A417 Missing Link

Preliminary Environmental Information Report

Chapter 14 Climate - Appendices

28 September 2020

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Appendix 14.1
Greenhouse gas assessment assumptions, methodology and emissions factors

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1 Greenhouse gas assessment assumptions, methodology and emissions factors

1.1 Carbon assessment supporting information

1.1.1 This appendix presents all assumptions made in the preliminary quantification of the capital carbon assessment, presented in Chapter 14 Climate of the Preliminary Environmental Information (PEI) report.

Table 1-1 Greenhouse gas assessment assumptions

Item Category	Location	Description	Units	Quantity	Assumptions
Pavements	Mainline	Pavements - Sub-base type 1 unbound mixture: in carriageway, hardshoulder and hardstrip	m^2	134,025	1. Assume the subbase type 1 is equivalent to natural aggregate, 2. Assume the density of subbase type 1 is 2000 Kg/m^3 3. 330mm thickness. = 88,456.50 tonnes
Pavements	Mainline	Pavements - Base - Dense bitumen macadam (DBM50): In carriageway hardshoulder and hardstrip	m^2	134,025	1. Assume the density of dense bitumen macadam is 2300 Kg/m^3 2. Assume the dense bitumen macadam has the same carbon factor as Asphalt, 6% binder content 3. 220mm thickness. = 67,816.65 tonnes
Pavements	Mainline	Pavements - Binder course - Dense bitumen macadam (DBM50) in carriageway hardshoulder and hardstrip	m^2	134,025	1. Assume the density of dense bitumen macadam is 2300 Kg/m^3 2. Assume the dense bitumen macadam has the same carbon factor as Asphalt, 6% binder content 3. 60mm thickness. = 18,495.45 tonnes
Pavements	Mainline	Pavements - Surface course - Close graded macadam - Thin - in carriageway, hardshoulder and hardstrip 10mm agg. 60PSV	m^2	134,025	1. Assume the density of close bitumen macadam is 2300 Kg/m^3 2. Assume that close graded macadam has the same carbon factor as Asphalt, 7% binder content 3. 40mm thickness. =12,330.30 tonnes
Pavements	Side roads	Pavements - Sub-base type 1 unbound mixture: in carriageway, hardshoulder and hardstrip	m^2	68,272	1. Assume the subbase type 1 is equivalent to natural aggregate, 2. Assume the density of subbase type 1 is 2000 Kg/m^3 3. 420mm thickness. = 57,348.48 tonnes
Pavements	Side roads	Pavements - Base - Dense bitumen macadam (DBM50): In carriageway hardshoulder and hardstrip	m^2	68,272	1. Assume the density of dense bitumen macadam is 2300 Kg/m^3 2. Assume the dense bitumen macadam has the same carbon factor as Asphalt, 6% binder content. 3. 160mm thickness. = 25,124.10 tonnes
Pavements	Side roads	Pavements - Binder course - Dense bitumen macadam (DBM50) in carriageway hardshoulder and hardstrip	m^2	68,272	1. Assume the density of dense bitumen macadam is 2300 Kg/m^3 2. Assume the dense bitumen macadam has the same carbon factor as Asphalt, 6% binder content. 3. 60mm thickness. =9,421.54 tonnes
Pavements	Side roads	Pavements - Surface course - Close graded macadam - Thin - in carriageway, hardshoulder and hardstrip 10mm agg. 60PSV	m^2	68,272	1. Assume the density of close bitumen macadam is 2300 Kg/m^3 2. Assume that close graded macadam has the same carbon factor as Asphalt, 7% binder content. 3. 40mm thickness. = 6,281.02 tonnes

Item Category	Location	Description	Units	Quantity	Assumptions
Pavements	Central reserve	Pavements - Sub-base type 1 unbound mixture: in carriageway, hardshoulder and hardstrip	m^2	30,710	1. Assume the subbase type 1 is equivalent to natural aggregate, 2. Assume the density of subbase type 1 is 2000 Kg/m^3, 3. 400mm thickness. = 24,568 tonnes
Pavements	Central reserve	Pavements - Binder course - Dense bitumen macadam (DBM50) in carriageway hardshoulder and hardstrip	m^2	30,710	1. Assume the density of dense bitumen macadam is 2300 Kg/m^3 2. Assume the dense bitumen macadam has the same carbon factor as Asphalt, 6% binder content, 3. 60mm thickness. = 4,237.98 tonnes
Pavements	Central reserve	Pavements - Surface course - Close graded macadam - Thin - in carriageway, hardshoulder and hardstrip 10mm agg. 60PSV	m^2	30,710	1. Assume the density of close bitumen macadam is 2300 Kg/m^3 2. Assume that close graded macadam has the same carbon factor as Asphalt, 7% binder content, 3. 40mm thickness. =2,852.32 tonnes
Barriers	Central reserve	Pre-cast concrete step barrier	m	6,300	Data provided via email 29/10/2019. Carbon factor taken from the ICE V3: Concrete> Precast concrete beams and columns - steel reinforced with 100kg world average steel per m^3. Volume of concrete step barrier taken to be 0.5m^3 per metre with density of 2.4tonnes per m^3. = 7,560tonnes
Barriers	Non-central reserve	Road restraint system/safety barrier	m	8,700	1. Assume Steel RRS barrier, single sided - data provided via email 29/10/19. Carbon factor taken from Highways England carbon tool. = 193.2 tonnes
Barriers		Fencing - Environmental barriers (absorptive and reflective) - Environmental/ Noise barriers; all types - including foundations 2.0m high	m	17,844.00	Assume fencing is a type of Timber noise barrier Highways England Carbon tool: Fencing> Noise barrier> Timber barrier 2m. Weight taken to be 33kg/m^2 (density 0.09) = 1,177.70tonnes
Fencing			m	20,063.00	Assume a type of steel/wire/chain fence (includes posts) Highways England Carbon tool: Steel/wire/chain fence. Weight of steel per metre estimate from supplier for a 1.8m high chain link fence and steel post to be 3.8kg. = 76.24tonnes
Culvert	Tributary of Normans Brook	Extension/replacement of existing culvert under widened A417, 600mm diam, 70m long	m	70.00	Assume the carbon factor for precast concrete culvert is equivalent to Precast concrete circular pipework, with 600mm diam. Factor from Highways England Carbon tool: Drainage>Precast concrete circular pipework>600mm diameter. = 34.16tonnes

