Lower Thames Crossing

6.3 Environmental Statement Appendices
Appendix 14.6 - Flood Risk Assessment - Part 6 (Clean version)

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Lower Thames Crossing

Appendix 14.6 - Flood Risk Assessment - Part 6 (Clean version)

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1 Introduction

1.1 Context

1.1.1 This document forms Part 6 of the Flood Risk Assessment (the FRA) for the A122 Lower Thames Crossing (the Project).

1.1.2 The FRA forms Appendix 14.6 of the Environmental Statement (ES) (Application Document 6.3).

1.2 Form of assessment

1.2.1 The FRA is presented in nine principal parts and one affiliated part. These parts and a brief description of their contents are detailed in Plate 1.1.

1.2.2 For the purposes of the FRA, the Project has been divided into five discrete flood risk catchments (EFR-1 to EFR-5). These catchments are listed in Table 1.1 and are shown on Drawing 00100.

Table 1.1 FRA catchments

Catchment	Title
EFR-1	South of River Thames
EFR-2	North Portal to Chadwell St Mary
EFR-3	A13 junction
EFR-4	Ockendon Link
EFR-5	North Section

1.2.3 All drawings referenced in this document can be found in Part 9 of the FRA.

1.2.4 The key points raised in this document are presented in 'Text boxes'.

1.3 Basis of assessment

1.3.1 The FRA is based on the design as presented in the Development Consent Order (DCO) application.

1.3.2 The FRA includes an assessment of flood risk for both the construction phase and operational phase of the Project.

1.4 Design Principles

1.4.1 The Design Principles (Application Document 7.5) are embedded measures that have been developed through an iterative design process. The Design Principles are secured by Requirement 3 of Schedule 2 of the DCO.

1.4.2 Elements of the surface water drainage strategy that would be secured through the Design Principles are identified in this document. Design Principles relevant to the surface water drainage strategy are identified by an alpha-numerical reference code, for example, SX.X or LSP.XX.

1.5 Register of Environmental Actions and Commitments

1.5.1 Good practice and essential mitigation are included in the Register of Environmental Actions and Commitments (REAC), which forms part of Appendix 2.2: Code of Construction Practice (Application Document 6.3).

1.5.2 Each action and commitment in the REAC has a unique alpha-numerical reference code.

1.5.3 Where appropriate, the REAC reference codes for secured commitments and actions have been cross- referenced in this document. For example, the code for a Road Drainage and Water Environment commitment would be [RDWE0XX].

1.6 Flood risk

1.6.1 This part considers all aspects of flood risk associated with the Project. It considers planning provisions, sources of flood risk, site-specific flood risk and the flood risk strategy. The contents of this part is set out in Plate 1.2.

Plate 1.1 Form of FRA

Principal parts	
Part 1: Introduction	This part sets out the objectives of the FRA and describes the methodology used in its development. It also includes a list of stakeholders and the glossary for the FRA.
Part 2: Planning policy	This part summarises the national, regional and local legislation that is directly or indirectly related to flood risk.
Part 3: Environmental setting	This part provides descriptive information about the existing environmental condition within the Order Limits.
Part 4: Hydraulic assessment – Mardyke	This part describes the hydraulic modelling undertaken to analyse flooding scenarios in the River Mardyke catchment.
Part 5: Hydraulic assessment – West Tilbury Main	This part describes the hydraulic modelling undertaken to analyse flooding scenarios in Tilbury Marshes. It also describes the hydraulic breach modelling undertaken to analyse tidal flood risk.
Part 6: Flood risk	**The probability and potential consequences of flooding from all sources are considered in this part along with a matrix of mitigation measures.**
Part 7: Surface water drainage	This part reviews the existing surface water drainage provisions and sets out the drainage strategy for the Project.
Part 8: Technical summary	This part includes a technical summary of the FRA and sets out conclusions that would be used to inform the design.
Part 9: Drawings	All drawings that support the FRA are included in this part.

Affiliated part	
Part 10: Watercourse crossings and diversions	This part details the watercourse crossings and diversions that would be required to construct and operate the Project.

Plate 1.2 Form of Part 6 of the FRA

Section 1: Introduction	This section sets out the context of the document and details the form of the assessment.
Section 2: Planning and flood risk	This section considers the decision making process when flood risk is a factor in determining an application for development consent.
Section 3: Sequential and Exception Test	This section considers the Project location, its vulnerability classification, exception testing and sequential testing in accordance with the provisions of the National Planning Policy Framework and the National Policy Statement for National Networks.
Section 4: Climate change	This section deals with climate change and its impact on the Project.
Section 5: Sources and impact of flood risk	This section describes the flooding mechanism for each source of flood risk and considers the magnitude of the impact of the flood risk.
Section 6: Flood risk management strategy	The strategies for dealing with all sources of flood risk are described in this section.
Section 7: Design flood and Project lifetime	The design flood and Project lifetime are detailed in this section.
Section 8: South of River Thames (Catchment EFR-1)	This section comprises the flood risk sources and flood risk management strategy for the part of the Project to the south of the River Thames.
Section 9: North Portal to Chadwell St Mary (Catchment EFR-2)	This section comprises the flood risk sources and flood risk management strategy for the part of the Project from the North Portal up to the junction between the Project road and the A13.
Section 10: A13 junction (Catchment EFR-3)	This section comprises the flood risk sources and flood risk management strategy for the junction between the Project, the A13 and the A1089.

Continued below

Continued from above

Section 11: Ockendon link (Catchment EFR-4)	This section comprises the flood risk sources and flood risk management strategy for the Ockendon Link.
Section 12: North Section (Catchment EFR-5)	This section comprises the flood risk sources and flood risk management strategy for the northern part of the Project.
Section 13: Combined flood events	This section considers flood risk from combined sources of flood risk.
Section 14: Thames Estuary 2100 Plan	This section considers the potential impact of the Project on the TE2100 Plan.
Section 15: Other elements of the Project	This section includes details of flood risk associated with parts of the Project that do not readily fit into the five flood catchments.
Section 16: Construction phase flood risk	This section considers the construction phase aspects of flood risk.
Section 17: Summary	This section presents a summary of the findings of this part of the FRA.

2 Planning and flood risk

2.1 General

2.1.1 When flood risk is a factor in determining an application for development consent, the decision making process is set out in the National Planning Policy Framework (NPPF) (Department for Levelling Up, Housing and Communities (DLUHC), 2021) and the National Policy Statement for National Networks (NN NPS) (Department for Transport, 2014).

2.1.2 The overall strategic aims of the NPPF and the NN NPS are broadly similar and their respective requirements are generally harmonised. However, the two have differing but equally important roles to play.

2.1.3 The NPPF provides a framework upon which local authorities can construct local plans to bring forward developments.

2.1.4 The NPPF makes clear that it is not intended to contain specific policies for development of Nationally Significant Infrastructure Projects (NSIPs) where particular considerations can apply. The NN NPS assumes that function and provides transport policy which will guide individual development brought under it.

2.2 National Planning Policy

National Planning Policy Framework

2.2.1 The NPPF sets out the Government's planning policies for England, sets out how these should be applied and provides advice on how to take account of and address the risks associated with flooding in the planning process.

2.2.2 To support the NPPF, the Department for Levelling Up, Housing and Communities has developed guidance to determine whether a flood risk assessment needs to be undertaken (DLUHC, 2022). This guidance also includes links to supplementary guidance which details how flood risk assessments should be undertaken so that a planning application can be completed.

2.2.3 Further details of the NPPF are provided in Part 2 of the FRA.

National Policy Statement for National Networks

2.2.4 The NN NPS sets out the Government's policies regarding development of NSIPs on the national road and rail networks in England.

2.2.5 Paragraph 5.98 of the NN NPS notes that the Secretary of State should be satisfied that, where relevant:

a. The application is supported by an appropriate FRA.

b. The Sequential Test has been applied as part of site selection and, if required, the Exception Test.

2.2.6 Paragraph 5.99 of the NN NPS notes that the Secretary of State should be satisfied that flood risk will not be increased elsewhere and only consider development appropriate in areas at risk of flooding where the following can be demonstrated:

a. Within the site, the most vulnerable development is located in areas of lowest flood risk unless there are overriding reasons to prefer a different location.

b. It can be demonstrated that development is appropriately flood resilient and resistant, including safe access and escape routes where required, and that any residual risk can be safely managed, including by emergency planning; and priority is given to the use of sustainable drainage systems.

2.2.7 Further details of the NN NPS are provided in Part 2 of the FRA.

2.3 Application of the decision-making process

2.3.1 Demonstration of how the Sequential Test and Exception Test have been applied to the Project is detailed in Section 3.

2.3.2 Demonstration of how the Project would be flood resilient and resistant and how residual risk would be managed is provided in Sections 8 to 12.

Text box 2.1 Decision-making process for planning

> The decision-making process for planning applications where flood risk is a factor, is set out in the NPPF and the NN NPS.
>
> Both documents stipulate that a flood risk assessment shall be undertaken to support the planning application and that this assessment should include the following:
>
> - Application of the Sequential Test, and where necessary, application of the Exception Test.
> - Details of flood alleviation measures included in the Project and assessment of residual flood risk.

3 Sequential Test and Exception Test

3.1 General

3.1.1 Before the Sequential Test is applied it is necessary to determine the location of the Project and its flood risk vulnerability classification.

3.1.2 Determination of these two factors influence the siting and acceptability of the Project in terms of flood risk.

3.2 Development site location

3.2.1 Table 1 of the DLUHC guidance (DLUHC, 2022) defines four flood zones. The definition of these zones is summarised in Table 3.1.

Table 3.1 Flood zones

Flood Zone	Definition
Flood Zone 1 Low probability	Land having a less than 0.1% annual probability of river or sea flooding (AEP ≤ 0.1%). In this zone, developers and local authorities should seek opportunities to reduce the overall level of flood risk in the area and beyond through the layout and form of the development, and the appropriate application of sustainable drainage systems.
Flood Zone 2 Medium probability	Land having between a 1% and 0.1% annual probability of river flooding (0.1% < AEP < 1%); or land having between a 0.5% and 0.1% annual probability of sea flooding (0.5% < AEP < 1.5%). In this zone, developers and local authorities should seek opportunities to reduce the overall level of flood risk in the area through the layout and form of the development, and the appropriate application of sustainable drainage systems.
Flood Zone 3a High probability	Land having a 1% or greater annual probability of river flooding (AEP ≥ 1%); or land having a 0.5% or greater annual probability of sea (AEP ≥ 0.5%). In this zone, developers and local authorities should seek opportunities to: • Reduce the overall level of flood risk in the area through the layout and form of the development and the appropriate application of sustainable drainage systems • Relocate existing development to land in zones with a lower probability of flooding • Create space for flooding to occur by restoring functional floodplain and flood flow pathways, and by identifying, allocating and safeguarding open space for flood storage

Flood Zone	Definition
Flood Zone 3b Functional floodplain	This zone comprises land where water from rivers or the sea has to flow or be stored in times of flood. The identification of functional floodplain should take account of local circumstances and not be defined solely on rigid probability parameters. Functional floodplain will normally comprise: • Land having a 3.3% or greater annual probability of flooding, with any existing flood risk management infrastructure operating effectively (AEP ≥ 3.3%). • Land that is designed to flood (such as a flood attenuation scheme), even if it would only flood in more extreme events (such as 0.1% annual probability of flooding.

Note: The AEP is the probability that a flood of a given magnitude will occur within a period of one year and is expressed as a percentage.

3.2.2 The Project comprises land that lies primarily in Flood Zone 1 but includes areas that lie in Flood Zones 2, 3a and 3b.

3.2.3 The extents of the Flood Zones are shown in Drawing Numbers 00110 to 00112.

3.2.4 The Flood Zones encountered in each flood catchment of the Project are shown in Table 3.2.

Table 3.2 Development site location

Catchment	Section	Flood Zone			
		1	2	3a	3b
EFR-1	South of River Thames	✓	✗	✗	✗
EFR-2	North Portal to Chadwell St Mary	✓	✓	✓	✓
EFR-3	A13 junction	✓	✗	✗	✗
EFR-4	Ockendon Link	✓	✓	✓	✓
EFR-5	North Section	✓	✓	✓	✓

3.3 Flood risk vulnerability

Vulnerability classification

3.3.1 Annex 3 of the NPPF details five flood risk vulnerability classifications and lists the types of development that fall into each classification. According to Annex 3, essential transport infrastructure is listed under the 'essential infrastructure' classification.

3.3.2 The Project is considered to represent essential infrastructure for the following reasons:

a. The Project will form an integral part of the strategic road network.

b. The Project is classified as an NSIP, as defined by the Planning Act 2008.

c. The Project was identified by HM Treasury (2014) as one of the top 40 priority investments in their National Infrastructure Plan 2014.

d. The National Infrastructure Delivery Plan 2016–2021 (Infrastructure and Projects Authority, 2016) lists the Project as a priority.

e. The National Infrastructure Strategy (HM Treasury, 2020) identifies the Project as part of the government's proposals to unite and level up the UK.

Flood risk compatibility

3.3.3 Table 3.3 is based on Table 2 of the DLUHC guidance (DLUHC, 2022). This table shows the compatibility of flood risk vulnerability classifications and Flood Zones. As essential infrastructure, the Project is appropriate in all Flood Zones. However, for development in Flood Zones 3a and 3b, an Exception Test must be undertaken.

Table 3.3 Flood risk vulnerability and flood zone compatibility

Flood Zone	Flood risk vulnerability classification				
	Essential infrastructure	Highly vulnerable	More vulnerable	Less vulnerable	Water compatible
Zone 1	✓	✓	✓	✓	✓
Zone 2	✓	Exception Test required	✓	✓	✓
Zone 3a†	Exception Test required†	✗	Exception Test required	✓	✓
Zone 3b*	Exception Test required*	✗	✗	✗	✓*

Key:

✗ *Development should not be permitted*

✓ *Exception test is not required*

† *In Flood Zone 3a essential infrastructure should be designed and constructed to remain operational and safe in times of flood*

* *In Flood Zone 3b (functional floodplain) essential infrastructure that has passed the Exception Test, and water-compatible uses, should be designed and constructed to:*
Remain operational and safe for users in times of flood.
Result in no net loss of floodplain storage.
Not impede water flows and not increase flood risk elsewhere

3.4 Sequential Test

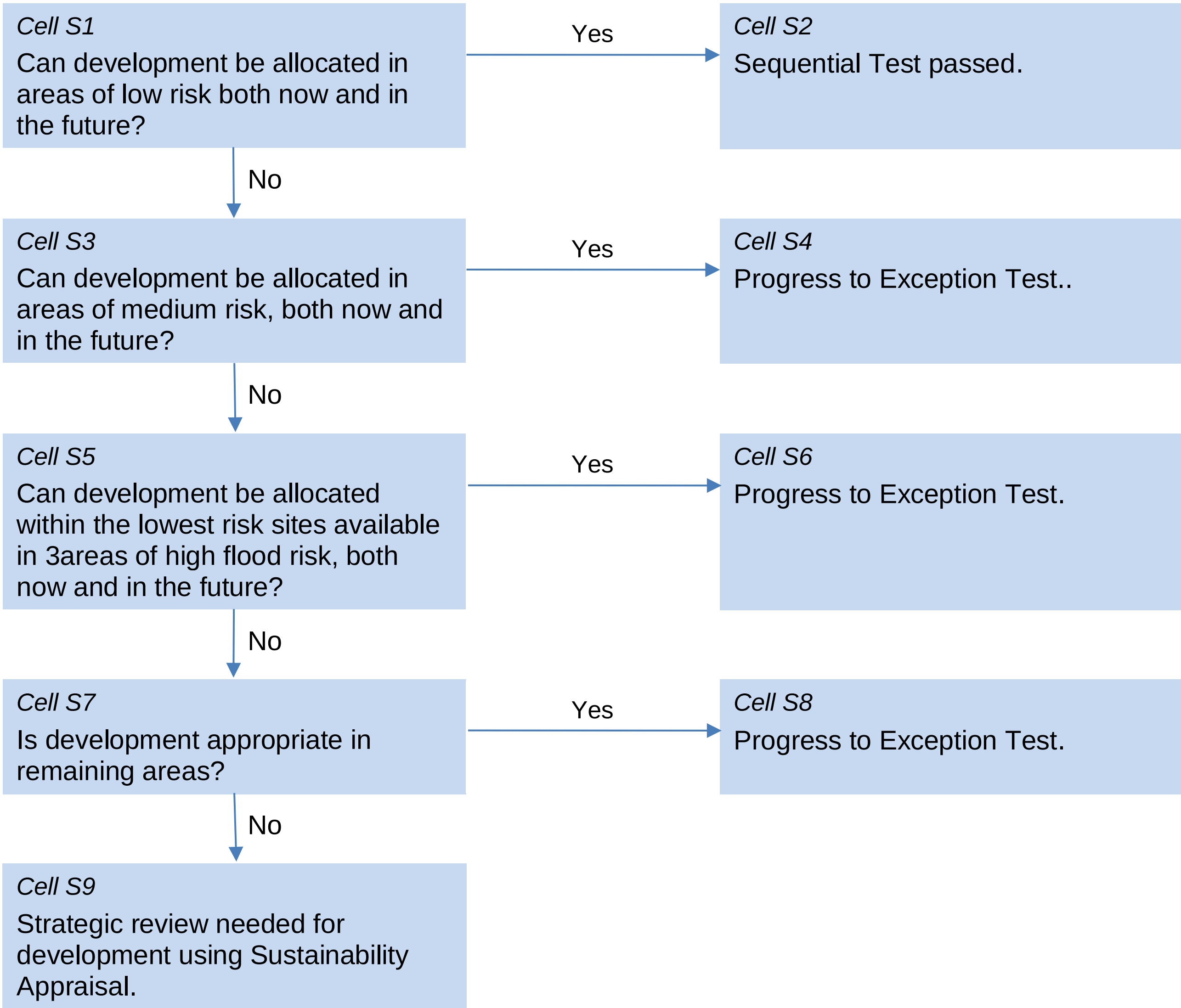
Application

3.4.1 The Sequential Test is a risk-based approach to locating a development. Its purpose is to either steer new development to areas with the lowest probability of flooding or demonstrate that there are no reasonably available sites in areas with a lower probability of flooding that would be appropriate to the development being proposed.

3.4.2 Application of the Sequential Test is set out in Diagram 2 of the DLUHC guidance (DLUHC, 2022) and described in paragraph 5.105 of the NN NPS.

3.4.3 Plate 3.1, which is based on Diagram 2 of the DLUHC guidance (DLUHC, 2022), sets out the application process for the Sequential Test.

Plate 3.1 Sequential Test flow chart



3.4.4 The results of the Sequential Test for each flood risk catchment are shown in Table 3.4.

Table 3.4 Sequential Test results

Catchment	Sequential Test result	Plate 3.1 conclusion
EFR-1	Pass	Cell S2
EFR-2	Exception Test required	Cell S8
EFR-3	Pass	Cell S2
EFR-4	Exception Test required	Cell S8
EFR-5	Exception Test required	Cell S8

Rationale for development in Flood Zone 3

3.4.5 The Project road forms a linear connection between the A2/M2 and the M25. The most viable route between these two points would involve crossing Flood Zone 3 in four locations[1].

3.4.6 Paragraph 5.102 of the NN NPS recognises that the nature of linear infrastructure means that there will be cases where the most viable route between two points that are not in flood risk areas may need to cross areas that are at risk of flooding.

3.4.7 Although NN NPS paragraph 5.102 recognises that linear infrastructure may need to cross areas at risk of flooding, the Sequential Test still needs to be carried out and steer new development to areas with the lowest probability of flooding.

3.4.8 The reasons why crossing areas at risk of flooding would be necessary are presented in Table 3.5.

Table 3.5 Reason for crossing Flood Zone 3

Location	Reason for crossing Flood Zone 3
River Thames floodplain – South (Catchment EFR-1)	To cross the River Thames it is also necessary to cross the tidal floodplain that runs alongside its southern bank. However, as the Project road would be in tunnel where it crosses the floodplain, above ground development in Flood Zone 3 would be avoided.
River Thames floodplain – North (Catchment EFR-2)	To cross the River Thames it is also necessary to cross the tidal floodplain that runs alongside its northern bank. In ES Chapter 3: Assessment of Reasonable Alternatives (Application Document 6.1), it was concluded that the preferred location of the North Portal would be to the south of the railway line (Tilbury Loop). The consequence of this approach is that development in the floodplain is unavoidable. The development in the floodplain would comprise part of the flood protection works for the tunnel and embankments to support the Project road. Consideration was given to extending the tunnel to a point north of the railway. This approach would reduce the amount of development in Flood Zone 3 as such an extension would take the tunnel beyond the limits of the floodplain. However, this approach was discounted because the critical risks relating to engineering and ground conditions outweighed the potential advantages. Moving the Project road immediately to the east or west of its proposed location would not significantly change the amount of development in Flood Zone 3.

[1] Further details about route selection are provided in ES Chapter 3: Assessment of Reasonable Alternatives (Application Document 6.1).

Location	Reason for crossing Flood Zone 3
Mardyke floodplain (Catchment EFR-4)	Realignment of the route to avoid the Mardyke floodplain would entail a much longer link between the A2/M2 and the M25; such an alignment was considered but was discounted during the route selection process. A tunnel under the Mardyke floodplain is not deemed to be necessary or economically viable.
West Mardyke floodplain (Catchment EFR-5)	The location of the junction between the Project road and the M25 is based on the provisions of Design Manual for Roads and Bridges (DMRB) TD 22/06[2] (Highways Agency, 2006), which states that the minimum desirable space between junctions (known as the weaving section) should be 2km for rural motorways. Application of the 2km weaving length from junctions 29 and 30 of the M25 would only leave a short section of road in which to construct the new junction with the Project road. A junction in this short section of the M25 would make development in the West Mardyke floodplain unavoidable.

3.5 Exception Test

Application

3.5.1 Where development is required in Flood Zone 3, the provisions of the Exception Test need to be satisfied. This applies to catchments EFR-2, EFR-4 and EFR-5 (see Table 3.4).

3.5.2 The Exception Test is a method to demonstrate and help ensure that flood risk to people and property will be managed satisfactorily, while allowing necessary development to go ahead in situations where suitable sites at lower risk of flooding are not available. The NPPF states that application of the Exception Test should be informed by a strategic or site-specific flood risk assessment[3].

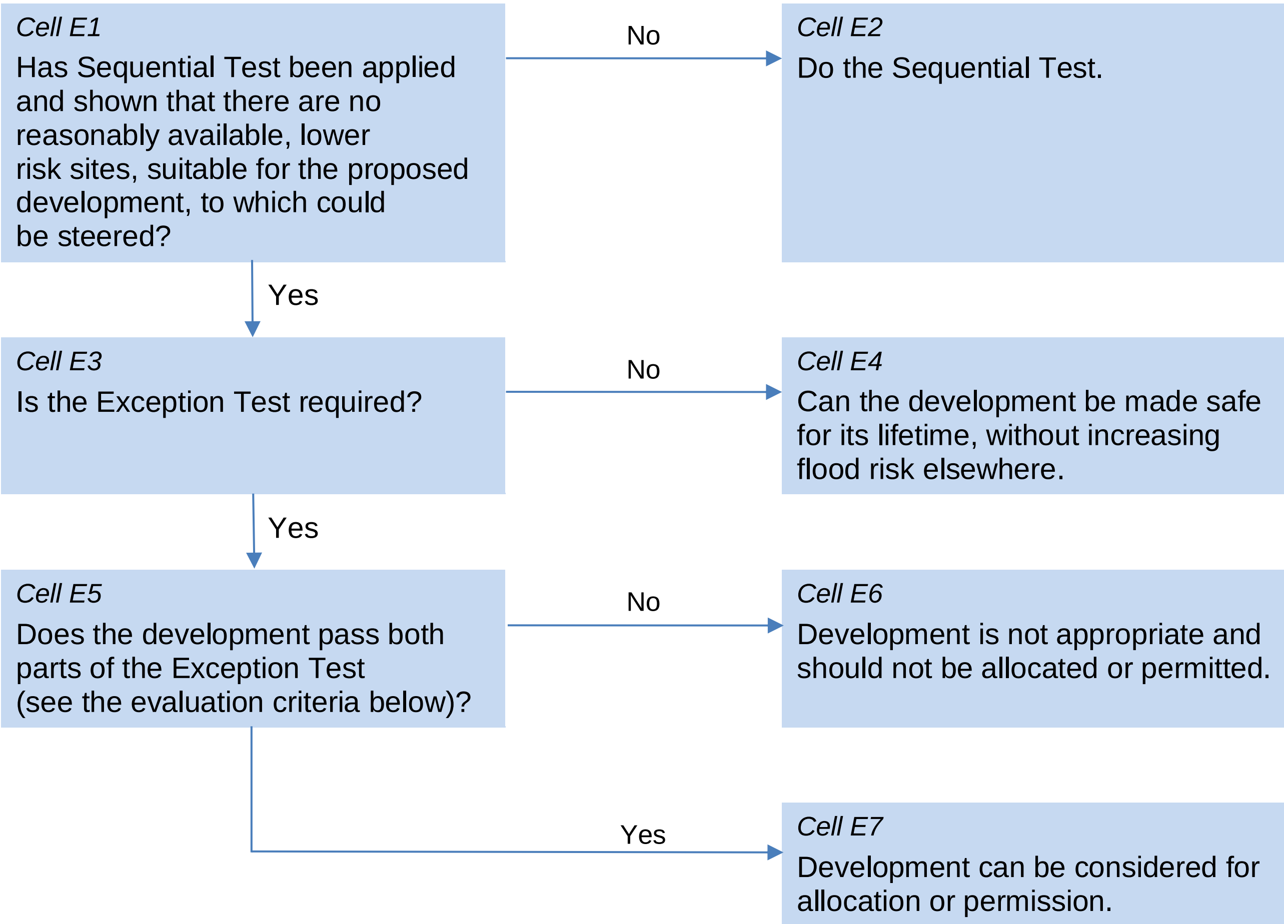
3.5.3 Application of the Exception Test is set out in Diagram 3 of the DLUHC guidance (DLUHC, 2022) and described in paragraphs 5.106 to 5.108 of the NN NPS.

3.5.4 Plate 3.2, which is based on Diagram 3 of the DLUHC guidance, sets out the application process for the Exception Test.

[2] Highways Agency (2006) DMRB TD 22/06 Layout of Grade Separated Junctions. Since adoption of this standard for the Project, it has been updated as DMRB CD 122 (National Highways, 2022a). It should be noted that DMRB CD 122 has slightly different requirements to those detailed in TD 22/06.

[3] The purpose of this site-specific Flood Risk Assessment is to describe the risk of flooding to and from the Project over its expected lifetime, including appropriate allowances for the impacts of climate change. This document forms part of the site-specific FRA for the Project. Also, see paragraph 160 of the NPPF.

Plate 3.2 Exception Test flow chart



Test evaluation criteria

3.5.5 The evaluation criteria for the Exception Test is set out in the DLUHC guidance (DLUHC, 2022) and paragraph 5.108 of the NN NPS. For the Exception Test to be passed, the following must be demonstrated:

a. The development provides wider sustainability benefits to the community that outweigh flood risk.

b. The development will be safe for its lifetime taking account of the vulnerability of its users, without increasing flood risk elsewhere, and, where possible, will reduce flood risk overall.

3.5.6 In addition to the above, paragraph 5.109 of the NN NPS states that any essential infrastructure project should be designed and constructed to remain operational and safe for users in times of flood, and any project in Zone 3b should result in no net loss of floodplain storage and not impede water flows.

3.5.7 Demonstration of achievement of the evaluation criteria and the requirements of paragraph 5.109 of the NN NPS is detailed below.

Wider sustainability benefits

3.5.8 Sustainability is generally defined as meeting the needs of the present without compromising the ability of future generations to meet theirs. The three main pillars of sustainability are as follows:

a. Economic (profit)

b. Environmental (planet)

c. Social (people)

3.5.9 The way in which the Project underpins the three pillars of sustainability is detailed in Table 3.6.

Table 3.6 Pillars of sustainability

Benefits of the Project	Pillar		
	Profit	**Planet**	**People**
It would help reduce congestion in the Dartford area. This will decrease forecasted high levels of pollution, benefiting the environment and local communities.		✓	✓
It would provide access for local and regional communities to jobs, leisure and retail, benefiting development and sustainable economic growth on both sides of the River Thames. The crossing will also improve journey times for national commercial traffic north and south of the river enabling quicker and more reliable access to key markets, resources and employees.	✓		✓
It would create better access on both sides of the river. This will improve journey times and reliability for communities and businesses, whether travelling short distances across the River Thames to visit family or looking for better access to job or business opportunities.	✓		✓
It would increase road capacity across the River Thames east of London. It will provide quicker, more reliable journeys locally and regionally between Kent, Thurrock and Essex, as well as nationally.	✓		

3.5.10 The wider sustainability benefits afforded by the Project are considered to outweigh flood risk, provided that appropriate mitigation, protection and resilience measures are implemented, and that the residual flood risk is evaluated and managed. Full details of the sustainability benefits are presented in the Sustainability Statement (Application Document 7.11).

Safety of the development over its lifetime

3.5.11 The Project would incorporate flood protection, flood mitigation and flood resilience measures.

3.5.12 These measures would ensure that the development will be safe for its lifetime taking account of the vulnerability of its users, without increasing flood risk elsewhere.

3.5.13 General details of these measures are included in Section 6 and site-specific measures are described in Sections 8 to 12.

Reduce flood risk overall

3.5.14 Under the Project, the existing balancing ponds along the M25 would be retained but with reduced outfall rates. These balancing ponds discharge directly or indirectly to the Mardyke. Reducing the rate of discharge from the ponds would help to mitigate flood risk along the Mardyke as it passes through Thurrock.

3.5.15 The environmental mitigation measures for the Project would include the creation of a wetland area in Orsett Fen. Wetlands hold back and slow down the flow of water before it reaches any receptors, thereby reducing flood risk on a catchment scale.

3.5.16 The Project road would obstruct flow in the floodplain following a breach event at Bowaters Sluice. This would alleviate the impact of breach flows in the area to the west of the Project road and to the south of Tilbury Loop.

Compliance with NN NPS paragraph 5.109

3.5.17 In areas susceptible to flooding, the Project road would mostly be on embankments or viaducts (flood resilience measures). These embankments and viaducts would be designed to be above the flood level for a 1% AEP event with climate change allowances up to 2130 and a 600mm freeboard (residual uncertainties) allowance. In areas that are susceptible to flooding but are located where embankments or viaducts cannot be used, the Project road would remain operational and safe for users by incorporating flood protection measures. The only section of the Project road where this situation arises is between Tilbury Viaduct and the North Portal. The flood protection measures here comprise strategically located bunds and concrete retaining walls. The flood protection would be designed to be above the flood level for a 0.1% AEP event with climate change allowances up to 2130 and a 1000mm freeboard (residual uncertainties) allowance. Further details of flood protection and resilience measures are detailed in Section 6.4 and 6.5.

3.5.18 Compensatory flood storage areas (CFSAs) would be incorporated into the Project to ensure that there is no net loss of floodplain storage (flood mitigation measure). CFSAs would be provided in all areas where development in the floodplain is unavoidable. The CFSAs in Tilbury Marshes and Orsett Fen were determined using the hydraulic models (see Parts 4 and 5 of the FRA). The CFSAs around the M25 were determined by computational analysis (see Annex A). General details on flood mitigation measures are included in Section 6.3 and specific measures are detailed in Sections 8.3, 11.4 and 12.3.

3.5.19 Sections of the Project road that are on embankments have the potential to impede flow paths. Details of the measures that would be taken to ensure that flow paths are maintained are outlined in Table 3.7.

