important to civilisation, it is can be seen as a social irritant through intrusive and persistent noise. Mitigation can offset the negative effects of infrastructure construction through improving connectivity of habitats and communities, purifying urban air, improving neighbourhood aesthetics and providing green infrastructure.

Appendix D Construction and Demolish Waste Management

Rail infrastructure development generates construction and demolition (C&D) waste such as concrete, bricks, glass, soil and stones (de Guzmán Báez *et al.*, 2012). This waste has an impact on the surrounding environment. Thus, it is necessary to have a proper management of C&D waste, which can be beneficial to sustainability and life quality (Ecorys, 2016). In order to have a proper waste management plan it is necessary to follow certain steps.

D.1.1 Improve Waste Identification, Source Separation and Collection

This should be at the beginning of the C&D waste management process. In order to improve waste identification, there should be clear and unambiguous definitions. In addition, prepared waste management plans and good-quality pre-demolition audits are required. The most important part of source separation is to eliminate hazardous waste and separate materials which hinder recycling. The improvement of collection of goods for recycling and re-use, requires suitable on-site operations and selective demolition (Ecorys, 2016).

D.1.2 Improve Logistics

It is necessary to reduce distances for transportation of bulk materials, particularly concrete and asphalt, which cannot be transported over long distances by road (usually maximum 35 km). During the transportation process, routing needs optimising for minimising fuel consumption. Also, nearby sorting and recycling plants are crucial for C&D waste. Waste transfer stations play an important role in local waste management system, providing a service to connect local C&D waste collection points with a final waste disposal facility. Finally, it is important to keep materials integrated (especially glass) when dismantling for recycling purposes (Ecorys, 2016).

D.1.3 Stockpiling and Proper Stocking

Stockpiling brings benefits to demolition sites, especially larger demolition sites. However, it needs to be built one year before disposal and three years before recycling. As C&D waste stockpiling could cause some risks and emissions such as water pollution, fire caused by heat generation and the emissions of dust, and other bio aerosols, therefore precautionary measures should be taken. For example, C&D waste ought to be segregated and disposed of in separate, dedicated, containers (Ecorys, 2016).

D.1.4 Waste Processing and Treatment

Preparation for re-use, recycling and the recovery of material and energy is a common order of waste processing and treatment.

Preparation for re-use

Preparation for re-use is promoted as it is more beneficial to the environment than recycling in theory, even though it is not always easy to realise in practice. High-value materials such as hardwood timbers and metals should be re-used. In recent years, their reclamation rates have increased. To ensure high re-use rates, there should be a market for these materials. In addition, the quality of these materials should be proved to create demand in the market (Ecorys, 2016).

Recycling

Economic benefits brought about from C&D waste recycling, can result in reduced use of primary materials, less landfilling and greater job creation. Additionally, reduced landfilling is good for the protection of the environment, energy saving, smarter use of natural resources, avoidance of excavation in rural or forest regions and decrease in greenhouse gas emissions. Materials can either be recycled off-site at a recycling point or on-site into new construction. The recycling of C&D waste needs promoting especially in densely populated areas, which can reduce transport and use of primary materials (Pacheco-Torgal *et al.*, 2013).

Material and energy recovery

When it is not possible to re-use and recycle, backfilling is one way that non-hazardous C&D waste can be re-used, in particular, excavated minerals and masonry materials. However, C&D waste needs to be treated before being backfilled to avoid adverse environmental impacts, such as substances leaching into groundwater. In the aspect of energy recovery, all the possibilities for recovery including refuse derived fuels (RDF) should be considered. Some C&D waste such as plastics, organic insulation materials, contaminated wood and wood-based products which cannot be re-used and recycled and bitumen based waterproofing membranes can be used as RDF if the logistics for distribution and collection of it exist (Ecorys, 2016).

Appendix E Air Pollution

E.1 Construction Pollution

The major types of pollution during the construction of the rail line are atmospheric and noise pollution.

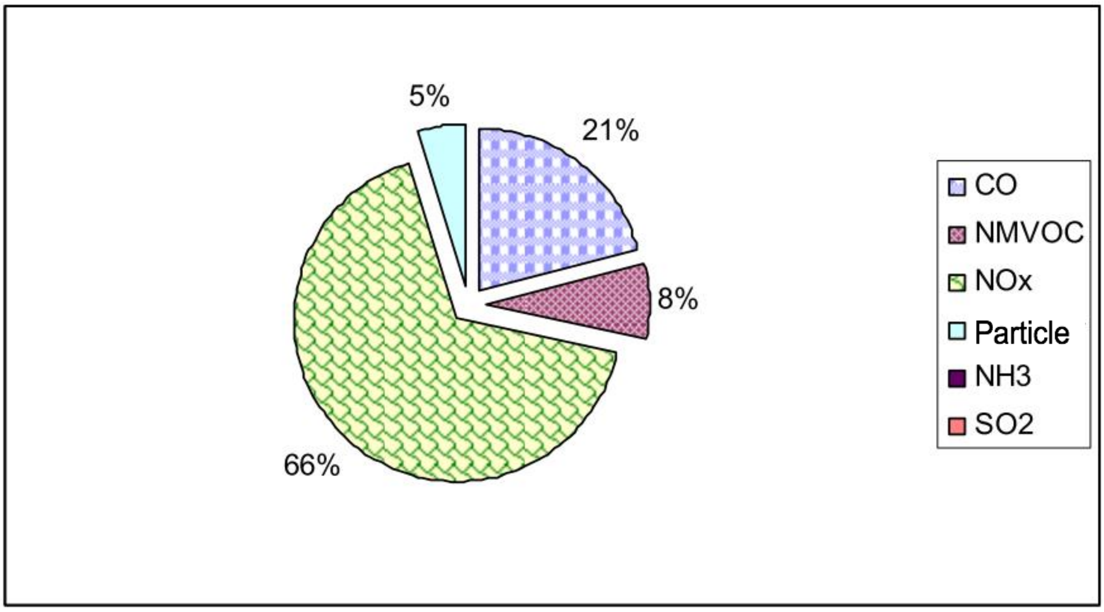
E.1.1 Atmospheric Pollution

The majority of construction induced atmospheric pollution emissions, occurs during the foundation work and the laying of under ballast, which is collectively considered as terracing (Phillips, Norra and Luleå, 2006). The example of a 270 km rail line construction in Sweden shows that terracing may produce air pollution emissions including carbon monoxide (CO), non-methane volatile organic compound (NMVOC), nitrogen oxides (NO_x), particulate matter (PM), ammonia (NH_3) and sulphur dioxide (SO_2) (Phillips, Norra and Luleå, 2006). Among the total air pollutants, NO_x accounts for about 66% with about 9.7t CO_2e/km and CO represents around 21% with 3 tCO_2e/km (Table E-1 and Fig. E-1)

Table E-1: Summary of the emissions (tCO_2e) while constructing a 270 km rail line Sweden.

Species	Terracing	Signal & Telephone Lining	Tracklaying & Superstructure	Electrical Lining	Total Construction Emissions
	tonnes				
CO	813,71	0,04	1,13	0,17	815,05
NMVOC	300,38	0,02	0,45	0,07	300,92
NO_x	2 612,22	0,15	4,35	0,61	2 617,34
Partiklar	187,38	0,01	0,31	0,05	187,75
NH_3	0,44	0,00	0,00	0,00	0,44
SO_2	0,35	0,00	0,00	0,00	0,35
N_2O	77,60	0,00	0,12	0,02	77,74
CH_4	11,09	0,00	0,02	0,00	11,11
CO_2	153 954,18	3,39	47,68	13,55	154 018,80
Total CO_2e	178 242,94	4,69	85,83	18,81	178 352,27

Source: (Phillips, Norra and Luleå, 2006).



Source: (Phillips, Norra and Luleå, 2006)

Figure E-1: Percentage of different air pollutants emitted in the construction of a 270 km rail line in Sweden.

E.1.2 Greenhouse Gases

As well as air pollutants, terracing could also generate some greenhouse gases (GHG) including nitrous oxide (N_2O), methane (CH_4) and carbon dioxide (CO_2) (Phillips, Norra and Luleå, 2006). The construction of a one-kilometre double track rail line may produce approximately 2,000 t CO2 (Table E-2). By contrast, CO_2 emissions from construction of a highway is greater than that from the construction of double track rail lines.

Table E-2: Comparison of CO_2 emissions from different rail and road construction.

Road / Rail	$tC0_2$ / $tC0_2e$	Unit	Details	Source
Rail	2,000	Double track km with OLE	No allowances for bridges, tunnels or other engineering	BFF current study
Rail	2,200	Double track km with OLE	No allowances for bridges, tunnels or other engineering	Atkins Carbon Critical Design (Atkins, 2009)
Road	3,000	Double lane highway	Average of range cited from other studies (US source).	GGLO, 2010
Road	2,400	Highway 401 3-lane (reduced to 2-lane)	LCA comparing asphalt and concrete road building (Canadian source). Figures given are for asphalt in line with UK norm.	Athena, 2007
Road	3,200	Urban freeway		
Road	2,300	High volume highway		

Source: (RSSB, 2010)

E.1.3 Noise Pollution

Machinery activity may cause noise pollution, which may affect nearby residents' health and their quality of life. Therefore, construction noise should be controlled and there should be a standard working time.

E.2 Operational Pollution

Similar to the construction of a rail line, the main pollution during the operation of the rail route is atmospheric (including GHGs) and noise pollution.

E.2.1 Greenhouse Gas Emissions

Among different transport activities, railways account for 8.5%, however, they only represents 0.6% of greenhouse gas emissions in the transport sector (1.5% if emissions from the generation of electricity are taken into consideration) (The Community of European Railway, 2015). In general, railways produce 0.040 kg CO_2/passenger/km, which is almost three times less than that released by road transport (0.110kg CO_2/passenger km). In the aspect of energy, railways may consume 400 kJ/passenger km. Rail consumes less than 2% of the total energy in the transport sector, even though it has a market share of more than 8.5% (The Community of European Railway, 2015).

Although distances may vary regarding to the route and peoples specific journeys, the 'Central Section' of the EWR project is predicted to engender 10,000 daily trips (Jacobs, 2016). For each of those passengers not taking their cars, a saving of 0.070 kg CO_2/km would occur, representing an amount of 700kg CO_2/km. With an average of 30 kilometres of trip distances equating to a saving of 21 t CO_2e/day.

E.2.2 Noise Pollution

Noise is a problem for all the main modes of transport and a big concern for people who live close to transport infrastructure. In European cities, approximately 10 million people are exposed to railway noise levels that exceed 55 decibels (dB) (the EU threshold marked by an average noise over 24 hours for excess exposure) (The community of European Railway, 2015). At night, in the same urban areas, about 8 million people are exposed to railway noise levels that are higher than 50 dB at night (the EU threshold marked at night time for excess exposure) (The Community of European Railway, 2015).

E.3 Comparison of Electric Vs Diesel traction

Electric trains do not produce atmospheric pollutants during their operation. Even taking the emissions from electricity generation into consideration, electric trains produce approximately 30% less GHGs than diesel trains (20 kg CO_2e/km per train and 28 kg CO_2e/km per train, respectively) (Henley, 2013).

According to a case study of air quality at London Paddington train station, hourly mean $PM_{2.5}$ concentration produced by diesel trains is 16 μg/m^3, during their 59-hour measurement, the minimum value of $PM_{2.5}$ concentration was 2 μg/m^3 and the maximum was 68 μg/m^3. Annual average European Union (EU) Ambient Air Quality Standards of $PM_{2.5}$ concentration is 25 μg/m^3 (Chong, Swanson and Boies, 2015). The concentrations of $PM_{2.5}$ observed, exceeded the EU standard multiple times, suggesting that the $PM_{2.5}$ emissions, produced by diesel trains, at station platforms, is currently an under addressed issue. Long-term exposure of particulate matter (PM_{10} and $PM_{2.5}$) can cause damage to people's respiratory and cardiovascular system. Damage to lung tissues and subsequently a reduction of lung function, causes adverse effects, especially in children, seniors, asthmatics and people who regularly exercise outside (HS2, 2017).

In respect to NO_x pollution, the hourly mean NO_2 concentration is 73 parts per billion (ppb) [min 49 ppb, max 120 ppb], while the EU hourly mean standard is 106 ppb. The hourly NO_2 concentration exceeded the EU standard value five times during the measurement (Chong, Swanson and Boies, 2015).

The pollution of NO_2 is less serious than that of $PM_{2.5}$. However, long-term exposure to NO_2 can result in symptoms of bronchitis, especially in asthmatic children (HS2, 2017).

Compared to diesel trains, electric trains have much less of an environmental impact. Additionally, the operating cost of electric trains is also less than that of diesel trains including fuel, maintenance and track wear costs. The fuel, maintenance and track wear costs of electric trains are £0.16/km, £0.25/km and £0.053/km respectively. Therefore, the general operating cost of electric trains is about £0.46/km (Railway Technology, 2010). The costs of diesel trains are £0.29/km, £0.37/km and £0.061/km respectively, which means that the general cost of diesel trains is approximately £0.73/km (Railway Technology, 2010). Hence, the operating cost of electric trains is less than that of diesel trains. However, the construction cost of electrified routes is higher than that of diesel routes. The construction of electrified track costs about £4.5 m/track km (Andress, 2011) and the international average construction cost of diesel routes is £2.5 m/track km (China Africa Research Initiative Blog, 2010). Additionally, track electrification cost is greater than £1.7m/track km (Clark, 2015).

Appendix F Land Cover

Four main natural land covers are represented from the study area:

- Woodlands
- Wetlands
- Grasslands
- Arable lands.

A financial value has been calculated for the four of them, based on an 'Ecosystem Services' approach. When possible, similar methods were used to gain these values. A considerable literature review has been studied first to reflect on a method applicable to every land cover.

Urban and sub-urban areas have also been considered through compensation schemes, combined with noise and air pollution studies. However, their economic valuation was different than the method used for natural capital.