Item Category	Location	Description	Units	Quantity	Assumptions
Culvert	Tributary of Normans Brook	Culvert headwall	m^3	11.44	Assume volume of concrete in each headwall is 5.72m^3 (see drawings tab), Assume 1.5% of the concrete volume is steel reinforcement. Assume density of concrete is 2400kg/m^3. Assume the density of reinforcement is 7850kg/m^3. Concrete factor - Concrete>C32/40>0% (Using CEM1) Steel factor - Steel>bar & rod = 1.35t Steel & 27.04t Concrete
Culvert	Tributary of Normans Brook	Culvert backfill	m^3	6.40	Factor from Highways England Carbon tool: Bulk materials>fil, aggregate and sand>general mixture. Assume density of 2000kg/m^3
Culvert	Dry valley under A417	New culvert 900mm diam, 90 m long	m	90.00	Assume the carbon factor for precast concrete culvert is equivalent to Precast concrete circular pipework, with 900mm diam. Factor from Highways England Carbon tool: Drainage>Precast concrete circular pipework>900mm diameter
Culvert	Dry valley under A417	Culvert Headwall	m^3	11.44	Assume volume of concrete in each headwall is 5.72m^3 (see drawings tab), Assume 1.5% of the concrete volume is steel reinforcement. Assume density of concrete is 2400kg/m^3. Assume the density of reinforcement is 7850kg/m^3. Concrete factor - Concrete>C32/40>0% (Using CEM1) Steel factor - Steel>bar & rod = 1.35t Steel & 27.04t Concrete
Culvert	Dry valley under A417	Culvert backfill	m^3	6.40	Factor from Highways England Carbon tool: Bulk materials>fil, aggregate and sand>general mixture. Assume density of 2000kg/m^3
Culvert	Dry valley under Shab Hill slip road	New culvert 900mm diam, 85 m long	m	85.00	Assume the carbon factor for precast concrete culvert is equivalent to Precast concrete circular pipework, with 900mm diam. Factor from Highways England Carbon tool: Drainage>Precast concrete circular pipework>900mm diameter
Culvert	Dry valley under Shab Hill slip road	Culvert Headwall	m^3	11.44	Assume volume of concrete in each headwall is 5.72m^3 (see drawings tab), Assume 1.5% of the concrete volume is steel reinforcement. Assume density of concrete is 2400kg/m^3. Assume the density of reinforcement is 7850kg/m^3. Concrete factor - Concrete>C32/40>0% (Using

Item Category	Location	Description	Units	Quantity	Assumptions
					CEM1) Steel factor - Steel>bar & rod = 1.35t Steel & 27.04t Concrete
Culvert	Dry valley under Shab Hill slip road	Culvert backfill		6.40	Factor from Highways England Carbon tool: Bulk materials>fil, aggregate and sand>general mixture. Assume density of 2000kg/m^3
Culvert	Dry valley under A417	New culvert 750mm diam, 40m long	m	40.00	Assume the carbon factor for precast concrete culvert is equivalent to Precast concrete circular pipework, with 750mm diam. Factor from HIGHWAYS ENGLAND Carbon tool: Drainage>Precast concrete circular pipework>900mm diameter (rounded up to nearest available factor)
Culvert	Dry valley under A417	Culvert Headwall	m^3	11.44	Assume volume of concrete in each headwall is 5.72m^3 (see drawings tab), Assume 1.5% of the concrete volume is steel reinforcement. Assume density of concrete is 2400kg/m^3. Assume the density of reinforcement is 7850kg/m^3. Concrete factor - Concrete>C32/40>0% (Using CEM1) Steel factor - Steel>bar & rod = 1.35t Steel & 27.04t Concrete
Culvert	Dry valley under A417	Culvert backfill	m^3	6.40	Factor from Highways England Carbon tool: Bulk materials>fil, aggregate and sand>general mixture. Assume density of 2000kg/m^3
Culvert	Chambers	1000mm diameter, 1.2m - 3m depth	No.	8.00	As per call with Water engineer (29/10/19) assume two chambers per culvert (=8) Factor from Highways England Carbon tool: Drainage>Precast concrete inspection chambers>1000mm diameter, 1.2m-3m depth
Attenuation ponds	Culverts	Assume average of 4 culverts above	No.	24.00	As per call with Water engineer (29/10/19) assume culvert design is same as drawing in "drawings" tab. 2 per pond = 24.
Attenuation ponds	Chambers	1000mm diameter, 1.2m - 3m depth	No.	48.00	As per call with Water engineer (29/10/19) assume two chambers per culvert (=48) Factor from Highways England Carbon tool: Drainage>Precast concrete inspection chambers>1000mm diameter, 1.2m-3m depth
Attenuation ponds	Geotextile membrane		m^2	4,469.20	As per call with Water engineer (29/10/19) assume 20% of attenuation ponds (by m^2 area) will require Geotextile membrane - 4,469.2m^2 Factor from Highways England