Table 3.7 Management of flow paths

Ref.	Area	Management measures
EFR-2	Tilbury Marshes	An existing flow path running east to west across Tilbury Marshes would be intercepted by a section of the Project road that is on an embankment (between the North Portal and Tilbury Viaduct). To ensure flows are not impeded and that connectivity is maintained, the capacity of West Tilbury Main would be increased, thereby affording an alternative flow path for the intercepted flows. This solution was developed using the hydraulic model developed for Tilbury (see Section 9 and FRA Part 5).
EFR-4	Mardyke floodplain (Orsett Fen)	The Project road would mostly be on viaducts where it crosses the Mardyke floodplain. The use of viaducts would enable flow paths through the Mardyke flood plain to be retained with minimal afflux. A small section of the Project road would be on an embankment where it crosses the Mardyke floodplain. This embankment would intercept part of the flow path through the floodplain. To ensure continuity of the flow path, a flood relief channel would be incorporated to direct the intercepted flow path under the viaduct. The viaducts and channel would ensure that flow paths through the Mardyke flood plain are not impeded. This solution was developed using the hydraulic model developed for the Mardyke (see Section 11 and FRA Part 4).
EFR-5	M25	The West Mardyke is in culvert where it crosses under the M25. The cross section of the culverts for the widened section of the M25 and the proposed M25 on-slip would match that of the existing culvert. This would ensure that the flow path through to West Mardyke flood plain would not be affected.

Text box 3.1 Planning and flood risk

The Project would lie primarily in Flood Zone 1 but would include three sections that cross Flood Zones 2, 3a and 3b.

The Project is regarded as essential infrastructure. The DLUHC guidance (DLUHC, 2022) notes that it is appropriate to construct essential infrastructure in Flood Zone 3.

The Sequential Test has been applied to the Project to ensure that it lies in areas with lower probability of flooding.

As the most viable alignment of the Project road includes four sections that cross Flood Zone 3, the Exception Test has also been applied to the Project.

As the Project is considered to provide wider sustainability benefits that outweigh flood risk, and will be safe for its lifetime without increasing flood risk elsewhere, it is deemed to satisfy the requirements of the Exception Test. The evaluation criteria for the Exception Test also requires that overall flood risk is lowered where if possible. Lowering flood risk overall would be achieved by reducing discharge rates from the existing retention ponds along the M25, and the creation of a wetland area in Orsett Fen.

To ensure that the provisions of Paragraph 5.109 of the NN NPS are satisfied:

- The Project road would remain operational and safe for users by incorporating flood resilience and protection measures.
- CFSAs would be incorporated in the design to ensure that there is no net loss in floodplain storage.
- Flow paths would not be impeded so far as is practicable. Where flow paths are impeded, mitigation measures would be incorporated in the design to ensure continuity of flow.

4 Climate change

4.1 General

4.1.1 Climate change has the potential to increase peak rainfall intensity. This results in a corresponding increase in the rate and volume of runoff being discharged to local watercourses and subsequently creates an escalation in flood risk. Furthermore, sea levels are also projected to increase as a result of climate change.

4.1.2 The Environment Agency's current guidance on climate change allowances for flood risk assessments (2022a) has undergone a number of iterations since publication of UK Climate Change Predictions 2018 (UKCP18) (Met Office, 2018). These iterations are detailed in Table 4.1.

Table 4.1 Environment Agency guidance update

Iteration	Update
17 December 2019	The following updates were made: 1) Updated sea level rise allowances using UKCP18 projections. 2) Added guidance on how to: a) Calculate flood storage compensation b) Use peak rainfall allowances to help design drainage systems c) Account for the impact of climate change on storm surge d) Assess and design access and escape routes for less vulnerable development 3) Changed guidance on how to apply peak river flow allowances so the approach is the same for both Flood Zones 2 and 3.
16 March 2020	Correction to example 3, to get sea levels: treat subsequent time periods 2066 to 2095 and 2096 to 2125 as 2036 to 2065 would be treated.
22 July 2020	The Environment Agency has edited the sections on peak river flow, sea level rise, wind speed, wave height and storm surge to include guidance on how to use High++ allowances in developments where they need to be assessed.
20 July 2021 and 27 July 2021	The Environment Agency has used the UKCP18 projections to update the peak river flow allowances and has based them on management catchments instead of river basin districts. The Project has also changed the guidance on how to apply peak river flow allowances. The guidance now uses (a) the central allowance for all assessments except for essential infrastructure, where the higher central allowance is applicable, (b) the upper end for 'credible maximum scenario' assessments and (c) the central allowance to calculate flood storage compensation, except for where essential infrastructure is affected, where the higher central allowance should be used.
10 May 2022	The Environment Agency has used the UKCP18 projections to update peak rainfall allowances. The new allowances are provided by management catchments instead of at a national scale (for England). Peak rainfall allowances are provided for 1% and 3.3% AEP events, and for two epochs rather than three. The guidance on how to apply peak rainfall allowances has changed, using the central allowance for development with a lifetime up

Iteration	Update
	to 2100 and the upper end allowance for development with a lifetime from 2100 to 2125.
27 May 2022	Clarification in section 'How to use the peak rainfall intensity allowances': surface water flood mapping in small catchments (less than 5 square kilometres) and modelling large areas (larger than 5 square kilometres).

4.2 Peak rainfall intensity allowance

4.2.1 Peak rainfall intensity allowances are based on management catchments. The Project lies across the Medway Management Catchment and the South Essex Management Catchment. Table 4.2 and Table 4.3 show anticipated changes in rainfall intensity by management catchment (Environment Agency, 2022b).

Table 4.2 South Essex Management Catchment peak rainfall allowances

Epoch	Allowance			
	3.3% AEP event		1% AEP event	
	Central	Upper end	Central	Upper end
2050s epoch (2022 and 2060)	20%	35%	20%	45%
2070s epoch (2061 and 2125)	20%	35%	25%	40%

Note: These peak rainfall allowances are for small catchments (less than 5 square km).

Table 4.3 Medway Management Catchment peak rainfall allowances

Epoch	Allowance			
	3.3% AEP event		1% AEP event	
	Central	Upper end	Central	Upper end
2050s epoch (2022 and 2060)	20%	35%	20%	45%
2070s epoch (2061 and 2125)	20%	35%	20%	40%

Note: These peak rainfall allowances are for small catchments (less than 5 square km).

4.2.2 The Environment Agency's guidance on climate change allowances (Environment Agency, 2022a) notes that the method of application of peak rainfall intensities depends upon the lifetime of the development.

4.2.3 The Project is planned to become operational in 2030 and have a minimum lifetime of 100 years (for the purposes of appraisal of climate change allowances, the lifetime of the Project is assumed to be up to 2130). The guidance stipulates that for developments with a lifetime beyond 2100, flood risk assessments should assess the upper end allowances for both the 1% and 3.3% AEP events for the 2070s epoch (2061 to 2125).

4.2.4 The guidance goes on to state that development shall be designed so that for the upper end allowance in the 1% AEP event:

a. There is no increase in flood risk elsewhere.

b. The development will be safe from surface water flooding.

4.2.5 Notwithstanding the above, the Environment Agency's guidance notes that in some locations, the allowance for the 2050s epoch is higher than that for the 2070s epoch. The guidance states that where this is the case, and development has a lifetime beyond 2061, the higher of the two allowances should be adopted.

4.2.6 The Environment Agency guidelines (2022a) do not specify peak rainfall allowances for extreme climate change scenarios (H++).

4.3 Peak rainfall intensity allowance for carriageway design

4.3.1 For the design of carriageway drainage, climate change allowances would be applied in accordance with the provisions of DMRB CG 501 (National Highways, 2022b). This standard states that climate change shall be accommodated by applying a 20% uplift in peak rainfall intensity. The standard also requires that a sensitivity test based on a 40% uplift in peak rainfall intensity is also undertaken.

4.3.2 These uplifts are based on the understanding that some short duration flooding on highways is acceptable. They are not supposed to replicate the uplifts on peak rainfall intensity as described in the Environment Agency's guidance (2022a).

4.4 Peak river flow allowances

4.4.1 Peak river flow allowances show the anticipated changes to peak flow by management catchment. Management catchments are sub-catchments of river basin districts.

4.4.2 The range of allowances is based on percentiles, which describe the proportion of possible scenarios that fall below an allowance level. The percentiles for peak river flow allowances are as follows:

a. The central allowance is based on the 50th percentile.

b. The higher central allowance is based on the 70th percentile.

c. The upper end allowance is based on the 95th percentile.

4.4.3 Table 4.4 shows anticipated peak river flow allowances for the South Essex Management Catchment (Department for Environment, Food and Rural Affairs (Defra), 2022). This catchment encompasses the part of the Project that lies to the north of the River Thames.

Table 4.4 South Essex Management Catchment peak river flow allowances

Epoch	Allowance		
	Central	Higher central	Upper
2020s epoch (2015 to 2039)	6%	11%	22%
2050s epoch (2040 to 2069)	5%	11%	27%
2080s epoch (2070 to 2125)	17%	26%	48%

4.4.4 The part of the Project that lies to the south of the River Thames falls within the Medway Catchment. As there are no watercourses in this part of the Project, peak river flow allowances are inconsequential in the context of this assessment and are not considered further.

4.4.5 The application of the allowance category is a function of flood risk vulnerability classification for the type of development and the Flood Zone. A matrix of allowances for peak river flows, based on the Environment Agency's guidance on climate change allowances (2022a), is presented in Table 4.5.

Table 4.5 Peak river flow allowances by flood risk vulnerability and the flood zone

Flood risk vulnerability classification		Essential infrastructure	Highly vulnerable	More vulnerable	Less vulnerable	Water compatible
Flood Zone	Zone 2	Higher central	Central	Central	Central	Central
Flood Zone	Zone 3a	Higher central	Development should not be permitted	Central	Central	Central
Flood Zone	Zone 3b	Higher central	Development should not be permitted	Development should not be permitted	Development should not be permitted	Central

4.4.6 The Environment Agency guidance on climate change allowances (2022a) states that the appropriate allowance to assess offsite impacts and calculate floodplain storage compensation depends on land uses in affected areas. The guidance recommends the following allowances to assess offsite impacts and calculate floodplain storage compensation:

a. Central allowance for most cases.

b. Higher central allowance when the affected area contains essential infrastructure.

4.4.7 The Environment Agency guidelines (2022a) do not specify peak river flow allowances for extreme climate change scenarios (H++).

4.5 Sea level rise allowances

4.5.1 The Environment Agency's guidance on climate change allowances (2022a) specifies sea level rise allowances to be applied in flood risk assessments. These allowances are reproduced in Table 4.6.

Table 4.6 Sea level allowances by river basin district for each epoch

Area of England	Allowance	2000 to 2035 (mm/yr)	2036 to 2065 (mm/yr)	2066 to 2095 (mm/yr)	2096 to 2125 (mm/yr)	Cumulative extrapolated rise 2017 to 2130 (m)
South east	Higher central	5.7 (200)	8.7 (261)	11.6 (348)	13.1 (393)	1.17
	Upper end	6.9 (242)	11.3 (339)	15.8 (474)	18.2 (546)	1.57

Notes
2017 is the baseline year of the Environment Agency Coastal flood boundary dataset (Environment Agency, 2018).
The Project lies in the Thames river basin district. The Environment Agency's guidance on climate change allowances (2022a) states that 'south-east' sea level rise allowances should be used for the Thames river basin district.
The total sea level rise for each epoch is shown in brackets (mm).
The cumulative rise 2017 to 2130 has been extrapolated beyond 2125.
The allowances in this table account for slow land movement. This is due to 'glacial isostatic adjustment' from the release of pressure at the end of the last ice age.

4.5.2 In order to understand the range of impact, the Environment Agency's guidance on climate change allowances (2022a) specifies:

'*For flood risk assessments and strategic flood risk assessments, assess both the higher central and upper end allowances.*'

4.5.3 The Environment Agency's guidance on climate change allowances (2022a) states the mean sea level rise for the H++ scenario for 2100 is 1.9m. H++ storm surge allowances are specified as annual rates of rise of 2mm/year from 2017 onwards.

4.6 Credible maximum scenarios

4.6.1 The Project is an NSIP and as such, it is necessary to assess the flood risk from a credible maximum climate change scenario.

4.6.2 For a credible maximum climate change scenario, Environment Agency's guidance on climate change allowances (2022a) recommends the following:

a. The H++ climate change allowances for sea level rise.

b. The upper end allowance for peak river flow.

c. The sensitivity test allowances for offshore wind speed and extreme wave height.

d. An additional 2mm for each year on top of sea level rise allowances from 2017 for storm surge.

4.7 Climate change allowances for the Project

Peak rainfall intensity

4.7.1 Climate change allowances for carriageway drainage design are calculated in accordance with the provisions of DMRB CG 501 (2022). This standard stipulates that a 20% uplift is applied to peak rainfall intensity and that a sensitivity test is undertaken with a 40% uplift.

4.7.2 For the remaining elements of the drainage design, peak rainfall intensity would normally be calculated in accordance with the Environment Agency's guidance on climate change for flood risk assessments (Environment Agency, 2022a). When the drainage design for the Project was undertaken the guidance stipulated that to accommodate climate change, a 20% uplift was to be applied to peak rainfall intensity and that a sensitivity test for a 40% uplift was to be undertaken. However, since the design was undertaken, the guidance has been updated with higher uplifts on peak rainfall intensity. As the revised guidance was published after the drainage design was undertaken, the Environment Agency verbally agreed at a meeting held on 4 May 2022 that a 5% departure on peak rainfall intensities was acceptable[4]. With this departure taken into account, the 20% and 40% uplift on peak rainfall intensity are deemed to be accepted for drainage design (excluding carriageway drainage).

4.7.3 The peak rainfall allowances in the Environment Agency's guidance on climate change allowances (2022a) only extend to 2125. In the absence of climate change allowances for 2130, the rainfall allowance for 2125 was adopted for the purposes of this assessment[5].

4.7.4 There are no rainfall allowances specified for the H++ scenario.

Peak river flow allowances

4.7.5 As the Project is designated as essential infrastructure, lies in Flood Zone 3b and has a minimum lifetime of 100 years, the 'higher central' peak river flow allowances for the 2080s epoch have been used to assess fluvial flood risk (see Table 4.4 and Table 4.5).

4.7.6 To understand the impact of peak river flow allowances over the lifetime of the Project, the 'higher central' peak river flow allowances for the 2030s epoch was also assessed.

4.7.7 Peak river flow allowances of +11% and +26% were applied for assessment of the 2030 and 2130 'higher central' climate scenarios.

4.7.8 To understand the impact of peak river flow allowances for different storm events, the 'central' peak river flow allowances for the 2030s epoch and 2080s

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[4] The departure on peak rainfall intensity is recorded in a Statement of Common Ground between National Highways and the Environment Agency (see Application Document 5.4).

[5] This approach was adopted in Adapting to Climate Change: Advice for Flood and Coastal Erosion Risk Management Authorities (Environment Agency, 2016). This document has been replaced by Flood and coastal risk projects, schemes and strategies: climate change allowances (Environment Agency, 2022b). The updated guidance does not give advice on allowances beyond 2125 for peak rainfall intensity allowances, or peak river flow allowances.

epoch were also assessed. Peak river flow allowances of +6% and +11% were applied for assessment of the 2030 and 2130 'central' climate scenarios.

4.7.9 The upper end peak river flow allowance (+48% in 2130) was applied to represent the 'credible maximum' climate change scenario (see Table 4.4 and Section 4.6).

4.7.10 It should be noted that the 2080s epoch only covers the period from 2070 to 2125. In the absence of climate change allowances for 2130, the peak river flow allowance for 2125 has been used for the assessment[6].

4.7.11 Further details of the application of peak river flow analysis are included in Parts 4 and 5 of the FRA.

Credible Sea level allowances

4.7.12 Sea level rise allowances have been specified and applied at Southend, according to current Environment Agency guidance (2022a) (Table 4.6). The effect of a sea level rise at Southend on the River Thames extreme water levels (EWLs) at the Project location, was assessed based on an interpretation of outputs of the Environment Agency's Thames Estuary 2100 modelled River Thames EWLs (detailed in Parts 4 and 5 of the FRA).

4.7.13 Sea level rise allowances at Southend for the 'upper end' and 'higher central' climate scenarios in 2030 are 0.09m and 0.07m respectively, relative to 2017. Sea level rise allowances at Southend for the 'upper end' and 'higher central' climate scenarios in 2130 are 1.57m and 1.17m respectively, relative to 2017.

4.7.14 Calculation of the EWL for the 0.1% AEP event for East Tilbury Marshes (the Project location) was based on the Thames Estuary 2100 Plan (TE2100) (Environment Agency, 2012) EWL for Southend and then adjusted using the current coastal boundary dataset (Environment Agency, 2018b) and the Environment Agency's guidance on climate change allowances for flood risk assessments (2022a). Using this approach, the EWL for the 0.1% AEP event at East Tilbury Marshes was taken as 6.83m above ordnance datum (mAOD). Full details of derivation of the EWL for East Tilbury Marshes can be found in Parts 4 and 5 of the FRA.

4.7.15 H++ sea level rise allowance are specified in the current guidance as +1.9m in 2100, with no specified value beyond 2100. H++ storm surge allowances are specified as annual rates of rise of 2mm/year from 2017 onwards. Applying +1.9m sea level rise and 2mm/year storm surge from 2017 to 2130 gives a H++ sea level rise and storm surge allowance of +2.13m at Southend relative to 2017.

Text box 4.1 Climate change

Peak rainfall intensity allowances of 40% and 20% respectively would be used for the purposes of carriageway drainage design.

The upper end and central peak rainfall intensity allowances of 40% and 20% respectively would be used for the purposes of highway drainage assets other than carriageway drainage.

[6] See Note 6

Peak river flow allowances of +6% and +11% were applied for assessment of the 2030 and 2130 ‘central’ climate scenarios.

Peak river flow allowances of +11% and +26% were applied for assessment of the 2030 and 2130 ‘higher central’ climate scenarios.

The upper end peak river flow allowance (+48% in 2130) was applied to represent the ‘credible maximum’ climate change scenario.

The effect of a sea level rise at Southend on the River Thames EWLs at the Project location, was assessed based on an interpretation of outputs of the Environment Agency’s Thames Estuary 2100 modelled River Thames EWLs (detailed in Parts 4 and 5 of the FRA).

Sea level rise allowances at Southend for the ‘upper end’ and ‘higher central’ climate scenarios in 2130 are 1.57m and 1.17m respectively, relative to 2017.

The H++ sea level rise and storm surge allowance at Southend in 2130 is +2.13m relative to 2017.

5 Sources and impact of flood risk

5.1 Introduction

5.1.1 The FRA must consider all sources of flood risk. These comprise the following:

a. Fluvial and tidal flooding

b. Surface water (pluvial) flooding

c. Groundwater flooding

d. Sewers

e. Water mains

f. Reservoirs

g. Canals

5.1.2 This section describes the flooding mechanism for each source of flooding and the methods by which each flood risk is analysed. This section also details the National Highways criteria for estimating the impact magnitude of flood risk.

5.2 Fluvial and tidal flooding

Mechanism

5.2.1 Fluvial flooding occurs when the flow in a watercourse exceeds its capacity. The flow in a watercourse is primarily a function of runoff from adjacent land and inflow of tributaries. Typically, fluvial flooding is a result of intense or sustained rainfall and can be exacerbated if the watercourse outfall is subject to blockage or tide locking, or at times when the catchment is waterlogged.

5.2.2 Severe storms or other extreme weather conditions combined with high tides can cause sea levels to rise above normal levels. This can cause flooding along undefended tidal rivers.

Defences

5.2.3 Local defences for fluvial and tidal flooding generally take the form of earth bunds, concrete walls and piled walls.

5.2.4 Watercourses that discharge to a tidal water body are generally defended by sluice gates.

5.2.5 River barriers can be used to defend wider areas. For example, the Thames Barrier protects most of Greater London from flooding by exceptionally high tides and storm surges moving up from the North Sea.

Analysis

5.2.6 Hydraulic models are generally developed to assess fluvial and tidal flood risk.

5.2.7 As part of their long-term flood risk information (Environment Agency, 2022c), the Environment Agency has produced an interactive map that identifies areas at high, medium, low and very low risk of flooding from rivers or the sea (see Table 5.1). These maps consider the effect of any flood defences in the area[7].

Table 5.1 Flood risk categories

Flood risk category	AEP
High	AEP ≥ 3.3%
Medium	3.3% > AEP ≥ 1%
Low	1% > AEP ≥ 0.1%
Very low	AEP < 0.1%

5.2.8 The Flood Map for Planning (Environment Agency, 2022d) indicates the undefended extent of flooding from rivers or the sea. This map also shows flood defences and identified areas that benefit from the defences.

5.2.9 It should be noted that the Flood Map for Planning and long-term flood risk information map, do not take climate change allowances into account.

5.3 Surface water flooding

Mechanism

5.3.1 Surface water flooding occurs when intense or sustained rainfall overwhelms the local drainage systems or gives rise to overland runoff. Local drainage systems comprise natural infiltration to groundwater, watercourses, surface water sewers, combined sewers and sustainable drainage system features.

5.3.2 Surface water flooding can be exacerbated when land has a low permeability, is waterlogged, frozen or developed.

Analysis

5.3.3 The sporadic and intense nature of rainfall that causes surface water flooding makes it very difficult to accurately predict or pinpoint where flooding will occur or how severe it will be. Furthermore, local features can greatly affect the probability and severity of flooding.

5.3.4 Analysis of surface water flooding is usually based on a topographic computational model which essentially identifies locations where water will naturally flow and collect under given rainfall scenarios.

5.3.5 The long-term flood risk information map for surface water (Environment Agency, 2022c) indicates the areas at high, medium, low and very low risk of surface water flooding. For the reasons given above, the Environment Agency includes an accuracy warning regarding the data included in this map. The surface water flood risk categories follow the same AEP ranges detailed in Table 5.1.

5.3.6 Local authorities also undertake surface water modelling.

[7] The defences reduce but do not completely stop the chance of flooding as they can be overtopped or fail.

5.4 Groundwater flooding

Mechanism

5.4.1 There are several definitions of groundwater flooding, but the position statement given in the Environment Agency's Approach to Groundwater Protection (Environment Agency, 2018b) provides a suitable summary:

'*Groundwater flooding happens when groundwater emerges at surface level or rises into underground infrastructure (such as cellars) when the 'normal' range of groundwater levels and groundwater flows is exceeded.*'

5.4.2 There are several possible types of groundwater flooding that might affect the Project, as detailed in Table 5.2.

Table 5.2 Types of groundwater flooding

Ref.	Type of groundwater flooding	Possible occurrence within Project area
1	Rise of typically high groundwater levels to extreme levels in response to prolonged extreme rainfall.	Typically, from the Chalk Formation, particularly south of the River Thames.
2	Rise of groundwater level in aquifers in hydraulic continuity with high in-bank river levels or extreme tidal conditions.	From permeable superficial deposits (e.g. River Terrace Deposits), particularly north of the River Thames.
3	Increases in groundwater levels and changed groundwater flow paths due to artificial obstructions or pathways (e.g. foundation structures), and loss of natural storage and drainage paths.	Deep foundations or structures associated with Project construction (e.g. tunnels, shafts, portals, piled structures, cuttings).
4	Rising groundwater levels in response to reduced groundwater abstraction in an urban area (groundwater rebound) or a mining area (mine water rebound).	Groundwater rebound may occur due to reduced (regional) abstraction from the Chalk Formation or from a reduction or cessation of dewatering operations in gravel pits.
5	Rise in groundwater levels associated with leaks from sewers, drains or water supply mains.	Possible in urban areas, but less likely than above types.

Analysis

5.4.3 Data on groundwater flooding is available through information retained in Strategic Flood Risk Assessments (SFRAs) undertaken by Lead Local Flood Authorities (LLFAs). These may include reference to groundwater flood susceptibility mapping developed by the British Geological Survey (BGS). Recording of specific groundwater flooding incidents within the SFRAs is sparse, but is identified within each flood risk catchment where available (see Sections 8 to 12).

5.4.4 Groundwater flood susceptibility mapping for the Project has been provided by GeoSmart (see Drawing Nos. 00151 to 00153). This mapping adopts a similar approach to BGS flood susceptibility mapping and utilises the underlying geology, groundwater level data and specific hydrogeological risk assessments (e.g. considering strata permeability, ground elevation data, historic groundwater flood incidents) to determine flood risk at a particular location. This is produced at a 5m resolution (compared to a 50m resolution for the BGS susceptibility mapping). Whilst the mapping defines specific flood risk probabilities (see below) such risks should still be subject to more localised analysis. The mapping identifies four different groundwater flood risk categories in accordance with underlying geology (bedrock and superficial deposits), hydrogeological properties and recorded groundwater levels. These categories are defined in Table 5.3.

Table 5.3 Groundwater flood risk categories

Risk category	Colour code	Definition	Comment
Class 1: High	Red	There is a high risk from groundwater flooding in this area with a probability of occurrence of 1 in 100 years or greater (AEP ≥ 1%).	It is likely that incidence of groundwater flooding will occur, which could lead to damage to property or harm to other sensitive receptors at, or near, this location.
Class 2: Moderate	Amber	There is a moderate risk from groundwater flooding in this area with a probability of occurrence of 1 in 100 years or greater (AEP ≥ 1%).	There will be a significant possibility that incidence of groundwater flooding could lead to damage to property or harm to other sensitive receptors at, or near, this location.
Class 3: Low	Yellow	There is a low risk from groundwater flooding in this area with a probability of occurrence of 1 in 100 years or greater (AEP ≥ 1%).	There will be a remote possibility that incidence of groundwater flooding could lead to damage to property or harm to other sensitive receptors at, or near, this location.
Class 4: Negligible	None	There is a negligible risk of groundwater flooding in this area and any groundwater flooding incidence has a probability of occurrence of less than 1 in 100 years (AEP < 1%).	Data may be lacking in some areas, so assessment as ‘negligible risk’ does not necessarily rule out local flooding.

5.4.5 Commentary on the mapped groundwater flood risk category is provided for each flood risk catchment in Sections 8 to 12.

5.5 Sewers

Mechanism

5.5.1 Sewer flooding occurs when sewers are overwhelmed by heavy rainfall or when they become blocked with debris and other detritus, become flood or tide locked or suffer structural failure. The likelihood of flooding depends on the capacity of the local sewerage system.

5.5.2 Land and property can be contaminated with raw sewage as a result of sewer flooding. Rivers can also become polluted by sewer overflows. Of primary consideration in this assessment is flooding from overwhelmed trunk sewers.

Analysis

5.5.3 The analysis of flooding from sewers is generally informed by utility asset data and flooding reports compiled by the LLFA.

5.6 Water mains

Mechanism

5.6.1 Of primary consideration in this assessment is flooding caused by burst distribution and transmission (bulk water) mains.

Analysis

5.6.2 The analysis of flooding from burst water mains is generally informed by utility asset data.

5.7 Reservoirs

Mechanism

5.7.1 Most reservoirs hold large volumes of water and are above ground level. Safe operation and management of reservoirs to reduce the risk of failure and the flooding that could result is paramount. A reservoir failure (breach or uncontrolled release) could have major consequences, including loss of life. However, there has been no loss of life due to a reservoir failure in UK since the introduction of reservoir safety legislation (1930).

5.7.2 Flooding from a reservoir can extend many kilometres from the site itself, so it is not just the people living and working in the immediate area who could be affected. Local topography could also mean the water is channelled in certain directions, making flooding worse some distance away.

5.7.3 The Environment Agency's Policy paper on Reservoir offences (2020) identifies four risk categories for a reservoir breach; these are detailed in Table 5.4.

Table 5.4 Potential effect of reservoir breach

Category	Effect
A	Where a breach could endanger lives in a community. A community is considered to be not less than 10 people.
B	Where a breach could: • Endanger lives not in a community (usually inhabitants of isolated houses and operatives in treatment works immediately below the dam and in other places of work in the flood path) • Result in extensive damage including erosion of agricultural soils and the severing of main road or rail communications
C	Where a breach would pose negligible risk to life and cause limited damage. Therefore, this includes flood-threatened areas that are 'inhabited' only

Category	Effect
	spasmodically. For example, footpaths across the floodplain and playing fields. In addition, this category covers loss of livestock and crops.
D	Special cases where no loss of life can be foreseen as a result of a breach and very limited additional flood damage would be caused. Many small reservoirs with low earth dams may cause no real problem, except that of replacement, if they wash out.

Analysis

5.7.4 The map for long-term flood risk from reservoirs (Environment Agency, 2022c) indicates the extent, depth and speed of flooding from large reservoirs[8].

5.8 Canals

Mechanism

5.8.1 The four mechanisms that can lead to flooding from canals are detailed in Table 5.5.

Table 5.5 Flood risk mechanisms for canals

Ref.	Risk	Mechanism
1	Failure or breach of an embankment	Failure or breach of canal embankments may result in flooding due to the release of large amounts of water which may cause flooding of surrounding areas.
2	Overtopping of the banks	Most canal water levels are managed around a normal operating zone (NOZ) by means of overflows and sluices. Water levels outside of the NOZ may be experienced during periods of intense or prolonged rainfall. If the volume of runoff entering the canal exceeds the volume of water which can be controlled, excess water can overtop the banks and may cause flooding of surrounding areas.
3	Operational issues	Water has to be managed through the canal system to keep all levels at their optimum. Lock-gates and sluices are used to control the amount of water flowing from one reach[9] to the next. Overtopping from a long reach to a shorter reach can result in the shorter reach being unable to discharge the volume of water and may result in flooding of the surrounding areas. Any failure of the lock-gates or interference with the sluices, whether deliberate through acts of vandalism or accidental,

[8] A large reservoir is one with more than 25,000m^3 of water above the natural level of any part of the surrounding land (DMRB LA 113) (Highways England, 2020a). The Flood and Water Management Act 2010 allows for changes to the reservoir regulatory regime, in particular by extending regulation to cover smaller reservoirs between 10,000m^3 and 25,000m^3, including reservoirs in cascade. However, Defra has decided not to make further changes to the regime at this time because the current evidence base does not support such changes.

[9] A canal reach, or pound, is the stretch of level water impounded between two canal locks.

Ref.	Risk	Mechanism
		can result in overtopping of a short reach (as described in row 2).
4	Overflow from rivers	Canals are generally located near watercourses. Flooding of the watercourse may lead to out of bank water entering a canal. If the volume of out of bank water entering the canal exceeds the volume of water which can be controlled, excess water can overtop the canal banks and may cause flooding of surrounding areas.

Analysis

5.8.2 Most canal water levels are managed around a NOZ which is typically the operational datum +/- 200mm, but water levels outside of the NOZ may be experienced at times. The range of level variation in canals is dependent on a number of factors, such as length of reach, proximity to controlled and uncontrolled inflows, amount that upstream and downstream locks are being used, navigable depth in relation to pound datum, and canal freeboard.

5.9 Combined flooding

5.9.1 Combined flood events occur when flooding from two or more sources occur simultaneously or subsequently within a short period of time.

5.9.2 The adverse consequences of a combined flood event can be disproportionally large.

5.9.3 The most relevant flooding from combined sources in the context of the Project would be:

a. Fluvial and tidal

b. Pluvial and tidal

5.10 Environment Agency Product 4 Data

5.10.1 Product 4 information was obtained from the Environment Agency (Ref. EAn/2018/76391) (Environment Agency, 2018a). This data includes the following:

a. Flood Map

b. Undefended Key Outlines – 20, 100 and 1,000 Map

c. Undefended Key Outlines – *CC 20 & 100 Map

d. 1D Levels & Flows Nodes Map

e. 1D (In-channel) Undefended Levels & Flows Table

f. Historic Flood Outlines Map

5.10.2 EAn/2018/76391 is appended as Annex B.

5.11 Summary of flood risk sources

5.11.1 A summary of the risk of flooding from all sources for each flood risk catchment is summarised in Table 5.6. The flood risk is categorised by one of the following:

N/A Not Applicable

N Negligible

P Potential

Table 5.6 Summary of flood risk sources

Catchment	Fluvial	Tidal	Pluvial	Groundwater	Sewers	Reservoirs	Water mains	Canals
EFR-1	N	N/A	P	N	N	N/A	N	N(1)
EFR-2	P	P	P	N	N	N/A	N	N/A
EFR-3	N	N/A	P	P	N	N/A	N	N/A
EFR-4	P	P	P	N	N	P	N	N/A
EFR-5	P	N/A	P	P	N	N/A	N	N/A

Notes: The Project road crosses the Thames and Medway Canal to the north of the South Portal. At the crossing point, the Project is in tunnel.