F.1 Woodlands

Woodlands can be significantly impacted by rail line developments. For instance, the Woodland Trust endeavours to protect trees from the development of the HS2 route, from London to Birmingham Manchester and Leeds (Woodland Trust, 2011). Other studies regarding this British project, including one by Golder Associates', confirms that the predicted reduction of journey time does not justify the destruction of woodland resources. Indeed, forest land covers have many benefits that cannot be properly quantified (Golder Associates, 2017).

There are different ways of ranking woodlands. Two of them are:

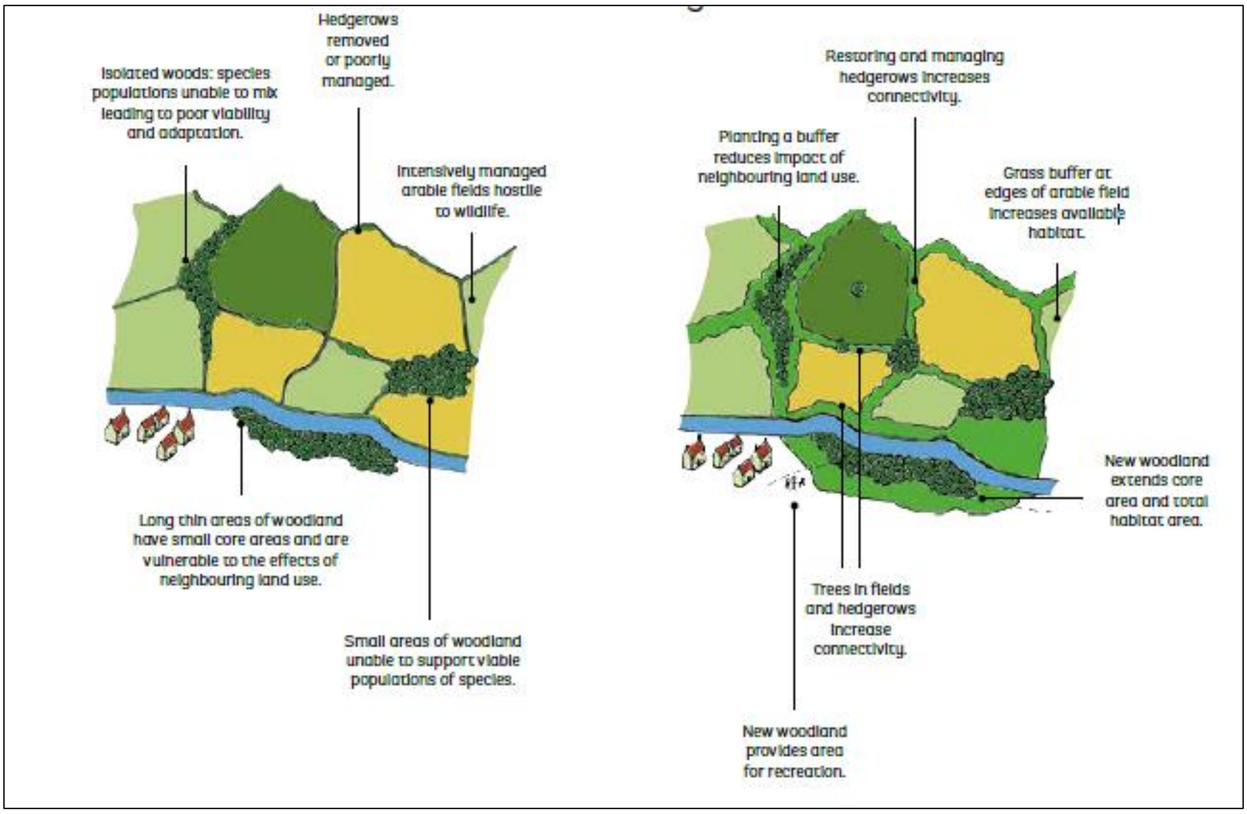
- Coniferous or broadleaved woodlands,
- Ancient (before 17th century) or semi-natural (after).

Certified ancient woodlands cover 551,000 ha of the United Kingdom, while certified semi-natural ones cover 646,000 ha, from a total of 1.197 million ha. Conifers are spread over 1.406 million ha and broadleaved cover 971,000ha. When adding felled, coppiced and open-spaces, woodland cover amounts to 2.8 million ha.

Consequently, woodland land cover represents 12% of the total land area. This percentage is far behind the global value of 30% (Quine *et al.*, 2011).

The term "Ancient woodlands" is used to describe areas that have been established pre-1600. Their stable condition has favoured the evolution of particular biodiversity, with undisturbed soils, veteran trees and multiple niche habitats. They cover only 2% of the UK's territory. They are usually small and surrounded by areas of human growth, unsuitable for species' expansion.

This fragmentation reduces total habitat area, increasing its isolation and vulnerability to disturbances. To mitigate it, quality woodland areas should be enlarged and closely connected when planning land development (Figure F-1).



Source: (Woodland Trust, 2011)

Figure F-1: Woods fragmentation mitigation.

Due to the environmental importance of ancient woodlands, many options exist to protect them (Woodland Trust, 2011). Consequently, if a train line is created close to ancient woodlands specific measures must be taken to avoid disturbances and pollution.

For instance, the plantation of other trees or the creation of a transition area between ancient woodlands and development areas may attenuate the negative impacts. Natural England recommends a security space of 15m between railways and woodlands and favours dense scrub areas over open grassland.

If it is necessary to cross sites of ancient woodlands, then tunnels are regarded as the better option. Indeed, ventilation shafts have a smaller impact on woodlands than cuttings, embankments and "cut and cover" tunnels. Relocation as compensation seems unfavourable, for ancient woodlands are the fruits of time, especially when mixed with a complex range of factors, including non-relocatable ones, such as geology and soils.

If tree cutting cannot be avoided and new trees are planted to compensate the loss of ancient ones, Natural England (2018) advises the use of a replacement ratio of 30:1 hectare, meaning, 1 hectare of ancient woodland lost should be replaced by 30 hectares of new woodlands.

Ecosystems can supply unseen services, sometimes even more important than physical goods (Quine *et al.*, 2011). Human well-being does not rely only on the supply of raw materials (Woodland Trust, 2011).

Moreover, trees possess an important regulating task: they cleanse air (storing carbon, phytoextraction and phytodegradation), cleansing of water (rhizofiltration and phytostabilisation) and the ability to act as a means of flood defence (improved water uptake and infiltration)

On an aesthetical side, they are also shelters for rich ecosystems and wildlife. Forests play a role in the physical and mental health of the population.

Woodlands can engender tourism and its associated revenue. They can, as well, provide wood or biofuel (provisioning service), when harvested. However, ancient woodlands are irreplaceable on a human timescale. For the other types of woods, trees must be re-planted if felled, and their number may be increased to attenuate other negative aspects associated with train line developments.

F.1.1 Ecosystem good and services

Woodlands provide extensive ecosystem services and are accompanied by an associated economic benefit. The benefit provided by the woodland will depend on the type of ecosystem service, as well as the age of the woodland. Table F-1 summaries the capitalised financial value per hectare in 2030 (the year that was assumed for rail line completion). The data was obtained from a variety of sources; the cultural services values are calculated as an average of the welfare provided by the woodland of the area according to the Outdoor Recreational Valuation (ORVal) software developed by Exeter University. The Economics for the Environment Consultancy (EFTEC) provided information about the timber value in order to calculate the main provisioning service from woodland (EFTEC, 2010). Finally, the remaining values were obtained from the UK National Ecosystem Assessment (UKNEA).

Table F-1: Woodland ecosystem services values per hectare in 2030.

Land Cover	Services	Ecosystems Goods and Services	Capitalised financial value per hectare (£/ha)
Ancient Wood	Cultural	Welfare	56,992
Wood New Planting			56,992
Ancient Wood	Habitat	Biodiversity	8,528
Wood New Planting			2,198
Ancient Wood	Provisioning	Timber value	428
Wood New Planting			3,420
Ancient Wood	Regulating	Carbon	5,208
Wood New Planting			
Ancient Wood		Air pollution absorption	6
Wood New Planting			

F.2 Wetlands

The United Kingdom's (UK) freshwater wetlands and waterways range from small ponds and trickling streams to gushing rivers and reservoirs. Historically, they were highly connected to each other, but nowadays, nearly half of all floodplains in England and Wales are fragmented and disconnected. There are more than 389,000 km of rivers, around 200,000 ha of lakes and nearly half a million ponds in the UK. According to the UKNEA (Morris and Camino, 2011) and in spite of these examples, the true extent of the UK's wetlands is not well defined. In England alone there are 113,305 ha of inland wetland (Maltby *et al.*, 2011; The Wildlife Trust, 2017b).

Unfortunately, wetlands are one of the most damaged habitats in the UK. Wetland habitats are decreasing due to drainage and over abstraction. Moreover, the remaining freshwater areas are being colonized by non-native invasive species and are under pressure from development. (The Wildlife Trust, 2017b).

Bedfordshire and Cambridgeshire wetland and rivers are a wealth of opportunity both for wildlife and people. On the one hand, rivers and streams provide wildlife such as the southern mayfly and white-clawed crayfish and are important habitats for threatened bird species such as bittern, marsh harrier, and bearded tit. On the other hand, wetlands support many species such as stickleback, pike, and roach among others. In addition, freshwater wetlands also have an economic value due to their importance as a source water, natural material and recreation, as well as providing (often undervalued) services including flood defence and water purification (The Wildlife Trust, 2017a)

The UKNEA Technical Report provided extensive information related to wetland. For the study, just those with a presence in the area were taken into consideration.

The Wildlife Trusts (2017a) pay a keen focus on the different types of wetland and rivers habitats that can be found, the following are found within the study area:

- *Lowland Fens*: According to the UK Biodiversity Action Plan (BAP) "Fens are peatlands which receive water and nutrients from the soil, rock and ground water as well as from rainfall" (Maddock, 2011). In general, fen habitat has a large diversity of plant and animal communities, being able to host up to 550 species of higher plants and several thousand insect species including aquatic beetles.
- *Lowland flushes, fens, and swamps*: According to the UK BAP "peat or mineral-based terrestrial wetlands in lowland situations, which receive water and nutrients from the surface and/or groundwater sources as well as rainfall" (Maddock, 2011). This habitat supports a rich flora of vascular plants, like scorched alpine-sedge or bristle sedge, and is also suitable for waders. Furthermore, this habitat supports a varied invertebrate fauna with the presence of a number of the following taxonomic families, *Diptera*, *Coleptera* and *Araneae*.
- *Ponds:* According to UK BAP priority habitat classification, ponds are defined as "permanent and seasonal standing water bodies up to 2 ha in extent" (Maddock, 2011). In spite of their small extension, ponds support a large number of priority species, especially invertebrates like the large red damselfly. The vegetation varies according to depth, therefore plants such as spiked water-milfoil could be found in deep water areas while creeping bent is typical from shallow water ponds.
- *Reedbeds:* There are wetlands with common reed where the water table is at or above ground level for most of the year. These habitats are important for birds, they support a notable number of breeding birds, including six nationally rare 'Red Listed' birds. In addition, reedbeds are used as roost sites for several raptor species in winter (Maddock, 2011).
- *River and streams:* All naturally running waters in the UK are encompassed under this broad habitat classification. Rivers and streams are considered as a priority area because they provide shelter and feeding opportunities for a wide range of plants and animals. In addition, they provide key services for people

such as water supplies, recreational areas, and flood defence. (Maddock, 2011; The Wildlife Trust, 2017a).

In order to simplify the evaluation, three broad habitats were selected according to the BAP: Priority Habitat classifications (Maddock, 2011): Lowland fens (including fens, marsh, and reedbeds); standing water (lake, Reservoirs, and pounds) and rivers.

The routes proposed do not cross many important waterbodies. However, wetland and freshwater bodies could, if needed, be crossed by bridges in order to minimise the environmental impacts of construction. If there is no way of avoiding any wetland habitat the new wetland should be created through appropriate compensation.

F.2.1 Ecosystem good and services

Wetlands provide many ecosystem services that have associated economic benefit. The benefit provided by the wetland will depend on the type of the ecosystem service. According to the UKNEA, inland wetlands have a default average value of £303/ha/year and the contribution of each individual benefit is added to that average (Morris and Camino, 2011). Table F-2 summarises the capitalised financial value per hectare in the year 2030, as it was assumed the railway would be completed by this date. Table F-2 contains the financial values of the cultural service. This value was calculated using the ORVal software as an average of the welfare benefits that this land cover provided to the population.

Table F-2: Wetland ecosystem services values per hectare in 2030.

Services	Ecosystems Goods and Services	Capitalised financial value per hectare (£/ha)
Cultural	Welfare	10,589
Habitat	Biodiversity	7,8497
Provisioning	Surface and groundwater supply	3,163
	Commercial fishing and hunting	3,017
	Harvesting of natural materials	1,804
	Material for fuel	767
Regulating	Flood control and storm buffering	9,446
	Water quality improvement	7663
	Carbon storage	861

F.3 Grasslands

Many different ways of classifying habitats can lead to misunderstanding. For the benefit of this study the terms 'Semi-Natural Grassland' and 'Grasslands' will be used interchangeably. Unsurprisingly grassland covers a broad range of BAP Priority habitats including; 'Floodplain Grazing Marsh', 'Rush Pasture', 'Purple Moor Grassland', 'Lowland Calcareous Grassland', 'Lowland Dry Acid Grassland', 'Lowland Meadows' and 'Arable Field Margins'. The study focussed on 'Lowland Calcareous Grassland', Lowland Acid Grassland' and 'Lowland Meadows' as these habitats will be disrupted by the current route proposals by EWR and 5th Studio.