Item Category	Location	Description	Units	Quantity	Assumptions
					Carbon tool: Earthworks>Geotextiles>Polypropylene geotextile/matting
Attenuation ponds	HDPE impermeable layer		m^2	4,469.20	As above - HDPE density = 0.097t/m^3 Assume 2mm thickness = 89.38m^3
Attenuation ponds	Sand		m^3	670.35	As per call with Water engineer (29/10/19) assume 20% of attenuation ponds (by m^2 area) require sand. 150mm depth.
Attenuation ponds	Compacted clay				Assume Site won soil - 0tCo2e
Line painting	Traffic sings and road markings - laying - continuous lines	Thermoplastic road marking	m	28,071	1. Assume road marking paint is thermoplastic 2. Assume the width of continuous road marking is 150mm (as per Traffic signs manual>Chapter 5 road marking> table 4-5 edge of carriageway markings: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/773421/traffic-signs-manual-chapter-05.pdf) 3. Assume the thickness of thermoplastic marking is 2mm (as per http://www.alharamain.com/prod01.htm) 4. Assume the density of thermoplastic road marking is 2150 kg/m^3 (as per Highways England carbon tool: Road pavement>road marking>thermoplastic road marking)
Line painting	Traffic sings and road markings - laying - intermittent lines	Thermoplastic road marking	m	26,056	1. Assume the road marking paint is thermoplastic 2. assume the length of road marking lines excludes blank spaces between lines 3. Assume the width of intermittent marking is 200mm 4. Assume the thickness of thermoplastic marking is 2mm 5. Assume the density of thermoplastic road marking is 2,150kg/m^3
Bridge	Shab Hill Junction underbridge	Steel-concrete composite - Average value for composite viaduct and girder bridges	m^2	2,883	Bridge and underpass factors taken from Collings.D, An environmental comparison of bridge forms. Proceedings of the Institution of Civil Engineers; Bridge engineering 159

Item Category	Location	Description	Units	Quantity	Assumptions
Bridge	Cowley overbridge	Steel-concrete composite - Average value for composite viaduct and girder bridges	m^2	544.5	(2006) Due to lack of design detail, a complexity factor was applied through engagement with bridge engineers.
Bridge	Stockwell overbridge	Steel-concrete composite - Average value for composite viaduct and girder bridges	m^2	544.5	
Underpass	Bridge - Bat underpass at CH 1+100	Precast Reinforced Concrete Box (I suggest we use the minimum value for concrete viaduct bridges as this is a relatively simple structure – 1499kg/m^2)	m^2	210	
Underpass	Wingwalls - Bat underpass at CH 1+100		m^3	48	Assume 3x8m reinforced concrete and 0.5m thickness per wing - 4 wings in total Assume 1.5% of volume is steel, Assume density of concrete is 2400kg/m^3. Assume the density of reinforcement is 7850kg/m^3. Concrete factor - Concrete>C32/40>0% (Using CEM1) Steel factor - Steel>bar & rod = 5.652t Steel & 113.47t Concrete
Underpass	Bridge - Grove Farm underpass	Precast Prestressed Concrete (I suggest we use the average value for concrete girder bridges – 2457 kg/m^2)	m^2	279	As above
Underpass	Wingwalls - Grove Farm underpass		m^3	960	Assume two lots of 20*30*0.75m and two lots of 10*4*0.75m. Reinforced concrete Assume 1.5% of volume is steel, Assume density of concrete is 2400kg/m^3. Assume the density of reinforcement is 7850kg/m^3. Concrete factor - Concrete>C32/40>0% (Using CEM1) Steel factor - Steel>bar & rod = 113.04t Steel & 2269.44t Concrete
Bridge	Bridge - Cotswold Way crossing	Steel Box Girder (I suggest we use the average value for steel girder bridges – 2810kg/m^2)	m^2	570	As above
Bridge	Bridge - Gloucestershi	Steel-Concrete Composite (I suggest we use the average	m^2	1,890	As above

Item Category	Location	Description	Units	Quantity	Assumptions
	re Way crossing	value for composite girder bridges – 2750kg/m^2)			
Maintenance			m^2	1,398,042.00	Assume surface course is replaced once every 10 years = 233,007*6 = 1,398,042m^2
Bridge	Transport of materials				Bridge-related emissions for A1-A3 equate to 46.35% of A1-A3 emissions. Transport emissions without bridges = 1,823.14 tCO2e. To estimate transport emissions relating to bridges assume adding 46.35% (845.03 tCO2e) onto transport total as an estimate of likely transport-related emissions.
A5 Earthworks excavation	scheme-wide		m^3	2,869,700.00	<u>Plant - Excavation Assumptions</u> Excavator Weight: 35 tonnes Excavator Bucket Size: 1.85M3 Mins worked/hour: 50 Output based on cycle time loading vehicles: 186m3/hr Fuel consumption Excavator: 35.6l/hr CO_2 per litre of fuel: 3.782Kg
A5 Earthworks movement /transport on site	scheme-wide		m^3	2,783,601.00	<u>Plant - Dumper/on site movement Assumptions</u> Weight: 22.5 tonnes Dump capacity: 16.6M3 Mins worked per hour: 50 Output based on cycle time moving earth: 186m3/hr (assuming 2 dumpers) Fuel consumption: 22.5l/hr CO_2 per litre of fuel :2.97049kg If excavator does 186m^3/hr then it can fill a dumper 11X per hour One dumper filled every 5 mins 10 mins to transport each load, dump and return Can shift 5 loads per hour So assume 2 dumpers working 50 mins per hour each

Item Category	Location	Description	Units	Quantity	Assumptions
A5 Earthworks transport of excess offsite	scheme-wide		m^3	86,099.00	Transport off site Assumptions Wagon size: 17 m^3 Transport distance: 20 Km each way CO_2e per tkm 100% laden: 0.00011kg CO_2e/tkm CO_2e per tkm 0% laden: 0.00012kg CO_2e/tkm Density factor for Earth: 1t/m^3

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Appendix 14.2
Climate Change Resilience Assessment

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1.1 Climate change resilience (CCR) assessment i

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1 Climate change resilience assessment

1.1 Climate change resilience (CCR) assessment

1.1.1 This appendix presents the details of the preliminary climate change resilience (CCR) assessment undertaken as part of the Preliminary Environmental Information (PEI) report. The assessment methodology is described in PEI report Chapter 14 Climate.