5.11.2 The sources of flood risk associated with the Project are detailed in Sections 8 to 12 on a catchment-by-catchment basis.

5.12 Impact of flooding

5.12.1 Table 3.71 of DMRB LA 113 (Highways England, 2020a) provides an estimation of the magnitude of an impact on an attribute; the parts of this table that are attributable to flood risk are presented in Table 5.7.

Table 5.7 Estimation of flood risk magnitude

Magnitude	Criteria	Typical example
Major adverse	Results in loss of attribute and / or quality	Increase in peak flood level (>100mm)
Moderate adverse	Results in effect on integrity of attribute, or loss of part of attribute	Increase in peak flood level (>50mm)
Minor adverse	Results in some measurable change in attributes, quality or vulnerability	Increase in peak flood level (>10mm)

Magnitude	Criteria	Typical example
Negligible	Results in effect on attribute, but of insufficient magnitude to affect the use or integrity	Negligible change to peak flood level (≤ +/- 10mm)
Minor beneficial	Results in some beneficial effect on attribute or a reduced risk of negative effect occurring	Creation of flood storage and decrease in peak flood level (>10mm)
Moderate beneficial	Results in moderate improvement of attribute quality	Creation of flood storage and decrease in peak flood level (>50mm)
Major beneficial	Results in major improvement of attribute quality	Creation of flood storage and decrease in peak flood level (>100mm)
No change		No loss or alteration of characteristics, features or elements; no observable impact in either direction.

Note: All references to peak flood level are for the 1% AEP event, including climate change.

5.12.2 Flood magnitude is used to describe the flood risk in Parts 4 and 5 of the FRA.

Text box 5.1 Sources of flood risk

The FRA must consider all sources of flood risk. For the Project, the flood risks comprise the following:

- Fluvial and tidal flooding
- Surface water (pluvial) flooding
- Groundwater flooding
- Sewers
- Water mains
- Reservoirs
- Canals
- Combined sources

National Highways sets out its criteria for estimating the magnitude of the impact of flood risk in DMRB LA 113. The magnitudes range from major adverse to major beneficial with five intermediate magnitudes.

6 Flood risk management strategy

6.1 Introduction

6.1.1 The flood risk management strategy considers the suite of flood alleviation measures required to make the Project safe without increasing flood risk elsewhere. Flood alleviation measures for the Project have been divided into three categories:

a. Flood mitigation measures; these comprise those measures necessary to manage floodwater levels in a way that reduces the impact of flooding.

b. Flood protection measures; these comprise targeted measures necessary to protect a development and its users during a flood event.

c. Flood resilience measures; these comprise those measures necessary to ensure that a development and its users are less vulnerable to the effects of flooding.

6.1.2 The manner in which mitigation commitments are applied to flood alleviation within the DCO application are categorised as follows:

a. Embedded measures: measures that form part of the Design Principles (Application Document 7.5).

b. Good practice: standard approaches and actions commonly used on infrastructure development projects to avoid or reduce environmental impacts, typically applicable across the whole Project.

c. Essential measures: any additional Project-specific measures needed to avoid, reduce or offset potential impacts that could otherwise result in effects considered significant in the context of the FRA.

6.1.3 The Design Principles are secured by Requirement 3 of Schedule 2 of the draft DCO (Application Document 7.5). Flood alleviation measures that would be secured through the Design Principles are identified in Sections 8 to 12 and Section 16 of this document.

6.1.4 Good practice and essential mitigation are secured through their inclusion within the Register of Environmental Actions and Commitments (REAC), which forms part of the Code of Construction Practice (Application Document 6.3, Appendix 2.2). Where appropriate, the REAC reference codes for secured commitments and actions have been cross referenced in this document; these codes are presented in square brackets.

6.2 Flood hazard characteristics

6.2.1 The flood hazard characteristics that must be assessed when developing a flood risk management strategy include the following:

a. Extent of flooding

b. Depth of flooding

c. Duration of flooding

d. Velocity (flow)

e. Onset of flooding

f. Water environment

g. Sediment

6.3 Flood mitigation measures

General

6.3.1 Flood mitigation in the context of the Project comprises those measures that are necessary to manage floodwater levels in a way that reduces the impact of flooding on the Project road itself and elsewhere in the catchment. Flood mitigation measures could include the following:

a. Provision of a CFSA.

b. Creating and restoring wetlands.

c. Surface water drainage provisions.

d. Inclusion of flood relief culverts.

e. Hydraulic structures.

f. Alterations to watercourse channels and structures.

g. Altering the floodplain.

h. Reducing discharge rates from existing flow attenuation structures.

Compensatory flood storage areas (essential mitigation)

General

6.3.2 If development is undertaken in the floodplain, the volume available for storage of flood water would be reduced. To offset this reduction, a CFSA could be formed.

6.3.3 Two forms of CFSA could be employed by the Project. The more common are areas that allow flood water to freely flow in and out of them (conventional CFSA). The other form of CFSA are areas where flood water is temporarily retained (flow retention CFSA).

Conventional CFSA

6.3.4 The principles of provision of a conventional CFSA are listed below:

a. Any loss of flood storage must be compensated for by the reduction in level of nearby ground, such that the same volume is available at every flood level before and after the works, and that it can freely fill and drain.

b. The timing at which the storage effect comes into operation is significant. If this volume is reduced for any stage of a flood then the lost storage results in floodwater being diverted elsewhere, leading to third-party detriment. The detriment caused by a small encroachment may not be significant, or even measurable when taken in isolation but the cumulative effect of many such encroachments could be significant.

c. Excavating holes in the floodplain is not an acceptable form of storage. During extreme events these may already be full and therefore offer no storage during a flood.

d. Landlocked areas of lower ground should not be created, even if connected to the main floodplain by channels or culverts.

Flow retention CFSA

6.3.5 Where compensation is required but principle (a) in paragraph 6.3.4 cannot be achieved for a conventional CFSA, a flow retention CFSA could be used. This situation typically occurs in flat, low-lying areas.

6.3.6 The purpose of a flow retention CFSA is to retain water in upstream catchments and release it at a controlled rate[10]. The controlled discharge will reduce the impact that runoff from upland catchments would have on lower catchments.

6.3.7 The retention and controlled release can offset the increase in flooding due to loss of floodplain storage caused by development.

6.3.8 The limits of the flow retention CFSA extend to the limits of the area occupied by retained water.

General considerations

6.3.9 Areas where ground levels are lowered to accommodate a CFSA may be susceptible to occasional waterlogging (i.e. when flood water recedes).

6.3.10 Areas where water accumulates for a flow retention CFSA may also be susceptible to occasional waterlogging (i.e. after retained water is released).

6.3.11 The use of a wetland area for compensatory flood storage is feasible.

6.3.12 CFSAs must be able to function before any floodplain storage volume is lost.

Wetland restoration (embedded mitigation)

6.3.13 Wetland restoration is an approach that uses opportunities in the landscape to hold back and slow down the flow of water before it reaches properties and businesses.

6.3.14 Wetlands work with, and restore, natural processes to reduce flood risk at a catchment scale. They can also complement and extend the lifetime of traditional defences and provide benefits to wildlife and people through the creation of healthy, nature-rich wetlands and water-friendly land management practices.

6.3.15 Restoring wetlands is an approach that not only meets objectives of the EU Floods Directive, but also the Water Framework Directive, and the EU Birds and Habitats Directives.

[10] A flow retention CFSA operates in a similar way to a retention pond, as described in DMRB CD 532 (National Highways, 2021b).

Surface water drainage provisions (embedded mitigation)

Surface water drainage provisions

6.3.16 The surface water drainage provisions would be designed in accordance with the provisions of the DMRB. Selected aspects of the DMRB are listed below:

a. The design criteria for all new carriageway drainage is that there would beno surcharge for the 1 in 1 year storm and no flooding for the 1 in 5 year storm, including an allowance of 20% on peak rainfall intensity for climate change.

b. The highway drainage system would be designed to make sure there is no increase in the rate of runoff discharged from a site when a 40% uplift on peak rainfall intensity for climate change is applied.

c. Preference would be given to the use of sustainable drainage systems.

d. Discharges to watercourse would be attenuated to greenfield runoff rates (unless betterment is stipulated by the Environment Agency or LLFA).

e. Retention ponds and infiltration basins would be designed as vegetated drainage systems where appropriate.

Existing surface water drainage provisions

6.3.17 The surface water drainage provisions for sections of the highway that are to be realigned or widened would be designed to the latest DMRB standards. If the latest drainage standards are more stringent that the ones used to design the current highway, a more robust drainage design would be afforded.

General

6.3.18 Further details of surface water drainage are provided in Part 7 of the FRA[11].

Flood relief culverts (essential mitigation)

6.3.19 A highway embankment may intercept surface water flows. The intercepted surface water may flow to low points which may give rise to local flooding or may direct the intercepted water to an area more susceptible to flooding. Introducing culverts where significant overland flow paths are intercepted by an embankment would reduce the risk of such surface water flooding.

6.3.20 Where an embankment runs across a fluvial floodplain, flow through limited openings could lead to afflux conditions. Addition of culverts may reduce the afflux by allowing improved flow continuity across the floodplain.

Hydraulic structures (essential mitigation)

6.3.21 A hydraulic structure is a device designed to retain, regulate, or control the flow of water. They are considered to be passive structures as they operate without intervention under different amounts of water flow and their impact changes based on the quantity of water passing through them.

[11] The drainage strategy is an embedded measure secured through the Design Principles (Application Document 7.5).

6.3.22 Hydraulic structures can be used in watercourses to manage flow of water between catchments or subcatchments, where unregulated flows may cause or exacerbate downstream flooding.

Alteration of watercourse channels and structures (good practice)

6.3.23 Alteration of watercourse channels and structures would only be considered as a last resort. Exceptions could include the following:

a. Where there is an opportunity to change an engineered (straight) channel to a more natural (meandering) channel

b. Replacing an undersized structure, which acts as a constraint to free water flow

c. Returning culverted sections of watercourse to open channel where possible and practicable

6.3.24 Where a change to a watercourse channel is unavoidable, consideration needs to be given to potential changes in flow velocity. Where flow velocity is likely to increase as a result of the change, suitable bed protection may need to be provided and maintained to ensure a stable hydraulic system is upheld.

Altering the floodplain (essential mitigation)

6.3.25 Flood flows can be mitigated by altering the resistance of the floodplain. This could be achieved by the following:

a. Removal of existing obstructions, including vegetation

b. Ground lowering

c. Creating new openings in existing embankments (to increase conveyance)

d. Creating flood relief channels to relieve localised flooding

e. Flow management bunds (creating bunds to ensure new flow paths are not created)

Reducing discharge rates from existing drainage assets (good practice)

6.3.26 Reducing discharge rates from existing highway drainage assets (e.g. retention ponds) will hold back and slow down the flow of water in watercourses, thereby reducing flood risk on a catchment level.

6.4 Flood protection measures

General

6.4.1 Flood protection in the context of the Project would comprise those measures necessary to protect the development during flood events. Flood protection measures could include flood bunds and flood walls.

6.4.2 Flood walls and flood bunds are designed to prevent flood water from flowing beneath them. This would entail keying the core or wall into a stratum with low permeability.

Flood bunds (essential protection)

6.4.3 Flood bunds are earthen structures which provide protection against fluvial and/or tidal flooding. Flood bunds deployed for tidal defences or severe fluvial flooding typically have a permeable shell around an impermeable core. Smaller bunds for protection of isolated features do not generally include an impermeable core.

Flood walls (essential protection)

6.4.4 A flood wall is a vertical artificial barrier designed to provide protection against fluvial and/or tidal flooding. There are two basic types of floodwall:

a. Those that also form part of the river frontage, such as a wharf, retaining wall or quay

b. Those that are remote from the source of flooding, generally with the sole purpose of providing a flood defence

6.5 Flood resilience measures

General

6.5.1 Flood resilience in the context of the Project comprises those measures necessary to ensure that the development is less vulnerable to the effects of flooding. Flood resilience measures could include the following:

a. Constructing roads on embankments and viaducts

b. Changing the road geometry

c. Designing with an allowance for projected climate change

d. Maintenance

e. Residual uncertainties allowance

Roads on embankments and viaducts – embedded resilience

6.5.2 Highways crossing a floodplain should be elevated to protect them and their users from tidal and fluvial flooding. To be protected from fluvial flooding, the highway will need to be set at, or higher than, the flood protection level for a 1% AEP fluvial event (plus an uplift for climate change). To be protected from tidal flooding, the highway will need to be set at, or higher than, the flood protection level for a 0.5% AEP tidal event (plus an uplift for climate change).

6.5.3 The flood protection level is defined as the design flood level plus the residual uncertainty allowance[12]. For a given location, the flood design level is the higher of the 1% AEP fluvial event (plus an uplift for climate) and a 0.5% AEP tidal event (plus an uplift for climate change).

[12] Evidence supporting flood risk management decisions will always have some degree of uncertainty associated with it, whether because flooding mechanisms might be poorly understood, or flood information is incomplete or inaccurate. Some of these uncertainties will have been addressed through standard design and appraisal procedures; others will not. Those uncertainties that remain are called residual uncertainties (e.g. wave action, settlement, model accuracy). The residual uncertainties allowance replaces the freeboard allowance.

6.5.4 Where required, embankments, bridges and viaducts could be used to attain the flood protection level.

Road geometry – embedded resilience

6.5.5 The vertical alignment of the highway should ensure that outfall levels are achievable, and that subgrade drainage can discharge above the design flood level of any outfall watercourses.

6.5.6 The vertical alignment and road edge detail should be selected to ensure efficient collection of surface water runoff.

Climate change – embedded resilience

6.5.7 To ensure that the Project is safe for its lifetime, the design of flood protection measures and flood mitigation measures should take account of predicted climate change allowances.

Residual uncertainties allowance – embedded resilience

6.5.8 The freeboard (residual uncertainties allowance) for highways is based on the requirements of DMRB CD 356 (Highways England, 2020d). This document, which applies to all new structures in or over rivers, estuaries and floodplains, states that a minimum freeboard allowance of 600mm would be provided above the design flood level.

6.5.9 There are no standard requirements for the design storm or freeboard allowance that should be applied for a tunnel. Given the consequences of inundation of the tunnel, a higher freeboard allowance of 1.0m would be provided above the design flood level.

Maintenance and inspection – essential resilience

6.5.10 All flood alleviation measures need to be inspected and maintained to ensure that they continue to operate in a safe, efficient and appropriate manner.

6.5.11 Maintenance would be planned on a risk based approach so areas that pose a higher risk of flooding could be inspected and maintained more frequently or prior to potential severe weather.

6.6 Residual flood risk

6.6.1 Residual risk is the risk that remains after the flood risk management strategy has been implemented. Although residual flood risks generally have a low probability of occurrence, their impacts can be severe.

6.7 Environmental considerations

6.7.1 Care would be taken to ensure that the construction of these mitigation, protection and resilience measures would not have a detrimental impact on upstream or downstream habitats of biodiversity; in some instances, there may be potential for biodiversity habitat benefits.

6.8 Natural flood management techniques

6.8.1 In addition to the broad aim of securing net sustainability benefits (see Section 3.5), the DLUHC guidance notes that opportunities in new development for reducing the causes and impacts of flooding by means of natural flood management techniques should be taken.

6.8.2 In some cases, natural flood management techniques may be capable of comprehensively addressing flood risk to a site on their own, but for the Project they would need to be used in a complementary way alongside more conventional flood risk management techniques.

6.8.3 Natural flood management techniques can also contribute to the delivery of biodiversity and environmental net gains.

6.8.4 Natural flood management techniques include:

a. Land management such as removing impermeable surfacing to maximise infiltration, planting trees to increase evapotranspiration, or making green space where flood waters are most likely to flow or collect, or where rivers and their meanders are likely to migrate.

b. River restoration such as removing culverts and other capacity restrictions, reintroducing meanders to provide additional storage, or naturalising river beds and banks to slow the flow.

6.9 Summary of alleviation measures and methods

6.9.1 The alleviation measures and methods that would be considered when developing the flood risk management strategy for the Project are summarised in Table 6.1.

Table 6.1 Flood alleviation measures considered for the Project

Alleviation measure	Alleviation method	Alleviation category
Mitigation	Provision of compensatory flood storage	Essential
	Creation and restoration of wetlands	Embedded
	Surface water drainage provisions	Embedded
	Inclusion of flood relief channels	Essential
	Alterations to watercourse structures	Good practice
	Alterations to watercourse channels	Good practice
	Alteration of the floodplain	Essential
	Discharge rates reductions from existing flow attenuation structures	Good practice
Protection	Flood bunds	Essential
	Flood walls	Essential

Alleviation measure	Alleviation method	Alleviation category
Resilience	Construction of roads on viaducts	Embedded
	Construction of roads on embankments	Embedded
	Change to the road geometry	Embedded
	Inclusion of climate change allowances	Embedded
	Maintenance and inspection	Essential
	Residual uncertainties allowance	Essential

6.9.2 The natural flood management techniques that would be considered when developing the flood risk management strategy for the Project would include:

a. Net reduction in the length of culverted watercourses.

b. Reintroduction of meanders in watercourses.

c. Naturalisation of watercourse beds (including those in culverted watercourses).

d. Planting trees (as part of the landscaping works).

Text box 6.1 Flood risk management strategy

The flood alleviation strategies for the Project have been divided into the following categories:

- Mitigation measures
- Protection measures
- Resilience measures

These measures are sub-categorised as embedded, good practice and essential measures. Embedded measures are secured in the Design Principles (Application Document 7.5). Good practice and essential mitigation are secured through their inclusion in the REAC (Application Document 6.3, Appendix 2.2).

Natural flood management techniques would be incorporated in the Project where appropriate and practicable.

7 Design flood and Project lifetime

7.1 Design flood

7.1.1 The Flood risk and coastal change guidance (DLUCH, 2022) defines the design flood as a flood event of a given annual flood probability. The guidance notes that the design flood is generally taken as:

a. River flooding likely to occur with a 1% annual probability with an appropriate allowance for climate change.

b. Tidal flooding with a 0.5% annual probability with an appropriate allowance for climate change.

c. Surface water flooding likely to occur with a 1% annual probability with an appropriate allowance for climate change.

7.1.2 These events has been adopted as the design flood for the Project along with the following additional parameter:

a. The North Portal flood protection bund has been designed to defend against tidal flooding likely to occur with a 0.1% annual probability with an appropriate allowance for climate change

7.1.3 The design flood is used to demonstrate compliance with the following requirements of paragraph 5.109 of the NN NPS:

a. Any essential infrastructure project should be designed and constructed to remain operational and safe for users in times of flood.

b. Any project in Zone 3b should result in no net loss of floodplain storage and not impede water flows.

7.1.4 The design flood is used to demonstrate compliance with the overarching requirements of NPPF:

a. Remain operational and safe for users in times of flood.

b. Result in no net loss of floodplain storage.

c. Not impede water flows and not increase flood risk elsewhere.

7.2 Project lifetime

7.2.1 The Project has adopted a climate change horizon of 2130. For an opening date of 2030, this equates to a lifetime for the Project of at least 100 years.

7.2.2 The Flood risk and coastal change guidance (DLUCH, 2022) advises that development that has an anticipated lifetime significantly beyond 100 years, such as major infrastructure projects, it may be appropriate to consider a longer period for the lifetime of development.

7.2.3 DMRB does not specify the lifetime for a highway, but it is anticipated that, for the Project, it would be in excess of 100 years[13].

[13] Highway design is undertaken on the basis of design life. This is not the same as the lifetime and differs for separate elements of the highway (eg the design life for new carriageway pavement is 40 years and for Category 5 structures, such as bridges and tunnels, it is 120 years).

7.2.4 A precautionary approach has been adopted for the assessment of flood risk, for example:

a. The Upper end climate change allowances (for sea level rise, peak river flow and peak rainfall) applied in the Project design are precautionary and equate to the 95th percentile of the UKCP18 RCP8.5 climate change scenario.

b. An extreme event has been considered for the flood protection measures at the North Portal (0.1% AEP compared to the design flood of 1% AEP).

c. The flood defence level of the flood protection bund at the North Portal has been specified as the 0.1% AEP tidal Extreme Water Level with climate change allowance, with a residual uncertainty allowance added.

d. The 0.1% AEP tidal Extreme Water Level at the North Portal has been specified as the 0.1% AEP tidal River Thames Extreme Water Level. This is precautionary as it does not allow for the reduction in flood levels that would occur if flood water were conveyed overland from the River Thames to the North Portal.

e. A residual uncertainties allowance of 1m has been used for the flood protection bund at the North Portal, compared to the 600mm allowance in DMRB CD 356 (Highways England, 2020d)

f. The Tilbury Main fluvial assessment assumes Bowater Sluice is blocked.

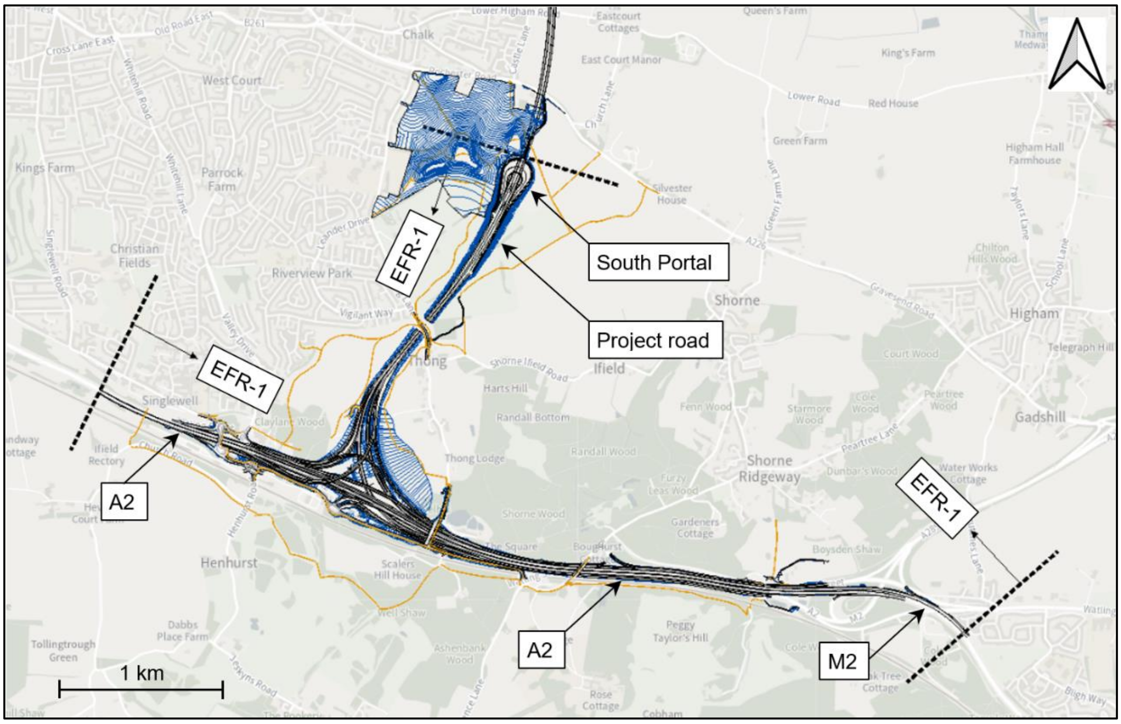
7.2.5 Whilst the Project has been designed to remain operational in 2130 during the design flood, and the 0.1% AEP tidal flood, with precautionary climate change allowances, the only part of the Project design determined by flood risk considerations is the level of the flood protection bund at the North Portal. At other locations, the vertical alignment of the Project road is determined by other more stringent Project design constraints. The flood protection bund at the North Portal would be readily adaptable to a higher level of protection if required (eg a more extreme climate change scenario or a longer Project lifetime), by raising the embankment protecting the tunnel and Project road, with the bund tying into higher ground as in the Project design. The Project would therefore be readily adaptable to a more extreme climate change scenario (including the credible maximum climate change scenario, as assessed in Part 5 of the FRA), or a longer Project lifetime than 100 years.

8 South of River Thames (EFR-1)

8.1 Overview

8.1.1 The part of the Project to the south of the River Thames (Catchment EFR-1) would comprise elements of the A2 and M2, the junction between the Project road and the A2, and the section of the Project road between the junction and the South Portal (see Plate 8.1).

Plate 8.1 Catchment EFR-1



8.1.2 The Flood Map for Planning (Environment Agency, 2022d) shows the extents of Flood Zones 1, 2 and 3 across England and Wales. An extract from this map is presented in Drawing 00110 and shows that Catchment EFR-1 falls entirely within Flood Zone 1.

8.1.3 The Sequential Test concludes that development in Catchment EFR-1 would be appropriate and that an Exception Test is not required (see Section 3.4).

8.1.4 Flood risk associated with construction phase activities in Catchment EFR-1 are detailed in Section 16.

8.1.5 For completeness, the part of the Project road between the South Portal and the River Thames is considered in this section. This part of the Project road would be in tunnel.

8.2 Site-specific flood risk

Fluvial and tidal

8.2.1 The Flood Map for Planning (Environment Agency, 2022d) indicates that the Project road would cross an area to the north of Catchment EFR-1 that lies in Flood Zone 3. The mechanisms for flood risk in this area are exceptionally high tides in the River Thames and surge tides moving up the Thames Estuary from the North Sea. The Project road would be in tunnel where it crosses the Flood Zone 3 area. An extract of the map showing the extents of the Flood Zone 3 area is shown in Drawing 00110.

8.2.2 The long-term flood risk information map (Environment Agency, 2022c) shows the extents of fluvial and tidal flooding with existing flood defences considered. This map indicates that the Project road would cross areas at low and high risk of fluvial flooding to the north of Catchment EFR-1. The areas at low risk benefit from flood defences. The areas at high risk lie between the defences and the River Thames. The Project road would be in tunnel where it crosses these high and low risk areas. An extract of the map showing the extents of fluvial flooding to the north of Catchment EFR-1 is presented in Drawing 00113.

Surface water

Long-term flood risk information

8.2.3 The long-term flood risk information map for surface water (Environment Agency, 2022c) indicates that this catchment lies in an area that is primarily at very low risk of surface water flooding.

8.2.4 Some isolated pockets of surface water flooding within the curtilage of the highway would be lost and some would be partially lost. This may cause a minor redistribution of surface flooding beyond the curtilage of the Project road, but this is not considered to present a significant flood risk. Furthermore, any such redistribution would mostly lie within land for which National Highways would be seeking permanent acquisition.

8.2.5 The risk of surface water to the Project road in Catchment EFR-1 would be negligible when considered in conjunction with the highway drainage (see Part 7 of the FRA).

8.2.6 Locations where the Project may have an offsite impact on surface water flooding are:

a. EFR-1-SW-01: Western end of the A2/M2 corridor (Marling Cross Interchange)

b. EFR-1-SW-02: M2/A2/Lower Thames Crossing junction

c. EFR-1-SW-03: Eastern end of the A2/M2 corridor (Park Pale Interchange)

8.2.7 Surface water flooding is shown on Drawing 00130. This drawing is based on the long-term flood risk information map for surface water (Environment Agency, 2022c).

8.2.8 Surface water flood risk in the three locations is described in Table 8.1, Table 8.2 and Table 8.3.

Table 8.1 Surface water flood risk – EFR-1-SW-01

EFR-1-SW-01: Western end of the A2/M2 corridor (Marling Cross)
Risk
The long-term flood risk information map (Environment Agency, 2022c) indicates that the existing carriageways of the A2 at Marling Cross Interchange are at high risk of surface water flooding. The A2 dips slightly in this location and surface water runoff naturally accumulates in the dip. In addition to the gullies allowed for along much of the A2/M2 corridor, the drainage in this section of highway is augmented with combined drainage and kerb systems. Highway runoff from this area drains to an infiltration basin located immediately to the north of the A2. It is worth noting that Highways Agency Drainage Data Management System (HADDMS) does not record any flooding in this area which suggests that the existing surface drainage provisions are operating effectively.
Proposed development
A2: Widening of the westbound carriageway A2: Widening of the off-slip
Risk management strategy – Mitigation
Where the Project ties in with the existing A2/M2 highway, the existing highway drainage infrastructure would be reconfigured to accommodate runoff from new catchments and catchments affected by the Project, all in accordance with current DMRB standards.

Table 8.2 Surface water flood risk – EFR-1-SW-02

EFR-1-SW-02: Junction between Lower Thames Crossing and A2/M2
Risk
The long-term flood risk information map (Environment Agency, 2022c) indicates that there is an overland flow path which crosses the A2 immediately to the west of the proposed junction between the Project road and the A2. The flow path is interrupted by a sheet piled wall adjacent to the A2. This sheet pile wall supports the earthworks for the A2, which is elevated at the point it crosses the flow path. To the south of the sheet piled wall, water flows under the High Speed 1 (HS1) embankment in culvert and discharges to a basin via a headwall. It is understood that this pond is an HS1 asset. As there are no outlets from the pond it is surmised that dispersal of water is by infiltration. To the north of the A2, the flow path continues in a northerly direction.
Proposed development
The proposed works include a slip road off the eastbound carriageway of the A2.
Risk management strategy – Mitigation
No mitigation required: The slip road would be on viaduct where it crosses the flow path (the level of the viaduct would exceed the surface water flooding level at the crossing point).

Table 8.3 Surface water flood risk – EFR-1-SW-03

EFR-1-SW-03: Eastern end of the A2/M2 corridor (M2 junction 1)
Risk
There is widespread surface water flooding at junction 1 of the M2 (Park Pale Interchange). There are two existing drainage basins in this low-lying area, one of which is a National Highways asset and the other, a HS1 asset. Both basins appear to discharge water to ground via boreholes. Flooding at this location is exacerbated by overland flows from the area to the south-west of the junction. The map for long-term flood risk from surface water (Environment Agency, 2022c) indicates that the flood risk extends across both existing carriageways of the A2 and M2. Although there is some risk of carriageway flooding in this area, the flood maps do not take account of actual road levels, surface water drainage provisions and the drainage basins.
HADDMS records several historic flooding events in this area. HADDMS also record that the western part of the junction lies in a C grade (moderate) flood hotspot. However, HADDMS also notes that all risks in this have been addressed.
Proposed development
Construction of additional lanes (M2 is being expanded from a dual three-lane carriageway to a dual four-lane carriageway).
Risk management strategy – Mitigation
Where the Project ties in with the existing A2/M2 highway, the existing highway drainage infrastructure would be reconfigured to accommodate runoff from new catchments and catchments affected by the Project, all in accordance with current DMRB standards.

HADDMS

8.2.9 HADDMS indicates that there is one flood risk hotspot along the A2/M2 corridor. The hotpot encompasses the western part of junction 1 of the M2 (Park Pale Interchange) end extends westward, along both carriageways, to Cobham junction.

8.2.10 HADDMS reports that there have been numerous flooding events along the A2/M2 corridor. The majority of the events are very low severity events (severity: 0 to 2)[14]. In addition, two moderate severity events (severity: 5 to 6) and one high severity event (severity: 7 to 8) have been reported.

8.2.11 HADDMS also reports that there have been numerous flooding events along the A2/M2 slip roads and side roads. The reported events are very low severity events (severity: 0 to 2) or low severity events (severity: 3 to 4).

8.2.12 The new drainage provisions under the Project would encompass the location of all reported flood events so any legacy issues associated with these events would be eliminated. Furthermore, the new drainage provisions would extend across the full length of the flood hotspot.

8.2.13 Part 7 of the FRA includes further details regarding the review of information of HADDMS.

[14] HADDMS reports the severity of flooding on a sliding scale of 1 (low) to 10 (high), with one special category ‘High Impact Floods’ for the highest severity.

Groundwater

Groundwater flooding records (LLFA)

8.2.14 Groundwater flood risk is described in the SFRA for Kent Thameside (Kent Thameside Delivery Board, 2005). The SFRA identifies some areas of groundwater flooding in the Swanscombe peninsula and in Northfleet but no specific incidence of groundwater flooding in the vicinity of the Project is identified.