The UKNEA technical report provided extensive information related to grasslands. Through including a variety of grasslands types, from both the Countryside Survey and BAP classification system, the variety of grassland habitats has resulted in the term 'semi-natural grasslands'. Whilst it is essential to recognise the changes in biodiversity, geology and associated cultivation requirements it is necessary to categorise the many different types of habitats for simplicity.

The option of conservation endorsement, through subsidy funding, has been possible since 2008, through application to Natural England (Natural England, 2012). This has encouraged the creation of farmland areas dedicated to the provision of habitats suitable for encouraging biodiversity such as headlands, winter stubble and buffer strips.

During 2007 it was estimated that only 2% of the 12.4 million ha dedicated to semi-natural grassland' contained a diverse population of plants and animals (Bullock, 2011). Further, a 90% decline in UK grassland areas is believed to have occurred since the end of the Second World War (Bullock, 2011). The importance that grasslands play in the wider sense is often overlooked. Suggestions in the literature include the decline of the bumblebee, which has been associated with the loss of semi-natural grasslands. Furthermore, grasslands provide a habitat suitable to almost a quarter of the 1,150 species which are of conservation concern (Bullock, 2011).

When undertaking site selection, the value of grasslands must be compared to other habitats and land classifications such as woodlands, wetlands, parklands and arable and horticultural land. The benefits that grasslands can provide in comparison to improved grassland, arable and horticultural land will vary depending on how they are managed. Nevertheless, there are general understandings supported by Bullock (2011) and colleagues, which include the ability for semi-natural grasslands, in comparison to arable and horticultural land, to:

- Contain higher densities of carbon per hectare.
- Reduce methane production due to lower or limited livestock.
- Reduce the production of nitrous oxide due to reduced or no use of fertilisers.
- Enable increased water infiltration rates due to greater storage capacity, aiding with flood prevention/reduction.
- Reduce the leaching of fertilisers into watercourses.
- Provide improved nutrient cycling due to extensive biodiversity.

There are drawbacks as with any cycle or system. Converting land use to semi-natural grasslands from agricultural land is likely to be unviable economically, with a reduction of animal and crop production being of consideration. In comparison, the difference in economic yield of a semi-natural grassland, compared to an improved pasture, could be as great as £500 ha/yr (Bullock, 2011). This figure is also unlikely to consider the economic value per animal which can be estimated to be between £60 – 1000 /head (DEFRA, 2015).

One of the major concerns that is currently underrated, in terms of ecosystem services, is the genetic diversity contained within semi-natural grasslands. The diversity of both fauna and flora is reducing, as are traditional methods of grassland management, such as shepherding as these methods give way to intensive agricultural practice (Bullock, 2011). In order to restore these habitats, a constant stream of funding is required for conservation purposes as the financial return that is gained by traditional methods does not compete against intensified agricultural methods (Bullock, 2011).

F.3.1 Ecosystem good and services

Different surveys, assessments, technical reports and manuals assess ecosystems good and services in a multitude of ways. A simplified table has been produced by the UKNEA as shown in Table F-3, demonstrating the goods and services provided from grasslands. An overview was also produced by the Office for National Statistics. This overview used a tick box method for association of key characteristics and services including; provisioning, regulating and cultural services offered by the various habitats (Office for National Statistics, 2015). De Groot *et al.*, (2010) used a system for providing financial valuation of provisioning, regulating and cultural services. This method is featured in a report conducted by Jacobs (for the Airport Commission) which focuses on ecosystem services at Gatwick and Heathrow airports (Airports Commission, 2014). Not all ecosystems services have been provided with a financial value. However, this research provides a starting point for the valuation of the natural capital that is provided by grasslands. The European Environment Agency endorse the Common International Classification of Ecosystem Services (CICES). This database contains information related to provisioning services (biotic and abiotic), regulating and maintenance services and cultural services broken down into groups and classes. The hierarchy used by CICES provides brief definitions with accompanying examples (European Environment Agency, 2018).

Table F-3: Goods and services provided by semi-natural grasslands from the UKNEA. Source (Bullock, 2011)

Service Group	Final ecosystem service	Goods and benefits
Provisioning	Livestock: forage for cattle, sheep, etc.	Food (meat, milk), fibre (wool), possibly enhanced quality of meat and milk
	Standing vegetation: biomass crops	Possibly fuel
	Crops: pollination and pest control spillover	Food (crops)
Cultural	Environmental settings: valued species and habitats, agricultural heritage, archaeological heritage, grazing for rare livestock breeds, ecological knowledge, training areas	Physical and psychological health, social cohesion, recreation and tourism, UK research base, UK military training
Regulating	Climate regulation: sequestration and storage of carbon and other greenhouse gases	Avoidance of climate stress
Provisioning	Water quantity: storage of water and recharging of aquifers	Potable water, water for food production, flood protection
	Purification: reduced pollution and storage of pollutants	Clean air, clean water, clean soils
Regulating	Wild species diversity: plant genetic diversity, seed for restoration projects	Genetic resources, bioprospecting, recreation and tourism, ecological knowledge

The Economics of Ecosystems & Biodiversity (TEEB) database provides a resource for assessing the value that individual ecosystems services provide worldwide. This coalition of data is extensive and provided an ideal starting point for assessing the value of ecosystems goods and services. Table F-4 illustrates the variety of ecosystem goods and services that can be quantified (European Commission, 2015)

Table F-4: Compilation of ecosystems goods and services provided by 'Grasslands'. The data has been collated from work by Groot et al (2010), Butcher Partners Limited (2006), DEFRA (2015), CICES (2018), Ministry van Landbouw (2006) Brenner-Guillermo (2007) within the TEEB database.

Services	Ecosystems Goods and Services	Monetary value per hectare (£/ha)
Provisioning Services	Upper nutritional crops value	£82
	Lower nutritional crops value	£4
	Upper drinking water supply value	£468
	Lower drinking water supply value	£20
	Irrigation water (unnatural)	£293
	Upper fresh water supply	£602
	Lower fresh water supply	£219
	Upper raw materials value	£31
	Lower raw materials value	£14
	Upper livestock production value (per head)	£1,000
	Lower livestock production value (per head)	£60
	Genepool protection (spores, seeds, DNA)	£298
	Biomass energy	£0
	Aquaculture	£0
	Peat extraction	£0
	Ornamental Resource	£0
Regulating Services	Influence of air quality	£219
	Lower climate regulation value	£5
	Upper climate regulation value	£1,661
	Carbon sequestration	£200
	Upper water purification value	£358
	Middle water purification value	£78
	Lower water purification value	£10
	Water flow, quantity and quality regulation	£5
	Lower erosion prevention value	£26
	Middle erosion prevention value	£47
	Upper erosion prevention value	£71
	Nutrient cycling and maintenance of soil fertility	£533
	Soil structure and pollution mediation	£5
	Life cycle maintenance: Pollination	£23
	Biological control pest control	£21
	Moderation of extreme events	£0
	Maintaining nursery population	£0
Cultural Services	Inspiration for culture, art and design	£144
	Educational and scientific knowledge	£0
	Opportunities for recreation and tourism	£8
	Spiritual experience	£0
	Military use	£0
	Heritage	£0

F.4 Arable lands

Agriculture is classified according to the base of crops, pastures, ploughed land and herbaceous vegetation. Arable land is usually based on annual crops. The major crops in the UK are cereals (66.7% of the total crop area), with wheat and barley accounting for 95% of the total cereal area (Les *et al.*, 2011).

The arable lands of the study area represent 70% of the total area. The percentage of cereals, fulfilling the role of predominant crop in the country, corresponds to 49% of the total area of cultivated crops. However, during recent years there has been a decrease in the number and size of these lands (Natural England, 2014).

The figure of 70% of land in agricultural use corresponds to 181,916 hectares and 1,798 farms. Of these farms, 84,922 hectares are dedicated to the cultivation of cereals, 27,717 hectares to oilseeds and 12,643 to other herbaceous crops (Natural England, 2014).

The decrease in the number of farms has been 6%, such as arable farms that have been reduced by 19% and mixed farms by 12%. However, livestock grazing farms have grown by 10% (Ridge, 2014). Solar farms were not considered.

Within the National Character Area (NCA): 88 Bedfordshire and Cambridgeshire Claylands the quantity and size of farms are classified using the following criteria (Natural England, 2014):

- Over 100 ha → 571
- 50 - 100 ha → 294
- 20 - 50 ha → 347
- 5 - 20 ha → 424
- Less than 5 ha →162

Farms over 100 ha equate to 79% of the total farmed area, with those under five ha accounting for less than 1%. Moreover, the numbers of farms in the smallest size categories have seen the greatest decline (Natural England, 2014)

The main agricultural land use links to cereals of which 47% of the total farmed area is allocated. The remaining fractions are; grass and uncropped land at 25%, oilseeds at 15% and other crops at 7%.

Other agricultural land uses each represented less than 1% (Natural England, 2014). During the last year, the area of cereals has reduced by 16%, and in addition, the area of grass and uncropped land has reduced by 18%.

Mixed cropping is seen more so than cereal production. However, wheat is the main crop. Although land is also cultivated for oilseed rape as a source of energy for biofuel production. Maize is also grown but on a small scale (Ridge, 2014).

The main objective of the classification of agricultural land is the planning of land use. In this way, the development of buildings in areas of greater agricultural potential is avoided. The factors used for the analysis of the five grades of which this classification is composed are: climate, soil, depth, texture, structure, stoniness and water capacity. The first grade is that of the best quality (Keay *et al.*, 2013).

As can be seen from Table F-5, there are several agricultural land classification options that are in the area (Natural England, 2014).

Table F-5: Agricultural Land Classification in Bedfordshire and Cambridgeshire.

Agricultural Land Classification	Area (ha)	% of NCA
Grade 1	5,386	2
Grade 2	90,690	35
Grade 3	124,851	48
Grade 4	14,504	6
Grade 5	0	0
Non-Agricultural	11,932	5
Urban	13,198	5

Source: (Ridge, 2014).

As described above, the principal soils are divided with only 2% of Grade 1 soil within the study area, followed by 35% of Grade 2 and 48% of Grade 3. Keay et al. (2013), points out that the main weakness with Grade 2 is its limitation for demanding crops, although it still has the capability to support a wide range of crops. On the other hand, in the Grade 3 land there are reasonable boundaries regarding the crop choice, timing and type of cultivation, harvesting or level of yield.

Appendix G Environmental Evaluation

G.1 Habitat Valuation

Any type of land cover may be removed for the purpose of railway development and future operations. A safeguarding space may even be created, to protect both rail lines from natural hazards and natural assets from permanent disruption. However, a balance between biodiversity and train efficiency must be respected (Network Rail, 2017). Therefore, the necessary compensation will mainly be calculated in relation to the biodiversity aspect. The financial valuation given for each land covers' habitat service will hence stand for the cost of recreating the lost biodiversity.

Many methods of assessing biodiversity compensation ratios exist. For this project, the methodology developed by the HS2 project was used (HS2, 2015). This methodology is based on various metric multipliers: distinctiveness, condition, difficulty of recreation and time to reach target condition. The multipliers are combined to give a biodiversity unit per ha before and after the impact. With these values, the replacement ratio is obtained.

According to DEFRA and Natural England (2012), "*distinctiveness is a collective measure of biodiversity and includes parameters such as species richness, diversity, rarity and the degree to which a habitat supports species rarely found in other habitats*". The majority of areas were assigned with a condition of "Good" (3). However, those that were isolated or that had a small area among other factors, were defined as "Moderate" (2).

Secondly, different habitats have different conditions, therefore standards and methodology should be agreed for measuring habitat conditions. According to HS2 (2015), all habitats with "very high", "high" and "moderate" distinctiveness should be rated with a three-point condition scale which is a reference to the Higher Level Stewardship (HLS) agri-environment scheme condition assessment tool (Natural England, 2012). In order to determine the importance of the land cover under study within the 'existing ecological network', the HS2 guidelines were followed (HS2, 2015). The majority of areas were assigned with a condition of "Good" (3).

Nevertheless, those that were isolated or that had a small area among other factors were defined as “Moderate” (2) or “Poor” (1).

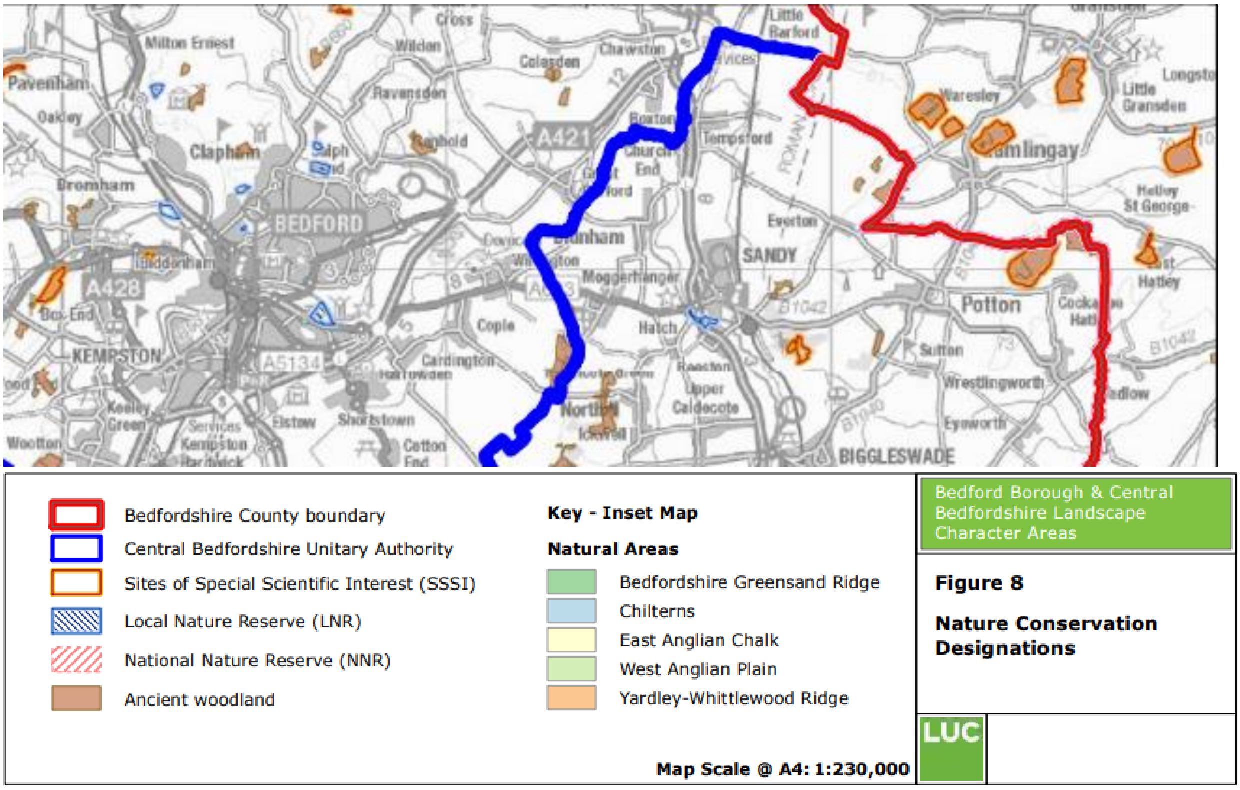
In order to calculate the replacement factor (or biodiversity units after recreation or restoration), the risk factor, difficulty of recreation and time to target condition, should be considered.