CCR assessment summary

1.1.2 This section presents a summary of the results from the preliminary CCR assessment, including the assessment of consequence and likelihood of each identified risk. Additional mitigation measures are proposed to increase resilience where relevant.

1.1.3 The likelihood and consequence for each risk is qualitatively assessed, as summarised in Table 1-1 and Table 1-2.

Table 1-1 Qualitative five-point scale of likelihood of climate change risks

Likelihood category	Description (probability and frequency of occurrence)
Very high	The event occurs multiple times during the lifetime of the project (60 years) e.g. approximately annually, typically 60 events.
High	The event occurs several times during the lifetime of the project (60 years) e.g. approximately once every five years, typically 12 events.
Medium	The event occurs limited times during the lifetime of the project (60 years) e.g. approximately once every 15 years, typically 4 events.
Low	The event occurs during the lifetime of the project (60 years) e.g. once in 60 years.
Very low	The event can occur once during the lifetime of the project (60 years).

Table 1-2 Qualitative five-point scale of consequences of climate change risks

Consequence of impact	Description
Very large adverse	Operation - national level (or greater) disruption to strategic route(s) lasting more than 1 week.
Large adverse	Operation - national level disruption to strategic route(s) lasting more than 1 day but less than 1 week or regional level disruption to strategic route(s) lasting more than 1 week.
Moderate adverse	Operation - regional level disruption to strategic route(s) lasting more than 1 day but less than 1 week.
Minor adverse	Operation - regional level disruption to strategic route(s) lasting less than 1 day.
Negligible	Operation - disruption to an isolated section of a strategic route lasting less than 1 day.

1.1.4 The overall risk is assessed using the matrix depicted in Table 1-3.

Table 1-3 Significance matrix

		Measure of likelihood				
		Very low	**Low**	**Medium**	**High**	**Very high**
Measure of consequence	**Very large**	NS	S	S	S	S
	Large	NS	NS	S	S	S
	Moderate	NS	NS	S	S	S
	Minor	NS	NS	NS	NS	NS
	Negligible	NS	NS	NS	NS	NS

Note: NS = Not significant; S = Significant

1.1.5 The preliminary CCR assessment results are shown in Table 1-4.

Table 1-4 Preliminary climate change resilience assessment summary

Risk ID	Climate hazard	Trend or likelihood of climate hazard	Potential climate change impact	Potential climate change risk to proposed scheme	Construction/ operation stage	Asset type	Existing or embedded mitigation measure	Result of mitigation measure on resilience	Hazard impact likelihood	Hazard impact consequence	Risk rating (NS = not significant; S =significant)
1	High temperatures	Mean and maximum temperatures in winter and summer projected to increase significantly.	Increased number of hot days may increase impact to staff.	Increased heat stress for staff, particularly for outdoor construction and maintenance workers.	Construction and operation	Health and Safety (H&S)	To be incorporated within proposed maintenance regimes. These can be reviewed regularly to ensure H&S requirements within Highways England are met.	Resilience achieved through monitoring and maintenance of asset.	Low	Minor adverse	NS
2	High temperatures	Mean and maximum temperatures in winter and summer projected to increase significantly.	Increased number of hot days may lead to shrinkage of soil and drying out of vegetation.	Extended periods of hot, dry weather may lead to a risk of spontaneous grassland fires in vicinity of the route, affecting safety on the road.	Operation	Road surface	Risk to be sufficiently mitigated through standard emergency procedures. Additionally, the road would act as a firebreak, providing a gap in combustible material that would act as a barrier to slow or prevent the progress of a wildfire from one side to the other.	Resilience achieved through standard measures already in place.	Low	Moderate adverse	NS
3	High temperatures	Mean and maximum temperatures in winter and summer projected to increase significantly.	Increase in number of hot days may impact the road surface increasing the danger to road users.	Asphalt surface may exhibit permanent deformation in long periods of hot, sunny conditions.	Operation	Road surface	This risk would be managed through the selection of suitable road surface material as well as through the proposed maintenance regimes for road surface.	Resilience achieved through design and maintenance.	High	Minor adverse	NS

Risk ID	Climate hazard	Trend or likelihood of climate hazard	Potential climate change impact	Potential climate change risk to proposed scheme	Construction/ operation stage	Asset type	Existing or embedded mitigation measure	Result of mitigation measure on resilience	Hazard impact likelihood	Hazard impact consequence	Risk rating (NS = not significant; S =significant)
4	High temperatures	Mean and maximum temperatures in winter and summer projected to increase significantly.	Increase in number of hot days may impact the road surface increasing the danger to road users.	High temperatures increase the risk of surfacing rutting leading to water ponding in the ruts. Higher temperatures also increase the risk of reduced skid resistance due to fatting and chipping embedment. This increase the risk of vehicle accidents.	Operation	Road surface	This risk would be managed through the selection of suitable road surface material as well as through the proposed maintenance regimes for road surface.	Resilience achieved through design and maintenance.	Low	Moderate adverse	NS
5	High temperatures	Mean and maximum temperatures in winter and summer projected to increase significantly.	Increased number of hot days may impact the bitumen binder hardening rate.	Inability to flex under traffic loads. Increased risk of road surface cracking and fretting with age.	Operation	Road surface	This risk would be managed through the proposed maintenance regimes.	Resilience achieved through maintenance of the asset.	Medium	Minor adverse	NS
6	High temperatures	Mean and maximum temperatures in winter and summer projected to increase significantly.	Increased number of hot days may impact the bitumen binder hardening rate.	Risk of being unable to lay road surface layers in hot weather.	Construction	Road surface	Risk to be mitigated by following procedures to be detailed in the Environmental Management Plan (EMP).	Resilience achieved through management plan monitoring environmenta l impacts.	Low	Minor adverse	NS
7	High temperatures	Mean and maximum temperatures in winter and summer projected to increase significantly.	Increased impact of diesel spills.	Decreased viscosity in heat leads to greater spreading of diesel in a smaller timeframe. Higher temperatures and increased number of hot, dry days increase the likelihood of ignition of this diesel leading to road and forest fires.	Operation	Road surface	Risk to be sufficiently mitigated through proposed maintenance procedures.	Resilience achieved through maintenance of the asset.	Low	Moderate adverse	NS