8.2.15 Groundwater is also identified as a potential source of flooding in the Thameside Stage 1 Surface Water Management Plan (Kent County Council, 2013), but no specific incidence of flooding attributable to groundwater is identified in the vicinity of the Project.

Flood risk mapping and hydrogeology

8.2.16 The GeoSmart flood risk mapping identifies the whole of the route to the south of the South Portal as being within an area of negligible groundwater flood risk (this area is underlain by the Seaford Chalk Formation). Between the South Portal and the River Thames, areas of low and moderate risk are shown, with one small 'hotspot' of high risk associated with a subcrop of Taplow Gravel (River Terrace Deposits) to the south of Lower Higham Road (and east of Church Lane). These locations of higher mapped groundwater flood risk are associated with the superficial deposits (Alluvium and River Terrace Deposits) beneath and adjacent to the south of the Thames Estuary and Marshes Ramsar site[15]. However, high risk of groundwater flooding here is unlikely to have an impact on the Project as the highway would be in tunnel beneath the superficial deposits.

8.2.17 The strata beneath the high ground around the A2 link road from Cobham through the Shorne Woods Country Park to Higham comprises the London Clay Formation underlain, at the highest parts, by the Harwich Formation. This, in turn, unconformably overlays clays and sands of the Lambeth Group and sand of the Thanet Formation. Although there is currently no recorded evidence of groundwater flooding in this area, where permeable or partly permeable strata (e.g. Harwich Formation sands and gravels) overlie less permeable strata (e.g. layered clays and silts within the Lambeth Group) there is a potential for perched water to occur.

8.2.18 There may also be perched water within more sandy layers of the Lambeth Group. Superficial deposits comprising Head Deposits, at the base of dry valleys and to the south of the A2, are likely to be predominantly low permeability and therefore not water bearing.

8.2.19 If perched water is intercepted (e.g. by cuttings or by local topographic change) there is the potential for groundwater to emerge locally. However, a drainage system incorporating an appropriate edge of pavement detail, such as combined surface and sub-surface drains in line with the standards set out in DMRB CD 524 (National Highways, 2021a), would mitigate this flood risk.

[15] The Thames Estuary and Marshes Ramsar site comprises a complex network of brackish, floodplain grazing marsh ditches, saline lagoons and intertidal saltmarsh and mudflat. It runs along the River Thames between Gravesend and Sheerness. The site reference number is 1025.

8.2.20 Cuttings have the potential to change the groundwater flow regime; this may lead to groundwater flooding occurring elsewhere. However, the cuttings in Catchment EFR-1 are all shallower than the deep Chalk Formation aquifer water table, and therefore there is no residual risk from interruption of groundwater flow.

Impact of drainage strategy on groundwater

8.2.21 In this part of the Project, the drainage strategy would generally be based on the use of gravity systems that discharge to infiltration basins for discharge to ground.

8.2.22 Due to a more direct flow pathway, the use of soakaway/infiltration systems would locally enhance groundwater recharge with a commensurate increase in local groundwater level. This can lead to potential groundwater mounding and an increased risk of local groundwater flooding both in the immediate vicinity of the infiltration system and further downgradient. However, the detailed assessment presented in Appendix 14.5: Hydrogeological Risk Assessment shows that the proposed infiltration basins would not cause mounding that would reach ground surface.

Reservoirs

8.2.23 The long-term flood risk information map for reservoirs (Environment Agency, 2022c) indicates Catchment EFR-1 is not in an area at risk from reservoir flooding.

8.2.24 Flood risk from reservoirs is shown on Drawing 00174.

Sewers and water mains

8.2.25 When trunk sewers are blocked or overwhelmed, they have the potential to cause flooding. When sewer rising mains are damaged or burst, they also have the potential to cause flooding. As all such assets would be diverted in advance of the works, the risk of flooding from sewers during the operational phase of the Project is considered to be negligible.

8.2.26 All water mains have the potential to cause flooding if they are damaged or burst, with transmission mains clearly presenting the bigger risk. As all such assets would be diverted in advance of the works, the risk of flooding from water mains during the operational phase of Project is considered to be negligible.

8.2.27 Water utility asset data in Catchment EFR-1 is shown in Drawing 00171.

Canals

8.2.28 As the Project road is in tunnel where it crosses the Thames and Medway Canal, it is at negligible risk of flooding from canals.

8.3 Flood risk management strategy

Flood mitigation measures

Highway drainage (embedded mitigation)

8.3.1 Surface water flood risk from highway runoff would be mitigated by inclusion of highway drainage provisions; these provisions would apply to all new and realigned roads in Catchment EFR-1. The surface water drainage provisions would be designed to prevent flooding in the highway without increasing risk elsewhere.

8.3.2 Highway drainage in this catchment would comprise gravity drainage systems that discharge to ground via infiltration basins.

8.3.3 The section of the A2 between Park Pale Interchange and Marling Cross junction would be reconfigured to accommodate the junction with the Project road. Drainage provisions for this section of highway would be enhanced as the latest DMRB standards are more demanding than those that were in place when the current highway was originally designed.

8.3.4 Further details of the surface water drainage strategy for Catchment EFR-1 are included in Part 7 of the FRA[16].

Flood protection measures

8.3.5 There is no requirement to provide flood protection measures in Catchment EFR-1.

Flood resilience measures

Increase drainage network robustness (embedded resilience)

8.3.6 Where existing highway drainage provisions need to be expanded or upgraded to accommodate the Project, they would be designed in accordance with the latest DMRB standards. This may afford improved efficiency and robustness in the existing drainage system as the latest DMRB standards are more demanding than the standards in place at the time that the road was originally designed.

Maintenance (essential resilience)

8.3.7 Drainage infrastructure and treatment systems would be inspected and maintained in accordance with the relevant provisions of DMRB GM 701 (Highways England, 2020c) and DMRB GS 801 (Highways England, 2020b), to ensure they continue to operate to their design standard. [RDWE012]

Climate change allowances (essential resilience)

8.3.8 The highway drainage design would include allowances for projected climate change (National Highways, 2022b).

8.3.9 The climate change allowances for the water environment that would be applied to the Project are detailed in Section 4.7.

[16] The drainage strategy is an embedded measure secured through the Design Principle LSP.28 and LSP.29 (Application Document 7.5).

Residual flood risk

8.3.10 Residual flood risks for Catchment EFR-1 along with associated mitigation measures are presented in Table 8.4.

Table 8.4 Catchment EFR-1 – Residual risks and mitigation

Ref	Residual risk	Mitigation measures
1	Overwhelming of the highway drainage network due to a severe storm event or a blockage may lead to onsite and/or offsite flooding.	Drainage asset inspections would be undertaken in accordance with relevant provisions of DMRB GS 801 Highways England, 2020b). [RDWE012] A planned, risk based maintenance programme in accordance with the relevant provisions of DMRB GM 701 (Highways England, 2020c) would be established. [RDWE012] Planned maintenance interventions would ensure efficient operation of the drainage network.
2	Overtopping of the infiltration basins may occur in the event of a severe storm; this may lead to development of secondary flow paths with surface water flooding in lower-lying areas.	Drainage asset inspections would be undertaken and maintenance programmes would be established, all as described above. [RDWE012] Planned maintenance interventions would ensure efficient operation of infiltration basins. Overland flow paths would be established to manage any overtopped flows where appropriate. [RDWE034] The infiltration basins have been located away from sensitive receptors to avoid potential risks resulting from residual impacts.
4	There is a risk of seepage if perched groundwater is encountered (e.g. in cuttings).	On account of their highly localised nature, identification of all occurrences of perched groundwater is difficult. If perched groundwater is encountered in cuttings, it would most likely occur as localised seepages only. This residual risk could be mitigated by provision of a drainage system incorporating appropriate edge of pavement detail, such as combined surface and sub-surface drains in line with DMRB CD 524 (National Highways, 2021a).
5	The use of infiltration systems in the drainage design may cause an increase in local groundwater levels due to enhanced recharge. This may cause local groundwater flooding.	The detailed assessment presented in Appendix 14.5: Hydrogeological Risk Assessment shows that the proposed infiltration basins would not cause mounding that would reach the ground surface.

Text box 8.1 Flood risk south of the Thames (EFR-1)

There is no significant risk of flooding from rivers, the sea, sewers, water mains or reservoirs in the Catchment EFR-1.

The long term flood maps (Environment Agency, 2022c) indicate that Catchment EFR-1 lies in an area that is primarily at very low risk of surface water flooding. It should be noted that the flood maps do not take account of infiltration, which is the primary means of surface water disposal in this area, so the actual extent of flooding is likely to be of a lower order than that indicated.

Some isolated pockets of surface water flooding within the curtilage of the highway would be lost or partially lost; this may cause a minor redistribution of surface water flooding but is not considered to present a significant flood risk.

The Project may cause offsite surface water flooding in three isolated areas. A suggested mitigation strategy for each of these areas has been developed and is presented in the text above.

Surface water flood risk caused by highway runoff would be mitigated by inclusion of highway drainage provisions; these provisions would apply to all new and realigned roads in the catchment. The drainage system would include upgrading parts of the existing drainage network and the addition of new drainage elements.

HADDMS indicates that there have been several historical surface water flooding incidents along the A2/M2 corridor. National Highways have already addressed some of these flooding issues. The remainder fall in areas where new drainage provisions would be included as part of the Project.

Although there is currently no recorded evidence of groundwater flooding in Catchment EFR-1, there is the potential for perched water to occur where permeable or partly permeable strata lie above less permeable strata. If encountered, the perched water would be expected to cause local seepages on cutting slopes. A drainage system incorporating an appropriate edge of pavement detail would mitigate this flood risk.

The new and existing infiltration systems along the A2/M2 corridor, which discharge to the Chalk Formation, are not anticipated to represent a risk of groundwater flooding.

Flood resilience is provided by making allowance for climate change in the highway drainage design, implementation of a maintenance and inspections programme and increasing the robustness of existing highway drainage assets where appropriate.

The residual risks comprise the following:

- Inundation of the highway drainage system may result in onsite and/or offsite flooding.
- Overtopping of the infiltration basins may lead to localised flooding.
- Potential seepage of perched groundwater in cuttings.

- The use of infiltration systems in the drainage design may result in an increase in local groundwater levels due to enhanced recharge.

The risk of intercepting perched groundwater would need to be managed during the construction phase of the Project. This risk could be mitigated by incorporating an appropriate edge of pavement detail (e.g. combined surface and subsurface drains).

The risk of groundwater mounding to unacceptably shallow depths is negligible.

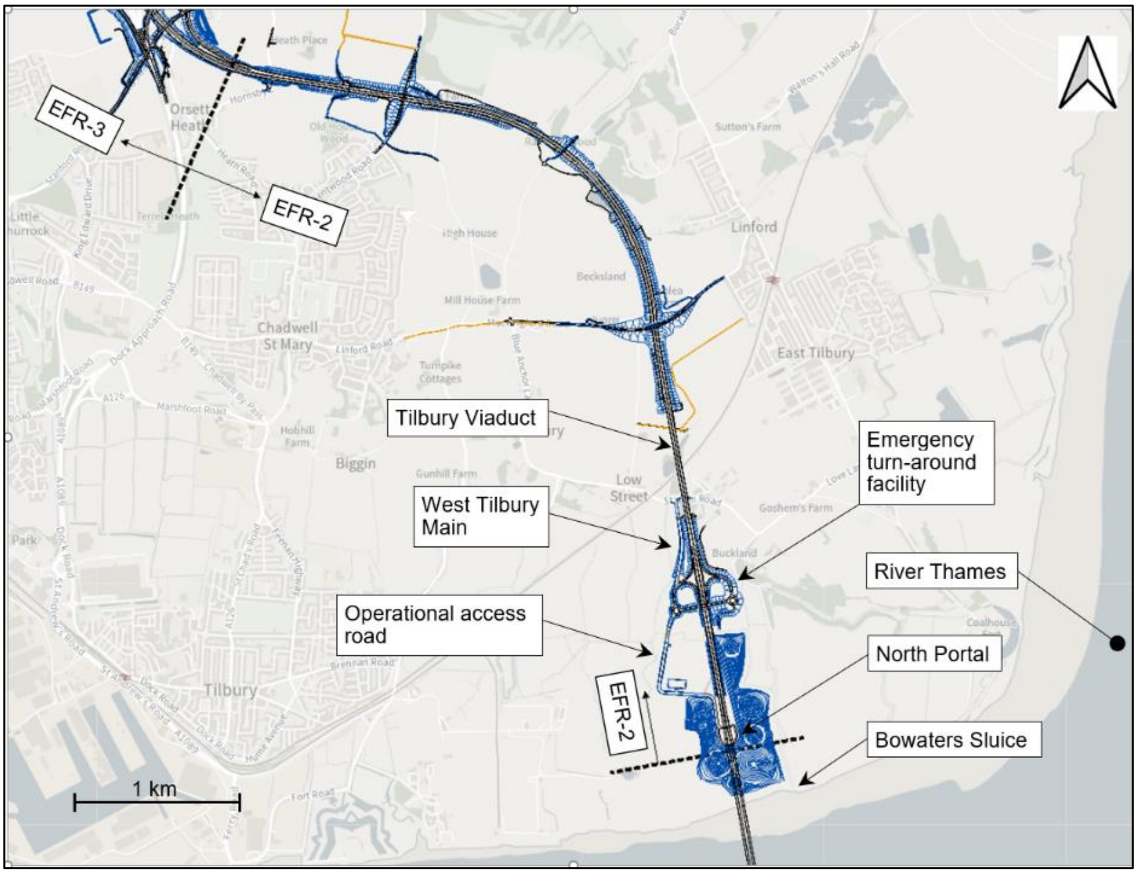
All other residual risks can be mitigated by implementation of an appropriate maintenance programme.

9 North Portal to Chadwell St Mary (EFR-2)

9.1 Overview

9.1.1 The part of the Project in Catchment EFR-2 comprises the North Portal approach, Tilbury Viaduct and the link road to the junction with the A13 and the A1089. Other Project works in EFR-2 include the tunnel service building at the North Portal, the North Portal service road and the emergency turn-around facility. The extents and principal elements of EFR-2 are shown in Plate 9.1

Plate 9.1 Catchment EFR-2



9.1.2 The Flood Map for Planning (Environment Agency, 2022d) shows the extents of Flood Zones 1, 2 and 3 across England and Wales. This map also shows the location of existing flood defences and areas that benefit from flood defences[17]. An extract from this map is presented in Drawing 0111 and shows that Catchment EFR-2 falls primarily in Flood Zones 1 and 3.

9.1.3 The Flood Zone 1 areas in Catchment EFR-2 comprise the naturally higher ground to the north of the railway line (Tilbury Loop) and the historic landfill sites closer to the River Thames. The Flood Zone 3 area primarily comprises the lower-lying ground to the south of Tilbury Loop railway line.

9.1.4 As parts of the highway in Catchment EFR-2 would lie in Flood Zone 3, an Exception Test has been undertaken. On the basis that the Project constitutes essential infrastructure, and that it would provide wider sustainability

[17] In the context of Catchment EFR-2, the flood defences that provide benefit are tidal defences.

benefits and be safe for its lifetime without increasing flood risk elsewhere, the provisions of the Exception Test would be met (see Section 3.5). Furthermore, the requirements of paragraph 5.109 of the NN NPS regarding essential infrastructure located in Flood Zone 3a or 3b would be met (see Section 3.5).

9.2 Site-specific flood risks

Fluvial and tidal

Sources of fluvial and tidal flooding

9.2.1 Fluvial flooding would occur when the flow through West Tilbury Main exceeds its capacity. West Tilbury Main discharges to the River Thames via Bowaters Sluice and is subject to tide locking. Contrary to normal expectations, tide locking at the point where West Tilbury Main discharges to the River Thames does not unduly impact fluvial flooding in Catchment EFR-2 (see Part 5 of the FRA).

9.2.2 Fluvial (tidal) flooding would also occur when tide levels in the River Thames are exceptionally high and when surge tides move up the Thames Estuary from the North Sea. The tidal flood mechanism would be overtopping or breaching of defences, resulting in the rapid onset of fast flowing and deep-water flooding with little or no warning. Mechanical failure of sluice gates may also result in tidal flooding.

Existing flood defences

9.2.3 The existing tidal flood defences in this catchment include sea walls along the River Thames, Bowaters Sluice and Star Dam.

9.2.4 The sea walls comprise earth embankments topped with concrete walls. They are only located along reaches of the River Thames where ground levels are low enough to make them susceptible to overtopping. There are no sea defences in the immediate vicinity of the Project. The nearest flood defences to the east are approximately 1.10km downstream of the Project road and the nearest flood defences to the west are approximately 0.85km upstream of the Project road. The Environment Agency maintains these defences.

9.2.5 The West Tilbury Main sluice (Bowaters Sluice) is a flap sluice gate on a 610mm diameter culvert. A 76m section of tidal wall stretches across the sluice and ties into higher ground at each end. The wall is a reinforced concrete structure with a coping level of 6.55mAOD. It is understood that the structure was completed in 1979. Since 1979, it is possible that the sluice gate structure has been subject to settlement and that the actual coping level is lower than the as-constructed level.

9.2.6 Bowaters Sluice is a failing asset. The culvert through the sluice is reported to be partially collapsed or blocked. For the purposes of the hydraulic analysis of West Tilbury Main, the Environment Agency suggested that the culvert should be assumed to be 75% blocked (see Section 9.3 and Part 5 of the FRA).

9.2.7 Star Dam is an inland defence that prevents tidal flood water travelling between West Tilbury Marshes and East Tilbury Marshes. The dam is approximately 61m long and ties into higher ground at each end. The dam is a reinforced concrete structure with a coping level of 6.55mAOD. A 300mm diameter culvert runs under the dam. It is understood that the structure was completed in 1979. Since its completion, it is possible that the Star Dam has been subject to settlement and that the actual coping level is lower than the as-constructed level.

Long-term flood risk information map

9.2.8 Drawing 00111 shows that all parts of the Project road in Catchment EFR-2 that are at risk of fluvial or tidal flooding would lie in areas that benefit from flood defences[18]. However, it should be noted that these defences reduce, but do not completely eliminate, the chance of flooding as they can be overtopped or fail.

9.2.9 The long-term flood risk information map (Environment Agency, 2022c) shows the extents of fluvial and tidal flooding with existing flood defences considered. This map indicates that most of the section of Project road in Catchment EFR-2 would lie in areas that are not at risk of fluvial or tidal flooding. The exception to this is towards the southern part of the catchment, where the Project road would traverse areas at low and very low risk of fluvial or tidal flooding.

9.2.10 An extract from the long-term flood risk map showing fluvial flooding in Catchment EFR-2 with existing flood defences considered, is presented in Drawing 00114.

Hydraulic modelling maps

9.2.11 Flood maps have been created using the hydraulic modelling undertaken for the Project.

9.2.12 These flood maps are more detailed than the long-term flood risk information map (Environment Agency, 2022c) and include climate change allowances.

9.2.13 The flood maps generated by the hydraulic model have been used to analyse pre-development and post-development fluvial flood risk in EFR-2. These flood maps have also been used to analyse the performance of flood alleviation measures.

9.2.14 Further details on the hydraulic models are included in Section 9.3 and Part 5 of the FRA.

Surface water

9.2.15 The long-term flood risk information map for surface water (Environment Agency, 2022c) indicates that this catchment lies in an area that is primarily at very low risk of surface water flooding. However, there are some areas at low, medium and high risk of surface water flooding; these areas generally follow watercourses, along roads (where overland drainage paths are interrupted) and in isolated pockets (local depressions).

9.2.16 Some of the isolated pockets of surface water flooding within the curtilage of the highway would be lost and some would be partially lost. This may cause a minor redistribution of surface flooding beyond the curtilage of the Project road, but this is not considered to present a significant flood risk. Furthermore, any

[18] In the context of Catchment EFR-2, the flood defences that provide benefit are tidal defences.

such redistribution would mostly lie within land for which National Highways would be seeking permanent acquisition.

9.2.17 The main overland flow paths in Catchment EFR-2 follow watercourse alignments. Where necessary, watercourses would be culverted where they cross under highways, thereby allowing continuity of the flow paths (see Part 10 of the FRA for details of watercourse culverts).

9.2.18 The exception to the above paragraph is the upstream end of an overland flow path would be lost to the Project road. The Project road would cover part of the flow path catchment and thereby reduce the flow channelled along it. This will ensure that offsite surface water flood risk will not be increased and possibly reduced.

9.2.19 The risk of surface water flooding in the Project road would be negligible when considered in conjunction with the highway drainage (see Part 7 of the FRA).

9.2.20 The extents of surface water flooding in Catchment EFR-2 are presented on Drawing 00131. This drawing is based on the long-term flood risk information map for surface water (Environment Agency, 2022c). The overland flow path that would be lost to the Project road is labelled EFR-2-SW-01 on Drawing 00131.

Groundwater

Groundwater flooding records (LLFA)

9.2.21 A generic description of groundwater flood risk is provided in Thurrock Council's (2018) Level 1 SFRA and includes reference to the BGS groundwater susceptibility mapping. The Level 1 SFRA identifies susceptibility to groundwater flood risk in the southern parts of Thurrock, particularly where the Chalk Formation is covered by permeable Alluvium and River Terrace Deposits. The Aveley and Purfleet areas are mentioned specifically, but being toward the mouth of the Mardyke, these areas are unlikely to be affected by or have an effect on the Project.

9.2.22 The Thurrock Level 1 SFRA provides mapping of historic flood incidents, but this does not attribute the cause of flooding and no specific incidence of groundwater flooding is identified in the vicinity of Catchment EFR-2.

9.2.23 The Thurrock Local Flood Risk Management Strategy (Thurrock Council, 2015) states that no incidents of groundwater flooding had been reported either to the council or the Environment Agency.

Flood risk mapping and hydrogeology

9.2.24 Adjacent to, and immediately north of, the North Portal, the GeoSmart flood risk mapping identifies the Project road to be in an area predominantly of low risk of groundwater flooding. To the west (and adjacent to West Tilbury Main) there is an area of medium risk, which extends northward then eastward, in the vicinity of Buckland, south of Church Road. These areas of low and medium risk are associated with the boundary between the sub-group of the Chalk Formation (to the south) and the Thanet Formation (to the north) and the overlying superficial deposits (Alluvium to the south, River Terrace Deposits to the north).

9.2.25 Just to the east of Railway Cottages (and Gravel Pit Farm) there is a small area identified as being at high risk of groundwater flooding; this appears to represent shallow, and potentially emergent groundwater (surface water is also mapped at this location). This area also coincides with an irrigation reservoir. Potentially this area may receive discharge from artesian groundwater from the underlying semi-confined Chalk Formation aquifer.

9.2.26 From this area of high risk to the northern boundary of Catchment EFR-2, the GeoSmart mapping shows negligible groundwater flood risk. However, there may be isolated locations where groundwater is close to the surface, particularly as perched layers, where there may be potential for groundwater seepage.

9.2.27 Throughout much of this area, groundwater level in the underlying Chalk Formation is influenced (and indeed managed) by pumping from the water supply well at Linford. Chalk Formation groundwater in this area is unconfined or semi-confined and in parts may exhibit artesian behaviour (i.e. the piezometric surface is locally above ground level). At low-lying areas where the confining cover thins or where there are permeable windows in the overlying Thanet Formation and superficial deposits, groundwater could emerge at the surface. For further details, refer to Appendix 14.5: Hydrogeological Risk Assessment.

9.2.28 Appendix 14.5: Hydrogeological Risk Assessment describes the mitigation to prevent groundwater ingress into the North Portal and ramp during the construction phase and confirms that the inflow to the North Portal and ramp area would be negligible during the operational phase. It can therefore be concluded that there would be a negligible risk of groundwater flooding at the southern end of Catchment EFR-2.

9.2.29 In the Chadwell St Mary Link area, the risk of groundwater flooding due to the proposed cuttings and buried structures has been assessed. Appendix 14.5: Hydrogeological Risk Assessment found that there would only be a negligible impact since the base of the cuttings is above groundwater level. Should any perched water be encountered then it would be expected to comprise localised areas of seepage, possibly after wet weather periods. A drainage system incorporating an appropriate edge of pavement detail, such as combined surface and sub-surface drains in line with DMRB CD 524, would mitigate this flood risk.

Impact of drainage strategy on groundwater

9.2.30 In this part of the Project, the drainage strategy would generally be based on the use of gravity systems that discharge to surface watercourses via retention ponds.

9.2.31 Drainage of small catchments that cannot be connected to one of the main drainage systems would be based on the use of swales with collected water discharged to ground (infiltration). With appropriate design, these swales would not contribute to groundwater flood risk. Use of swales is secured in the Design Principles (Application Document 7.5).

Sewers and water mains

9.2.32 When trunk sewers are blocked or overwhelmed, they have the potential to cause flooding. When sewer rising mains are damaged or burst, they also have the potential to cause flooding. As all such assets would be diverted in advance of the works, the risk of flooding from sewers during the operational phase of the Project is considered to be negligible.

9.2.33 All water mains have the potential to cause flooding if they are damaged or burst, with transmission mains clearly presenting the bigger risk. As all such assets would be diverted in advance of the works, the risk of flooding from water mains during the operational phase of Project is considered to be negligible.

9.2.34 Water utility asset data in Catchment EFR-2 is shown in Drawing 00172.

Reservoirs

9.2.35 The Environment Agency long-term flood risk information map for reservoirs (Environment Agency, 2022c) indicates that the catchment is not in an area at risk from reservoir flooding.

9.2.36 Flood risk from reservoirs is shown on Drawing 00175.

9.3 Flood analysis

General

9.3.1 A hydraulic model was developed for the analysis of flooding in Catchment EFR-2. A precis of the modelling is presented below.

9.3.2 Further details regarding the hydraulic modelling in Catchment EFR-2 are presented in Part 5 of the FRA.

9.3.3 Peak river flow allowances (climate change) used in the simulations are described in Section 4.4.

9.3.4 The simulations considered the pre-development and post-development cases. The post-development case was simulated both without and with mitigation measures.

Fluvial flooding

Project (onsite) fluvial flooding

9.3.5 Fluvial flooding modelling for the Project considered the design flood (1% AEP) as well as the 50% AEP, 5% AEP and 0.1% AEP events.

9.3.6 The higher central peak river flow allowances have been applied to these events (+11% in 2030 and +26% in 2130) in accordance with current guidance (Environment Agency, 2022a).

9.3.7 The simulated flood levels adjacent to the Project for the 0.1% AEP fluvial flood event with +26% peak river flow allowances are 2.90mAOD for the case without mitigation and 2.32mAOD for the case with mitigation.

9.3.8 The simulated fluvial flood levels for the 0.1% AEP event with +26% peak river flow allowances are substantially lower than the crest level of the flood protection measures (7.83mAOD). The Project will therefore remain operational during such a flood event.

9.3.9 As the Project will remain operational for the 0.1% AEP event with +26% peak river flow allowances, it can be concluded that the Project will remain operational for the design flood and the other (smaller) events.

Offsite fluvial flooding

9.3.10 Depth difference plots for the 1% AEP event in 2130 with the +26% higher central peak river flow allowance applied demonstrate that the offsite impacts of the design, without mitigation, do not affect any essential infrastructure. On this basis, and in accordance with Environment Agency guidelines (2022a), central peak river flow allowances (+6% in 2030 and +17% in 2130) have been used to assess the offsite impacts and fluvial floodplain compensation requirements.

9.3.11 The depth difference plots for the 50%, 5% and 1% AEP events in 2030 with +6% central peak river flow allowance applied and in 2130 with a +17% central peak river flow allowance applied, demonstrate that the mitigation measures and floodplain compensation specified do provide the required mitigation and compensation.

Bowaters Sluice

9.3.12 Due to its deteriorating condition, the Environment Agency advised that the Bowaters Sluice outfall should be regarded as 75% blocked for modelling purposes.

9.3.13 Sensitivity runs were undertaken to compare pre-development model results with a 75% and 100% blockage of Bowaters Sluice outfall. Results for both 75% and 100% blockage scenarios show similar maximum depths and maximum flood extents, which indicates the impact of simulating a 100% blockage condition compared to 75% is minor.

9.3.14 Given this insensitivity of model results to the blockage condition, design model simulations apply a 100% blockage condition for the Bowaters Sluice tidal outfall. This provides slightly conservative (precautionary) outputs.

Credible maximum scenarios

Introduction

9.3.15 The climate change analysis for flood risk assessment (Environment Agency, 2022a) requires that credible maximum scenarios should be considered for NSIPs.

Peak river flow allowance

9.3.16 The current climate change guidance (Environment Agency, 2022a) stipulates that upper end peak river flow allowances should be applied to represent a credible maximum climate change scenario. The upper end peak river flow allowance for the Project in 2130 is +48% (see Section 4.4).

9.3.17 The proposed protection measures at the North Portal would be designed with a crest level of 7.83mAOD. The maximum simulated flood level adjacent to the Project road with mitigation measures is 2.33mAOD for a 0.1% AEP fluvial event in 2130 with +48% peak river flow allowance applied (and simulating Bowaters Sluice to be 100% blocked). The Proposed road would therefore not be impacted by fluvial flooding under the credible maximum scenario.

Sea level rise and storm surge (H++)

9.3.18 Derivation of the H++ sea level rise allowances is detailed in Section 4.5.

9.3.19 The H++ EWL at East Tilbury Marshes in 2130 is estimated to be 7.28mAOD. This is approximately 0.45m higher than the 0.1% AEP EWL at East Tilbury Marshes in 2130, of 6.83mAOD.

9.3.20 The proposed protection at the North Portal would be designed with a crest level of 7.83mAOD (ie design EWL of 6.83mAOD plus 1m residual uncertainties allowance allowance), and the level of this structure determines the standard of flood protection of the Project road in the West Tilbury Main catchment.

9.3.21 If the H++ climate change scenario were realised, the Project could be adapted at this location by raising the protection to 8.28mAOD (the H++ EWL plus a residual uncertainties allowance of 1m). In the West Tilbury Main catchment, the Project is therefore considered readily adaptable to the H++ climate change scenario.

Breach analysis

9.3.22 Tilbury breach models were used to simulate the pre-development and post-development scenarios for a breach of the River Thames defences during the following tidal events:

a. The 0.5% AEP tidal flood event in 2030 and 2130

b. The 0.1% AEP tidal flood event in 2030 and 2130

9.3.23 Breaches were considered at the following locations:

a. Near the former Tilbury power station site

b. Bowaters Sluice

9.3.24 Overtopping of the existing defences would occur if River Thames EWLs exceed the defence crest levels. The TE2100 Plan (Environment Agency, 2012), sets out how tidal flood risk is expected to be managed; this includes recommendations for defence heights. TE2100 recommends the flood risk management for the policy unit in which the Project lies is to take action to keep up with climate and land use change so that flood risk does not increase. On this basis, overtopping over the defence crest levels was not considered in the Project breach modelling as the TE2100 Plan policy details that the crest levels will be increased in the future to maintain a 0.1% AEP standard of protection (as a minimum)[19]. Further details of TE2100 are included in Section 14.

9.3.25 If the River Thames tidal defences were not upgraded in the future, and overtopped during extreme River Thames tidal events, flooding on the landward side of the defences would be more gradual than after a breach, and the Project road and tunnel would remain operational (see below).

9.3.26 A conservative estimate of peak water levels in the tidal River Thames floodplain is assumed to be equal to River Thames flood levels (this is

[19] The crest levels for TE2100

considered to a precautionary approach as EWLs would not persist for long enough for landward flood levels to rise to the same level).

9.3.27 The 0.1% AEP tidal event EWL in 2130 for East Tilbury Marshes (Project location) is 6.83mAOD.

9.3.28 The proposed protection at the North Portal is designed with a top level of 7.83mAOD. The parts of the highway that do not benefit from the protection are also designed to be above 7.83mAOD.

9.3.29 If the River Thames tidal defences were not upgraded in the future, the Project road and tunnel would therefore remain operational during the 0.1% AEP event EWL in 2130.

9.3.30 Further details regarding the hydraulic modelling of tidal flooding in Catchment EFR-2 are presented in Part 5 of the FRA.