On the one hand, some habitats are more difficult than others to restore, therefore using expert opinion, referred to as the ‘DEFRA: Biodiversity Offsetting Pilot methodology’, the use of specific categories for difficulty of restoration, and its related multipliers can be gained (DEFRA, 2012). On the other hand, the difference in time between the negative impact and the offset reaching the required quality should be considered, as the duration to creation can be undervalued resulting in unaccountable and undercompensated losses of biodiversity. The pilot methodology has proposed a time discounting rate of 3.5%, as agreed and available in the Treasury’s Green Book (HM Treasury, 2011).

For instance, an ancient woodland in a good condition (3/3) with a high distinctiveness (8/8) will have a value of 24 units/ha whereas a common woodland from the 18th century, considered to have a satisfying distinctiveness of 6/8 and a medium condition (2/3), will rise at 12 units/ha. Based on a worst-case assumption, as in HS2, this common woodland, just planted, would require a long time to establish (0.33) and much difficulty (0.1) to be recreated. This recently planted common woodland would possess a value of 0.40 units/ha. To attenuate the loss of a 24 units’/ha ancient forest, 60 ha (24/0.40) of recreated wood would need to be replanted.

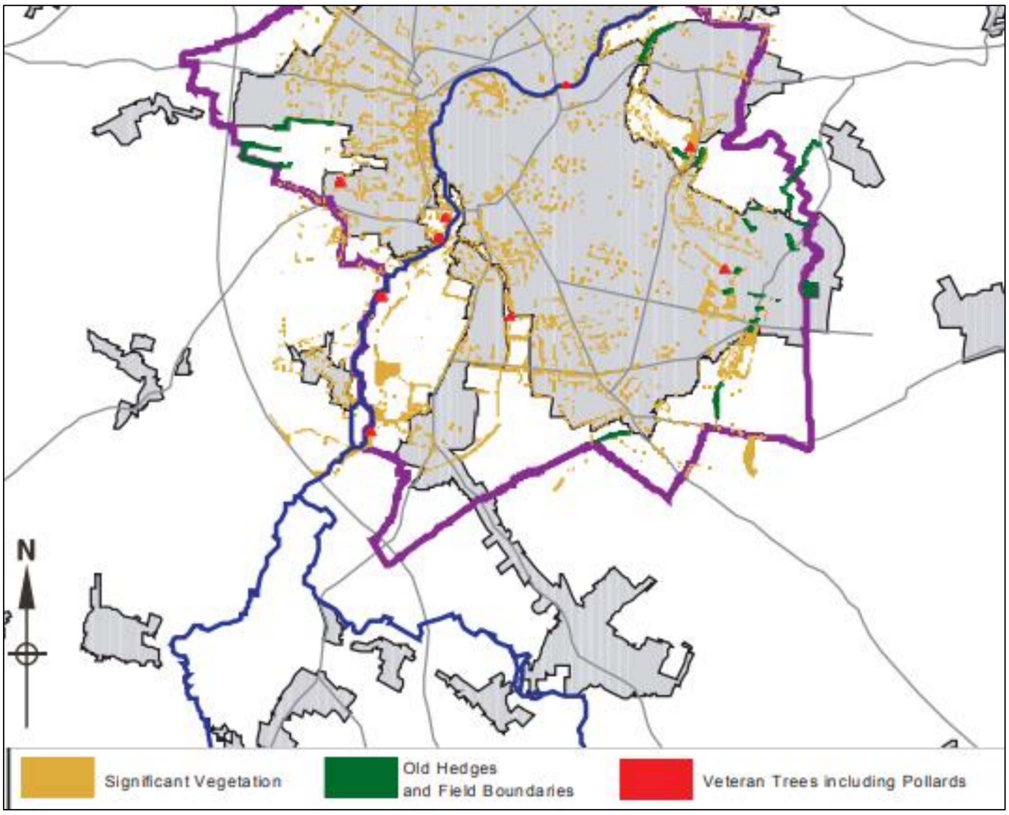
G.1.1 Woodlands

Ancient woodlands are identified on local authorities' landscape character assessments. Natural England also proposes their location on an open database for Geographical Information Analysis (Natural England Open Data, 2018). Figures G-1 and G-2 were used to locate them.



Source: (Land Use Consultants Ltd, 2015)

Figure G-1: Ancient woodlands' locations Central Bedfordshire.



Source: (Cambridge City Council, 2003)

Figure G-2: Ancient woodlands' locations Cambridge

Every ancient woodland, listed and particularly protected, has been seen to have a very high distinctiveness (factor 8) and to be in good condition (factor 3). Other woods, impossible to be correctly dated within the means and timeline of the project, were assessed at a distinctiveness of 6 for broadleaf forests and 5 for coniferous ones. Coniferous woodlands are not as species rich as broadleaf woodlands and are therefore attributed with a lower value (The Environment Bank, 2013a). Their condition was quantified with regard to their position and size: a wide forest is likely to have a more flourishing biodiversity than a small wooded surface, a wood situated in a park is likely, as well, to be protected compared to a wood near to a busy road.

Finally, replacement woods can be created. However, they are assumed to be difficult to grow (factor 0.1) but to reach a high distinctiveness (6) and a good condition (3) after more than 33 years (0.33). Consequently, the replacement woods stand at a biodiversity factor of 0.59, as per the DEFRA metric used for HS2. The planting of replacement woods has been assumed to utilise native broadleaf trees species with a spacing of individual trees at 2 m intervals. The total plantation cost is expected to be £7,888/ha (Environment Agency, 2015).

G.1.2 Wetlands

In order to assess the biodiversity compensation ratios of wetland, the procedure explained above was followed. Firstly, the distinctiveness of each freshwater area was designated following the HS2 report. Table G-1 is a summary of the distinctiveness values considered for the evaluation.

Table G-1: Distinctiveness values assumed for this report.

Land Type	Distinctiveness
Lowland Fen	Very high (8)
Reedbeds	Medium (4)
Standing water (Lakes, Ponds, Reservoir…)	High (6)

Secondly, the importance of the existing ecological network of the wetland within the area was evaluated. This evaluation was undertaken following the HS2 classification (HS2, 2015). The majority of the areas were assigned with a condition of "Good" (3). Those that were isolated or that had a small area among other factors, were defined as "Moderate" (2).

Finally, according to DEFRA and HS2, the difficulty in restoration of the waterbodies under study was regarded as "Medium": A metric multiplier of 0.75 was designated (DEFRA and Natural England, 2012). Moreover, for this study and in accordance with the HS2 report, it was assumed that wetlands need greater than 33 years or above to achieve the target condition of restoration. Consequently, assuming that after restoration the area could reach a high distinctiveness (6) and good condition (3), the replacement factor was 4.46. Additionally, the 2018 cost of recreating inland water bodies was £23,854/ha or £11,576/ha for marshes (Environment Agency, 2015). Examples of the calculated replacement ratio are summarised in Table G-2.

Table G-2: Summary of ratios obtained for wetland replacement.

Distinctiveness	Condition	Biodiversity Units	Difficulty of recreating	Time to target	Replacement factor	Ratio
6	2	12	0.75	0.33	4.5	1 : 2.7
6	3	18	0.75	0.33	4.5	1 : 4.0
8	3	24	0.75	0.33	4.5	1 : 5.4

G.1.3 Grasslands

At the time of seeking data for this project, the Office for National Statistics were undertaking work on a publication titled ‘UK Natural Capital: Developing semi-natural grassland ecosystems accounts’ (Office for National Statistics, 2018). Due to limited information regarding the replacement of biodiversity, it was seen fit to utilise an updated metric utilised in the HS2 ‘No Net Loss in Biodiversity’ report which is based on the DEFRA biodiversity offsetting metric (DEFRA and Natural England, 2012). The metric takes into account the distinctiveness of the existing habitat and the importance of the habitat within the existing ecological network. This provides the biodiversity unit of that habitat. For application of a compensation ratio, difficulty in re-creation/restoration of the habitat and the years to taken to reach target condition were considered.

DEFRAs Biodiversity offsetting metric provides tables with ratings for difficulty in recreating a habitat, restoring a habitat and the expected duration to reach target condition (DEFRA and Natural England, 2012). For example, lowland calcareous grassland has a ‘technical difficulty to recreate habitat rating of Medium’, a ‘years to target condition’ estimation of 50-100 years and ‘technical difficulty of restoration value of ‘Low’. A likely reference to this study is the scenario involving the replacement of grassland with high distinctiveness (6/6) and in good condition (3/3). This would be attributed a value of 18 biodiversity units. Such habitat is moderately difficult to create (0.75/1) and would take 10 years to establish (0.71/1). The multiplication of all factors resulted in a biodiversity replacement factor value of 9.585.

The biodiversity unit of an existing habitat of high distinctiveness which is highly important within the existing ecological network was divided by the biodiversity replacement factor giving the value of 1.87. Based on this metric a suitable replacement ratio would be 1.88 ha for every 1 hectare under consideration for removal.

Certain constraints are presented through the restrictions of valuation of Sites of Special Scientific Interest (SSSI). The aforementioned and accepted method does not include such sites within an assessment; the result is each site affected would need to undergo discussion with Natural England in regards to compensation and mitigation (HS2, 2015). Therefore, none of the following sites have been included within the detailed valuation that follows as their importance is of the upmost concern and shall be required to be assessed on a site by site basis: SSSI, The Wildlife Trusts Royal Society for the Protection of Birds (RSPB), Local Nature Reserves (LNR) or areas of BAP: Priority Habitat.

A collation of data is presented in Table G-3. This presents the justification for assessment of each priority habitat area with the study based on the factors required for providing compensation ratios. Unfortunately, this table provides limited use for the study as it was decided that ArcGIS would be used when presenting the suggested routes. The free version 'Magic Map' was compared to frequently for the locations of SSSI's, LNR's and BAP Priority Habitats. The confliction of habitat types and classification was first discovered when ArcGIS was used for assessing grasslands. The options for focusing on grasslands were either 'neutral grassland', 'improved grassland' or 'heather'. This immediately posed difficulties relating to direct comparison of routes through multiple software applications including Magic Map, ORVal and ArcGIS.

Table G-3: Collation of metric criteria for grassland habitat compensation ratios.

Habitats	Department for Transport: HS2 London -West Midlands (2015)							
	DEFRA Biodiversity Offsetting Pilots (2012)							
	Phase 1 Code	Distinctiveness	Distinctiveness weighting	Technical difficulty to recreate habitat	Consideration of difficulty of recreating /restoring (multiplier)	Years to target condition	Consideration of time to get to target condition (Multiplier)	Technical difficulty of restoration
Lowland calcareous grassland	B3.1	High (Unimproved)	6	Medium	0.75	50-100 years	0.33	Low
Lowland calcareous grassland	B3.2	*High/moderate (Semi-improved)	6/4	Medium	0.75	50-100 years	0.33	Low
Calaminarian grasslands	B1.1	*High (unimproved acid grassland)	6	High	0.33	N/A	N/A	Medium
Lowland dry acid grassland	D5	High	6	Medium	0.75	*50-100 years (Heathland)	0.33	Low
Lowland meadows	B2.2	*High (marshy grassland)	6	Medium	0.75	*20-100 years (Oligotrophic grasslands)	0.50	Low
Improved grassland	B4	Low	2	*Low	*1.00	0-5 years	0.83	*Low
Amenity grassland	J1.2	Low	2	*Medium	*1.00	0-5 years	0.83	Low
Neutral grassland	B2.1	High	6	*Medium	*1.00	N/A	N/A	N/4
Neutral-grassland – semi-improved	B2.2	Moderate	4	N/A	N/A	N/A	N/A	N/4
Dry heath	D5	Very High	8	Medium	0.75	50-100 years	0.33	Medium

*Authors judgement

G.1.4 Arable Lands

Arable lands, contrary to the other land covers, are too numerous to be accounted for one by one. They were considered globally, looking at their proportion of land and their classification.

Arable land may be easier to recreate than the previously cited ones. It was considered that poor-condition agricultural lands would be planted to replace good-condition ones. Cereal crops and arable fields, representing 75% of Bedfordshire agriculture, are ranked by the Environment Bank with 6 units/ha in good condition, against 2 in poor condition (The Environment Bank, 2013b). Uncultivated strips, representing 25% of Bedfordshire agriculture, possessed a biodiversity value of 12 units/ha in good condition and 4 if not (The Environment Bank, 2013b). The replacement ratio, calculated by dividing both situations, was 3. (The Environment Bank, 2013b). The replacement cost assumed, in the context of the lack of other data, was the Environment Agency (EA)drier grassland category of £1,403/ha.