Risk ID	Climate hazard	Trend or likelihood of climate hazard	Potential climate change impact	Potential climate change risk to proposed scheme	Construction/ operation stage	Asset type	Existing or embedded mitigation measure	Result of mitigation measure on resilience	Hazard impact likelihood	Hazard impact consequence	Risk rating (NS = not significant; S =significant)
8	High precipitation	+5% (2020s) & +23% (2080s) in winter precipitation rate.	Increased risk of flooding from river/streams, surface and groundwater sources.	Flooding of road surface.	Operation	Drainage	Attenuation ponds designed for 1/100 year event +20% for climate change (check performed for 40% increase) Climate change allowance in critical drainage areas increased to +40%.	Resilience achieved through design.	Very low	Moderate adverse	NS
9	High precipitation	+5% (2020s) & +23% (2080s) in winter precipitation rate.	Increased risk of flooding from river/streams, surface and groundwater sources.	Flooding of access roads and/or road infrastructure.	Operation	Drainage	Attenuation ponds designed for 1/100 year event +20% for climate change (check performed for 40% increase) Climate change allowance in critical drainage areas increased to +40%.	Resilience achieved through design.	Very low	Moderate adverse	NS
10	High precipitation	+5% (2020s) & +23% (2080s) in winter precipitation rate.	Increased risk of flooding from river/streams, surface and groundwater sources.	Increase risk of sewage overflow in floodwater causing damage and impacting health of maintenance workers.	Operation	Drainage	Attenuation ponds designed for 1/100 year event +20% for climate change (check performed for 40% increase) Climate change allowance in critical drainage areas increased to +40%.	Resilience achieved through design.	Very low	Moderate adverse	NS
11	High precipitation	+5% (2020s) & +23% (2080s) in winter precipitation rate.	Increased risk of flooding from river/streams, surface and groundwater sources.	Increased risk of scouring of culverts.	Operation	Drainage	Attenuation ponds designed for 1/100 year event +20% for climate change (check performed for 40% increase) Climate change allowance in critical drainage areas increased to +40%.	Resilience achieved through design.	Low	Minor adverse	NS

Risk ID	Climate hazard	Trend or likelihood of climate hazard	Potential climate change impact	Potential climate change risk to proposed scheme	Construction/ operation stage	Asset type	Existing or embedded mitigation measure	Result of mitigation measure on resilience	Hazard impact likelihood	Hazard impact consequence	Risk rating (NS = not significant; S =significant)
12	High precipitation	+5% (2020s) & +23% (2080s) in winter precipitation rate.	Increased risk of flooding from river/stream s, surface and groundwater sources.	Flooding causing damage to fibre optic cables running near to site.	Operation	Drainage	Attenuation ponds designed for 1/100 year event +20% for climate change (check performed for 40% increase) Climate change allowance in critical drainage areas increased to +40%.	Resilience achieved through design.	Very low	Negligible	NS
13	High precipitation	+5% (2020s) & +23% (2080s) in winter precipitation rate.	Increased risk of flooding from river/stream s, surface and groundwater sources.	Increased pore water pressure in embankments/cuttin gs.	Construction and operation	Earthworks	To be mitigated through drainage design Risk likely to be absorbed by conservative assumptions made during design.	Resilience achieved through design.	Very low	Large adverse	NS
14	High precipitation	+5% (2020s) & +23% (2080s) in winter precipitation rate.	Increased risk of flooding from river/stream s, surface and groundwater sources.	Increased erosion at toe of embankment.	operation	Earthworks	To be mitigated through drainage design Risk likely to be absorbed by conservative assumptions made during design.	Resilience achieved through design.	Low	Large adverse	NS
15	High precipitation	+5% (2020s) & +23% (2080s) in winter precipitation rate.	Increased risk of flooding from river/stream s, surface and groundwater sources.	Water ingress to critical construction equipment.	Construction	Drainage	Drainage on site to be suitably managed, to be specified within the EMP.	Resilience achieved through management plan monitoring environmenta l impacts.	Very low	Minor adverse	NS
16	High precipitation	+5% (2020s) & +23% (2080s) in winter precipitation rate.	Increased risk of flooding from river/stream s, surface	Water ingress to signalling, lighting and other operational electrical equipment.	Operation	Electrical equipment	Watertight cables housed in plastic ducts. No water ingress to underground cables.	Resilience achieved through design.	Very low	Minor adverse	NS