Residual uncertainties allowance

9.3.31 The crest level of the flood protection at the North Portal includes a (residual uncertainties) allowance of 1m.

9.3.32 The Project road would normally incorporate a 600mm freeboard in accordance with the relevant provisions of DMRB CD 356 (Highways England, 2020d). However, as the section of the highway that needs to be protected falls towards the North Portal, the flood protection measures for the highway need to match those afforded for the North Portal.

9.4 Flood risk management strategy

Flood mitigation measures

Alteration of watercourse channels and structures (good practice)

9.4.1 The Project road would dissect a flow path running east to west across East Tilbury Marshes.

9.4.2 To offset the loss of this flow path, flow capacity in the West Tilbury Main would be enhanced by making changes to structures that cross it. These changes would comprise the following:

a. Enlargement of an existing culvert, X-EFR-2-02, to the west of the Project road, as shown on Drawing 00180. [RDWE046]

b. Removal of two of the three existing culverts to the east of the Project road, as shown on Drawing 00180. [RDWE046]

9.4.3 Structures on West Tilbury Main that would be altered or removed are shown on Drawing 00180. Further details of alteration of watercourse channels and structures is included in Part 10 of the FRA.

Compensatory flood storage areas (essential mitigation)

9.4.4 The hydraulic modelling identified that flood plain storage would be lost to the embankment for part of the Project road in Catchment EFR-2. To offset this loss, compensatory flood storage would need to be provided.

9.4.5 As the West Tilbury Main floodplain is flat and low-lying, a conventional CFSA would not be an appropriate approach to replace the floodplain volume that would be displaced by the Project.

9.4.6 On this basis, a flow retention type CFSA would be used to compensate for the floodplain volume displaced by the Project. [RDWE037]

9.4.7 This CFSA would be located to the north of Tilbury Loop and intercept flows from upstream catchments before they reach the floodplain. The flow entering the CFSA would cascade downstream through four compartments. The compartments would be connected by culverts and high-level overflow spillways to convey exceptionally high flows. At the downstream end of the CFSA, a non-return valve (duckbill valve or similar non-mechanical device) would be incorporated on the outlet to prevent backflow.

9.4.8 The CFSA would need to be able to function before there is any permanent or temporary loss in floodplain storage [RDWE037]. This would be accounted for in the construction programme[20].

9.4.9 The area set aside for provision of compensatory flood storage is shown on Drawing 00180.

Highway drainage (embedded mitigation)

9.4.10 Surface water flood risk from highway runoff would be mitigated by inclusion of highway drainage provisions. The surface water drainage provisions would prevent flooding in the highway without increasing risk elsewhere.

9.4.11 In this part of the Project, the drainage strategy would generally be based on the use of gravity systems that discharge to surface watercourses via retention ponds.

9.4.12 Further details of the surface water drainage strategy for Catchment EFR-2 are included in Part 7 of the FRA[21].

Hydraulic structures

9.4.13 The hydraulic model indicated that for the post-development scenario without mitigation, the existing West Tilbury Main culverts limit conveyance of flood flows between the floodplain east and west of the Project road. These existing culverts would be removed or enlarged as part of the mitigation measures. This would result in no change in conveyance for smaller events, but for larger events there will be an increase in conveyance via the enlarged culvert.

9.4.14 A two-stage structure would be required to mitigate the impacts of larger events, whilst not changing the hydraulic behavior during smaller events. This will be achieved by installing a hydraulic structure, with an inset thin plate notch to control flows at lower levels. [RDWE046]

9.4.15 Further details on hydraulic structures are included in Part 10 of the FRA.

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[20] The Contractor could elect to adopt a phased approach to the provision of the CFSA; with this approach, the volume of storage made available would be increased in stages to suit the compensation needs of the construction programme. The Contractor may also elect to mobilise temporary compensation during the construction phase of the Project.

[21] The drainage strategy is an embedded measure secured through the Design Principle LSP.28 and LSP.30 (Application Document 7.5).

Flood protection measures

Flood walls and flood bunds

9.4.16 Two sections of the Project road between the North Portal and the Tilbury Viaduct would be vulnerable to overtopping during a tidal flood event and would need to be protected.

9.4.17 The first vulnerable section would be a 265m long stretch that straddles the West Tilbury Main. The protection would be keyed into the existing high ground around the North Portal and tie-in with the earthworks for the (elevated) emergency turn-around facility. The flood protection level would be 7.83mAOD (see Annex A). The form of construction would comprise an earth retaining wall with an earth mound behind it rising to the design flood level. [RDWE029]

9.4.18 The second vulnerable section would be along part of the northbound on-slip and southbound off-slip for the emergency turn-around facility. The protection would tie-in earthworks for the (elevated) emergency turn-around facility and continue northwards until the level of the Project road matches the flood protection level (7.83 mAOD – see Annex A). The protection would be incorporated into the on-slip and off-slip formation. [RDWE029]

9.4.19 Details and extents of the flood protection measures are shown on Drawing 00180.

Flood resilience measures

Road geometry (embedded resilience)

9.4.20 To the north of Catchment EFR-2, the Project road would be on a viaduct or on high embankments. The level of the viaduct and embankments would be substantially higher than the flood protection level, thereby affording embedded flood resilience to this section of the road.

Maintenance (essential resilience)

9.4.21 Drainage infrastructure and treatment systems would be inspected and maintained in accordance with the relevant provisions of DMRB GS 801 (Highways England, 2020b) and DMRB GM 701 (Highways England, 2020c), to ensure they continue to operate to their design standard. [RDWE012]

Climate change allowances (essential resilience)

9.4.22 The design of the compensatory flood storage and the flood protection measures would all be designed to include allowances for projected climate change. [RDWE029] [RDWE037]

9.4.23 The highway drainage design would also include allowances for projected climate change (National Highways, 2022b).

9.4.24 The climate change allowances for the water environment that would be applied to the Project are detailed in Section 4.7.

Residual uncertainties allowance

9.4.25 A residual uncertainties (freeboard) allowance of 1.0m would be added to the 0.1% AEP tidal flood level to determine the crest level of the flood protection measures for the North Portal. [RDWE029]

Residual flood risk

9.4.26 Residual flood risks for EFR-2 along with associated mitigation measures are presented in Table 9.1.

Table 9.1 Catchment EFR-2 – Residual risk and mitigation

Ref.	Residual risk	Mitigation measures
1	Overwhelming of the highway drainage system due to a severe storm event or a blockage may result in onsite and/or offsite flooding and the potential for runoff to enter the tunnel (the entire section of highway in Catchment EFR-2 all slopes down towards the tunnel).	Drainage asset inspections would be undertaken in accordance with relevant provisions of DMRB GS 801. [RDWE012] A planned, risk based maintenance programme in accordance with the relevant provisions of DMRB GM 701 would be established. [RDWE012] Planned maintenance interventions would ensure efficient operation of the drainage network (including pumping stations).
2	Overtopping of the retention ponds and detention basin that form part of the highway drainage system may occur in the event of a severe storm. This may lead to development of secondary flow paths with surface water flooding in lower-lying areas.	The capacity of retention ponds and detention basins would include provision for climate change allowances in accordance with the Environment Agency guidance. [RDWE035] [RDWE048] Drainage asset inspections would be undertaken and maintenance programmes would be established, all as described above. [RDWE012] Planned maintenance interventions would ensure continued efficient operation of the retention ponds and detention basin. Overland flow paths would be established where required to manage any overtopped flows. [RDWE035] [RDWE048] The retention ponds and detention basins would be located away from sensitive receptors to avoid potential risks resulting from residual impacts.
3	Overtopping of the CFSA may occur in the event of a severe storm; this may lead to development of secondary flow paths with surface water flooding in lower-lying areas.	The design of the CFSA would include allowances for climate change in accordance with the latest Environment Agency guidance (Environment Agency, 2022a), thereby reducing residual risk of overtopping.
4	Overtopping of the flood protection due to a severe tidal event could result in inundation of the tunnel.	A tunnel safety consultation has been undertaken on emergency preparedness. This consultation establishes measures to be implemented during an incident.
5	Structural failure (breach) of the flood protection measures could result in inundation of the tunnel.	A planned, risk based maintenance programme would be established. [RDWE012] Mitigation measures for structural failure of the flood protection bund would involve periodic inspections. The inspection would assess the structural integrity of the

Ref.	Residual risk	Mitigation measures
		protection. Any structural integrity issue identified would then trigger a maintenance response.
6	There is a risk of seepage if perched groundwater is encountered (e.g. in cuttings).	On account of their highly localised nature, identification of all occurrences of perched groundwater is difficult. If perched groundwater is encountered in cuttings, it would most likely occur as localised seepages only. This residual risk could be mitigated by provision of a drainage system incorporating an appropriate edge of pavement detail, such as combined surface and sub-surface drains in line with DMRB CD 524.
7	Failure of Bowaters Sluice.	For the West Tilbury Main hydraulic model, the Environment Agency advised that the Bowaters Sluice outfall is 75% blocked. To reflect its current condition, sensitivity runs were undertaken to compare pre-development model results with a 75% and 100% blockage of Bowaters Sluice outfall. Results for both blockage scenarios show similar maximum depths and maximum flood extents, which indicates that the impact of simulating a 100% blockage condition compared to 75% blockage, is minor. Given this insensitivity of model results to the blockage condition, design model simulations apply a 100% blockage condition for the Bowaters Sluice tidal outfall (i.e. design simulations for West Tilbury Main have therefore been undertaken on the basis that this residual risk has been realised).
8	Breach of River Thames tidal flood defences.	The 0.1% AEP tidal event EWL of the River Thames in 2130 for East Tilbury Marshes (Project location) is 6.83mAOD. The proposed protection at the North Portal is designed with a top level of 7.83mAOD. The parts of the highway that do not benefit from the protection are also designed to be above 7.83mAOD.

Text box 9.1 Flood Risk – North Portal to Chadwell St Mary (EFR-2)

Catchment EFR-2 would lie mainly in Flood Zones 1 and 3. The Flood Zone 3 area lies primarily in the low-lying areas to the south of the railway line (Tilbury Loop). The Flood Zone 1 areas comprise the historic landfill sites in the southern part of the catchment and the area to the north of the railway line.

Fluvial flooding would occur when the flow through West Tilbury Main exceeds its capacity. West Tilbury Main discharges to the River Thames via Bowaters Sluice and is subject to tide locking, however, hydraulic modelling indicates that this condition does not unduly impact fluvial flooding in the catchment. Tidal flooding would occur when tide levels in the River Thames are exceptionally high and when surge tides move up the Thames Estuary from the North Sea.

To assess onsite fluvial flood modelling for the Project, several events were considered with ‘higher central’ peak river flow allowances applied. The most severe event assessed was the 0.1% AEP event with +26% peak river flow allowances for 2130. Simulation of this event demonstrated that the flood level (2.32mAOD with mitigation) would be substantially lower than the crest level of the flood protection measures (7.83mAOD). The Project would therefore remain operational during such a fluvial flood event.

The depth difference plots for the 50%, 5% and 1% AEP events in 2130 with a +17% ‘central’ peak river flow allowance applied were assessed to determine the offsite impacts of the Project. The plots demonstrate that the mitigation measures and floodplain compensation specified provide the required mitigation and compensation.

The credible maximum scenario for fluvial flooding is the 0.1% AEP event with +48% peak river flow allowances for 2130. Simulation of this event demonstrates that flood level for the credible maximum event (2.33mAOD) would be substantially lower than the crest level of the flood protection measures (7.83mAOD). The proposed road would therefore not be impacted by fluvial flooding under the credible maximum scenario.

Tilbury breach models were used to simulate scenarios for a breach of the River Thames defences. Overtopping of the existing defences would occur if River Thames EWLs exceed the defence crest levels. The 0.1% AEP tidal event EWL in 2130 for East Tilbury Marshes (Project location) is 6.83mAOD. The proposed protection at the North Portal is designed with a top level of 7.83mAOD. The parts of the highway that do not benefit from the protection are also designed to be above 7.83mAOD.

The EWL in the River Thames for the H++ event in 2130 would be 7.28mAOD. This is approximately 0.45m higher than the 0.1% AEP EWL at East Tilbury Marshes (6.83mAOD). If the H++ climate change scenario were realised, the Project could be adapted at this location by raising the protection to 8.28mAOD (the H++ EWL plus a residual uncertainties allowance of 1m).

Catchment EFR-2 lies in an area that is primarily at very low risk of surface water flooding (Environment Agency, 2022c). Some isolated pockets of surface water flooding within the curtilage of the highway would be lost or partially lost; this may cause a minor redistribution of surface flooding but is not considered to present a significant flood risk. The main overland flow paths follow watercourse alignments, thereby ensuring their continuity without offsite impacts. Part of one overland flow path would be lost to the Project road but this would not increase offsite surface water flood risk. The risk of surface water flooding on the Project road would be negligible on account of the Highway drainage provisions.

To the south of the railway line, the Project road lies in areas at low and moderate risk of groundwater flooding. There is a negligible risk of groundwater flooding to the north of the railway. The risk of groundwater flooding in Project road cuttings would be negligible. It is possible that perched water may be encountered in cuttings where permeable or partly permeable strata overlie less permeable strata.

There is no significant risk of flooding from sewers, water mains or reservoirs in Catchment EFR-2.

Flood mitigation measures for Catchment EFR-2 would comprise alteration of watercourse channels, provision of a CFSA, incorporating a hydraulic structure in West Tilbury Main and inclusion of a highway drainage system. West Tilbury Main channel alterations would comprise removal of two culvert crossings and enlargement of one existing culvert crossing.

Flood protection measures would comprise implementation of flood defence structures to protect low sections of the Project road and the tunnel. The structural form of the protection would be a combination of earth bunds and concrete retaining walls.

Flood resilience would be provided by making allowance for climate change projections in the design of the flood mitigation and protection measures, elevating the Project road in fluvial flood risk areas, implementation of a maintenance and inspections programme, and inclusion of a residual uncertainties allowance.

Residual flood risks comprise the following:

- Inundation of the highway drainage system may result in onsite and/or offsite flooding.
- Overtopping of the balancing ponds may lead to localised flooding.
- Inundation of the compensatory flood storage area may lead to localised flooding.
- Potential seepage of perched groundwater in cuttings.
- Breach or overtopping of the flood protection.
- Failure of Bowaters Sluice.
- Breach flooding at tidal defences.

The risk of intercepting perched groundwater would need to be managed during the construction phase of the Project. This risk could be mitigated by incorporating an appropriate edge of pavement detail (e.g. combined surface and subsurface drains).

The hydraulic modelling was undertaken on the basis that risk of failure of Bowaters Sluice has been realised.

The risk of a breach of River Thames tidal flood defences at Bowaters Sluice is considered to be negligible.

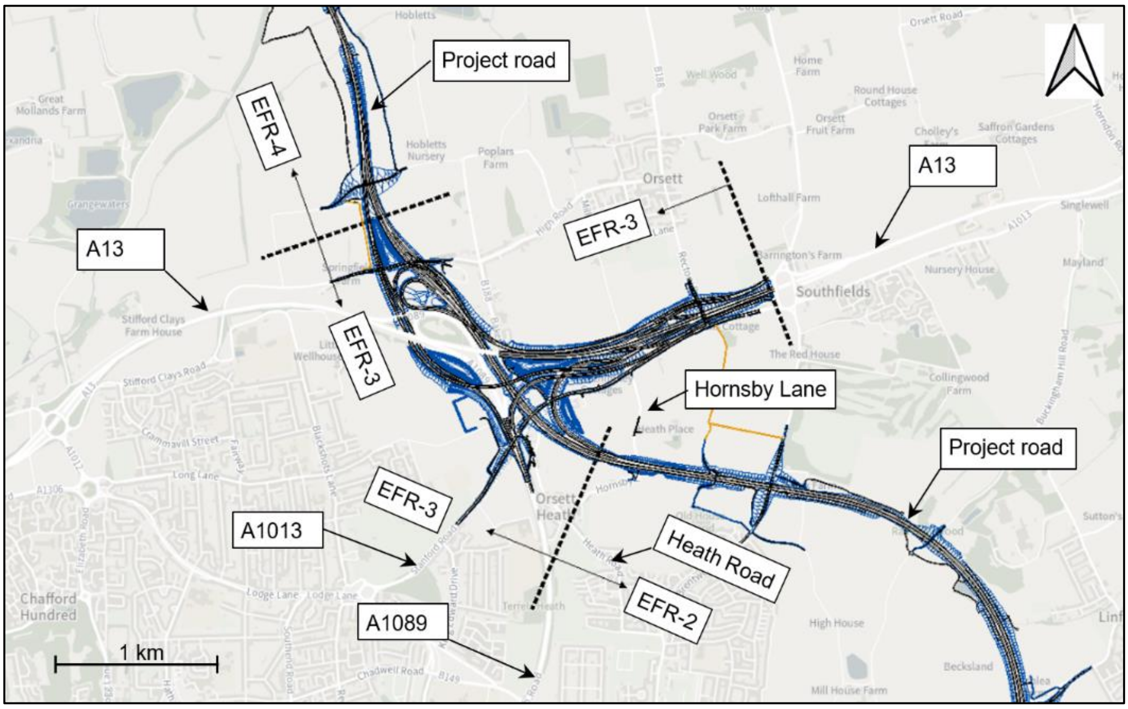
All other residual risks can be mitigated by implementation of an appropriate maintenance programme.

10 A13 junction (EFR-3)

10.1 Overview

10.1.1 Catchment EFR-3 includes the split-level interchange between the Project road, the A13 and the A1089[22]. See Plate 10.1

Plate 10.1 Catchment EFR-3



10.1.2 The Flood Map for Planning (Environment Agency, 2022c) shows the extents of Flood Zones 1, 2 and 3 across England and Wales. An extract from this map is presented in Drawing 0111 and shows that Catchment EFR-3 falls entirely within Flood Zone 1.

10.1.3 The Sequential Test concludes that the development would be permissible and that an Exception Test is not required (see Section 3.4).

10.2 Site-specific flood risk

Fluvial

10.2.1 The long-term flood risk information map for rivers or the sea (Environment Agency, 2022c) shows the extents of fluvial and tidal flooding with existing flood defences considered. This map indicates that the section of the Project road in Catchment EFR-3 would lie in areas that are at low risk of fluvial flooding.

10.2.2 An extract of the map showing the extents of fluvial flooding in Catchment EFR-3 is presented in Drawing 00114.

[22] The existing junction between the A13 and the A1089 is sometimes referred to as the Baker Street Interchange.

Surface water

Long-term flood risk information

10.2.3 The long-term flood risk information map for surface water (Environment Agency, 2022c) indicates that this catchment lies in an area that is primarily at very low risk of surface water flooding. However, there are some areas at low, medium and high risk of surface water flooding; these generally follow roads (where drainage paths are interrupted) and in isolated pockets (local depressions).

10.2.4 Some of the isolated pockets of surface water flooding within the curtilage of the highway would be lost and some would be partially lost. This may cause a minor redistribution of surface flooding beyond the curtilage of the Project road, but this is not considered to present a significant flood risk. Furthermore, any such redistribution would mostly lie within land for which National Highways would be seeking permanent acquisition.

10.2.5 The risk of surface water to the Project road in Catchment EFR-3 would be negligible when considered in conjunction with the highway drainage (see Part 7 of the FRA).

10.2.6 The extents of surface water flooding in Catchment EFR-3 are shown on Drawing 00131. This drawing is based on the long-term flood risk information map for surface water (Environment Agency, 2022d).

10.2.7 Locations where the Project may have an offsite impact on surface water flooding are:

a. EFR-3-SW-01: Area to the north of Stanford Road (A1013)

b. EFR-3-SW-02: Where the A1089 crosses the A1013

c. EFR-3-SW-03: Area running east to west between Heath Road and Hornsby

10.2.8 Surface water flood risk in these areas is described in Table 10.1, Table 10.2 and Table 10.3.

Table 10.1 Surface water flood risk – EFR-3-SW-01

EFR-3-SW-01: Area to the north of Stanford Road (A1013)
Risk
There is an area of surface water flooding on the northern side of the A1013 (Stanford Road), just to the west of the crossing over Hornsby Lane. Ground level in this area is slightly lower than the surrounding land so surface water naturally gravitates towards it. The A1013 effectively impounds this water leading to surface water flooding.
Proposed development
Realignment of A1013
Risk management strategy appraisal
Provided the realigned section of the A1013 maintains the same vertical alignment as the existing alignment, there would be no change to surface water flooding in this area and no new flood risk issues to address.

Table 10.2 Surface water flood risk – EFR-3-SW-02

EFR-3-SW-02: Where the A1013 crosses the A1089
Risk
The A1013 crosses over the A1089 to the south of the A13. At the crossing, there is surface water flooding to the west of the A1089. It appears that an overland flow path has been intercepted by the A1089 and surface water is impounded in the area immediately west of it. The A1013 is on a viaduct at the crossing and does not appear to have an impact on surface water flooding.
Proposed development
Major reconfiguration of both the A1013 and the A1089, including new horizontal alignments, a new viaduct for the A1013 and widening of the A1089.
Risk management strategy appraisal
There would be no increase in surface water flooding on the A1089 provided that the level of the realigned section of highway matches that of the existing section. As the A1013 would be on a viaduct where it crosses A1089, it would remain at negligible risk of flooding. An unnamed side road that turns off the northbound carriageway of the A1013 would pass through the impounded area of surface water flooding. Elevating the section of the road through this area would ensure safe operation during flood events. Migration of surface water flow from the west of the A1089 to the east may increase risk of flooding at properties along Heath Road. Care would need be taken in the drainage design to prevent this migration of surface water.

Table 10.3 Surface water flood risk – EFR-3-SW-03

EFR-3-SW-02: Area running east to west from Heath Road and Hornsby Lane
Risk
Part of the overland flow path running west to east between Heath Road and Hornsby Lane would be lost under the curtilage of the Project road. Surface water from the flow path may flow onto the Project road and settle in any low points.
Proposed development
New highway
Risk management strategy appraisal
The highway drainage design would take account of overland flows to ensure that the risk of carriageway flooding is mitigated and that surface water flood risk is not increased elsewhere.

HADDMS

10.2.9 HADDMS records indicate that there has only been one moderate flooding event (severity: 5 to 6) at the A13 interchange and that it occurred in 2011. The lack of any other recorded surface water events suggests that the existing drainage system is adequate. The new drainage provisions for the Project would encompass the historic flooding incident location so any legacy issues of flooding in this location would be eliminated.

10.2.10 Part 7 of the FRA includes further details regarding the review of information of HADDMS.

Groundwater

Groundwater flooding records (LLFA)

10.2.11 A generic description of groundwater flood risk is provided in Thurrock Council's (2018) Level 1 SFRA. No incidents of groundwater flooding are reported in the immediate vicinity of Catchment EFR-3.

Flood risk mapping and hydrogeology

10.2.12 Throughout Catchment EFR-3, the GeoSmart flood risk mapping identifies the Project to be in an area entirely of negligible risk from groundwater flooding.

10.2.13 The underlying bedrock is predominantly Lambeth Group strata, overlying the Thanet Sand Formation, although this occurs at subcrop to the south of the catchment. The bedrock is in turn overlain by River Terrace Deposits (Boyn Hill Gravel) and Head Deposits.

10.2.14 The Phase 2 ground investigation (GI) groundwater level monitoring data (Appendix 14.5: Hydrogeological Risk Assessment) confirms groundwater levels are generally below the proposed cuttings. Also, recent trial pits (Phase 2 GI exploratory holes) suggest that the River Terrace Deposits gravels are generally dry. However, potential for groundwater seepage is inferred at the deepest cutting, the A13 westbound to southbound A122 link road, as the maximum groundwater levels recorded in the Phase 2 GI long-term monitoring in the Thanet Formation are higher than the lowest road level here, over a road length of less than 100m. Further information is presented in Appendix 14.5: Hydrogeological Risk Assessment. In addition, generally in EFR-3, there may be isolated locations of perched water tables in the superficial deposits or in more permeable beds in the Lambeth Group that overlay less permeable clay and silt horizons in the Lambeth Group strata.

10.2.15 Perched groundwater, if encountered, would be expected to cause local seepages on cutting slopes. However, a drainage system incorporating an appropriate edge of pavement detail, such as combined surface and sub-surface drains in line with DMRB CD 524 (National Highways, 2021a), would mitigate this flood risk.

10.2.16 Cuttings have the potential to change the groundwater flow regime; this may lead to groundwater flooding occurring elsewhere depending on the presence of retaining structures that could act as barriers to flow, or of collected water infiltrating back to ground further downgradient. However, the Hydrogeological Risk Assessment (Appendix 14.5) reports that, except for one short length of road discussed above, all the proposed cuttings would be above the groundwater level in Catchment EFR-3. Cuttings would generally comprise graded slopes cut into ground without retaining structures so that significant barrier effects would not be created. Collected groundwater would be removed or infiltrated to ground as part of the highway drainage system. As a consequence, changes to groundwater flow regimes would therefore be negligible.

Impact of drainage strategy on groundwater

10.2.17 In this part of the Project, the drainage strategy would generally be based on the use of piped systems that discharge to surface watercourses via retention ponds. The exceptions to this are a highway drainage catchment in the centre of the junction, and small road catchments. For the highway drainage catchment in the centre of the junction, an infiltration basin would be incorporated in the highway drainage design. For small road catchments, swales would be incorporated in the highway drainage design.

10.2.18 Runoff draining to swales and an infiltration basin would be discharged to ground by infiltration. Due to a more direct flow pathway, the use of infiltration systems would locally enhance groundwater recharge with a commensurate increase in local groundwater level (mounding). This can lead to an increased risk of groundwater flooding both in the immediate vicinity of the infiltration system and further downgradient. Appendix 14.5: Hydrogeological Risk Assessment describes the proposed use of infiltration techniques for disposal of highway runoff at the junction between the Project road and the A13.
The Hydrogeological Risk Assessment has assessed the potential for mounding considering infiltration rates and local ground conditions and has demonstrated that the proposed swales and infiltration basin would avoid the potential for mounding to unacceptable shallow depths and therefore would avoid the risk of groundwater flooding.

Sewers and water mains

10.2.19 When trunk sewers are blocked or overwhelmed, they have the potential to cause flooding. When sewer rising mains are damaged or burst, they also have the potential to cause flooding. As all such utility assets would be diverted in advance of the works, the risk of flooding from sewers during the operation phase of Project is considered to be negligible.

10.2.20 All water mains have the potential to cause flooding if damaged or burst, with transmission mains clearly presenting the bigger risk. As all such utility assets would be diverted in advance of the works, the risk of flooding from water mains during the operation phase of the Project is considered to be negligible.

10.2.21 Utility asset data in Catchment EFR-1 is shown in Drawing 00171.

Reservoirs

10.2.22 The map for long-term flood risk from reservoirs (Environment Agency, 2022c) indicates that the catchment is not in an area at risk from reservoir flooding.

10.2.23 Flood risk from reservoirs is shown on Drawing 00175.

10.3 Flood risk management strategy

Flood mitigation measures (embedded mitigation)

10.3.1 Surface water flood risk from highway runoff would be mitigated by inclusion of highway drainage provisions; these provisions would apply to all new and realigned roads in Catchment EFR-3. The surface water drainage provisions would prevent flooding in the highway without increasing risk elsewhere.

10.3.2 The drainage strategy in Catchment EFR-3 would be based primarily on the use of piped systems that discharge to surface watercourses via retention ponds. Isolated areas that cannot readily be connected to the piped systems would be drained to swales and/or infiltration basins.

10.3.3 The junction between the A13 and the A1089 would be reconfigured to incorporate the Project road. Drainage provisions for this junction would be enhanced as the latest DMRB standards are more demanding than those that were in place when the current junction was designed.

10.3.4 Further details of the surface water drainage provisions are included in Part 7 of the FRA[23].

Flood protection measures

10.3.5 There is no requirement to provide flood protection measures in Catchment EFR-3.

Flood resilience measures

Increase drainage network robustness (embedded resilience)

10.3.6 Where existing highway drainage provisions need to be expanded or reconfigured to accommodate the Project, they would be designed in accordance with the latest DMRB standards. This may afford some benefits as the latest standards are more demanding than the standards in place at the time the road was originally constructed.

Maintenance (essential resilience)

10.3.7 Drainage infrastructure and treatment systems would be inspected and maintained in accordance with the relevant provisions of DMRB GS 801 (Highways England, 2020b) and DMRB GM 701 (Highways England, 2020c), to ensure they continue to operate to their design standard. [RDWE012]

Climate change allowances (essential resilience)

10.3.8 The highway drainage design would also include allowances for projected climate change (National Highways, 2022b).

Residual flood risk

10.3.9 Residual flood risks for Catchment EFR-3 along with associated mitigation measures are presented in Table 10.4.

[23] The drainage strategy is an embedded measure secured through the Design Principles (Application Document 7.5).

Table 10.4 Catchment EFR-3 – Residual risk and mitigation

Ref	Residual risk	Mitigation measures
1	Overwhelming of the highway drainage network due to a severe storm event or a blockage may lead to onsite and/or offsite flooding.	Drainage asset inspections would be undertaken in accordance with relevant provisions of DMRB GS 801. [RDWE012] A planned, risk based maintenance programme would be established in accordance with the relevant provisions of DMRB GM 701. [RDWE012] Planned maintenance interventions would ensure efficient operation of the drainage network.
2	Overtopping of the retention ponds and/or infiltration basin may occur in the event of a severe storm; this may lead to development of secondary flow paths with surface water flooding in lower-lying areas.	Drainage asset inspections would be undertaken and maintenance programmes would be established, all as described above. [RDWE012] Planned maintenance interventions would ensure efficient operation of the retention ponds and infiltration basin. Overland flow paths would be established to manage any overtopped flows. [RDWE034] [RDWE035] The retention ponds and infiltration basin have been located away from sensitive receptors to avoid potential risks resulting from residual impacts.
3	There is a risk of seepage if perched groundwater is encountered (e.g. in cuttings).	On account of their highly localised nature, identification of all occurrences of perched groundwater is difficult. If perched groundwater is encountered in cuttings, it would most likely occur as localised seepages only. Potential for groundwater seepage is inferred at the deepest cutting (A13 westbound to southbound A122 link road), over a road length of less than 100m. This residual risk would be mitigated by provision of a drainage system incorporating an appropriate edge of pavement detail, such as combined surface and sub-surface drains in line with DMRB CD 524.
4	Variable ground conditions may inhibit the operation of infiltration basins.	Mitigation measures discussed in Appendix 14.5: Hydrogeological Risk Assessment would ensure adequate operation of the infiltration basins.
5	Cuttings have the potential to alter groundwater flow direction and change the groundwater flow regime. This may lead to flooding elsewhere.	Appendix 14.5: Hydrogeological Risk Assessment indicates that the proposed cuttings are generally above the groundwater level in Catchment EFR-3. Also, groundwater collected by highway drainage would be removed or infiltrated to ground as part of the highway drainage system. Therefore, groundwater flooding would not be caused elsewhere as a consequence of the cuttings.

Ref	Residual risk	Mitigation measures
6	The use of infiltration systems in the drainage design may result in an increase in local groundwater levels due to enhanced recharge causing local groundwater flooding.	Assessment of the proposed infiltration systems, considering infiltration rates and local ground conditions, has demonstrated that mounding would not occur to unacceptable shallow levels (Appendix 14.5). The residual risk of groundwater flooding due to enhanced recharge would therefore be low, so no mitigation measures are deemed necessary.

Text box 10.1 Flood risk – Catchment EFR-3

Catchment EFR-3 would lie wholly within Flood Zone 1. There are no watercourses in this catchment and it is too high to be affected by tidal flooding.

The long term flood maps (Environment Agency, 2022c) indicate that Catchment EFR-3 lies in an area that is primarily at very low risk of surface water flooding.

Some isolated pockets of surface water flooding within the curtilage of the highway would be lost or partially lost; this may cause a minor redistribution of surface water flooding but is not considered to present a significant flood risk.

The Project may cause offsite surface water flooding in three isolated areas. A suggested mitigation strategy for each of these areas has been developed and is presented in the text above.