G.1.5 Recreational Cost

Recreation costs are provided by the EA (Environment Agency, 2015). Coming from the same source, they have been favoured for the project continuation. They are similar to figures from other sources. Indeed, though lesser than the ones given by the Forestry Commission in 2011 and presenting a cost of £3/tree, i.e. £7,500/ha for a density of one tree every 2 m (Forestry Commission England, 2011), they are from a global source gathering values for many land covers.

Sources have been quoted and dated by the EA. The inflation rate, replacement costs have been levelled at the 2018 pound value (Alioth Finance, 2017).

The recreation costs of different land covers, was levelled at the 2018 £ value. The values are represented in Table G-4.

Table G-4: Replacement costs associated with different land covers

Habitat type	Replacement cost (£/ha)	Replacement cost without land purchase (£/ha)	Date of cost	Replacement cost without land purchase in 2018 (£/ha)	Source
Inland water bodies and lagoons	23,174	17,000	2006	23,854	FD2017
Mudflats – medium		15,000	2000	24,485	CIRIA C565
Wet grasslands	15,174	9,000	2006	12,629	FD2017
Bogs, marshes, fens	14,424	8,250	2006	11,576	FD2017
Reedbed habitat – low (freshwater)		2,800	2000	4,570	CIRIA C565
Broad-leaved woodland – high		7,500	2002	11,832	CIRIA C565
Broad-leaved woodland – low		5,000	2002	7,888	CIRIA C565
Heath, scrub and open vegetation	11,174	5,000	2006	7,016	FD2017
Grazing marsh – high		4,000	2002	6,310	CIRIA C565
Wet woodlands	9,674	3,500	2006	4,911	FD2017
Broad-leaved and mixed woodland	9,174	3,000	2006	4,210	FD2017
Coniferous woodland	8,674	2,500	2006	3,508	FD2017
Drier grasslands	7,174	1,000	2006	1,403	FD2017

Source: (Environment Agency, 2015)

The above values served for estimations of replacement works and gave the biodiversity value of a specific land. Indeed, multiplying the compensation area needed to be created, after the destruction of an ecosystem, with its re-creation cost per hectare, is equal to the cost of replacement of this ecosystem's biodiversity.

G.2 Regulating Services

Carbon sequestration and storage is one of the regulating ecosystem services provided by the different land covers'; consequently, this service was evaluated in this study. In order to evaluate this ecosystem services for the land covers of the study area, the carbon storage value associated with every land cover was highlighted, according to different literature sources. This amount was multiplied by the carbon value in 2030 to give a financial index of the regulating service. According to the Department for Business Energy & Industrial Strategy (2018b), the carbon value of 2030 was estimated to be £79.43/t CO_2e.

Other regulating services (water and air quality), which were not quantifiable or non-existent, were not taken into account by this study for most of the land covers.

G.2.1 Woodland

Exmoor National Park provided an example for specifically calculating the carbon sequestration benefits associated with woodlands (Sandwood Enterprise, 2013). This report gathers the carbon storage amount associated with types and ages of trees with examples shown in Tables G-5 and G-6. Due to the lack of map information (the project maps represent only ancient forests and not any other age value) an average of the medium age classes was taken. Young trees were identified using the global forest watch tool (Hansen *et al.*, 2003) and ancient trees are presented on the project GIS maps. There are some young tree covers in the western part of the area, notably around Marston Vale and the Grange Estate (Figure G-3). Their covers are however scarce and realistically unaccountable.

Carbon emissions are likely to reach a cost of £79.43/tCO_2 in 2030 (Department for Business Energy & Industrial Strategy, 2018b).

Table G-5: Carbon storage in Exmoor woodlands regarding their age and types

Woodland Type		Age class (years)							Total
		0-20	21-40	41-60	61-80	81-110	111-150	Over 150	
Conifer	Area (ha)	1001	956	839	0	0	45	0	2841
	Total C (tCO2)	53626	286144	369586			32658		742014
Broad	Area (ha)	0	227	1324	980	773	1980	206	5490
	Total C (tCO2)		45002	625382	548128	506116	1544806	172394	3441828
Total	Area (ha)	1001	1183	2163	980	773	2025	206	8331
	Total C (tCO2)	53626	331146	994968	548128	506116	1577464	172394	4183842

Source: (Sandwood Enterprise, 2013)

Table G-6: Calculation of carbon sequestrated value per hectare of woodland (at 2030 carbon values).

	tCO_2/ha	£/ha
Broad Leaf Young	198	15,743
Broad Leaf Unknown	638	50,644
Broad Leaf Ancient	837	66,474
Coniferous Young	54	4,257
Coniferous Unknown	254	20,151
Coniferous Ancient	726	57,642

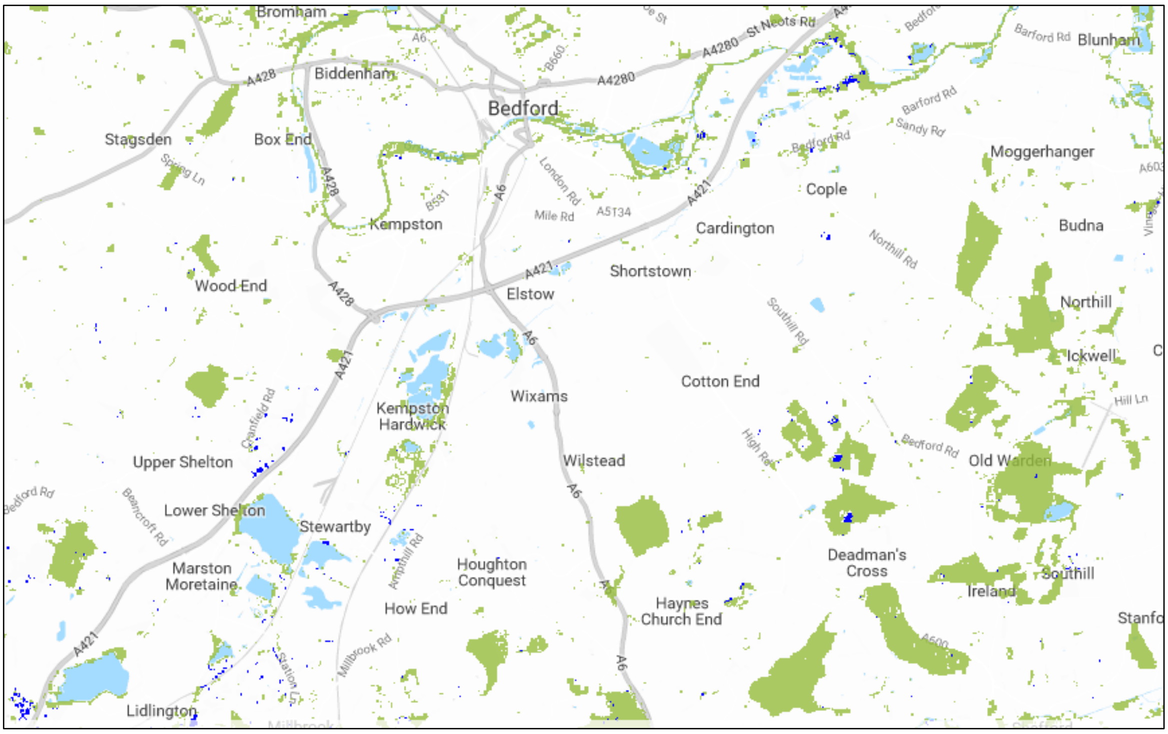


Figure G-3: New trees cover (blue surfaces) in Central Bedfordshire.

The same method was followed for the annual amount of carbon sequestrated by trees, this is shown in Table G-7. It is logical that the importance balance is inverted between young and old: mature trees have slowed down their growth and their carbon ingestion. The financial value of this annual amount is capitalised until 2030, using the HM Treasury discount factor (Lowe, 2008)

Table G-7: Calculation of annual carbon sequestration per hectare of woodland (at 2030 carbon values).

	tCO2/ha/year	£/ha/year	Capitalised value (2030)
Broad leaf young	17	1,327	13,755
Broad leaf unknown	4	302	3,130
Broad leaf ancient	1	103	1,071
Coniferous young	11	891	9,241
Coniferous unknown	8	620	6,424
Coniferous ancient	1	79	824

G.2.2 Wetlands

The highest rates of carbon decomposition are found in wetland surfaces. Therefore, the top 15 cm of soil of fen, marsh, and swamp were taken from the Countryside Survey (2007), with the purpose of estimating the soil carbon stock. According to the results, fen, marsh and swamp carbon stock is 76 t C ha^{-1}. In order to meet the CO_2 equivalent that this wetland type could store, the molecular weight of that component was considered. In conclusion, an inland wetland could store 278.67 tCO_2 ha^{-1} (Natural England, 2010).

In addition, according to Rouquette, (2016), “carbon storage capacity indicates the amount of carbon stored naturally in soil and vegetation”. Furthermore, Morris and Camino, (2011), do not consider carbon regulation as an ecosystem service for freshwater rivers and lakes. As consequence, it was assumed that those water bodies do not have carbon storage potential.

G.2.3 Grasslands

A central estimation for carbon emissions is likely to reach a cost £79.43/tCO_2 by 2030 (Department for Business Energy & Industrial Strategy, 2018b). Based on this value a cost per hectare can be devised through a simple multiplication of the tCO_2/ha. Multiplication of that value by the area of the habitat likely to replaced, as a whole area provides the area total. The whole area must be considered rather than the percentage of habitat within that area, as the disruption through even the smallest area will disturb and interfere with the existing ecological network.

The work conducted by Scottish Natural Heritage on behalf of the Countryside Survey (2007), led to the conclusion, that of all the broad habitats in the UK, acid grassland is the one with superior capabilities for sequestering carbon stock, equal to 87 t/ha (Scottish Natural Heritage, 2007). Carbon stock held in neutral grasslands has been estimated at 60 t/ha (Scottish Natural Heritage, 2007). The capability that grasslands have to render carbon storage makes them areas which may be potentially undervalued. Due to the carbon stock values being limited to either acid grassland or neutral grasslands further values were required.

Through utilising the UK Soil Observatory's mapping application, an understanding of topsoil carbon concentration (g/kg) was gained. Noteworthy are the following values which were taken from 2007. The mapping application estimates were provided for the entire study area with a focus on 'managed grassland' and 'improved grassland.

Managed grassland (amenity recreational areas) was attributed a value of 54.62 g/kg. This was based on an average of amenity recreational areas, where typical values ranged between 49.04-60.02 g/kg (Bedford Priory Country Park 49.04 g/kg (2007) and John O'Gaunt Golf Course 60.2 g/kg (2007)) (UK Soil Observatory, 2017). 'Improved grassland was attributed with a value of 62.4 g/kg. This average was based on three samples including Tempsford 61.60 g/kg (2007), Sandy 62.80 g/kg (2007) and The Grange Estate East, Bedford 62.80 g/kg (2007) (UK Soil Observatory, 2017).

Once the mass balance calculations were undertaken the managed grasslands value becomes an equivalent of 81.9 t/ha (in the top 15cm of the soil). Likewise, the figure for improved grassland becomes an equivalent of 93.6 t/ha (within the top 0.15m of the soil). An assumption has been made that natural grassland will hold a minimum of 93.6 tC/ha as these habitats are not likely to undergo land management practices such as cultivation.

Unfortunately, the dominant land covers within the Soil Observatory mapping application are limited to: arable and horticultural, improved grassland and broadleaved woodland, limiting the ability to be more specific when attributing carbon stock values. Noticeable differences can be observed under improved grassland, whereby classification by the user can lead to the sub-categories of 'managed grassland' and 'improved grassland' based on identification of amenity recreational areas. Understanding gained regarding carbon concentration leads to subsequent comparison against alternate sources of data, such as the Countryside Survey Report, whereby a lower value of 60 t/ha is attributed to neutral grassland. For the benefit of this study neutral grassland and natural grassland was assumed to be the same (Scottish Natural Heritage, 2007). Whilst it is recognised that the UK Soils Observatory mapping application is a useful tool it does have its limitations. Historic data and user assumptions does provoke concern as to its reliability.

Being specific, in terms of attributing carbon stock held within each habitat is a complex task, with conflicting information and lack of specifics such as soil profiles and their associated qualities. For example, podzols are estimated to store an average of 193 tC/ha and gley soils 438 tC/ha (Alonso *et al.* 2010). Further investigation could focus on specific habitats and their associated soil types. The understanding gained may allow further protection of such sites due to their carbon storage capacity.

Mass Balance Calculations for Developing Carbon Storage Capacities

Managed grasslands (Amenity Grassland)

- 54.62 g/kg → 54.62 kg/t
- Hectare volume: 0.15m * 100m * 100m = 1500m^3
- 1 hectare at a depth of 0.15m is equal to 1500m^3
- 1500 m^3 = 1500 t
- 1500 t * 54.6 kg = 81,900 kg / hectare
- 81,900 kg / 1000 = 81.9 t
- 81.9 t / hectare

Improved grassland

- 62.4 g/kg → 62.5 kg/t
- Hectare volume: 0.15m * 100m * 100m = 1500m^3
- 1 hectare at a depth of 0.15m is equal to 1500m^3
- 1500 m^3 = 1500 t
- 1500 t * 62.4 kg = 93,600 kg/h
- 93,600 kg / 1000 = 93.6 t
- 93.6 t / hectare.

Formula for converting tonnes of carbon into carbon dioxide equivalent:

81.9*(83333 mol/1tc) * (1tCO_2/22727) = 300.30

93.6*(83333 mol/1tc) * (1tCO_2/22727) = 343.20

G.2.4 Arable Lands

Regulatory services associated with arable lands have been found to generate a negative value. However, these value can be improved through sustainable use of fertilisers leading to increased nutrient efficiency. This may also be achieved through a reduction of cattle heads per hectare (Les et al., 2011) and the use of cover crops over winter.