Risk ID	Climate hazard	Trend or likelihood of climate hazard	Potential climate change impact	Potential climate change risk to proposed scheme	Construction/ operation stage	Asset type	Existing or embedded mitigation measure	Result of mitigation measure on resilience	Hazard impact likelihood	Hazard impact consequence	Risk rating (NS = not significant; S =significant)
			and groundwater sources.								
17	High precipitation	+5% (2020s) & +23% (2080s) in winter precipitation rate.	Increased risk of flooding from river/streams, surface and groundwater sources.	Change in ground water level affecting earth pressures and foundation settlement causing possible large ground movement.	Operation	Drainage	To be mitigated through drainage design. Risk likely to be absorbed by conservative assumptions made during design.	Resilience achieved through design.	Very low	Large adverse	NS
18	High precipitation	+5% (2020s) & +23% (2080s) in winter precipitation rate.	Increased risk of flooding from river/streams, surface and groundwater sources.	Increased risk of debris deposit from water seeping up to the surface through the pavement e.g. calcium sulphate leading to reduced skid resistance.	Operation	Road surface	Weather and weather effects on traffic considered within pavement design.	Resilience achieved through design.	Low	Moderate adverse	NS
19	High precipitation	+5% (2020s) & +23% (2080s) in winter precipitation rate.	Increased risk of flooding from river/streams, surface and groundwater sources.	Construction site flooding during construction phase, excavations flooded and site roads impassable. Safety risk of slips, trips and falls to construction workers.	Construction	Drainage	Drainage on site to be suitably managed, to be specified within the EMP. H&S procedures to be further specified within the EMP.	Resilience achieved through management plan monitoring environmental impacts.	Low	Moderate adverse	NS
20	High precipitation	+5% (2020s) & +23% (2080s) in winter precipitation rate.	Increased risk of flooding from river/streams, surface and groundwater sources.	Increased ground water level in winter may lead to flooding of underpasses.	Operation	Drainage	To be mitigated through drainage design.	Resilience achieved through design.	Low	Minor adverse	NS

Risk ID	Climate hazard	Trend or likelihood of climate hazard	Potential climate change impact	Potential climate change risk to proposed scheme	Construction/ operation stage	Asset type	Existing or embedded mitigation measure	Result of mitigation measure on resilience	Hazard impact likelihood	Hazard impact consequence	Risk rating (NS = not significant; S =significant)
21	High precipitation	+5% (2020s) & +23% (2080s) in winter precipitation rate.	Increased soil moisture levels.	Increased risk of earthworks failure and landslides. Exacerbated by variance between high and low precipitation events and soil moisture levels.	Construction and operation	Earthworks	To be mitigated through geotechnical and drainage design. Risk likely to be absorbed by conservative assumptions made during design.	Resilience achieved through design.	Low	Large adverse	NS
22	High precipitation	+5% (2020s) & +23% (2080s) in winter precipitation rate.	Increase likelihood of debris and sediment run-off.	Reduced capacity of attenuation ponds due to sediment build-up.	Operation	Drainage	Risk to be mitigated through the monitoring and maintenance procedures specified for the relevant attenuation ponds.	Resilience achieved through monitoring and maintenance of asset.	Medium	Minor adverse	NS
23	High precipitation	+5% (2020s) & +23% (2080s) in winter precipitation rate.	Increase likelihood of debris and sediment run-off.	Increased risk of debris washing into drainage gulleys, blocking them. A blockage may result in flooding and resulting effects.	Operation	Drainage	Mitigated through drainage design and monitoring and maintenance procedures proposed for drainage systems.	Resilience achieved through design and monitoring and maintenance of asset.	Low	Moderate adverse	NS
24	High precipitation	+5% (2020s) & +23% (2080s) in winter precipitation rate.	Increase in number of wet days may impact the damage to road surface.	Increase stripping rate of the road surfaces.	Operation	Road surface	This risk would be managed through the proposed maintenance regimes for road surface.	Resilience achieved through maintenance.	Low	Minor adverse	NS
25	High precipitation	+5% (2020s) & +23% (2080s) in winter precipitation rate.	Increase in number of wet days may impact the damage to road surface.	Wetter surface may lead to reduced skid resistance.	Operation	Road surface	This risk would be managed through the selection of suitable road surface material as well as through the proposed maintenance regimes for road surface.	Resilience achieved through design and monitoring and maintenance of asset.	Low	Moderate adverse	NS

Risk ID	Climate hazard	Trend or likelihood of climate hazard	Potential climate change impact	Potential climate change risk to proposed scheme	Construction/ operation stage	Asset type	Existing or embedded mitigation measure	Result of mitigation measure on resilience	Hazard impact likelihood	Hazard impact consequence	Risk rating (NS = not significant; S =significant)
26	High precipitation	+5% (2020s) & +23% (2080s) in winter precipitation rate.	Increase in number of wet days may impact the damage to road surface.	Increased likelihood of potholing, rutting and cracking from moisture entering and remaining in road surfaces.	Operation	Road surface	This risk would be managed through the proposed maintenance regimes for road surface.	Resilience achieved through maintenance.	High	Minor adverse	NS
27	High precipitation	+5% (2020s) & +23% (2080s) in winter precipitation rate.	Increased flow of groundwater .	Increased flow of groundwater causing accelerated weathering effects, weakening the embankment.	Operation	Earthworks	Risk likely to be absorbed by conservative assumptions made during design.	Resilience achieved through design.	Very low	Large adverse	NS
28	Low precipitation	-6% (2020s) and -37% (2080s) in summer precipitation rate.	Increased risk of soil shrinkage around foundations of structures.	Potential risk of soil shrinkage impacting foundations, including bridges and other structures. Possible ground movement (check differential settlement due to different types of foundations).	Operation	Earthworks	To be confirmed. Risk likely to be absorbed by conservative assumptions made during design.	Resilience achieved through design.	Very low	Large adverse	NS
29	Low precipitation	-6% (2020s) and -37% (2080s) in summer precipitation rate.	Dry weather for extended periods of time could lead to increased desiccation of soils.	Reduced slope stability and potential earthworks failure during or immediately after summer storm events falling on desiccated soils.	Construction and operation	Earthworks	To be confirmed. Risk likely to be absorbed by conservative assumptions made during design.	Resilience achieved through design.	Low	Large adverse	NS
30	Low precipitation	-6% (2020s) and -37% (2080s) in summer precipitation rate.	Reduced inflow into attenuation ponds.	Anaerobic conditions may occur, risking die back of sediment collecting species, reducing attenuation pools functional capacity.	Operation	Drainage	Risk to be mitigated through the monitoring and maintenance procedures specified for the relevant attenuation ponds.	Resilience achieved through monitoring and maintenance of asset.	Medium	Minor adverse	NS

A417 Missing Link

Preliminary Environmental Information Report

Appendix 14.3
In-combination climate change impacts assessment

28 September 2020

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1 Preliminary in-combination climate change impacts assessment

1.1 Purpose of this document

1.1.1 This appendix presents the outcomes of the preliminary in-combination climate change impact (ICCI) assessment of the proposed scheme where the focus is on those effects of the proposed scheme identified by an environmental aspect that are also affected by climate change. The preliminary assessment does not identify any new or different significant in-combination effects as a result of the proposed scheme's effects combining with future climate conditions.