Surface water flood risk caused by highway runoff would be mitigated by inclusion of highway drainage provisions; these provisions would apply to all new and realigned roads in the catchment. The drainage system would include upgrading parts of the existing drainage network and the addition of new drainage elements.

Catchment EFR-3 is in an area of negligible groundwater flood risk. However, there is the potential for perched water to occur where permeable or partly permeable strata overlie less permeable strata.

There is no significant risk of flooding from sewers, water mains or reservoirs in Catchment EFR-3.

There are no flood protection measures in Catchment EFR-3.

Surface water flood risk from highway runoff would be mitigated by inclusion of highway drainage provisions; these provisions would apply to all new and realigned roads in Catchment EFR-3.

Embedded flood resilience would include application of climate change allowances in the highway drainage design.

Residual flood risks comprise the following:

- Inundation of the highway drainage system may result in onsite and/or offsite flooding.
- Overtopping of the retention ponds and/or infiltration basin may lead to localised flooding.

- Potential seepage of perched groundwater in cuttings.
- Variable ground conditions may inhibit the operation of the infiltration basin.
- Cuttings have the potential to alter the groundwater flow regime. This may lead to flooding elsewhere.
- The use of infiltration systems in the drainage design may result in an increase in local groundwater levels due to enhanced recharge.

The risk of intercepting perched groundwater would need to be managed during the construction phase of the Project. This risk could be mitigated by incorporating an appropriate edge of pavement detail (e.g. combined surface and subsurface drains).

The risk of groundwater mounding to unacceptably shallow depths is negligible.

The risk that cuttings may alter groundwater flow regime is negligible.

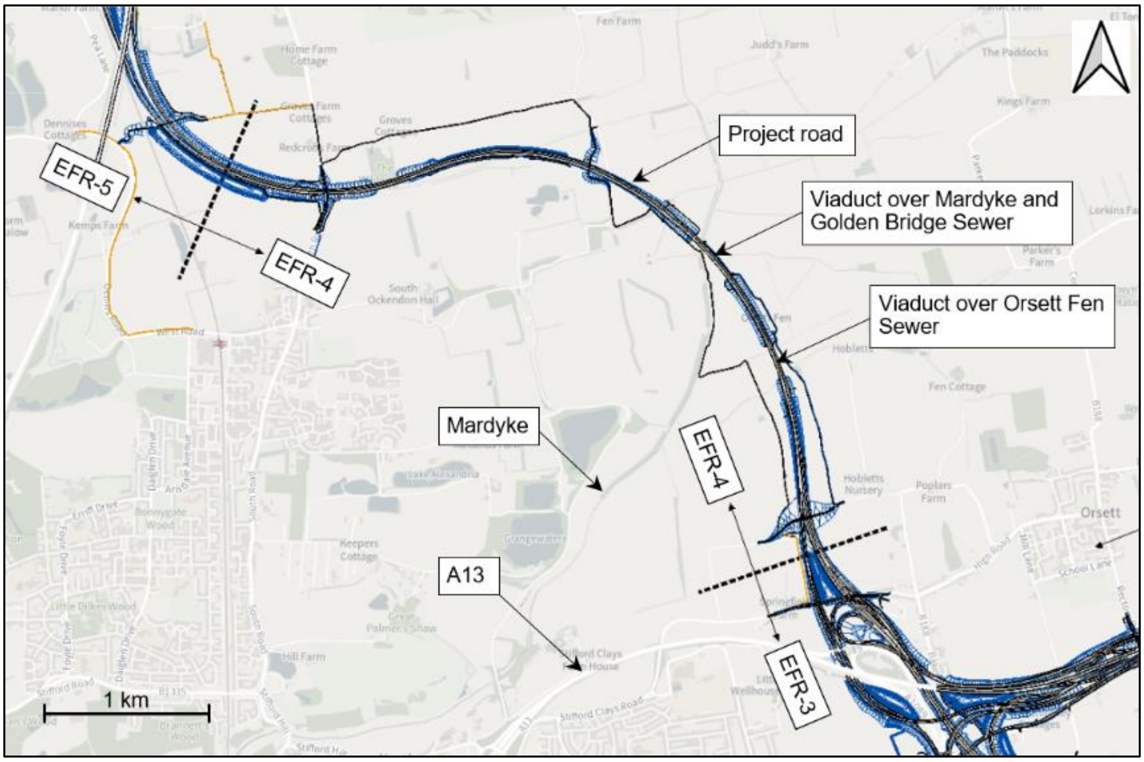
All other residual risks can be mitigated by implementation of an appropriate maintenance programme.

11 Ockendon Link (EFR-4)

11.1 Overview

11.1.1 Catchment EFR-4 comprises the section of the Project road between its junctions with the A13 and the M25. The Project road is on embankments, in cuttings and on viaducts in Catchment EFR-4. The extents and principal elements of EFR-4 are shown in Plate 11.1.

Plate 11.1 Catchment EFR-4



11.1.2 The Flood Map for Planning (Environment Agency, 2022d) shows the extents of Flood Zones 1, 2 and 3 across England and Wales. This map also shows the location of existing flood defences and areas that benefit from them. An extract from this map shows that Catchment EFR-4 falls primarily in Flood Zones 1 and 3 (see Drawing 00111). The parts of the catchment that run through Flood Zone 1 are in the naturally higher ground at its northern and southern extents. The Flood Zone 3 areas primarily comprise drained fenland (Orsett Fen).

11.1.3 As parts of the highway in Catchment EFR-4 would lie in Flood Zone 3, an Exception Test has been undertaken. On the basis that the Project constitutes essential infrastructure, and that it would provide wider sustainability benefits and be safe for its lifetime without increasing flood risk elsewhere, the provisions of the Exception Test have been met (see Section 3.5). Furthermore, the requirements of paragraph 5.109 of the NN NPS regarding essential infrastructure located in Flood Zone 3a or 3b have been met (see Section 3.5).

11.2 Site-specific flood risk

Fluvial and tidal

Sources of fluvial and tidal flooding

11.2.1 The Project road crosses three main rivers in Catchment EFR-4:

a. Mardyke

b. Orsett Fen Sewer

c. Golden Bridge Sewer

11.2.2 Orsett Fen Sewer and Golden Bridge Sewer are tributaries of the Mardyke. A fourth main river, Stringcock Sewer, flows into the Mardyke just to the north of the Project.

11.2.3 Fluvial flooding will occur when the flow through these main rivers exceeds their capacity. Tide locking at the point where the Mardyke discharges to the River Thames could exacerbate fluvial flooding. When the Mardyke is tide locked, flooding in the tributaries will also be effectively tide locked, thus further exacerbating fluvial flooding.

11.2.4 The primary tidal flood mechanism is failure of Mardyke Sluice, which may result in the rapid onset of fast flowing and deep water flooding with little or no warning. The Mardyke Sluice is a vertical hinged leaf type gate. The Environment Agency is responsible for the maintenance of the sluice.

Long-term flood risk information map

11.2.5 The long-term flood risk information map (Environment Agency, 2022c) shows the extents of fluvial and tidal flooding with existing flood defences considered. This map indicates that most of the section of Project road in Catchment EFR-4 would lie in areas that are not at risk of fluvial or tidal flooding. The exceptions to this would be where the Project road crosses the floodplains of the Mardyke, Orsett Fen Sewer and Golden Bridge Sewer. In this area, flood risk ranges from very low to high. Refer to Table 5.1 for flood risk category parameters.

11.2.6 An extract from the long-term flood risk map showing fluvial and tidal flooding in Catchment EFR-4 with existing flood defences considered, is presented in Drawing 00114.

11.2.7 The section of the Project road in Catchment EFR-4 would be on embankments and viaducts where it crosses the areas at risk of fluvial flooding. The risk of fluvial or tidal flooding along this elevated section of the Project road would be negligible. The hydraulic modelling reported in Part 4 of the FRA indicates the proposed highway will be more than 5m above the credible maximum climate change scenario.

Hydraulic modelling

11.2.8 Flood maps have been created using the hydraulic modelling undertaken for the Project.

11.2.9 These flood maps are more detailed than the long-term flood risk information map (Environment Agency, 2022c) and include climate change allowances.

11.2.10 The flood maps generated by the hydraulic model have been used to analyse pre-development and post-development fluvial flood risk in EFR-4. These flood maps have also been used to analyse the performance of flood alleviation measures.

11.2.11 Further details on the hydraulic models are included in Section 11.3 and Part 4 of the FRA.

Surface water

11.2.12 According to the long-term flood risk information map for surface water (Environment Agency, 2022c), the higher ground to the northern and southern extents of Catchment EFR-4 would be at very low risk of surface water flooding. The section of the Project road across the Mardyke floodplain would lie in areas at low, medium and high risk of surface water flooding. Refer to Table 5.1 for flood risk category parameters.

11.2.13 The Project road would be on embankments and viaducts where it crosses the area at medium and high risk of surface water flooding. These forms of construction would make the highway free from the risk of flooding from surface water.

11.2.14 Some of the isolated pockets of surface water flooding within the curtilage of the highway would be lost and some would be partially lost. Surface water draining to any lost or partially lost pockets would be collected by the highway drainage networks (i.e. it would not contribute to offsite surface water). There may be a minor redistribution of surface water flooding beyond the curtilage of the Project road embankments, but this is not considered to present a significant flood risk. Furthermore, any such redistribution would mostly lie within land for which National Highways would be seeking permanent acquisition.

11.2.15 The extents of surface water flooding in Catchment EFR-4 are shown on Drawing 00131. This drawing is based on the long-term flood risk information map for surface water (Environment Agency, 2022c).

Groundwater

Groundwater flooding records (LLFA)

11.2.16 A generic description of groundwater flood risk is provided in Thurrock Council’s (2018) Level 1 SFRA and includes reference to the BGS groundwater flooding susceptibility mapping. The Level 1 SFRA identifies susceptibility to groundwater flood risk in the southern parts of Thurrock, particularly where the Chalk Formation is covered by permeable Alluvium and River Terrace Deposits. The Aveley and Purfleet areas are mentioned specifically, but being toward the mouth of the Mardyke, these areas are unlikely to be affected by, or have an effect on, the Project.

11.2.17 Thurrock’s Level 1 SFRA provides mapping of historic flood incidents, but this does not attribute the cause of flooding and no specific incidence of groundwater flooding is identified in the vicinity of the Catchment EFR-4.

11.2.18 Preliminary Flood Risk Assessment reporting by Thurrock Council suggested that areas most likely to be susceptible to groundwater flooding are in an area between South Ockendon and Orsett. This probably coincides largely with the Mardyke floodplain (i.e. through the central part of Catchment EFR-4).

Flood risk mapping and hydrogeology

11.2.19 In the most north-westerly part of Catchment EFR-4, the GeoSmart flood risk mapping identifies the Project road to be in an area of negligible risk from groundwater flooding. Low and moderate risk of groundwater flooding is identified in the central and south-eastern parts of the catchment. As above, this source of groundwater flooding is associated with the floodplain of the Mardyke and its tributaries.

11.2.20 In this location, the superficial deposits are wholly underlain by London Clay Formation which may lead to the development of shallow groundwater. However, Phase 2 GI suggests that the Mardyke floodplain comprises thin cohesive Alluvium underlain by shallow London Clay Formation. This suggests that there is an absence of a significant shallow aquifer here and therefore a negligible risk of groundwater flooding.

11.2.21 Whilst the Chalk Formation (beneath the London Clay) beneath the central part of Catchment EFR-4 was historically confined and artesian, the thickness of the London Clay in this area is assumed to prevent any emergence of Chalk Formation aquifer groundwater.

11.2.22 The cutting at the junction between the Project road and the M25 starts at the north-western end of Catchment EFR-4 and continues into Catchment EFR-5. As the cutting primarily falls in EFR-5, associated groundwater flood risk is described in Section 12.

Impact of drainage strategy on groundwater

11.2.23 In this part of the Project, the drainage strategy would generally be based on the use of gravity systems that discharge to surface watercourses via retention ponds.

11.2.24 Drainage of small road catchments would be based on the use of swales with collected water discharged to ground (infiltration). With appropriate design, these swales would not contribute to groundwater flood risk.

11.2.25 The proposed drainage strategy for EFR-4 is detailed in Part 7 of the FRA[24].

Sewers and water mains

11.2.26 When trunk sewers are blocked or overwhelmed, they have the potential to cause flooding. When sewer rising mains are damaged or burst, they also have the potential to cause flooding. As all such assets would be diverted in advance of the works, the risk of flooding from sewers during the operation phase of Project is considered to be negligible.

11.2.27 All water mains have the potential to cause flooding if damaged or burst, with transmission mains clearly presenting the bigger risk. As all such assets would be diverted in advance of the works, the risk of flooding from water mains during the operation phase of Project is considered to be negligible.

[24] The drainage strategy is an embedded measure secured through the Design Principles (Application Document 7.5).

11.2.28 Water utility asset data in Catchment EFR-4 is shown in Drawing 00172.

Reservoirs

11.2.29 The map for long-term flood risk from reservoirs (Environment Agency, 2022c) indicates that there is reservoir flood risk in four locations. The reservoir flood risk emanates from:

a. Unnamed lake to the north-east of Grangewaters (Orsett Fen)

b. Church Lake (near Childerditch)

c. Sticking Hill Reservoir (Orsett Fen)

d. Hobletts Reservoir (Orsett Fen)

11.2.30 The extent of flooding from reservoirs in Catchment EFR-4 is shown on Drawing 00175. The locations of the reservoirs presenting the flood risk in Catchment EFR-4 are shown on Drawings 00175 and 00176.

11.2.31 The areas at risk of flooding following a breach are undeveloped (rural) and are only inhabited on an occasional basis. In accordance with the Environment Agency's Policy paper on Reservoir offences (2020), this would constitute a Category C breach (see Table 5.4).

11.2.32 The flooding follows the local watercourses so the areas at risk for the Project road would be where it crosses the Mardyke, Golden Bridge Sewer and Orsett Fen Sewer.

11.2.33 At the crossing points, the Project road would be on viaducts or embankments. The risk of flooding due to a reservoir breach along these elevated sections of the Project road would be negligible.

11.3 Flood analysis

General

11.3.1 A hydraulic model was developed for the analysis of flooding in Catchment EFR-4. A precis of the modelling is presented below.

11.3.2 Further details regarding the hydraulic modelling in Catchment EFR-4 are presented in Part 4 of the FRA.

11.3.3 Peak river flow allowances (climate change) used in the simulations are described in Section 4.4.

11.3.4 The simulations considered the pre- and post-development cases. The post-development case was simulated both without and with mitigation measures.

Credible maximum scenarios

11.3.5 The climate change analysis for flood risk assessment (Environment Agency, 2022a) requires that credible maximum scenarios should be considered for NSIPs.

11.3.6 The current climate change guidance (Environment Agency, 2022a) stipulates that upper end peak river flow allowances, and H++ sea level rise and storm surge allowance, should be applied to represent a credible maximum climate change scenario. The upper end peak river flow allowance for the Project in 2130 is +48%. The H++ sea level rise and storm surge allowance give a credible maximum sea level rise and storm surge allowance of +2.13m at Southend in 2130 relative to 2017.

11.3.7 At the Mardyke and its floodplain, the Project road would be more than 5m above the flood level during the credible maximum climate change scenario. The Project road would therefore remain operational during this event.

Project (onsite) fluvial flooding

11.3.8 Fluvial flooding modelling for the Project considered the 50%, 10%, 4%, 1% and 0.1% AEP events with storm area and critical duration for the flood estimation points (FEP) at Stifford Gauging Station and Orsett Fen. These storm events were selected to represent critical events in terms of peak flood levels in the Mardyke and Orsett Fen catchments. Further details are in Part 4 of the FRA.

11.3.9 The higher central peak river flow allowances have been applied to these events (+11% in 2030 and +26% in 2130) in accordance with current guidance (Environment Agency, 2022a).

11.3.10 As noted above, the Project road would remain operational during the credible maximum climate change scenario. This satisfies requirements of the current climate change guidance for NSOPs (Environment Agency, 2022a).

11.3.11 As the Project will remain operational for the 0.1% AEP event with +48% peak river flow allowances, it can be concluded that the Project will also remain operational for the other (smaller) events.

Offsite fluvial flooding

11.3.12 Depth difference plots for the 1% AEP event in 2130 with the +26% higher central peak river flow allowance applied demonstrate that the offsite impacts of the design, without mitigation, do not affect any essential infrastructure. On this basis, and in accordance with Environment Agency guidelines (2022a), central peak river flow allowances (+6% in 2030 and +17% in 2130) have been used to assess the offsite impacts and fluvial floodplain compensation requirements.

11.3.13 The depth difference plots for the 10%, 4% and 1% AEP events in 2030 with +6% central peak river flow allowance applied and in 2130 with a +17% central peak river flow allowance applied, demonstrate that the mitigation measures and floodplain compensation specified provide the required mitigation and compensation.

Breach analysis

11.3.14 The hydraulic mode was used to simulate a breach of River Thames tidal flood defences at Mardyke Sluice.

11.3.15 Simulation results indicate that following a breach at Mardyke Sluice during the 0.1% AEP River Thames tidal event in 2130, flooding remains in channel at the point where the Project road crosses the Mardyke. As the flooding remains in channel for this event, it will have no impact on the Project and the Project will have no impact on breach flood risk elsewhere.

11.3.16 Further details regarding the hydraulic modelling of the impacts of a breach at Mardyke during tidal flooding on Catchment EFR-4 are presented in Part 5 of the FRA.

Residual uncertainties allowance

11.3.17 A 600mm freeboard is stipulated in DMRB CD 356 (Highways England, 2020d). For the viaducts, the freeboard is measured from the peak water level to the viaduct soffit. As the Project road is more than 5m above the 0.1% AEP flood level in 2130 with the upper end peak flow allowance, this freeboard requirement can be assumed to be fulfilled.

Residual risks

11.3.18 In addition to the above, simulations were undertaken to assess residual flood risks to the Project. The residual risks simulated include the following:

a. Failure of Mardyke Sluice gate with the gate assumed to be stuck fully open and fully closed

b. Breach of River Thames tidal flood defences at Mardyke Sluice

11.3.19 The design simulations show that the proposed mitigation measures would fully mitigate offsite impacts for all events up to the 1% AEP fluvial flood in 2130 with climate change allowances, such that any increased flood risk is limited to land for which National Highways will be seeking permanent acquisition.

11.3.20 Full details of the hydraulic model for EFR-4 are included in Part 4 of the FRA. The flood mapping outputs from the hydraulic models are included in Part 9 of the FRA.

11.4 Flood risk management strategy

Flood mitigation measures

Compensatory flood storage areas (essential mitigation)

11.4.1 It would be necessary to provide compensatory flood storage to offset the volume of existing floodplain storage displaced by the Project. [RDWE037]

11.4.2 The CFSAs would be in locations hydraulically connected to the displaced floodplain storage. Furthermore, the displaced floodplain volumes would be replaced on a level-for-level basis.

11.4.3 The compensatory flood storage would be developed in conjunction with the restoration of a wetland in Orsett Fen (Mardyke Wetland)[25].

11.4.4 The area in which compensation would be formed is shown on Drawing 00181. Further details of the flood compensation area and an example of how the required compensation could be achieved, are included in Part 4 of the FRA.

[25] Restoration of the wetland is an embedded measure secured through the Design Principles (Application Document 7.5).

11.4.5 The CFSA would need to be able to function before there is any permanent or temporary loss in floodplain storage. This would be accounted for in the construction programme[26].

Flood relief channel (essential mitigation)

11.4.6 The embankment supporting part of the Project road would intercept an overland flow path across the Mardyke floodplain. To ensure that connectivity is retained across the floodplain, a flood relief channel would be formed immediately to the west of the Mardyke at the point it crosses under the proposed viaduct. The channel is shown on Drawing 00181. [RDWE040]

11.4.7 The channel would be approximately 10m wide and run for approximately 180m. The depth would vary and would be approximately 0.6m at its deepest.

11.4.8 The hydraulic model for the Mardyke was used to develop and test this measure. Further details of the hydraulic modelling are included in Part 4 of the FRA.

Altering the floodplain (essential mitigation)

11.4.9 The restoration of the Mardyke wetland and creation of the water vole habitat may result in the formation of a new flow path between Golden Bridge Sewer and the Mardyke during some storm events. To prevent the formation of a new flow path and maintain the local flow pattern between Golden Bridge Sewer and the Mardyke, a bund would be formed on the eastern side of the wetland. The bund would be approximately 185m long and would have a maximum elevation of approximately 3.64mAOD. The bund is shown on Drawing 00181. [RDWE039]

11.4.10 The hydraulic model for the Mardyke was used to develop and test this measure. Further details of the hydraulic modelling are included in Part 4 of the FRA.

Highway drainage (embedded mitigation)

11.4.11 The drainage strategy in EFR-4 is based primarily on the use of gravity systems that discharge to watercourses via retention ponds.

11.4.12 Surface water flood risk from highway runoff would be mitigated by inclusion of highway drainage provisions; these provisions would apply to all new and realigned roads in Catchment EFR-4. The surface water drainage provisions would prevent flooding in the highway without increasing risk elsewhere.

11.4.13 Surface water drainage provisions are detailed in Part 7 of the FRA[27].

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[26] The Contractor could elect to adopt a phased approach to the provision of the CFSA; with this approach, the volume of storage made available would be increased in stages to suit the compensation needs of the construction programme. The Contractor may also elect to mobilise temporary compensation during the construction phase of the Project.

[27] The drainage strategy is an embedded measure secured through the Design Principle LSP.28 ad LSP.30 (Application Document 7.5).

Wetland restoration

11.4.14 The Project would include restoration of a wetland in Orsett Fen (Mardyke Wetland)[28]. In addition to providing part of the flood compensation requirement for Catchment EFR-4, this wetland may also mitigate flood risk further down the Mardyke. As well as the biodiversity benefits of a wetland and the flood mitigation it provides, the wetland would also form part of the Project's ecological mitigation measures by creating a habitat suitable for reintroduction of water voles.

Flood protection measures

11.4.15 There is no requirement to provide flood protection measures in Catchment EFR-4.

Flood resilience measures

Road geometry (embedded resilience)

11.4.16 The hydraulic modelling reported in Part 4 of the FRA indicates the proposed highway would be more than 5m above the credible maximum climate change allowance.

Maintenance (essential resilience)

11.4.17 Flood mitigation measures and drainage infrastructure and treatment systems would be inspected and maintained in accordance with the relevant provisions of DMRB GS 801 (Highways England, 2020b) and DMRB GM 701 (Highways England, 2020c), to ensure they continue to operate to their design standard. [RDWE012]

Climate change allowances (essential resilience)

11.4.18 The design of the compensatory flood storage, the bund to prevent formation of a new flow path and the flood relief channel would all be designed to include allowances for projected climate change. [RDWE037] [RDWE039] [RDWE040]

11.4.19 The highway drainage design would also include allowances for projected climate change (National Highways, 2022b).

11.4.20 The climate change allowances for the water environment that would be applied to the Project are detailed in Section 4.7.

Residual flood risk

11.4.21 Residual flood risks for EFR-4 along with associated mitigation measures are presented in Table 11.1.

[28] Restoration of the wetland and creation of water vole habitat are embedded measures secured through the Design Principles (Application Document 7.5).

Table 11.1 Catchment EFR-4 – Residual risk and mitigation

Ref	Residual risk	Mitigation measures
1	Overwhelming of the highway drainage network due to a severe storm event or a blockage may lead to onsite and/or offsite flooding.	Drainage asset inspections would be undertaken in accordance with relevant provisions of DMRB GS 801. [RDWE012] A planned, risk based maintenance programme in accordance with the relevant provisions of DMRB GM 701 would be established. [RDWE012] Planned maintenance interventions would ensure efficient operation of the drainage network.
2	Overtopping of the retention ponds may occur in the event of a severe storm; this may lead to development of secondary flow paths with surface water flooding in lower-lying areas.	Drainage asset inspections would be undertaken and maintenance programmes would be established, all as described above. [RDWE012] Planned maintenance interventions would ensure efficient operation of the retention ponds. Overland flow paths would be established to manage any overtopped flows. [RDWE035] The retention ponds have been located away from sensitive receptors to avoid potential risks resulting from residual impacts.
3	Overtopping of the flood compensation area may occur in the event of a severe storm; this may lead to development of secondary flow paths with surface water flooding in lower-lying areas.	Floodplain compensation areas have been located away from sensitive receptors to avoid potential risks resulting from residual impacts.
4	Failure of the connectivity channel to convey flows	A planned, risk based maintenance programme would be established. [RDWE012] Periodic maintenance would be required to ensure that the channel is kept operational and clear of obstructions.
5	Reservoir breach	Reservoir safety is regulated through the Reservoirs Act 1975, as amended by the Flood and Water Management Act 2010. The Reservoirs Act 1975 requires that large reservoirs be inspected at least every 10 years by specially licensed civil engineers. The reservoir owner must act on any '*measures in the interests of safety*' identified in an inspection report. It is assumed that the reservoirs that would be a flood risk to the Project are operated in line with reservoir safety legislation.

Ref	Residual risk	Mitigation measures
6	There is a risk of seepage if perched groundwater is encountered (e.g. in cuttings).	On account of their highly localised nature, identification of all occurrences of perched groundwater is difficult. If perched groundwater is encountered in cuttings, it would most likely occur as localised seepages only. This residual risk would be mitigated by provision of a drainage system incorporating an appropriate edge of pavement detail, such as combined surface and sub-surface drains in line with DMRB CD 524.
7	Cuttings have the potential to alter groundwater flow direction and change the groundwater flow regime. This may lead to flooding elsewhere.	Appendix 14.5: Hydrogeological Risk Assessment indicates that the proposed cuttings are above the groundwater level in Catchment EFR-4. Given the level of the cuttings in relation to groundwater level, the likelihood of groundwater flooding elsewhere is negligible. Details of groundwater flooding in the cutting at the junction between the Project road and the M25 is included in Section 12 (EFR-5).
8	Failure of sluice gate with the gate assumed to be stuck fully open and fully closed.	Simulation results from the hydraulic modelling indicated that, for a 1% AEP event with climate change allowances and the sluice gate fully closed, the difference in peak flood level would be negligible (± 10mm), and with the sluice gate stuck fully open, the difference in peak flood level would be minor adverse (>10mm and <50mm).
9	Breach of River Thames tidal flood defences at Mardyke Sluice.	Breach of the River Thames tidal flood defences at Mardyke Sluice have been simulated using the hydraulic model. The simulation results indicate that following a breach at Mardyke Sluice during the 0.1% AEP event with climate change allowances in 2130, flooding would remain in channel in Catchment EFR-4.

Text box 11.1 Flood risk – Ockendon Link (EFR-4)

EFR-4 would lie in Flood Zone 1 except where the Project road crosses the Mardyke floodplain, which is predominantly Flood Zone 3. Fluvial flooding would occur when the flow through the Mardyke, Golden Bridge Sewer and/or Orsett Fen Sewer exceeds its channel capacity.

Mitigation measures for fluvial flooding would include provision of a flood relief channel under the Project road to maintain connectivity through the Mardyke floodplain, altering the floodplain locally to prevent the creation of a new flow path (ground raising); and provision of floodplain compensation areas to replace floodplain displaced by the Project road embankment, bridge piers and ground raising.

In the northern and southern extents of Catchment EFR-4, there would be a very low risk of surface water flooding. The section of the Project road across the Mardyke floodplain would lie in areas at low, medium and high risk of surface water flooding. As the Project road would either be on embankments or viaducts where it crosses the Mardyke floodplain, surface water risk would be negligible.

There is unlikely to be a risk of groundwater flooding where the Project road crosses the Mardyke floodplain. In the northern and southern extents of Catchment EFR-4, there is the potential for perched water to occur where permeable or partly permeable strata overlie less permeable strata. However, a drainage system incorporating an appropriate edge of pavement detail, such as combined surface and sub-surface drains, would mitigate this flood risk.

A highway drainage system would be included to mitigate flooding of the Project road.

There is no significant risk of flooding from sewers, water mains or reservoirs in Catchment EFR-4.

Flood resilience is provided by making allowance for climate change in the sizing of the compensatory flood storage areas, flood relief channel, the bund to prevent formation of a new flow path and the highway drainage design. Resilience of the highway is also achieved by elevating it where it crosses the Mardyke floodplain.

Residual flood risks include the following:

- Inundation of the highway drainage system may result in onsite and/or offsite flooding.
- Overtopping of the retention ponds may lead to localised flooding.
- Inundation of the compensatory flood storage area may lead to localised flooding.
- Potential seepage of perched groundwater in cuttings.
- Failure of the connectivity channel to convey flows.
- Reservoir breach.
- Failure of Mardyke Sluice gate.
- Breach of River Thames tidal flood defences at Mardyke Sluice.

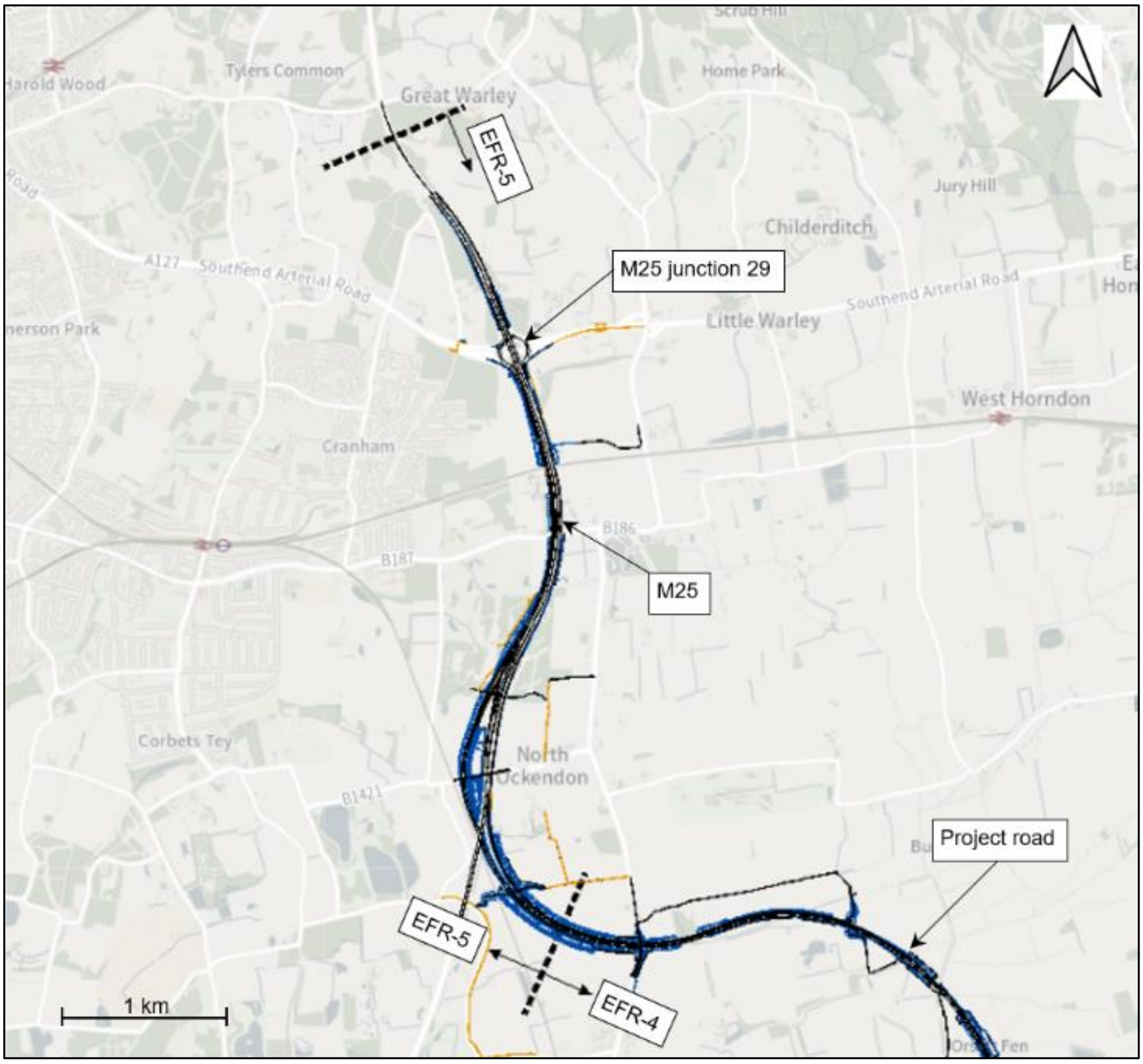
The risk of intercepting perched groundwater would need to be managed during the construction phase of the Project. This risk would be mitigated by incorporating an appropriate edge of pavement detail (e.g. combined surface and subsurface drains). Flood risk due to a reservoir breach is relatively minor provided that the regulatory inspection requirements are undertaken and any necessary remedial measures are actioned. Flood risk due to failure of Mardyke Sluice would be low. In the stuck fully open position, flood risk to the Project would be negligible. In the stuck fully closed position, flood risk to the Project would be minor adverse. Flood risk to the Project from a tidal breach at Mardyke Sluice would be low as flood flows resulting from a breach would remain in channel. All other residual risks can be mitigated by implementation of an appropriate maintenance programme.