Negative values associated with arable lands (in relation to regulating services) is primarily due to the inability for arable soils to sequester carbon or purifying water.

In fact, the release of methane from pastoral agriculture and application of pesticides and fertilisers all contribute to a negative value being associated with agriculture. Although the aforementioned have not been studied in this project understanding the implications that they have and ways of mitigating such implications would further complement this study.

For the regulation value, for the entire UK, a value of 48 Mt CO_2 has been taken. Taking into account that the total agricultural area in the UK is 4,681,000 ha (Department for Business Energy & Industrial Strategy, 2018a), the project team has calculated the average emission per hectare to be equal to 10.25 tCO_2e/ha. Therefore, the emission value is the price of carbon in 2030, which will be £79.43, multiplied by the average emission. The capitalized value estimated is as £8,445.56 /ha for UK farmlands in 2030.

G.3 Provisioning Services

The provisioning services are the ones coming from the biggest variety of sources. Contrary to the two first services, the values found are often characterised as an annual income emerging from the sustainable harvesting of a particular land cover. Hence, to give a value per hectare, this annual income was capitalised until 2030, using HM Treasury data (Treasury, 2018)

G.3.1 Woodlands

Forests can provide timber when harvested in a viable manner. The Forestry Commission has been provided with such an economic valuation, in 2010, by EFTEC (Tinch *et al.*, 2010). Despite EFTEC providing more values for timber, just those mentioned below were considered in this study:

- Conifers and Plantations on Ancient Woodland Sites (PAWS) - which can be related to the relatively new plantations - valued at £120/ha/year (capitalised at £3,420/ha);
- Ancient Semi-Natural Woodlands (ASNW) and restored PAWS, grossly identified as ancient forests, valued at £15/ha/year (capitalised at £428/ha).

G.3.2 Wetlands

Water supply is fundamental for agricultural irrigation, public domestic supply, and abstraction for industrial processes. Around 52% of the 22 billion m^3 of water abstracted in the UK each year comes from rivers and lakes. Therefore, water supply is one of the most valued freshwater provisioning services. According to UK NEA (2011), the economic value in 2030 of this ecosystem services could be £3,163/ha.

G.3.3 Grasslands

Initial scoping for provisioning values included: DEFRAs' Environmental Value Look-Up Tool (DEFRA, 2015), the UKNEA, The Office for National Statistics and the EA with final assessment being extracted for The Economics of Ecosystems and Biodiversity (TEEB) database. Due consideration must be taken with these values as they are not all based on UK studies.

The TEEB database was the only source found during the study which presented suitable values for grassland ecosystem goods and services. The values were stated in multiple currencies and have undergone conversion for the purpose of harmonisation.

G.3.4 Arable Lands

Provisioning services are the most important ecosystem service of arable lands. As a consequence, it helps the UK agri-food sector, in contributing more than 6% of UK GDP (Les *et al.*, 2011). Although there is a decrease, with respect to the total area of land in agricultural use, this continues to be important within the area, occupying up to 70% (Natural England, 2014). Arable lands mostly operate for the provision of humans or livestock with food (Les *et al.*, 2011).

According to Les et al. (2011) ,the total area of arable lands in the United Kingdom is 4,610,000 ha. The production of major agricultural crops in the study area are shown in Table G-8 (Natural England, 2014)

Table G-8: Annual average income of a Bedfordshire agricultural land.

	Income (£/ha)	Crops %
Cereal	954	49
Oilseed	1,112	15
Other	14,327	7
Uncropped	0	25
Total (£/ha)	**1,638**	

As seen above, arable lands rotate every four years, therefore it is impossible to estimate if the land will be in cereals, uncropped or used for biomass. As a consequence, the reversion of woodlands, wetlands and grasslands studies, arable lands provide an average per hectare value. The provision value of £1,638/ha/yr amounts to £16,980/ha when capitalised to 2030.

The main parameter that has been used to calculate provisioning value is a percentage of each agricultural land classification of both land cover and efficiency. The yield efficiency values, in Table G-9 have been assumed by the project team. The percentages decrease as the grades increases. As the quality of the land declines so does the development of agricultural activities.

Table G-9: Provision value per hectare and per grade.

Grade	Quality (literature)	Percentage of land cover in Bedfordshire (%)	Yield efficiency (%)	Weighed value if % of 1 ha (£)	Provision value (£/ha)
1	Excellent	2	140	476	23,772
2	Very Good	35	130	7,726	22,074
3	Good to Moderate	48	98	7,987	16,640
4	Poor	6	75	764	12,735

G.4 Cultural Services

Welfare value associated with land covers mainly depends on populations and regions. The ORVal tool provides welfare values of different sites throughout England, their area and the percentage of their land coverage. This software even allows the user to alter the composition of the site and area to assess the possible welfare changes.

This software, with all its components, and despite some missing sites, presented a good opportunity to assess Central Bedfordshire and South Cambridgeshire welfare values.

Many sites are not composed of a singular land cover. Hence, the tools 'Alter site' function were used for the four natural covers studied. Land cover changes were simulated, with the entire percentage of a particular land cover having been turned into the same percentage of buildings (to feature changes that may occur when turning this particular land cover into rail infrastructure).

The often negative change was assessed afterwards, and divided by the modified area of the studied site. This gave an annual per-hectare welfare value (£/ha) for the studied site.

All those values were averaged, and discounted at 2030, to give a general financial value for the area. This general financial value was used in the specific assessment when the studied section of land cover was not referenced in the ORVal software.

G.4.1 Woodlands

Woodlands do not have the same value for local populations if they are generously spread over an underpopulated area or scarcely seen at crowded locations. Bedfordshire and Cambridge are rather populated and wealthy places and will continue growing demographically and economically. Hence cultural forest values should be relatively high compared to Scotland or Wales for example. The highest values have been checked and validated, being town parks with minimal wood content (Russell Park) or culturally important areas (RSPB: The Lodge and Wimpole Estate).

The lowest values appeared as too low. Indeed, it seemed incorrect to assess that the cultural value of countryside forests such as Gamlingay, Waresley or Potton Woods, would lose less than £30/ha if the entire forests are replaced by buildings, whereas they all have a standing welfare value superior to £1,300/ha. Hence it was decided that, if the percentage of wood, on the assessed areas, was greater than 70%, the disappearance of the entire forested area would be considered for the valuation.

A few outliers were excluded from the calculation of the average welfare value associated with woodlands because they were out of step with the normal values obtained.

The average welfare value of forests in Bedfordshire and South Cambridgeshire was valued at £5,496/ha/year. The standing value at the horizon 2030 reached £56,992/ha, when the railway should established, according to the HM Treasury's Green Book discount rate (Lowe, 2008).

Hence, when the area was not part of the ORVal tool from Exeter university and DEFRA (Day and Smith, 2016), this calculated average of £56,992/ha was used. Otherwise, the area was selected using this mapping tool and altered by buildings replacing trees. This process provided recreational values for woodlands of the studied area.

G.4.2 Wetlands

As mentioned before, freshwater has a high recreational value. However, this value can change from one area to another in accordance with their location, accessibility, size or condition. Most of the waterbodies within the study area are from gravel pits (standing water) used for recreational purposes such as fishing or other outdoor sport. For example, Priory Country Park, located in Bedford, was opened in 1986 on the site of former gravel pits. Nowadays, the park consists of lakes, woodland, reedbeds and the river where numerous recreational activities takes places (University of Greenwich *et al.*, 2018).

ORVal can provide a better idea of this regional wetland value. A welfare value of different areas was given as well as its land cover percentages. Changes can be simulated to assess their impact on the valuation. Many specific areas of the Bedford-Sandy-Cambridge corridor have been assessed through a table gathering their total surface areas, proportion of “fen or marsh”, “lake or reservoir” and “rivers and canals”, current value and value if those areas are replaced by buildings.

When the values obtained were checked, some outliers were identified due their values being higher than average. Hence, it was decided that, with the purpose of obtaining a sensible welfare value, those outliers would be deleted. Consequently, values higher than £3000/ha in fen, marsh, river or reservoir and higher than £14,000/ha in river were not taken into consideration in the calculation.

It was assumed that the railway would be established by 2030. Therefore, according to the HM Treasury’s Green Book discount rate (Lowe, 2008), the average welfare value of freshwater was calculated in both years.

Table G-10: Average welfare value of UK inland wetland and freshwater

	Average Welfare value 2018 (£/ha/year)	Average Welfare value 2030 (£/ha)
Fen/Marsh	1,021	10,589
Lake/Reservoir	1,141	11,830
Rivers	5,323	55,193

G.4.3 Grasslands

A buffer strip of one mile was attributed to each route allowing consideration of the habitats within it. Due to the large amount of grassland within half a mile proximity to each route it was decided to register only those grasslands which could be assessed using the ORVal tool. This tool enabled the assessor to provide; ‘Welfare Value’ for habitats either as ‘Natural Grassland’ or ‘Managed Grassland’ and ‘Welfare Loss Value’, should the habitat be replaced by infrastructure. It was at this point a confliction in habitat classification was discovered in comparison between the ArcGIS and Magic Map data.

Availability of this software as a mapping layer for integration with ArcGIS and Digimap could have aided substantially with attributing values to specific habitats and considerably saved time in providing a valuation of the grasslands within the study areas. Nevertheless, a register of habitats provided a focus for evaluation of the size of the area and percentage cover of either ‘Managed Grassland’, ‘Natural Grassland’, ‘Sports Pitches’ or ‘Playgrounds’.

The average welfare changes of each of type of grasslands that could be replaced by buildings were calculated.

G.4.4 Arable lands

When the area was not part of the ORVal tool, the calculated average for the general valuation was used. Otherwise, the area was selected on this mapping software and altered by buildings replacing crops. The capitalised value in 2030 obtained was £11,007 ha.

Appendix H Specific Assessment

H.1 Routes Length and Journey Times

For comparing journey times, it was assumed that the journey time for the 5th Studio route will be calculated based on the same starting point as the Northern and EWR routes. The generation of journey times was based on a locomotive travelling at a speed of 100mph, without any stops. All of the options would greatly reduce the current journey time of 51 minutes by car between Bedford and Cambridge.

In relation to construction and in order to minimise the impact on natural capital, the three routes were planned to follow sections of existing and running tracks. The most southern option (5th Studio route) would take the Marston Vale Line (MVL) resulting in a saving of 5,270m of construction as well as the West Anglia Main Line (WAML), whereby a further 12,971m of construction can be avoided. The most northerly option ues the East Coast Main Line (ECML) between Sandy and St Neots for a duration of 8,205m with further use of the WAML for the approach into Cambridge from the South, avoiding an additional 1,668m of construction. The EWR route is also assumed to use the same stretch of track resulting in avoidance of construction for 1,688m.

H.2 Housing Compensations

Existing buildings, accounted for in Table H-1, are eligible for compensation. The use of existing railway routes as well as the construction of tunnels will significantly reduce the buildings affected by the proposed routes of this project.

Table H-1: Buildings situated within 30, 45, 60 and 75m of the routes' sketches.

Route	Buildings within a 30m distance	Buildings within a 45m distance	Buildings within a 60m distance	Buildings within a 75m distance
EWR	209	74	64	66
5th studio	155	55	53	47
Northern Route	195	59	68	72

Existing rail lines can be utilised for lessening the impact of new rail infrastructure on both rural and urban areas. The intersection that is common for all proposed routes is at Addenbrooke's. This location has been mentioned by the NIC (2017) as an area that is rapidly growing and is also the location of a renowned medical teaching facility, Addenbrooke's Hospital. The Greater Cambridge Partnership (2018) have also stated the possibility of a new 'Cambridge South Station' close to the Cambridge Biomedical Campus and Addenbrooke's Hospital.

The 5th Studio route would utilise the MVL starting at Marston Moretaine and the Cambridge Line from Shepreth which merges with the WAML at Great Shelford which then leads into Cambridge. The Northern Route utilises a small section of the MVL, the ECML to the North of Sandy and the WAML into Cambridge south of Trumpington. Any sections where existing rail lines are being utilised have not be considered for compensations or land purchase and are not accounted for in Table H-2.

Moreover, tunnels are planned to be constructed along the routes. The project team has suggested that two tunnels should be constructed at specific sections on the 5th Studio route. One tunnel is recommended for the EWR proposal. All the suggestions are within close proximity to Everton. In this scenario, the use of tunnels for the 5th Studio route will save demolition of 21 houses and avoid further compensation of another 29 home owners. Further details are exhibited in Table H-2.

Table H-2: Buildings situated on planned tunnels' routes or use of existing rail.

Existing railways						
Route	Start sector	End sector	Buildings within a 30m distance	Buildings within a 45m distance	Buildings within a 60m distance	Buildings within a 75m distance
EWR	(52.179537;0.130823)	End of the route	24	10	7	10
5th studio	From the start	(52.098462;-0.481235)	22	9	5	2
5th studio	(52.115782;0.036796)	End of the route	76	18	21	21
Cranfield	(52.150726;-0.28331)	(52.221727;-0.253634)	58	13	14	14
Cranfield	(52.179537;0.130823)	End of the route	24	3	4	9
Planned tunnels						
Route	Start sector	End sector	Buildings within a 30m distance	Buildings within a 45m distance	Buildings within a 60m distance	Buildings within a 75m distance
EWR	Tunnel 1-EWR entrance	Tunnel 1-EWR exit	11	5	2	4
5th studio	Tunnel 1 entrance	Tunnel 1 exit	21	11	8	10
5th studio	Tunnel 2 entrance	Tunnel 2 exit	0	0	0	1

Through utilising existing railways and constructing tunnels, many buildings may be saved. This would greatly reduce the impact of the rail line on buildings and avoid the associated compensation. The 5th Studio route appears to be the least costly of the options regarding the compensation schemes potentially involved.