1.2 Assessment of in-combination climate change impacts

1.2.1 The Preliminary Environmental Information (PEI) report considers effects related to climate change as per the requirements of EU Directive 2014/52 and the 2017 EIA Regulations. The assessment of effects considers the combined effects of the impacts of the proposed scheme and potential climate change impacts on the receiving environment during construction and operation. The future climate conditions have been reviewed as part of the assessment, including changes to long term seasonal averages and extreme weather events as projected by the UK Climate Projections 2018 as presented within section 14.7 of Chapter 14 Climate of this PEI report. The preliminary assessment outcomes for each environmental aspect are set out below.

Air quality

1.2.2 Potential effects which could arise due to air quality impacts from the proposed scheme in combination with future projected climate conditions on air quality receptors include the following:

- An increase in hotter and drier conditions and increased frequency of droughts and heatwaves could exacerbate dust generation during construction. Mitigation measures would be included in the Environmental Management Plan (EMP) to limit the generation and dispersion of construction dust. This climate change effect would therefore not affect the significance of the air quality assessment.
- Increased wind speed could influence dispersion of pollutants during construction and operation. There is considerable uncertainty in projecting wind changes, from wind speed to wind direction, and studies show statistically insignificant variation in wind speed. Construction dust mitigation measures would be included in the EMP which would mitigate any further impacts due to climate change impacts.
- An increase in hotter and drier conditions could increase concentrations of air pollutants such as ozone and nitrogen oxides (NOx). Vehicle emissions are predicted to reduce based on Defra's national fleet projections. Therefore, the consequence of hotter and drier conditions is low due to overall reductions in total emissions.
- Increased frequency and intensity of heavy rainfall events and flooding could reduce dust and pollutant concentrations due to wet deposition. This climate change effect would therefore not affect the significance of the air quality assessment.

1.2.3 While the impacts of climate change are likely to affect air quality in general terms, no preliminary significant in-combination effects with the proposed scheme have been identified and no mitigation is proposed.

Cultural heritage

1.2.4 Potential effects which could arise due to heritage impacts from the proposed scheme in combination with future projected climate conditions on heritage receptors have been considered. It is considered that while the impacts of climate change are likely to affect the heritage resource in general terms, no preliminary significant in-combination effects with the proposed scheme have been identified, and no mitigation is proposed.

Landscape and visual

1.2.5 Climate change may have an impact on local landscape character and views as follows:

- drier/drought conditions may lead to loss of vegetation and defoliation and receptors could become more vulnerable to stress. This could further disrupt views to and from the proposed scheme;
- drought tolerant trees may become more prevalent (therefore also changing landscape character);
- wetlands may disappear (also dependent on elevation and spilt type) and certain soil types may be less readily available;
- hotter and wetter conditions could lead to an increase in increased spread of pests and diseases leading to loss of vegetation and defoliation, making species more susceptible to external stress;
- increase in frequency and intensity of heavy rainfall events/flooding could cause the loss of species in certain areas, because soils become water-saturated and can no longer support existing species;
- hotter and wetter conditions may lead to a longer growing seasons and increased rate of growth of vegetation. This could constitute a beneficial impact, as increased growth rate could allow trees to sequestrate more carbon at a faster rate; and
- increased wind speed could impact the landscape through potential tree losses. This could further disrupt views to and from the proposed scheme.

1.2.6 While the impacts of climate change are likely to affect landscape character, views and visual resource in general terms, no preliminary significant in-combination effects with the proposed scheme have been identified. However, a range of tree species that would be better adapted to climate change will be included within the detailed mitigation design planting proposals. This is to provide a balance between the native species planting that will fit with the existing landscape character and non-native plant species that will better adapt to climate change over time.

Biodiversity

1.2.7 The combined effects relating to ecological impacts of the proposed scheme and potential climate change on receptors include the following:

- Drier and potentially drought-like conditions could occur as a result of global climate change leading to changes in hydrological and groundwater conditions. There is an increased risk of impact on water quantity in the headwaters of the River Frome and Norman's brook as a result of the proposed scheme due to the limestone geology of the area. Bushley Muzzard fen grassland Site of Special Scientific Interest (SSSI) is spring fed and is reliant on groundwater. This site is not anticipated to be affected by the proposed scheme and therefore no in-combination effects are likely within the SSSI.

- Impacts on groundwater as a result of the proposed scheme could affect the calcareous grasslands and woodland of Crickley Hill and Barrow Wake SSSI and potentially the Cotswolds Beechwood Special Area of Conservation (SAC). Tree species such as beech, which is a common component of existing woodlands in proximity to the proposed scheme, would be increasingly vulnerable to drought, especially on areas of free draining soil. The composition of woodland could therefore be altered by drier drought like conditions as a result of climate change.
- Increases in wind speed, temperature variations and rainfall patterns associated with climate change and the increase in extreme weather events such as storm events have the potential to cause habitat loss and degradation due to impacts such as defoliation, soil erosion from wind or water, structural damage to trees or tree loss, especially of mature or veteran trees. Habitat loss and fragmentation would also occur as a result of the proposed scheme. The in-combination effect has the potential to result in large scale habitat degradation, habitat loss and loss of connectivity between habitats. However, temperature changes are expected to be within the tolerance of habitats within the proposed scheme and not to have a significant impact upon local species of flora and fauna over the expected operational life of the proposed scheme.
- Increases in intensity and frequency of rainfall and likelihood of flooding would have an effect on groundwater, surface waterbodies and consequently the protected species that live in or rely on them. Increases in water volume within rivers due to flooding could cause riparian habitat loss and changes in food resource which would affect riparian mammals such as otters. Such impacts could cause species to relocate to other habitats or in a worst-case scenario cause mortality.