12 North Section and M25 junction (EFR-5)

12.1 Overview

12.1.1 Catchment EFR-5 comprises the sections of the Project road between its junction with the M25 and M25 junction 29. The Project road is on embankments, in cuttings and on viaducts in Catchment EFR-5. The extents and principal elements of EFR-5 are shown in Plate 12.1

Plate 12.1 Catchment EFR-5



12.1.2 The Flood Map for Planning (Environment Agency, 2022d) shows the extents of Flood Zones 1, 2 and 3 across England and Wales. An extract from this map detailing flood zone extents in Catchment EFR-5 is shown on Drawing 00112. In Catchment EFR-5, the Project road would generally lie in Flood Zone 1 but a small section that crosses the West Mardyke would lie in Flood Zones 2 and 3.

12.1.3 As parts of this section of Catchment EFR-5 would lie in Flood Zone 3, an Exception Test has been undertaken. On the basis that the Project constitutes essential infrastructure, and that it would provide wider sustainability benefits and be safe for its lifetime without increasing flood risk elsewhere, the provisions of the Exception Test would be met (see Sections 3.4 and 3.5).

Furthermore, the requirements of paragraph 5.109 of the NN NPS regarding essential infrastructure located in Flood Zone 3a or 3b would be met (see Section 3.5).

12.2 Site-specific flood risk

Fluvial

12.2.1 The Project crosses one main river in Catchment EFR-5 (West Mardyke).

12.2.2 Fluvial flooding would occur when the flow through the West Mardyke exceeds its capacity.

12.2.3 The long-term flood risk information map for rivers or the sea (Environment Agency, 2022c) indicates that in Catchment EFR-5, the Project road would lie in areas that are predominantly at very low and low risk of fluvial flooding. The exception to this is where the Project road crosses the West Mardyke floodplain; in this section, the Project road lies in areas at low, medium and high risk of fluvial flooding.

12.2.4 An extract of the map showing the extents of fluvial flooding in Catchment EFR-5 is presented in Drawing 00115.

12.2.5 The Project road would be on embankments where it crosses the areas at medium and high risk of fluvial flooding. This form of construction would reduce the risk of fluvial flooding to negligible.

Surface water (pluvial)

12.2.6 The map for long-term flood risk from surface water (Environment Agency, 2022c) indicates that this catchment lies in an area that is primarily at very low risk of surface water flooding. However, there are some areas at low, medium and high risk of surface water flooding; these generally fall within the West Mardyke floodplain.

12.2.7 An extract of the map showing the extents of fluvial flooding in Catchment EFR-5 is presented in Drawing 00132.

12.2.8 HADDMS indicates that there have been two historical flooding incidents on the section of the M25 that would be upgraded as part of the Project. The first of these events occurred in November 2009 at a location approximately 900m south of M25 junction 29 and was of low severity. The second occurred in May 2010 at a location approximately 2.5km south of M25 junction 29, and was of moderate severity.

Groundwater

Groundwater flooding records (LLFA)

12.2.9 This catchment is covered by the London Borough of Havering’s (2016) Level 1 SFRA. The Level 1 SFRA includes the Environment Agency groundwater flood susceptibility mapping that indicates that within most of the route footprint, including the area from Orsett Fen to just south of the A127, groundwater flooding from superficial deposits may represent a risk (in 75% of most of the 1km squares mapped). The Level 1 SFRA also maps groundwater flood records that show groundwater flood incidents at Great Warley Hall (east of M25 junction 29, just south of the A127) in September 2005 and near Heron Way, Cranham (January 2005). No further details are provided for these incidents in the Level 1 SFRA.

12.2.10 The Preliminary Sources Study Report Addendum (Highways England, 2018) records a verbal communication with the London Borough of Havering regarding an incident of groundwater flooding that occurred around Stubbers Adventure Centre (west of the M25 junction 29). No further information on this incident has been forthcoming, although this is likely to relate to movement of shallow groundwater through the Lynch Hill Gravel Member (River Terrace Deposits). In this location the gravels are wholly underlain by London Clay Formation which may lead to the development of shallow groundwater within the superficial deposits. This area appears to be at the top end of the catchment on a tributary of the River Ingrebourne and may be poorly drained which could lead to local waterlogging and flooding from groundwater.

Flood risk mapping and hydrogeology

12.2.11 For most of EFR-5, the GeoSmart flood risk mapping identifies the Project to be in an area of negligible risk from groundwater flooding (predominantly of low risk). Through the central part of the catchment, and more or less coincident with the fluvial water flood risk associated with the West Mardyke, there are areas identified as low flood risk (moderate risk in the extreme east). These areas are underlain primarily by Alluvium, where shallow groundwater may occur. Such shallow groundwater may be intersected by cuttings. Throughout this section, the underlying bedrock comprises the largely impermeable London Clay Formation, so groundwater flooding from bedrock is unlikely to occur. Whilst the Chalk Formation (beneath the London Clay) beneath the central part of this area was historically confined and artesian, the thickness of the London Clay in this area is assumed to prevent any emergence of Chalk Formation groundwater.

12.2.12 Phase 2 Ground Investigation has confirmed the presence of River Terrace Deposits at the proposed location of the cutting at the new junction with the M25. These deposits include granular materials. Groundwater monitoring has confirmed these deposits are water bearing with levels shallower than the proposed cutting. Appendix 14.5: Hydrogeological Risk Assessment presents a groundwater model of the potential effects on the groundwater levels and shows drawdown towards the cutting. Measures to reduce groundwater drawdown beyond the M25 cutting (eg through the implementation of seepage control) would be required [RDWE038]. The final measures would be confirmed and its effectiveness, during both construction and operation, demonstrated in consultation with the Environment Agency. Details of the groundwater modelling are shown in Appendix 14.5: Hydrogeological Risk Assessment.

Impact of drainage strategy on groundwater

12.2.13 In this part of the Project, the drainage strategy would combine existing M25 drainage, which would be retained or upgraded, and new drainage networks. The drainage is primarily based on the use of edge of pavement collection with piped systems that discharge to surface watercourses via retention ponds.

12.2.14 The design does not include any drainage systems that rely on infiltration for disposal of runoff and, as such, would be unlikely to contribute to groundwater flooding.

Sewers and water mains

12.2.15 When trunk sewers are blocked or overwhelmed, they have the potential to cause flooding. When sewer rising mains are damaged or burst, they also have the potential to cause flooding. As all such assets would be diverted in advance of the works, the risk of flooding from sewers during the operational phase of Project is considered to be negligible.

12.2.16 All water mains have the potential to cause flooding if they are damaged or burst, with transmission mains clearly presenting the bigger risk. As all such assets would be diverted in advance of the works, the risk of flooding from water mains during the operational phase of the Project is considered to be negligible.

12.2.17 Water utility asset data in Catchment EFR-5 is shown in Drawing 00173.

Reservoirs

12.2.18 The map for long-term flood risk from reservoirs (Environment Agency, 2022c) indicates that the catchment is not in an area at risk from reservoir flooding.

12.2.19 Flood risk from reservoirs is shown on Drawing 00176.

12.3 Flood risk management strategy

Fluvial flood levels

12.3.1 The Product 4 data provided by the Environment Agency (2018b) includes flood level data for the main rivers in Orsett Fen.

12.3.2 The flood level data for the West Mardyke incudes nodes at the upstream and downstream ends of the culvert that crosses under the M25. Table 12.1 shows the flood levels for a number of storm events at these two nodes.

Table 12.1 Flood levels at M25 crossing

Node	Location	Flood level (mAOD)		
		AEP 1% (1:100)	AEP 1% (1:100+20%)	AEP 0.1% (1:1,000)
MTRB08_2183	M25 crossing upstream of culvert	8.20	8.26	8.48
MTRB08_2138	M25 crossing downstream of culvert	8.19	8.23	8.41

Flood mitigation measures

Compensatory flood storage areas (essential mitigation)

12.3.3 As EFR-5 includes development in the floodplain, it would be necessary to provide compensatory flood storage to offset the volume of existing floodplain storage that is lost to the Project. [RDWE037]

12.3.4 The work in Flood Zone 3 comprises the following elements of the Project:

a. A new slip road on to the M25

b. A widened section of the M25

12.3.5 An area has been identified for the provision of compensatory flood storage. This area is shown on Drawing 00182.

12.3.6 The compensatory flood storage area for Catchment EFR-5 would be a conventional type of CFSA. [RDWE037]

12.3.7 The CFSA would be available to function before floodplain storage volume is lost (i.e. the volume of compensatory flood storage available at any point in time would equal, or surpass, the compensatory storage volume required).

12.3.8 An example of how the required compensatory flood storage could be achieved is detailed in Annex A.

Reducing flood risk overall

12.3.9 In addition to the CFSA described above, further compensation would be provided by widening the channel of the West Mardyke upstream of the culvert.

12.3.10 This widening would only provide compensation for relatively minor flooding events. Its main purpose would be to try to keep flows in the West Mardyke in channel during storm events. The long-term flood risk information map (Environment Agency, 2022c) suggests that some reaches of the West Mardyke upstream of the culvert, flow out of channel. Widening a length of the West Mardyke would not solve upstream flood risk but would afford some mitigation. [RDWE037]

12.3.11 This compensatory flood storage area is shown on Drawing 00182.

Highway drainage

12.3.12 Surface water flood risk from highway runoff would be mitigated by inclusion of highway drainage provisions; these provisions would apply to all new and realigned/reconfigured roads in Catchment EFR-5. The surface water drainage provisions would prevent flooding in the highway without increasing risk elsewhere.

12.3.13 Further details of the surface water drainage provisions are included in Part 7[29] of the FRA.

12.3.14 The existing retention ponds in EFR-5 lie in the London Borough of Havering but flows discharged from them flow into Thurrock via the Western Mardyke. Following discussions with Essex County Council it was agreed that discharge rates from the existing motorway networks that discharge flows to Thurrock should be reduced by at least 50%[30]. This reduced discharge would mitigate flooding along the Mardyke and some of its tributaries. [RDWE035]

[29] The drainage strategy is an embedded measure secured through the Design Principle LSP.29 and LSP.30 (Application Document 7.5).

[30] In the interests of improving flood protection, Essex County Council has developed a policy for existing developments stating that during any proposed works, existing discharge rates should be reduced to 50% of the current flow rate or better.

Flood protection measures

12.3.15 There is no requirement to provide flood protection measures in Catchment EFR-5.

Flood resilience measures

Road geometry (embedded mitigation)

12.3.16 The minimum level of the Project road at the point where it crosses the West Mardyke would be several metres above the 1% AEP fluvial flood level (design flood) for 2130 with river flow allowances applied. This will reduce fluvial, surface water and groundwater flood risk to negligible levels.

Maintenance (essential resilience)

12.3.17 Flood mitigation and protection measures, and drainage infrastructure, flood alleviation measures and treatment systems would be inspected and maintained in accordance with the relevant provisions of DMRB GS 801 (Highways England, 2020b) and DMRB GM 701 (Highways England, 2020c), to ensure they continue to operate to their design standard. [RDWE012]

Climate change

12.3.18 The design of the compensatory flood storage would be designed to include allowances for projected climate change. [RDWE037]

12.3.19 The highway drainage design would also include allowances for projected climate change (Design Principles, Application Document 7.5).

12.3.20 The climate change allowances for the water environment that would be applied to the Project are detailed in Section 4.7.

Residual flood risk

12.3.21 Residual flood risks for EFR-5 along with associated mitigation measures are presented in Table 12.2.

Table 12.2 Catchment EFR-5 – Residual risk and mitigation

Ref	Residual risk	Mitigation measures
1	Overwhelming of the highway drainage network due to a severe storm event or a blockage, may lead to onsite and offsite flooding.	Drainage asset inspections would be undertaken in accordance with relevant provisions of DMRB GS 801. [RDWE012] A planned, risk based maintenance programme in accordance with the relevant provisions of DMRB GM 701 would be established. [RDWE012] Planned maintenance interventions would ensure efficient operation of the drainage network. Overland flow paths would be established to manage exceedance flows.
2	Overtopping of the retention ponds may occur in the event of a severe storm; this may lead to development of secondary flow paths with surface water flooding in lower-lying areas.	Drainage asset inspections would be undertaken and maintenance programmes would be established, all as described above. [RDWE012] Planned maintenance interventions would ensure efficient operation of the retention ponds.

Ref	Residual risk	Mitigation measures
		Overland flow paths would be established to manage any overtopped flows. [RDWE035] The retention ponds have been located away from sensitive receptors to avoid potential risks resulting from residual impacts.
3	Overtopping of the flood compensation area may occur in the event of a severe storm; this may lead to development of secondary flow paths with surface water flooding in lower-lying areas.	Floodplain compensation areas have been located away from sensitive receptors to avoid potential risks resulting from residual impacts.
4	There is a risk of seepage if perched groundwater is encountered (e.g. in cuttings).	On account of their highly localised nature, identification of all occurrences of perched groundwater is difficult. If perched groundwater is encountered in cuttings, it would most likely occur as localised seepages only. This residual risk would be mitigated by provision of a drainage system incorporating an appropriate edge of pavement detail, such as combined surface and sub-surface drains in line with DMRB CD 524.

Text box 12.1 Flood risk – North Section (EFR-5)

There is no significant risk of flooding from groundwater, sewers, water mains or reservoirs in Catchment EFR-5.

Mitigation of fluvial flooding in Catchment EFR-5 would be achieved by provision of compensatory flood storage areas.

Mitigation of surface water flooding in Catchment EFR-5 would be achieved by provision of a highway drainage system and reducing discharge rates from existing retention ponds that drain to the West Mardyke.

Flood resilience is provided by making allowance for climate change in the sizing of the compensatory flood storage areas and the highway drainage design.

Residual flood risks include the following:

- Inundation of the highway drainage system may result in onsite and/or offsite flooding.
- Overtopping of the retention ponds may lead to localised flooding.
- Inundation of the compensatory flood storage area may lead to localised flooding.
- Potential seepage of perched groundwater in cuttings.
- Encountering groundwater in deep cuttings.
- Cuttings may interrupt groundwater flow and change the groundwater flow regime.

The risk of intercepting perched groundwater would need to be managed during the construction phase of the Project. This risk would be mitigated by incorporating an appropriate edge of pavement detail (e.g. combined surface and subsurface drains).

The risk of encountering groundwater in deep excavations would also be mitigated by incorporating an appropriate edge of pavement detail.

The risk that cuttings may alter groundwater flow regime is negligible.

All other residual risks can be mitigated by implementation of an appropriate maintenance programme.

13 Combined flood events

13.1 Introduction

13.1.1 Two flood events resulting from combined sources of flooding have been considered for the Project:

a. Combined tidal and fluvial events

b. Combined fluvial and urban pluvial events

13.1.2 These combined events are detailed below. Further details of the hydraulic modelling can be found in Part 4 (Mardyke) and Part 5 (West Tilbury Main) of the FRA.

13.2 Combined tidal and fluvial events

Mardyke

13.2.1 The Mardyke Sluice is designed to prevent River Thames tide events from propagating upstream in the Mardyke.

13.2.2 The sensitivity of fluvial flooding to River Thames tide conditions was tested with the hydraulic model. Modelling simulations indicated that fluvial flooding in the Mardyke floodplain in the vicinity of the Project road is not sensitive to River Thames tide conditions.

13.2.3 Based on the above, combined fluvial and tidal events in the Mardyke were not considered further.

Tilbury

13.2.4 Bowaters Sluice is designed to prevent River Thames tide events from propagating upstream in the West Tilbury Main.

13.2.5 The West Tilbury Main fluvial modelling assumes that Bowaters Sluice is fully blocked (i.e. the simulations represent a worst case, such that the outfall is permanently tide locked), so River Thames tide conditions do not influence model results.

13.2.6 Based on the above, combined fluvial and tidal events in the West Tilbury Main were not considered further.

13.3 Combined fluvial and urban pluvial events

Mardyke

13.3.1 For the Project road, the critical duration for fluvial flood events in the Mardyke catchment is 30 hours. At Stifford Gauging Station, the critical duration for fluvial flood events is 36 hours.

13.3.2 The Mardyke model catchment inflows for fluvial design events represent the influence of urbanisation on fluvial flooding through specification of subcatchment urbanisation in the Flood Estimation Handbook (FEH) (Centre for Ecology and Hydrology, 1999) rainfall-runoff model inflows. Typically, critical durations for urban flood events due to the exceedance of urban drainage capacity are much shorter (eg 30 minutes).

13.3.3 As the mechanisms for long and short-duration extreme design events are typically different (e.g. catchment-wide frontal long-duration event, and short-duration convective storm), there is expected to be only a weak dependence between the occurrence of long and short-duration storms.

13.3.4 Therefore, the occurrence of a short-duration extreme design storm during a longer-duration extreme fluvial design event would have a much lower occurrence probability than the occurrence of the individual events alone. On this basis, joint fluvial and urban pluvial events were not considered further.

Tilbury

13.3.5 Applying the FEH classification of urbanisation, the West Tilbury Main catchment is Essentially Rural and so urban runoff contributions to fluvial events are insignificant.

13.3.6 On this basis, combined fluvial and urban pluvial events in the West Tilbury Main were not considered further.

Text box 13.1 Combined flood events

The hydraulic modelling undertaken for the FRA considers flood risk for the following flood source combinations:

- Combined tidal and fluvial events
- Combined fluvial and urban pluvial events
- An assessment of these combined events found the following:
- Fluvial flooding in the Mardyke floodplain in the vicinity of the Project road is not sensitive to River Thames tide conditions.
- The West Tilbury Main fluvial modelling assumes that Bowaters Sluice is fully blocked, so River Thames tide conditions do not influence model results.
- The Mardyke model catchment inflows for fluvial design events represent the influence of urbanisation on fluvial flooding. The mechanisms for long (fluvial) and short-duration extreme design events (exceedance of urban drainage) are typically different. There is expected to be only a weak dependence between the occurrence of long and short-duration storms. The occurrence of a short-duration extreme design storm during a longer-duration extreme fluvial design event would have a much lower occurrence probability than the occurrence of the individual events alone.
- West Tilbury Main catchment is Essentially Rural and so urban runoff contributions to fluvial events are insignificant.

14 Thames Estuary 2100 Plan

14.1 Introduction

14.1.1 The TE2100 Plan (Environment Agency, 2012) is the Environment Agency's long-term strategy for managing tidal flood risk in the Thames Estuary.

14.1.2 The TE2100 Plan splits the Thames Estuary into a number of policy units and proposes a flood risk policy for each unit. Table 14.1 details the policy units for lengths of the Thames Estuary of interest to the Project.

Table 14.1 TE2100 policy units and policies

Policy unit	TE2100 policy
North Kent Marshes (Catchment EFR-1)	Continue with existing or alternative actions to manage flood risk. Continue to maintain flood defences at their current level accepting that the likelihood and/or consequences of a flood will increase because of climate change.
East Tilbury and Mucking Marshes (Catchment EFR-2)	
Purfleet, Grays and Tilbury (Catchment EFR-2)	Take further action to keep up with climate and land use change so that flood risk does not increase.

Notes.
The data in this table is based on the TE2100 Plan.
The 'Purfleet, Grays and Tilbury' unit includes West Tilbury Marshes.
The tidal defences to the east of Bowaters Sluice are in the Purfleet, Grays and Tilbury policy unit.
Coalhouse Point Wetland would lie outside of the TE2100 policy units. The TE2100 Plan does not allocate a floodplain management strategy for the area in which it would lie. Further details of the Coalhouse Point Wetland are included in Section 15.2.

14.1.3 The status of the proposed work under the TE2100 Plan is conceptual so any potential benefits it could bring would not be considered for the Project. An FRA can only consider existing development, development under construction (or demolition) and development with planning permission that is due to start imminently[31].

14.2 Impact of the Project

14.2.1 The Project has been reviewed with regard to its potential impact on the TE2100 Plan. The review concluded that the ability to implement the TE2100 Plan would not be affected by the Project. The finding of this review is detailed in Table 14.2.

[31] The FRA allows for TE2100 policy when considering breach flood risk, When assessing breach flows, the FRA assumes that flood defences will be increased in line with the TE2100 policy. See Annex E of Part 5 of the FRA.

Table 14.2 Impact of the Project on the TE2100 Plan

Policy unit	Policy
North Kent Marshes (Catchment EFR-1)	The Project road will be in tunnel where it crosses under the existing tidal defences and will not impact any work proposed under the TE2100 Plan.
East Tilbury and Mucking Marshes (Catchment EFR-2)	All Project work would be undertaken to the north of any existing flood defence assets, except for the Coalhouse Point Wetland area which would be located south-west of existing flood defence assets with Coalhouse Fort and Princess Margaret Road between the Coalhouse Point Wetland area and the existing flood defence assets.
Purfleet, Grays and Tilbury (Catchment EFR-2)	There are no existing formal flood defences immediately upstream and downstream of the point where the Project road crosses the Thames Estuary. Existing ground levels adjacent to the estuary are high enough to make it safe from tidal flooding. Any formal defences constructed along this part of the estuary would need to take account of the tunnel if they incorporate deep cut-off walls. The Coalhouse Point Wetland area would be located east of the TE2100 Purfleet, Grays and Tilbury policy unit. The wetland works would be more than 50m east of the nearest Environment Agency flood defence infrastructure (Star Dam).

Notes
The 'Purfleet, Grays and Tilbury' unit includes West Tilbury Marshes.

14.2.2 The TE2100 Plan and its context in relation to the Project is included in Part 2 of the FRA.

14.2.3 Following consultation with the Environment Agency, a technical note was prepared that extends the FRA breach assessment to consider breaches with the future Thames barrier in place. This note is presented in Annex C.

15 Other elements of the Project

15.1 Introduction

15.1.1 This section includes details of flood risk associated with parts of the Project that do not readily fit into the five flood catchments.

15.2 Coalhouse Point Wetland

Introduction

15.2.1 As part of the overall Environmental Mitigation Plan, a wetland area would be established to the east of Catchment EFR-2 and immediately to the west of Coalhouse Point, on the north embankment of the River Thames. The wetland would be recharged locally with brackish water from the Thames Estuary.

TE2100 Plan

15.2.2 The area identified for creation of this wetland is not included in the TE2100 Plan and therefore does not have a TE2100 recommended policy. The proposed wetland area lies to the east of the Purfleet, Grays and Tilbury policy unit, and to the south of the East Tilbury & Mucking Marshes policy unit.

15.2.3 The area to the south of the proposed wetland includes tidal defences adjacent to the River Thames. These are in poor condition and provide only a low standard of protection (the crest level is approximately 4mAOD, which is between the Mean High Water Springs level and the 1 year return period River Thames flood level in 2030).

15.2.4 The Environment Agency recommended policies for the TE2100 policy units adjacent to the proposed wetland area are:

a. (P4) for the Purfleet, Grays & Tilbury policy unit, i.e. take further action to keep up with climate and land use change so that flood risk does not increase

b. (P3) for the East Tilbury & Mucking Marshes policy unit, i.e. continue with existing or alternative actions to manage flood, and continue to maintain flood defences at their current level accepting that the likelihood and/or consequences of a flood will increase because of climate change

Source of water for the wetland

15.2.5 The source of brackish water for the wetland would be the River Thames. The water would be sourced via a self-regulating water inlet. The structure would be formed within, or partly within, the existing tidal defences (grid reference TQ686 761) [HR010] [HR011].

15.2.6 The existing watercourse that would continue to run through the wetland is connected to a watercourse that eventually discharges to West Tilbury Main. A level control structure (weir) would be established at the end of the wetland watercourse to retain the brackish water in the wetland. [RDWE050]

Tidal flood defences and intake structure

15.2.7 The existing tidal defences adjacent to the River Thames are in poor condition and provide only a low standard of protection (the crest level is approximately 4mAOD, which is between the Mean High Water Springs level and the 1 year return period River Thames flood level in 2030).

15.2.8 As these tidal defences do not determine the standard of protection for the nearby TE2100 policy units Purfleet, Grays & Tilbury and East Tilbury & Mucking Marshes, which are protected to a higher standard by flood defences located further inland, incorporating an intake structure at this location would not compromise implementation of the TE2100 Plan policy recommendations.

Flood risk

15.2.9 The existing tidal defences adjacent to the River Thames overtop relatively frequently as the defence crest level is between the Mean High Water Springs level and the 1 year return period River Thames flood level in 2030. The frequency of overtopping is projected to increase during the Project lifetime (up to 2130 as a minimum) due to sea level rise. In 2130, the existing defence crest level will be below the Mean High Water Springs level. Inundation of the wetland area by overtopping could result in a significantly larger area and depth of standing water than during non-flood conditions. Flood water would drain down after a flood event by gravity through the new structure (if built), and through the existing drainage network northwards and then onwards through the West Tilbury Main towards Bowaters Sluice. Inundation of the wetland area by overtopping would not compromise its ecological mitigation function.

15.2.10 The impacts of a breach of the existing tidal defences adjacent to the River Thames on the proposed wetland area would be qualitatively similar to overtopping. If a breach occurred when River Thames water levels were similar to the defence crest level (approximately 2m above landward ground levels), inundation would be more rapid than during overtopping and velocities would be higher locally. If a breach occurred during significantly higher River Thames water levels, the landward side of the defence would already be inundated and therefore the impacts of a breach would be insignificant.

15.2.11 The proposed wetland design would include earthworks (excavation) and control of water levels within the wetland area. The proposed earthworks would result in a lowering of existing levels only, and all arisings would be removed from the site. Normal water levels in the wetland area would be managed to be no higher than existing ground levels with no reduction in available floodplain storage during a flood event. The proposed wetland design would therefore not increase flood risk impacts following overtopping or a breach of the existing River Thames flood defence.

15.2.12 The proposed wetland works would not increase the likelihood of a breach of the existing tidal River Thames flood defences. If an intake structure were required to be incorporated into the existing flood defences, this would be designed such that there would be no localised weakening of the flood defences.

15.2.13 The proposed wetland area would not include visitor access paths or car parking facilities, and would not be promoted as a visitor destination. It is therefore anticipated that the proposed wetland area would not attract a significant number of people and so would not significantly increase the associated impacts following a breach or overtopping of the existing tidal defences adjacent to the River Thames.

Text box 15.1 Coalhouse Point Wetland

The area identified for creation of this wetland is not included in the TE2100 Plan and therefore does not have a TE2100 recommended policy. The area to the south of the proposed wetland includes tidal defences adjacent to the River Thames. These are in poor condition and provide only a low standard of protection.

Brackish water for the wetland would be sourced from the River Thames self-regulating tide gate or equivalent structure. The gate/structure would be formed within, or partly within, the existing tidal defences and would be designed to allow ingress and egress of eels.

The watercourse that would continue to run through the wetland is connected to a watercourse that eventually discharges to West Tilbury Main. A level control structure (weir) would be established at the end of the wetland watercourse to retain the brackish water in the wetland.

The existing tidal defences overtops relatively frequently as the defence crest level is between the Mean High Water Springs level and the 1 year return period River Thames flood level in 2030. The frequency of overtopping is projected to increase during the Project lifetime (up to 2130 as a minimum) due to sea level rise.

The impacts of a breach of the existing tidal defences adjacent to the River Thames on the proposed wetland area would be qualitatively similar to overtopping. If a breach occurred when River Thames water levels were similar to the defence crest level, inundation would be more rapid than during overtopping and velocities would be higher locally. If a breach occurred during significantly higher River Thames water levels, the landward side of the defence would already be inundated and therefore the impacts of a breach would be insignificant.

The proposed wetland design would include earthworks and control of water levels within the wetland area. The proposed earthworks would result in a lowering of existing levels only. Normal water levels in the wetland area would be managed to be no higher than existing ground levels with no reduction in available floodplain storage during a flood event. The proposed wetland design would therefore not increase flood risk impacts following overtopping or a breach of the existing River Thames flood defence.

15.3 Energy infrastructure

Introduction

15.3.1 This section considers the flood risk associated with energy infrastructure; this includes elements of energy infrastructure in the floodplain and under a separate sub-heading, elements of infrastructure that are classified as NSIPs.

15.3.2 The Government's policy for delivery of major energy infrastructure is set out in a suite of six technology-specific NPSs (EN-1 to EN-6). Flood risk associated with major energy infrastructure is set out in EN-1, Overarching National Policy Statement for Energy (NPS EN-1) (Department for Business, Energy and Industrial Strategy, 2011).

15.3.3 The purpose of NPS EN-1 is to inform decisions made by the by the Infrastructure Planning Commission (IPC)[32] on applications for energy developments that fall within the scope of the NPSs.

15.3.4 The current version of NPS EN-1 was issued in 2011 by the Secretary of State for Energy and Climate Change. Although this document is not harmonised with the NPPF (DLUHC, 2021), the overarching requirements remain pertinent[33].

15.3.5 Paragraph 5.7.3 of NPS EN-1 notes that the aims of planning policy on development and flood risk are to ensure that flood risk from all sources of flooding is taken into account at all stages in the planning process to avoid inappropriate development in areas at risk of flooding, and to direct development away from areas at highest risk. Where new energy infrastructure is, exceptionally, necessary in such areas, policy aims to make it safe without increasing flood risk elsewhere and, where possible, by reducing flood risk overall.

15.3.6 NPS EN-1 paragraph 5.7.4 states that a flood risk assessment shall be prepared for sites of 1 hectare or over. This document forms part of the site specific flood risk assessment (see Plate 1.1).

15.3.7 Paragraph 5.7.9 notes that when determining an application for development consent, the IPC should be satisfied that where relevant:

a. The application is supported by an appropriate flood risk assessment.

b. The Sequential Test has been applied and satisfied as part of site selection.

c. The proposal is in line with any relevant national and local flood risk management strategy

d. The proposal is in line with any relevant national and local flood risk management strategy.

e. Priority has been given to the use of sustainable drainage systems (SuDS)

f. In flood risk areas the project is appropriately flood resilient and resistant, including safe access and escape routes where required, and that any residual risk can be safely managed over the lifetime of the development.