The crossing of Bedford, South Gamlingay and Little Eversden would result in high compensation costs, this significantly increases the cost involved with construction of the EWR route. Although urban settlements were avoided, the distance of the Northern Route has resulted in a large number of buildings that would be eligible for compensation.

Total costings for compensating householders were calculated with compensations of £22,500, £15,000, £7,500 subject to distance from the rail line (within 45m, 60m, 75m). Purchasing schemes of 110% of the house value are suggested, for building within 30m-distance from the track centre, and have been based on the average price of a dwelling in the Bedford area being £328,354 (Land Registry, 2018).

H.3 Noise Barriers

Placement of artificial noise barriers has been decided, based on, strategic points along the three routes. Their placement is depicted in Figure H-1. The total length of the barriers is as follows: EWR route 13,051m, Northern Route 15,966m and 5th Studio route 18,992m. Tunnels and the use of existing rail lines will enable a reduction in the initially stated values. A reduction in length can be achieved based on the following points.

For the EWR route, utilising the WAML, will result in a saving of 1,718m from the initial suggestion of 13,051m. For the 5th Studio route, utilising the MVL (-1,562m), Cambridge Line (-2,236m) and the WAML (-5,574m) would reduce the need for noise barriers by 9,372m from the initially anticipated 18,992m. For the Northern Route, utilising the ECML (-2,318m) and WAML (-1,718m) would enable a reduction of 4,036m in comparison to the initially stated 15,966m.

Barriers of 3m in height would cost approximately £1,174/m (1,350€/m, with £1 = 1.15€) and would be set on each side of the route, effectively doubling the length required.

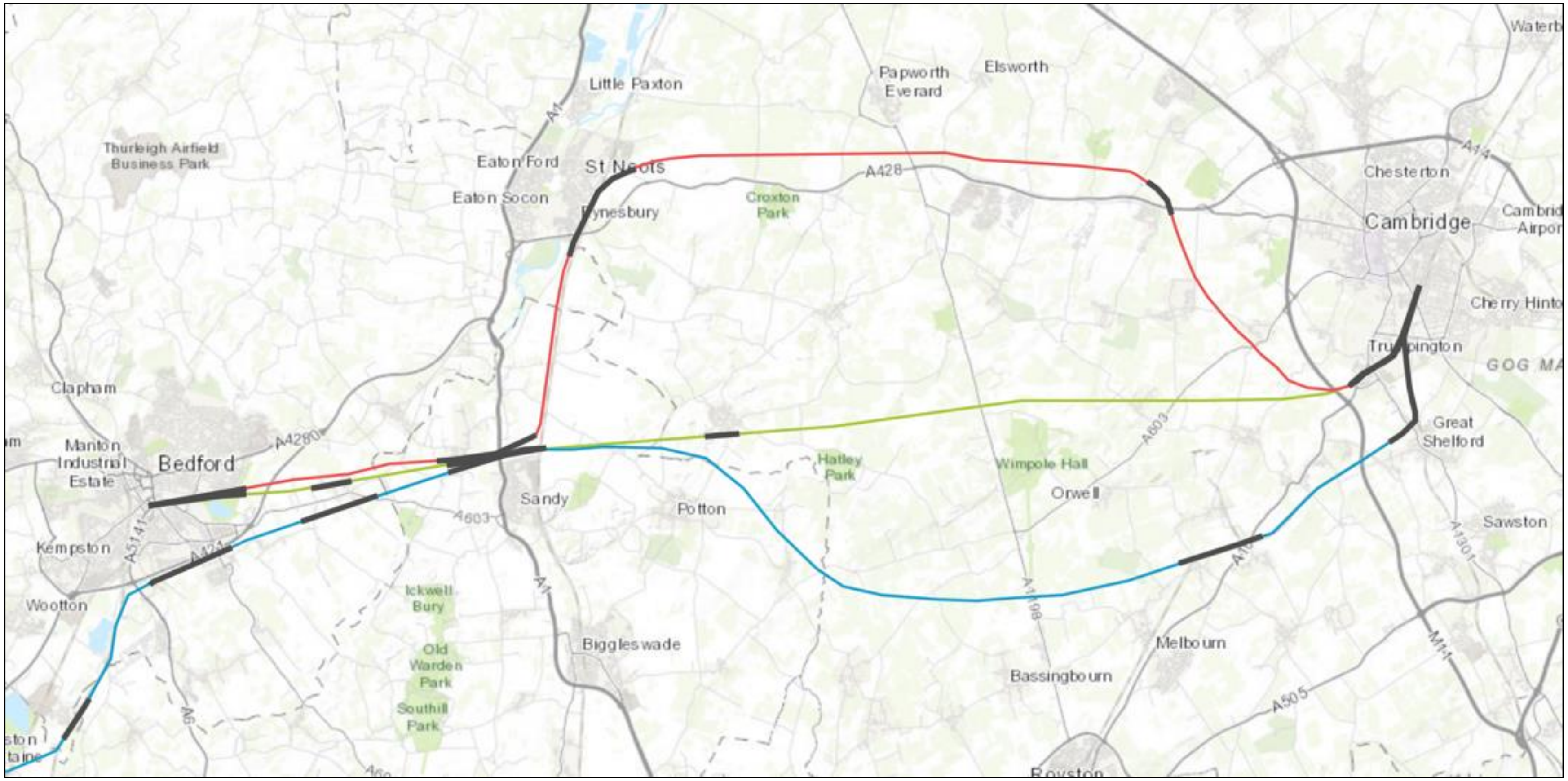


Figure H-1: Artificial noise barriers at strategic points throughout the three routes, are shown as grey line segments

H.4 Land Cover Natural Capital

H.4.1 Woodlands

Following the route options drawn, woodlands within one mile of the proposed rail routes were studied and their quality assessed (Table H-3). Following an initial assessment, the routes have been segmented to provide a specific evaluation of the area directly impacted by the rail line footprint (Table-H4). In the segmentation study, tunnels and existing rail line(s) were excluded from the assessment. The use of civil construction has a positive effect on the natural capital assessment, especially around Everton, where the tunnel planned on the 5th Studio route would avoid crossing a large area of woodland. The tunnel suggested for the EWR route would save 150m² of ancient woodland. Moreover, use of existing routes would save approximately 3.7 ha of woodland.

Tables H-3a, H-3b and H-3c are examples of the spreadsheets that were used for the woodland natural capital assessment following the procedure stated in this document.

Table H-3: Example of the specific assessment for woodland: a) sum up the cultural services; b) sum up the biodiversity offsetting, c) sum up the regulating and provisioning services as well as the total loss.

a)

			Cultural Services			
Route	Area	Type	ORVal Area	ORVal wood percentage	ORVal total change (£/ha)	ORVal change (£/ha)
CU	Marston Vale Millennium	Broadleaf	147	22%	-47,628	-1,472
	Wootton and South Wootton	Broadleaf	8	97%	-90,075	-12,010
	Wootton onwards	Broadleaf	?			-5,496
	Priory Country Park	Broadleaf	95	26%	-67,372	-2,733
	Cople	Broadleaf	30	93%	-128,649	-4,280
	The Grange Estate	Broadleaf	117	33%	-28,219	-730

b)

			Biodiversity						
Route	Area	Type	Age	Distinct	Condition	Biodiversity value	Replacement factor	Replacement ratio	Biodiversity replacement cost (£/ha)
CU	Marston Vale Millennium	Broadleaf	unknown	6	3	18	0.594	30	-239,030
	Wootton and South Wootton	Broadleaf	unknown	6	3	18	0.594	30	-239,030
	Wootton onwards	Broadleaf	unknown	6	2	12	0.594	20	-159,354
	Priory Country Park	Broadleaf	unknown	6	3	18	0.594	30	-239,030
	Cople	Broadleaf	unknown	6	3	18	0.594	30	-239,030
	The Grange Estate	Broadleaf	unknown	6	3	18	0.594	30	-239,030

c)

			Regulating				Provisioning	
Route	Area	Type	Total carbon sequestration	Total carbon sequestrated (2030) (£)	Annual carbon sequestration (tCO2/ha/year)	Capitalised annual carbon sequestration (2030) (£)	Capitalised timber value over 2030 (£/ha)	Total loss (£/ha)
Northern Route	Marston Vale Millennium	Broadleaf	638	-50,645	3.8	-3,130	-1,244	-295,521
	Wootton and South Wootton	Broadleaf	638	-50,645	3.8	-3,130	-1,244	-306,059
	Wootton onwards	Broadleaf	638	-50,645	3.8	-3,130	-1,244	-219,868
	Priory Country Park	Broadleaf	638	-50,645	3.8	-3,130	-1,244	-296,782
	Cople	Broadleaf	638	-50,645	3.8	-3,130	-1,244	-298,329
	The Grange Estate	Broadleaf	638	-50,645	3.8	-3,130	-1,244	-294,779

H.4.2 Wetlands

Following the route options drawn, freshwater within one mile of the proposed rail routes have been studied and their quality assessed. This is shown in Table H-5. Following an initial assessment, the routes were segmented to provide a specific evaluation of the area directly impacted by the rail line footprint (Table H-6). In the segmentation study, tunnels and existing rail lines have also been assessed. None of them have an influence on freshwater areas.

Finally, the areas of the individual sections were combined with their associated values per hectare given in the specific assessment. Consequently, this permitted the identification of the potential impact the rail infrastructure could have on different land covers and their associated ecosystem services. After reviewing the results obtained, it was concluded that, in spite of the small area crossed by the route options, the economic impact on freshwater was not negligible, especially on the 5th Studio route. It is important to mention that lowland fens are not crossed by any of the suggested routes. Consequently, the financial losses are lower than expected.

Tables H-4a, H-4b, H-4c and H-4d are examples of the spreadsheets that were used for the wetland natural capital assessment following the procedure stated in this document.

Table H-4: Wetland natural capital assessment. a) Name, size and type, b) Cultural services assessment, c) Habitat offsetting and d) Regulating and Provisioning service and the total value of the wetland natural capital.

a)

Name	Route	Type Magic Map	Type	Area (ha)
Marston Vale Millennium	5th Studio	Unknown	Standing water	4
Marston Vale Millennium	5th Studio	Lowland Fens	Lowland Fens	147
Bedford River Great Ouse	Northern Route	Unknown	River	22
Boating Lake	Northern Route	Unknown	Standing water	5
Finger Lake (Priory Park)	EWR	Unknown	Lowland Fens	5
Priory Business Park	EWR	Unknown	Standing water	1

b)

Cultural services									
ORVal Area (ha)	Fen Marsh	ORVal Total Change (Fen/Marsh) (£/year)	ORVal Change per ha (Fen/Marsh) (£/ha) 2030	Lake / Reservoir	ORVal Total Change (Lake/Reservoir) (£/year)	ORVal Change per ha (Lake/Reservoir) (£/ha) 2030	River Canal	ORVal Total Change (River/Canal) (£/year)	ORVal Change per ha (River/Canal) (£/ha) (2030)
?			-2,544			-2,544			-2,544
147	8%	-29,935	-11,830	17%	-50,301	-11,830	5%	-25,475	-11,830
?			-55,193			-55,193			-55,193
?			-11,830			-11,830			-11,830
?			-10,589			-10,589			-10,589
?			-11,830			-11,830			-11,830

c)

Habitat							
Distinctiveness	Condition	Biodiversity Units (pre)	Difficulty of recreating	Time to target	Replacement factor (Biodiversity post)	Ratio	Biodiversity replacement cost (per ha) 2018
8	3	24	0.75	0.33	4.46	5.39	62,362
6	3	18	0.75	0.33	4.46	4.04	96,380
-	-	-	-	-	0.00	-	0
6	3	18	0.75	0.33	4.46	4.04	96,380
8	3	24	0.75	0.33	4.46	5.39	24,620
6	3	18	0.75	0.33	4.46	4.04	96,380

d)

Regulating		Provisioning		
Total carbon storage (tCO_2/ha)	Total carbon storage (£/ha) (2030)	Commercial Fishing (£/ha) (2030)	Water Supply (£/ha) (2030)	TOTAL
279	-22,135	-3,017	-3,163	26,414
0	0	-3,017	-3,163	54,711
0	0	-3,017	-3,163	-171,759
0	0	-3,017	-3,163	54,711
279	-22,135	-3,017	-3,163	-35,462
0	0	-3,017	-3,163	54,711

H.4.3 Grasslands

Specific areas that have been assessed by the creators of ORVal were utilised to gain an understanding of the potential worth of natural capital assets. Mill Meadows, an area potentially affected by the EWR proposal, is 6.38 ha, of which 25% is managed grassland. The entire area is assigned a value of £133,787. It would be unsuitable to attribute 25% of the total worth of the area (£33,447) to managed grassland, as this would suggest that the other remaining land covers have an equivalent value to that of managed grasslands, where this may not be the case. Therefore, consideration was placed on a future scenario, whereby, a focus was directed at the reduction in welfare that would occur should the habitat be replaced by buildings. For instance, a decrease of £21,840 would be reflected in the wealth of Mill Meadows through replacing managed grassland with buildings.

This method of assessment was reproduced for all of the possible areas within the one-mile buffer zone. This zone covered many different areas which have been assessed in multiple ways. Therefore, an averaged value has been produced to avoid any bias. This value may over or under estimate the worth of an area of grassland, but for the purpose of assigning financial values to areas (which ORVal has not covered), it was seen as fit for purpose. An average welfare value (£112,364), welfare value loss if the grass is replaced by buildings (£11,380) and welfare value remaining after replacement (£11,144) was based on the averaged total of each segment of grassland from each route within the ArcGIS map. An average loss based on the average loss value of each grassland is exhibited in Table H-5.

Table H-5: Average welfare value of each route.