1.2.8 While the impacts of climate change are likely to affect habitats and consequently species in general terms, no preliminary significant in-combination effects with the proposed scheme have been identified. However, a number of measures will be included in the detailed mitigation design planting proposals to increase the resilience of the habitat to climate change as follows:

- Landscape planting will include a diverse mix of native tree species to ensure resilience to the effects of climate change including pest and disease;
- Species selection will include trees that may be more tolerant of drought conditions or those that will be adaptable to an increase in frequency and intensity of heavy rainfall events or longer growing seasons. Non-native tree species will be considered where appropriate to increase resilience;
- Woodland planting will be designed to include edge habitat comprising a diverse mix of species of varying structure. Edge habitat creates a buffer for the existing woodland against additional stresses from variable environmental factors such as exposure to wind and increased airborne pollutants; and
- The landscape planting design aims to connect previously isolated habitats, providing habitat corridors to enable species to disperse across the landscape

in immediate response to extreme weather events (such as flooding) or gradually in response to climate change.

Geology and soils

1.2.9 Potential effects which could arise due to impacts from the proposed scheme in combination with future projected climate conditions include:

- Increasing frequency and severity of precipitation and storms may accelerate the erosion of soil and engineered slopes, and result in increased runoff of sediments;
- Increasing frequency and intensity of drought periods may result in increased soil erosion, surface cracking and the formation of infiltration pathways into slopes;
- Increased temperatures and occurrence of heat waves may enhance breakdown of organic matter resulting in increased ground gas production rate (but this may be ameliorated by lower moisture content associated with dry weather) and increased volatility of organic compounds, if present, causing unpleasant odours locally;
- Increasing repeated cycles of drying and re-wetting may result in increased fracture propagation within the bedrock;
- Increasing frequency and intensity of drought periods may increase the frequency of shrink-swelling of the soils, potentially leading to significant volume reductions and differential settlement; and
- Increasing long spells of hot weather and wildfires may result in soils developing water repellence, which may reduce or temporarily impede water infiltration, leading to preferential flow and increased surface runoff.

1.2.10 While the impacts of climate change are likely to affect geology and soils in general terms, no preliminary significant in-combination effects with the proposed scheme have been identified, and no mitigation is proposed.

Material assets and waste

1.2.11 The potential combined effects relating to material assets for the proposed scheme and potential climate change on receptors includes the risk of contamination through increased heavy rainfall events and flooding which may result in a reduced capacity at both non-hazardous waste landfill facilities and hazardous waste landfill facilities. Additionally, wetter conditions could lead to excavated material being classed as unsuitable for re-use, therefore, requiring disposal off-site or treatment to reduce the water content. Conversely, material that is too dry may be unsuitable for re-use, therefore, the material may need to be wetted. The increase in frequency of extreme weather events may result in a reduction in quality of available material assets and therefore further reduce capacity at waste landfill facilities.

1.2.12 While the impacts of climate change are likely to affect material assets and waste in general terms, no preliminary significant in-combination effects within the proposed scheme have been identified and no mitigation is proposed.

Noise and vibration

1.2.13 The main consequence of climate change with regard to noise would relate to changes in humidity and temperature leading to a greater number of people sleeping with windows open. The thresholds used in the assessment for night-time noise are based on World Health Organisation (WHO) Night Noise

Guidelines[1] which are set assuming that people should be able to sleep with bedroom windows open. Therefore, no preliminary significant in-combination effects with the proposed scheme have been identified, and no mitigation is proposed.

Population and human health

1.2.14 There are a range of in-combination effects related to climate change that have been considered including raised temperatures, increased rainfall and storm events. These are likely to result in people changing their behaviour such as spending more time outdoors or sleeping in their homes with windows open during warmer periods. Alternatively, during wetter or stormier periods, people may choose not to spend as much time outdoors enjoying green and open spaces than they otherwise would. These behavioural variations would also reflect on the frequency with which people may choose to visit social gathering places such as tourist attractions or sports facilities.

1.2.15 It is considered that while the impacts of climate change are likely to affect population and human health receptors in general terms, no preliminary significant in-combination effects with the proposed scheme have been identified and no mitigation is proposed.

Road drainage and the water environment

1.2.16 Future climate conditions derived from the UK Climate Projections 2018 (UKCP18) indicate that the study area may undergo climatic changes including higher temperatures, increase in heat waves, reduced precipitation in summer and increased precipitation in winter.

1.2.17 These conditions are likely to reduce the amount of recharge to the groundwater which may have impacts upon features in the study area and cause some perennial features to become ephemeral. Abstractions, springs, groundwater fed watercourses, areas of flooded ground and Bushley Muzzard SSSI are likely to be particularly sensitive to these impacts. Groundwater quality is also likely to be affected by a reduction in the flushing of aquifers, which may increase the residence time of groundwater within them.

1.2.18 Surface water flows are likely to become more variable, with more frequent extremes including wetter winters and drier summers.

1.2.19 Increasing long spells of hot weather and wildfires may result in soils developing water repellence, which may reduce or temporarily impede water infiltration, leading to preferential flow and increased surface runoff.

1.2.20 While the impacts of climate change are likely to affect the water environment, no preliminary significant in-combination effects are predicted as a result of the proposed scheme with future climate conditions. The proposed scheme design incorporates embedded mitigation such as climate change allowances in the drainage design, as identified within the Flood Risk Assessment (FRA), which will be submitted with the Environmental Statement.

[1] World Health Organisation, “Night Noise Guidelines for Europe,” Copenhagen, 2009