	Welfare Value (£/year)	Welfare Value lost if grass is replaced by buildings (£/ha)	Welfare value remaining after replacement (£/yr/ ha)
EWR	132,803	15,966	19,358
Northern Route	137,606	15,481	10,908
5th Studio	66,683	2,693	3,167
Average	112,364	11,380	11,144

ArcGIS was utilised to classify grasslands into the categories: improved, neutral and heather. The areas that underwent evaluation consisted solely of improved grassland. No direct cross references were made between ArcGIS and ORVal, except for the values obtained from ORVal which underwent analysis to provide a base cultural value for each polygon assessed.

The segmented, improved grassland areas impacted by each route proposal were attributed a reference number and latitude and longitude coordinates (from the far west point of each polygon). The 22m rail line traversing through the area was measured to provide the total area for each segment that is directly impacted by each proposed route. It was then possible to provide all the financial values calculated during the specific assessment to provide a figure for specific habitat loss.

The 2006 values from the cost estimation by the EA, were assigned to individual habitats in the general evaluation (Environment Agency, 2015) The values of mixed grassland types for each proposed route included lowland meadows / floodplain grazing marsh (wet grassland) at £9000/ha; managed/improved grassland (drier grassland) at £1000/ha; heathland, lowland calcareous grassland and lowland dry acid grassland (heath, scrub and open vegetation) at £5000/ha. These values can be seen in Table H-6.

Table H-6: Replacement costs of specific individual habitat.

Name	Area (ha)	Non-Capitalised 2006 purchase (£/ha)
Mill Meadows	6	9,000
East of Cardington Road	8	1,000
East of Cardington Road	3	1,000
Russell Park	7	1,000
Russell Park	7	1,000
East of A600	3	1,000
Jubilee Park	21	1,000
Jubilee Park	21	1,000
Fenlake Meadow	22	9,000
Fenlake Meadow	22	9,000
Gudgeons Meadow	3	9,000

Source: (Environment Agency, 2015)

Though the aforementioned costings are based on priority habitat replacement costs it is worthwhile noting that priority habitats, LNRs and SSSIs have not been included in attaining averaged values for any valuation as they were considered irreplaceable and require a site by site analysis. The inclusion of these sites would present a certain amount of bias, resulting in increased habitat replacement costings and higher replacement ratios.

Initially the non-capitalised replacement cost (without land purchase) of grasslands habitat was £2,447/ha. This was generated through multiplying the averaged habitat replacement cost of all the routes (£1,344), by the average replacement ratio of all routes (1.82 ha). The average replacement cost was then taken for each of the three routes resulting in the non-capitalised value of £2,447/ha.

This average provided a suitable habitat replacement cost for grasslands with unassigned land use cover. At the time, this was seen as a suitable method. However, this method proved to be unsuitable, resulting in both the replacement cost and replacement ratio values differing from other values in the report. The idea was to provide a specific assessment for each segment of varying grassland habitats within the routes, though it was discovered that this would not be possible.

This method was simplified, due to a restriction in intersecting BAP Priority Habitats with the ArcGIS data. Although disappointing, as specific values could have been attributed to specific habitats, necessarily the project team decided, due to the valuation of one generic habitat in ArcGIS, (improved grasslands) that a generic value would be attributed. The value stated in 2006 of £1000/ha was brought to its present day worth of £1403 (utilising an inflation calculator) and attributed as the generic biodiversity replacement value (Alioth Finance, 2017).

Table H-6 also indicates some duplicate areas. This is due to multiple land covers, as classified by ORVal, within that area. For example, Russell Park is 74% natural grassland and 1% sports pitches the cost of replacing either of the habitats will be £1000/ha before inflation. Therefore, both grassland types are necessarily accounted for in the average.

The area of each proposed route was multiplied by the capitalised total carbon sequestered value of £26,537/ha/yr the other capitalised regulating services of £7,839/ha/yr and the provisioning services of £16,207/ha/yr. These values were then utilised to gain the total loss of capitalised ecosystem services for each area.

The values displayed in Table H-7, were generated through the judgement of the project team for each applicable ecosystem service, with the values being sourced from the TEEB database (European Commission, 2015). It is worthwhile noting the values used are from global sources and have been converted to GBP.

Table H-7: Grassland Ecosystem Good and Services, Biodiversity and Replacement Costs

	Value
Welfare Value specific to grassland sites (assessed using ORVal) (£/yr/ ha)	11,380
2030 Capitalised Total Carbon Sequestered (£/ha)	26,537
Other Capitalised Regulating Services (£/ha/yr)	7,839
Provisioning Services 2030 Capitalised Value (£/ha)	16,207
Replacement Cost without land purchase Non-Capitalised (£/ha)	2,447
Carbon Sequestered (tCO^2/ha)	334

The value of carbon held in each routes' grassland habitats, was quantified based on the values taken from the TEEB database (carbon sequestration, climate regulation, influence on air quality). Unfortunately, it was discovered late into the project that this method was inconsistent with other approaches taken. The correct method should have been based on the volume of carbon dioxide sequestered per hectare, (tCO_2/ha) multiplied by the number of hectares and further monetised by multiplying with the future (2030) carbon cost of £79.43/tCO_2 (Department for Business Energy & Industrial Strategy, 2018a). Following this method would have provided substantial differences to the values attributed in the report.

The total planned financial loss attributed to grasslands represented in the study area were generated from capitalised 2030 values and are visible in Table H-8. The comparisons that can be drawn include the greatest planned grassland financial loss being associated with the route proposed by 5th Studio. Whereas, the least loss of ecosystem services from grasslands can be attained through the Northern Route.

The costs of constructing a tunnel are unlikely to be outweighed by the areas natural capital, though the avoidance of further loss of natural capital can be achieved by their use. Such benefits are highlighted in green and observed Table H-8.

Table H-8: Total Planned financial losses/gains for individual routes and tunnels.

	Type	Total Planned financial loss/gain (£/yr)
EWR	Improved grassland	67,686
Tunnel	N/A	130,738
Northern Route	Improved grassland	335,346
5th Studio	Improved grassland	615,532
Tunnel 1	N/A	155,902
Tunnel2	N/A	6,320

Finally, Tables H-9a, H-9b and H-9c are examples of the spreadsheets that were used for the grassland natural capital assessment following the procedure stated in this document.

Table H-9: Grassland natural capital assessment. a) Name, size and type and Cultural services assessment, b) Habitat offsetting and Regulating and c) Provisioning service of the grassland

a)

				Cultural Ecosystem Services			
Route	Area	Area (ha)	Type of grass	Area Cover	Welfare Value (£/year)	Welfare Value lost if grass is replaced by building (£/ha)	Welfare value (£/yr/ ha)
EWR	Mill Meadows	6	Managed grassland	25%	133,787	21,840	13,693
EWR	East of Cardington Road	8	Managed grassland	47%	126,209	22,188	5,764
Northern Route	Mill Meadows	6	Managed grassland	25%	133,787	21,840	13,693
Northern Route	East of Cardington Road	8	Managed grassland	47%	126,209	22,188	5,764
5th Studio	Coton End	2	Managed grassland	85%	53,231	1,897	966
5th Studio	Shortstown	0	Managed grassland	100%	80,313	176	568

b)

Habitat offsetting						*Regulating Services*				
Distinctiveness	Condition	Difficulty to recreate	Time to target	Biodiversity replacement factor	Replacement Ratio / ha	Carbon Sequestered (tCO2/ha)	2030 Capitalised Total Carbon Sequestered (£/ha)	Total (£/ha)	Other Capitalised Regulating Services (£/ha/yr)	2030 Capitalised Value (£/ha/yr)
6	3	0.75	0.50	6.75	2.67	343.20	27,261	173,923	58,878	232,800
4	3	1.00	0.83	9.96	1.20	344.30	27,348	223,980	75,581	299,561
6	3	0.75	0.83	2.14	8.40	343.20	27,261	173,923	58,878	232,800
4	3	1.00	0.83	2.41	4.98	343.20	27,261	223,264	75,581	298,846
4	2	1.00	0.83	6.64	1.20	343	27,261	62,972	21,318	84,290
4	2	1.00	0.83	6.64	1.20	343	27,261	8,451	2,861	11,312

c)

Provisioning Services		
Current Value (£/ ha)	2030 Capitalised Value (£/ha)	Provisioning Area Total (£)
1,563	16,206	103,394
1,563	16,206	132,727
1,563	16,206	103,394
1,563	16,206	132,727
1,563	16,206	37,436
1,563	16,206	5,024

H.4.4 Arable Lands

The Agricultural Land Classification system is a framework that is used for assessing the soil limitations imposed on agronomic practice. The framework classifies soils into different grades. These grades can then be used to understand the impact of each route on different grades of arable land.

The area of arable land crossed by the different routes has been segmented by grade, then combined with the calculated per hectare values given in the specific assessment. The calculations have highlighted the potential impact that each route could have on different ecosystem services.

In the case that arable lands are lost, the ecosystem service that would be impacted most would be the provisioning services because of the economic benefit. Table H-10 shows the provisional values. These values are generated by assessing the hectarage of each grade of arable land impacted along each route. The total hectares of each land grade are then multiplied by the provisioning service values. These values are exhibited in Table H-10.

From the values obtained, the Northern Route is the one that would suffer from the greatest economic loss due to the loss of provisioning services.

Table H-10: Provisional values of each route and grade.

Route	Grade 1	Grade 2	Grade 3	Grade 4
EWR	£218,049	£561,064	-	-
Northern Route	£137,388	£1,135	£171,309	£45,040
5th Studio	£199,282	£750,730	£59,626	£41,828

Table H-11: Arable Land natural capital assessment. a) Name, size and type and Habitat services assessment, b) Cultural values c) Regulation values.

Route	Grade	Surface (ha)	*Habitat*							
			Cereal crops and arable field - Good	Percentage of land cover	Uncultivated strip - Good	Percentage of land cover	Biodiversity index replaced land (good conditions)	Biodiversity index replacing land (poor conditions)	Replacement ratio	Replacement cost (EA - "drier grassland") (£)
Average		1	6	0.75	12	0.25	7.5	2.5	3	4,209
EWR	1	9.17								
	2	25.41								
	Total	34.59								145,589
Northern Route	1	5.78								
	2	51.44								
	3	10.29								
	4	3.54								
	Total	71.05								299,039
5th Studio	1	8.38								
	2	34.01								
	3	3.58								
	4	3.28								
	Total	49.26								207,338

b)

Route	Surface (ha)	*Cultural*
		Welfare average value (£)
Average	1	11,006
EWR	34.59	380,717
Northern Route	71.05	781,989
5TH Studio	49.26	542,190

c)

Route	Grade	Surface (ha)	*Regulation*				
			UK arable emissions (NEA) Mt CO2e	UK total arable area (NEA) (ha)	Average emission (tCO2e/ha)	Emission value (2030 carbon valuation) £/ha/year	Emission value
Average		1	48	4,681,000	10.25	-814.49	-8,445
EWR	1	9.17					
	2	25.41					
	Total	34.59					-292,134
Northern Route	1	5.78					
	2	51.44					
	3	10.29					
	4	3.54					
	Total	71.05					-600,040
5th Studio	1	8.38					
	2	34.01					
	3	3.58					
	4	3.28					
	Total	49.26					-416,036

Appendix I Ready Reckoner

The values for the 'Ready Reckoner' table were obtained from the literature sources summarised in Table I-1

Table I-1: Sources for Ready Reckoner data

	Source
Discount rate	Treasury Green Book
UK non-traded carbon price	DECC (2011) A brief guide to the carbon valuation
Inflation 2017-present	Bank of England inflation target as of Feb2018
Inflation 2008-2017	ONS, CPI Nov 2017 release. Q12008:Q12017 for CPI
Habitat areas	EFTEC for the EA 2010, Annex 1
Recreation factor	EFTEC for the EA (2010) ibid.
Net annual carbon sequestration (tCe/ha/yr)	Dawson and Smith (2007) via NE (2012) NERR043

Additionally, Table I-2 contains the Ready Reckoner values obtained when an inland wetland area is created from different existing land covers (arable, grassland, brownfield and degraded wetland).

Table I-2: Ready Reckoner values for wetland.

Habitat type	**Inland marsh/fen/reedbed**	**Inland marsh/fen/reedbed**	**Inland marsh/fen/reedbed**	**Inland marsh/fen/reedbed**
Hectarage of habitat to be created	10	10	10	10
In what year will habitat creation be complete?	2030	2030	2030	2030
Will site management be guaranteed in perpetuity?	No	No	No	No
If no - for how many years will site management be guaranteed?	25	25	25	25
What is the site's existing land use?	**Arable**	**Grassland**	**Brownfield**	**Degraded wetland**
Is the type of habitat being created scarce or common in the county?	Scarce	Scarce	Scarce	Scarce
Will the site be open for public use?	Yes	Yes	Yes	Yes
Will the site be less than 200m from a village or town?	Yes	Yes	Yes	Yes
Central economic estimate	**£496,027**	**£421,992**	**£421,992**	**£295,075**
Lower economic estimate	£277,694	£228,798	£228,798	£204,351
Upper economic estimate	£895,063	£811,958	£811,958	£467,665
Lower non-carbon estimate	£200,858	£200,858	£200,858	£200,858
Central non-carbon estimate	£256,295	£256,295	£256,295	£256,295
Upper non-carbon estimate	£348,943	£348,943	£348,943	£348,943
Lower carbon estimate	£76,836	£27,940	£27,940	£3,493
Central carbon estimate	£239,732	£165,697	£165,697	£38,780
Upper carbon estimate	£546,119	£463,014	£463,014	£118,722
Total standard discount factor	10.94842639	10.94842639	10.94842639	10.94842639
Total longer discount factor	12.25534687	12.25534687	12.25534687	12.25534687
Total low carbon value/annual tCO2e	2175	2175	2175	2175
Total central carbon value/annual tCO2e	4391	4391	4391	4391
Total upper carbon value/annual tCO2e	6605	6605	6605	6605
Area value	1	1	1	1
Category value	InlSc1	InlSc1	InlSc1	InlSc1
Urban + Recreation multiplier	1.4	1.4	1.4	1.4
Min end year	2055	2055	2055	2055

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