Energy infrastructure in the floodplain

15.3.8 Energy infrastructure for the Project that is located in the floodplain comprises gas and electric power transmission assets. The only elements of above

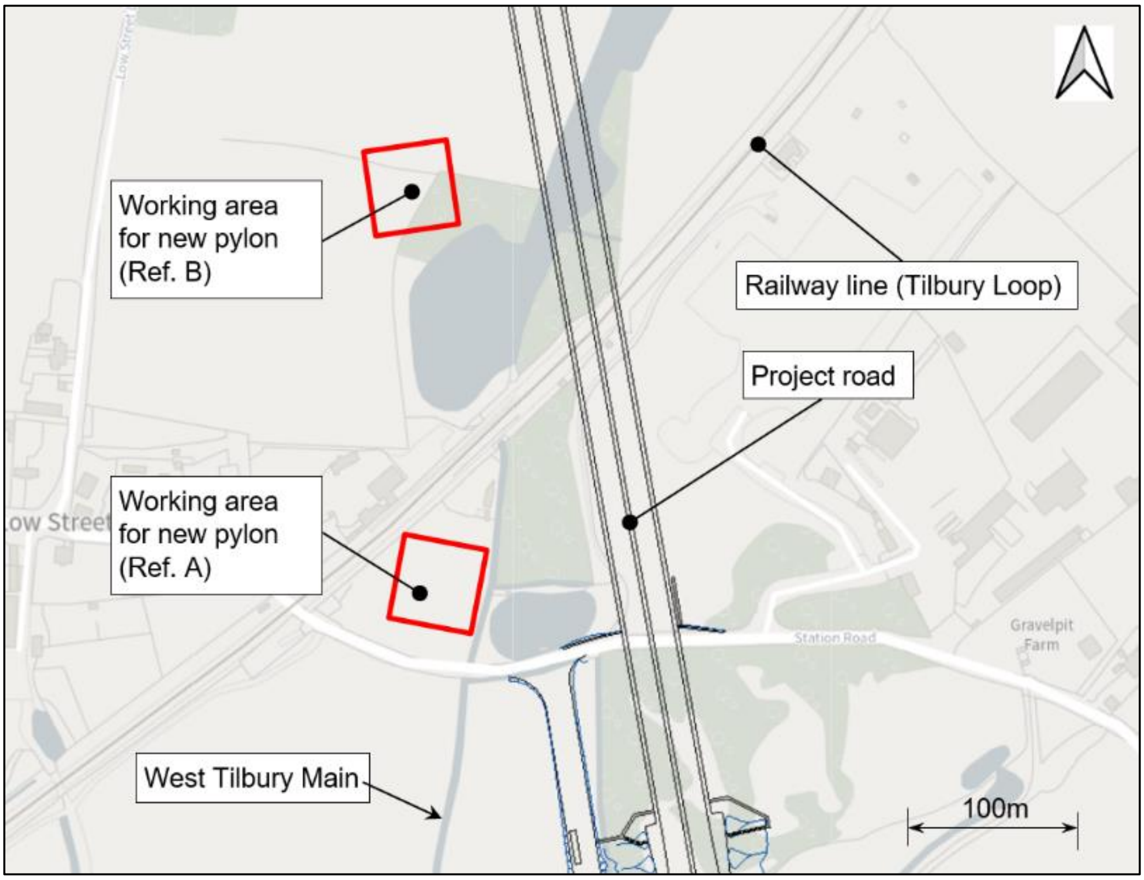
[32] The IPC was a non-departmental public body responsible for the examining and in certain circumstances the decision making body for proposed NSIPs. The Commission was abolished in 2012 with responsibility being passed to the Planning Inspectorate.

[33] A draft update of EN-1 has been released in September 2021 by the Department for Business, Energy and Industrial Strategy. The draft update is aligned with the National Planning Policy Framework. The requirements of the draft update are broadly similar to those of the current version.

ground energy infrastructure within the floodplain are limited to electric transmission pylons.

15.3.9 Most of the pylons located in the floodplain are existing and will be retained or replaced as required by the Project. Only two pylons are of interest in terms of flood risk. The working area for these two new pylons is presented in Plate 15.1. The new pylons would be centrally placed within the working areas.

Plate 15.1 New pylons with flood risk associations



15.3.10 According to the flood maps generated by the hydraulic modelling of West Tilbury Main, the new pylon to the south of the railway line (Ref. A) is in an area at negligible risk of fluvial flooding (see Section 9.2). This pylon, which lies in Catchment EFR-2, is not at risk of flooding from reservoirs, water mains or sewers, and is in a location with a negligible risk of groundwater flooding and a low risk of surface water flooding. Further details on flood risk in Catchment EFR-2 are presented in Section 9.

15.3.11 The pylon to the north of the Tilbury Loop (Ref. B) is not in the floodplain. This pylon is also located in Catchment EFR-2 and is not at risk of flooding from reservoirs, water mains or sewers, and is in a location with a negligible risk of groundwater flooding and a low risk of surface water flooding.
The compensatory flood storage area in Catchment EFR-2 has been modelled to avoid encroachment into the working area for this pylon. Further details on flood risk in Catchment EFR-2 are presented in Section 9.

National Significant Infrastructure Projects

15.3.12 Some of the utility diversions required to deliver the Project are NSIPs in their own right when tested against the relevant sections of the Planning Act 2008. The energy infrastructure that are designated as NSIPs are presented in Table 15.1 along with the basis for their qualification as an NSIP.

Table 15.1 Schedule of energy infrastructure NSIPs

NSIP	Scope	Basis of qualification
Works No. G2	Diversion of National Grid HP-Gas Pipeline in the vicinity of Claylane Wood	Significant environmental impact
Works No. G3	Diversion of National Grid HP-Gas Pipeline in the vicinity of Claylane Wood	Significant environmental impact
Works No. G4	Diversion of National Grid HP-Gas Pipeline from Thong Lane to the A226	Significant environmental impact
Works No. OH7	Diversion of National Grid Electricity Transmission network around the A13	Length to be modified surpasses 2km threshold

15.3.13 The approximate alignment of the four NSIPs is presented in Plate 15.2 and Plate 15.3.

Plate 15.2 Plan – Works Nos. G2, G3 and G4

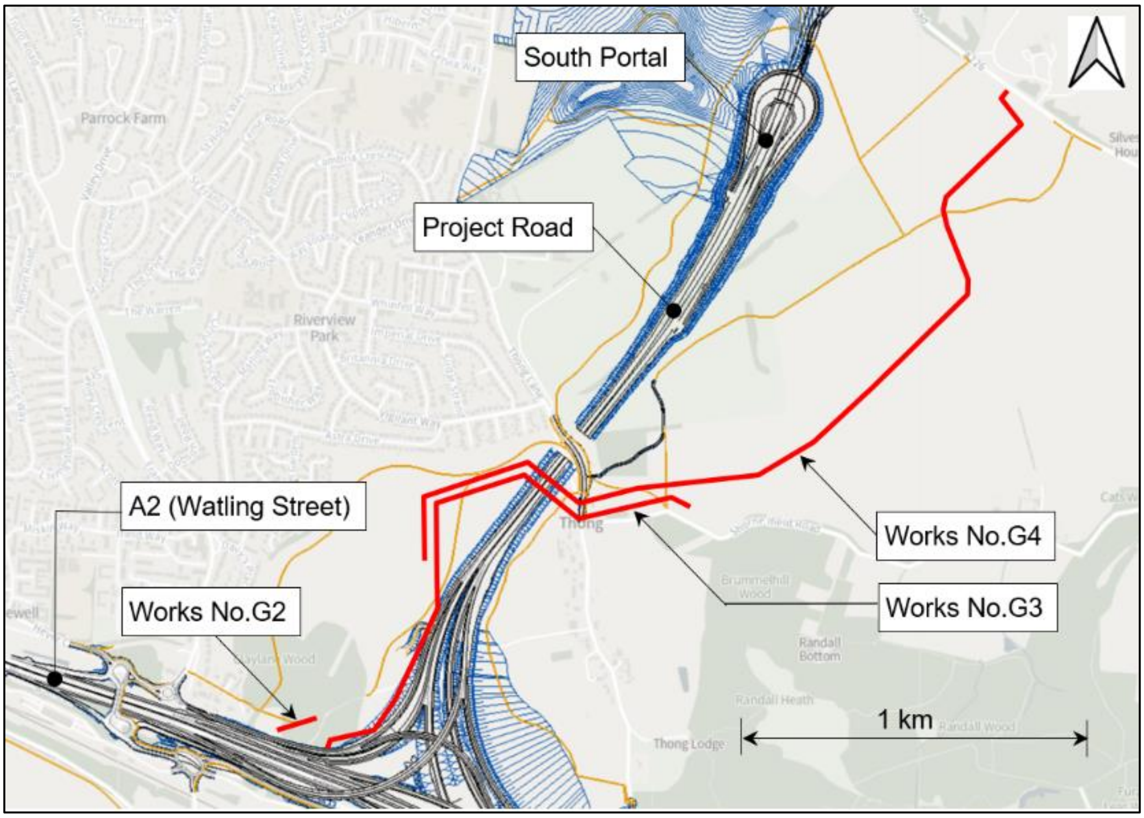
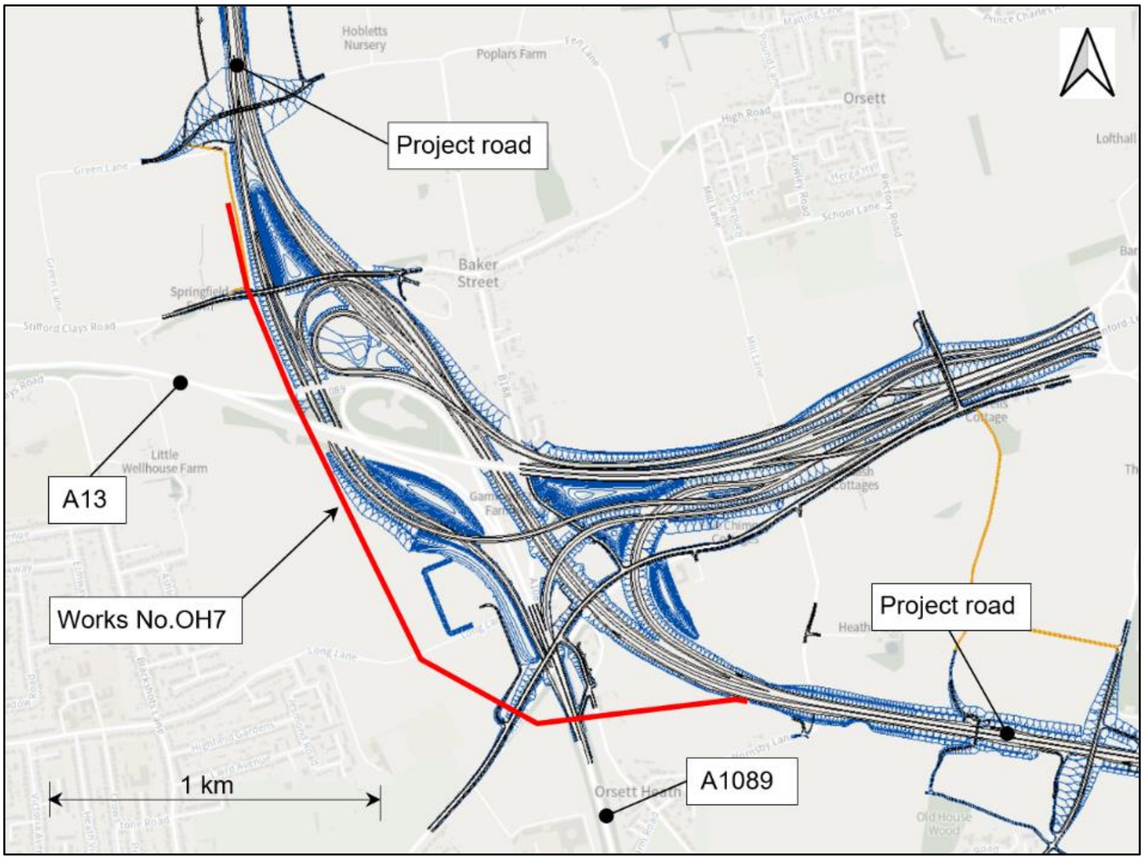


Plate 15.3 Plan – Works No. OH7



15.3.14 Consideration of the conditions presented in paragraph 5.8.11 of NPS EN-1 (2021) are presented in Table 15.2.

Table 15.2 Requirements of NSIPs EN-1 paragraph 5.8.11

Requirement	Discharge of requirement
The application is supported by an appropriate flood risk assessment.	This document forms part of the flood risk assessment for the Project. The other parts of the flood risk assessment are presented in Plate 1.1.
The Sequential Test has been applied and satisfied as part of site selection.	The Project comprises land that lies primarily in Flood Zone 1 but includes areas that lie in Flood Zones 2, 3a and 3b. Table 3.3, which is based on Table 3 of the DLUHC guidance (DLUHC, 2022), shows the compatibility of flood risk vulnerability classifications and Flood Zones. As essential infrastructure, the Project is appropriate in all Flood Zones (see Section 3.3 for the reasons why the Project is classified as essential infrastructure). As all NSIPs lie in Flood Zone 1, they meet the requirements of the Sequential Test.
The proposal is in line with any relevant national and local flood risk management strategy.	The Project would comply with all pertinent local, regional and national flood risk strategy and policy. Full details of the applicable local, regional and national flood policy and strategy are included in Part 2 of the FRA.

Requirement	Discharge of requirement
Priority has been given to the use of sustainable drainage systems (SuDS).	Not applicable to the energy infrastructure NSIPs included on the Project. SuDS would be incorporated into the Project wherever appropriate in accordance with the Design Principles (Application Document 7.5). Further details of SuDS are included in Part 7 of the FRA.
In flood risk areas the project is appropriately flood resilient and resistant, including safe access and escape routes where required, and that any residual risk can be safely managed over the lifetime of the development.	Not applicable to the energy infrastructure NSIPs included on the Project as they all lie in Flood Zone 1.

15.3.15 Section 4.9 of NPS-EN-1 (Department for Business, Energy and Industrial Strategy, 2011) states that the Secretary of State should be satisfied that applicants for new energy infrastructure have taken into account the potential impacts of climate change using the latest UK Climate Projections and associated research and expert guidance. NPS EN-1 (Department for Business, Energy and Industrial Strategy, 2021) refers to the Environment Agency guidance on climate change allowances for flood risk assessments (2022a) as an example of acceptable expert guidance. This guidance is the primary source of climate change information used in the FRA and has been used to assess flood risk for all elements of the Project (see Section 4 for details on climate change allowances).

Text box 15.2 Nationally Significant Infrastructure Projects

- The Government's policy for delivery of major energy infrastructure is set out in a suite of National Policy Statements. Flood risk associated with major energy infrastructure is set out in ES-1, Overarching National Policy Statement for Energy (NPS EN-1, 2011).
- All four NSIPs are located in areas that are at negligible risk of flooding (AEP ≤ 0.1%).
- The requirements to enable the Secretary of State to determine an application for development consent have been fulfilled.
- Climate change in accordance with the Environment Agency guidance on climate change allowances for flood risk assessments (2022a) has been applied to the Project. NPS EN-1 (2011) notes that this guidance is acceptable for assessing the impact of climate change energy infrastructure.

Construction of energy infrastructure

15.3.16 To construct the energy infrastructure, it would be necessary to work in floodplains as follows:

a. Construction of gas pipework, cabling and pylons and stringing pylons between the River Thames and Tilbury Loop railway (Catchment EFR-2).

b. Re-stringing pylons in Orsett Fen (Catchment EFR-4).

c. Constructing pipework across West Mardyke (Catchment EFR-5).

15.3.17 The Contractor would establish emergency response measures for construction activities in floodplains.

15.3.18 Installation of pipework and cables by open trench techniques creates corridors of surface clearance and excavation that can potentially affect watercourses, aquifers and areas prone to flooding. Trenching could cause inadequate or excessive drainage, interference with groundwater flow pathways and flooding. Impacts during construction would be mitigated and the ground would be reinstated after construction. An assessment of construction related flood risks and any associated mitigation measures would be undertaken by the Contractor. The assessment would also include a review of remedial risks and proposed mitigation measures.

15.3.19 For watercourse crossings, pipework and cabling would be installed by trenchless techniques in order to avoid disturbance to channel form, flow regimes and riparian habitats and species, unless other techniques are agreed with the Environment Agency or LLFA, where relevant. [RDWE008]

16 Construction phase flood risk

16.1 Introduction

General

16.1.1 The Project would necessitate construction work being undertaken in Flood Zones 1, 2 and 3.

16.1.2 Whilst construction in Flood Zones 2 and 3 will be minimised, it is not possible to avoid it.

Temporary works

16.1.3 Temporary works are the parts of a construction project that are needed to enable the permanent works to be built. Typically, these would comprise site facilities and temporary structures for construction.

16.1.4 For the Project, site facilities would include, but are not limited to, the following:

a. Site accommodation (offices and car parks)
b. Worker accommodation
c. Welfare facilities (canteen, changing rooms, showers and toilets)
d. Medical facility
e. Satellite welfare facilities (toilets, first aid stations, mess rooms)
f. Batching plant
g. Workshops
h. Fabrication yards and sheds
i. Storage sheds, yards and compounds
j. Materials yards (stockpiling)
k. Plant yards
l. Electrical substation
m. Bunded diesel tank
n. Contaminated ground treatment area
o. Wheel wash area
p. Segregated waste area
q. Settlement lagoons
r. Tunnel boring machine launching frame

16.1.5 Temporary structures for construction include, but are not limited to, the following:

a. Dewatering works
b. Cofferdams
c. Cut-off walls

d. Crane supports

e. Falsework

f. Formwork for in-situ concrete

g. Trench supports

h. Working platforms and gantries

i. Scaffolding

16.1.6 In addition to the above, the construction would be supported by a network of haul roads, site roads and utilities (power, lighting, communications, water, wastewater).

16.1.7 The Contractor would be responsible for preparing a site-specific flood risk assessment to demonstrate that the site set up and temporary works comply with the requirements of the NPPF. [RDWE001]

16.1.8 Surface water drainage would be provided for any surfaced roads and yards, buildings and any other hard or impermeable surfaces. Depending upon the final site layout, berms and bunds may be constructed to manage surface water runoff. Typically, this would be done to protect watercourses, prevent ponding and to keep general runoff separate from contaminated runoff. [RDWE006]

16.1.9 The Contractor would establish a planned maintenance programme to keep the site drainage system in good working order. [RDWE002]

16.1.10 This section considers flood risk associated with the temporary works, other construction-related work and the safety of construction personnel. This section also sets out the requirements for temporary works and other construction-related work in flood risk areas.

Climate change

16.1.11 Fluvial flood risk would be assessed for a range of events up to the 1% AEP event with the allowances for climate change.

16.1.12 Construction is due to be completed in 2030. The climate change allowances for the construction phase are based on the information in Section 3 and are presented in Table 16.1.

Table 16.1 Climate change allowances for construction

Type of allowance	Division	Allowance for 2030
Peak rainfall intensity*	Central	20%
Peak river flow allowance	Upper end	22%
	Higher central	11%
	Central	6%
Sea level rise	Upper end (higher central not specified here as similar to Upper end for the change period 2017 to 2030)	Sea level rise at Southend (applies UKCP18 allowances relative to the 2017 baseline of Environment Agency Coastal Flood Boundary dataset, 2018). EWLs are calculated following the method set out in Section 4.8 of Part 4.

** The current Environment Agency guidance says 'For development with a lifetime up to 2060, take the same approach but use the central allowance for the 2050s epoch (2022 to 2060)'. Following Environment Agency guidance, the 2050s central allowance for peak rainfall intensity would be applied for the construction phase, which is 20% for both the 3.3% and 1% AEP events.*

16.1.13 Application of these climate change allowances would be as detailed in Section 4.

16.2 South of River Thames (Catchment EFR-1)

16.2.1 For the purposes of the construction phase flood risk, all areas to the south of the River Thames have been considered as part of Catchment EFR-1.

16.2.2 The construction stage activities would include the provision of temporary works including the establishment of haul roads, stockpiling areas and site compounds. There would be five compound areas to the south of the River Thames:

a. Marling Cross compound

b. A2 compound

c. Southern tunnel entrance compound

d. A226 Gravesend Road compound

e. Milton compound

16.2.3 Marling Cross compound, A2 compound and southern tunnel entrance compound would lie in Flood Zone 1 so would be in an area that is at negligible risk of flooding from rivers or the sea.

16.2.4 A226 Gravesend Road compound and Milton compound would lie in Flood Zone 3 but are in areas that benefit from flood defences[34]. With the flood defences taken into account, these two compounds would be in an area at low

[34] In the context of the A226 Gravesend Road compound and Milton compound, the flood defences that provide benefit are tidal defences.

risk of flooding from rivers or the sea. The temporary works in these two compounds would be for construction of the ground improvement tunnel[35].

16.2.5 A summary of construction phase flood risks to the south of the River Thames is presented in Table 16.2.

Table 16.2 Construction phase flood risk in Catchment EFR-1

Parameter	Description
Flood risks	The principal flood risks for the compounds to the south of the River Thames are as follows: • Fluvial flooding • Tidal flooding • Surface water flooding Refer to Section 8 for further details of site-specific flood risk in Catchment EFR-1. In addition to the above, the Contractor would need to make an assessment of potential offsite flood impacts caused by the temporary works. Details of mitigation measures that would be needed to prevent offsite flooding would be included in the construction phase flood risk assessment. [RDWE001] [RDWE022]
Surface water drainage	The Contractor would be responsible for designing, constructing and maintaining a surface water drainage system for runoff from site roads, hardstanding areas and buildings. [RDWE002] [RDWE006] Surface water drainage for Marling Cross compound and A2 compound would be discharged to ground by infiltration techniques using existing National Highways drainage assets if possible. For the other compounds, surface water drainage would be discharged to the network of watercourses to the north of the catchment following appropriate treatment. [RDWE006]
Protection	No flood protection measures would be required for the compounds in Catchment EFR-1.
Temporary works in Flood Zone 3	Introduction The ground improvement tunnel will be located in the Flood Zone 3 area adjacent to the south bank of the River Thames. A226 Gravesend Road compound and Milton compound are located in Food Zone 3.
	Sequential Approach The location of temporary works and construction related activities is primarily determined by the alignment of the Project road. The route selection process is further detailed in ES Chapter 3: Assessment of Reasonable Alternatives (Application Document 6.1). Temporary works and construction activities would be undertaken in Flood Zone 1 where possible but due to the alignment of the Project road, working in Flood Zone 3 would be necessary.

35 The purpose of the Ground Improvement Tunnel is to stabilise the ground to reduce ground movement, facilitate construction of tunnel cross passages and operation of the tunnel boring machines and for the maintenance of the cutterheads.

Parameter	Description
	As working in Flood Zone 3 would be necessary, the Contractor would demonstrate that the site would be safe for the workforce during times of flooding by preparing a construction phase flood risk assessment. [RDWE001] [RDWE022] The construction phase flood risk assessment would be used to develop safe systems of working in flood risk areas.
	Mitigation Compensatory flood storage would be required to offset any temporary loss of floodplain storage resulting from the construction of the Ground Improvement Tunnel. [RDWE037] The storage would follow the requirements for a conventional CFSA detailed in Section 6.3. The amount of compensatory flood storage required would depend upon the temporary works and methodology that the Contractor intends to use to construct the Ground Improvement Tunnel. The Contractor would develop a construction phase flood risk assessment to demonstrate how the compensation will be provided. [RDWE001] [RDWE022] The flood storage areas would be available to function before floodplain storage volume is lost. Upon demobilisation of the temporary works, the land used to form the flood storage areas would be reinstated. [RDWE037]
Resilience	The compensatory flood storage area needed for temporary works and the site drainage design would make allowances for climate change.
Residual risks	Residual flood risks in EFR-1 would include the following: • Inundation of A226 Gravesend Road compound and Milton compound if the existing tidal defences are breached or fail. • Inundation of A226 Gravesend Road compound and Milton compound if the design storm exceeds the design capacity of the compensatory flood storage. • Inundation of the site drainage network caused by an exceptional storm event may lead to surface water flooding. • Excavations may become inundated during a storm event if dewatering operations fail to operate as intended or are undersized. Management of residual flood risk would depend upon the Contractor's preferred method of working. Residual risks would be detailed in the construction phase flood risk assessment along with associated mitigation measures.
Flood compatibility of temporary works	Temporary works located in Flood Zone 3 should be limited to the following: • Water compatible facilities[36] • Site roads

[36] Water compatible facilities are ones that would be largely unaffected by flooding; this includes site facilities such as storage yards for precast concrete components or bagged aggregate.

Parameter	Description
	• Flood-resilient facilities[37] • Flood repairable facilities[38]
Contractor's personnel	The Contractor would be responsible for establishing emergency response measures for personnel working in areas at risk of flooding. Further information regarding emergency response measures is detailed in Section 16.7.

16.3 North Portal to Chadwell St Mary (Catchment EFR-2)

16.3.1 The construction stage activities would include the provision of temporary works including the establishment of haul roads, stockpiling areas and site compounds. There are three compound areas in Catchment EFR-2:

a. Northern tunnel entrance compound and Station Road compound

b. Station Road compound

c. Brentwood Road compound

16.3.2 The locations of these compounds are shown on Drawing 00251.

16.3.3 Northern tunnel entrance compound would lie in Flood Zones 1 and 3. The parts that lie in Flood Zone 3 benefit from flood defences[39]. With the flood defences taken into account, the parts of the compound in Flood Zone 3 would be in areas of very low and low risk of flooding from rivers or the sea (refer to Section 4 for definitions of flood risk levels). The parts of the compound lying in Flood Zone 1 would be in areas that are at negligible risk of flooding from rivers or the sea.

16.3.4 Brentwood Road compound would lie in Flood Zone 1 so would be in an area that is at negligible risk of flooding from rivers or the sea.

16.3.5 A summary of flood risk in EFR-2 is presented in Table 16.3.

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[37] 'Flood resilience' means constructing a building in such a way that although flood water may enter the building, its impact is minimised (i.e. no permanent damage is caused, structural integrity is maintained and drying and cleaning are facilitated).

[38] Flood repairable' means constructing a building in such a way that although flood water enters a building, elements that are damaged by flood water can be easily repaired or replaced.

[39] In the context of northern tunnel entrance compound, the flood defences that provide benefit are tidal defences.

Table 16.3 Construction phase flood risk in EFR-2

Parameter	Description
Flood risks	The principal construction phase flood risks in EFR-2 are as follows: • Tidal flooding • Fluvial flooding • Surface water flooding Refer to Section 9 for further details of site-specific flood risk in Catchment EFR-2. In addition to the above, the Contractor would need to make an assessment of potential offsite flood impacts caused by the temporary works. Details of mitigation measures that would be needed to prevent offsite flooding would be included in the construction phase flood risk assessment. [RDWE001]
Surface water	The Contractor would be responsible for designing and constructing a surface water drainage system for runoff from site roads, hardstanding areas and buildings. [RDWE002] [RDWE006] Surface water drainage for the compounds would be discharged to local watercourses after appropriate treatment. [RDWE006]
Protection	No flood protection measures would be established for the compounds but temporary inundation protection would be required around the North Portal to safeguard the tunnel during construction (see below for further details). The method of protecting the tunnel would depend upon the Contractor's preferred method of working. The protection measures would be informed by the construction phase flood risk assessment. [RDWE001] [RDWE022]
Temporary works in Flood Zone 3	**Introduction** Temporary works in Catchment EFR-2 that lie in Flood Zone 3 would comprise facilities and structures needed for the following: • Northern tunnel entrance compound [REAC022] • Provision of flood protection around the North Portal to mitigate the risk of inundation of the tunnel due to overtopping or breach of the existing flood defences • Construction of sections of the Project road on embankments • Construction of structures needed to construct the tunnels • Construction of Tilbury Viaduct
	Sequential Approach The location of temporary works and construction related activities is primarily determined by the alignment of the Project road. The route selection process is further detailed in ES Chapter 3: Assessment of Reasonable Alternatives (Application Document 6.1). Temporary works and construction activities would be undertaken in Flood Zone 1 where possible but due to the alignment of the Project road, working in Flood Zone 3 would be necessary. [RDWE022] As working in Flood Zone 3 would be necessary, the Contractor would demonstrate that the site would be safe for the workforce during times of flooding by preparing a construction phase flood risk assessment. [RDWE001] The construction phase flood risk assessment would be used to develop safe systems of working in flood risk areas.

Parameter	Description
	Mitigation The amount of compensatory flood storage required would depend upon the temporary works and earthwork activities. The Contractor would develop a construction phase flood risk assessment to demonstrate how the compensation will be provided. [RDWE001] The operational phase flood storage areas would be made available to function before floodplain storage volume is lost. [RDWE037]
Resilience	The compensatory flood storage areas needed for temporary works, and the site drainage design would make allowances for climate change.
Residual risk	Residual flood risks in EFR-2 would include the following: • Inundation of the site drainage system due to an exceptional storm event could lead to surface water flooding. • Breaching or overtopping of the existing defences could lead to widespread flooding across Flood Zone 3. • Fluvial flooding due to an exceptional storm event could lead to flooding that extends beyond predicted limits (i.e. into Flood Zone 1). • Excavations may become inundated during a storm event if dewatering operations fail to operate as intended or are undersized. Management of residual flood risk would depend upon the Contractor's preferred method of working. Residual risks would be detailed in the construction phase flood risk assessment along with associated mitigation measures.
Flood compatibility of temporary works	Temporary works located in Flood Zone 3 should be limited to the following: • Water compatible facilities • Site roads • Flood-resilient facilities • Flood repairable facilities
Contractor's personnel	The Contractor would be responsible for establishing emergency response measures for personnel working in areas at risk of flooding. Further information regarding emergency response measures is detailed in Section 16.7.

16.4 A13 junction (Catchment EFR-3)

16.4.1 The construction stage activities would include the provision of temporary works including the establishment of haul roads, stockpiling areas and site compounds. There are five compound areas in Catchment EFR-3:

a. Stanford Road compound

b. Long Lane compound A

c. Long Lane compound B

d. Stifford Clays Road compound West

e. Stifford Clays Road compound East

16.4.2 The locations of these compounds are shown on Drawing 00251.

16.4.3 All five compounds would lie in Flood Zone 1 so would be in an area that is at negligible risk of flooding from rivers or the sea.

16.4.4 A summary of flood risk in EFR-3 is presented in Table 16.4 along with the proposed flood risk strategy.

Table 16.4 Construction phase flood risk in EFR-3

Parameter	Description
Flood risks	The principal construction phase flood risk in EFR-3 is from surface water. Refer to Section 10 for further details of site-specific flood risk in EFR-3. In addition to the above, the Contractor would need to make an assessment of potential offsite flood impacts caused by the temporary works. Details of mitigation measures that would be needed to prevent offsite flooding would be included in the construction phase flood risk assessment. [RDWE001]
Surface water	The Contractor would be responsible for designing and constructing a surface water drainage system for runoff from site roads, hardstanding areas and buildings. [RDWE002] [RDWE006] Surface water runoff from the compounds would be discharged to watercourses following appropriate treatment. [RDWE006] Where discharge to watercourses is not possible, runoff would be discharged to ground by infiltration techniques.
Protection	No flood protection measures are required for construction phase activities in EFR-3.
Mitigation	No flood mitigation measures are required for construction phase activities in EFR-3.
Resilience	The site drainage system design would make allowance for climate change.
Residual risk	Residual risks in Catchment EFR-3 would include the following: • Inundation of the drainage network caused by an exceptional storm event may lead to surface water flooding. • Excavations may become inundated during a storm event if dewatering operations fail to operate as intended or are undersized. Management of residual flood risk would depend upon the Contractor's preferred method of working. Residual risks would be detailed in the construction phase flood risk assessment along with associated mitigation measures.
Flood compatibility of temporary works	EFR-3 lies in Flood Zone 1, so there are no restrictions or special provisions regarding the location of site facilities or any temporary structures.

16.5 Ockendon link (Catchment EFR-4)

16.5.1 The construction stage activities would include the provision of temporary works including the establishment of haul roads, stockpiling areas and site compounds. There are two compound areas in Catchment EFR-4:

a. Mardyke compound

b. Medebridge compound

16.5.2 The two compounds would lie in Flood Zone 1 so would be in an area that is at negligible risk of flooding from rivers or the sea.

16.5.3 Elements of the Project in Catchment EFR-4 lie in Flood Zone 3. The temporary works required for these elements would therefore also be in Flood Zone 3.

16.5.4 A summary of flood risk in EFR-4 is presented in Table 16.5 along with the proposed flood risk strategy.

Table 16.5 Construction phase flood risk in EFR-4

Parameter	Description
Flood risks	The principal construction phase flood risks in EFR-4 are as follows: • Tidal flooding • Fluvial flooding of the Mardyke, Golden Bridge Sewer and Orsett Fen Sewer • Localised surface water flooding Refer to Section 11 for further details of site-specific flood risk in Catchment EFR-4. In addition to the above, the Contractor would need to make an assessment of potential offsite flood impacts caused by the temporary works. Details of mitigation measures that would be needed to prevent offsite flooding would be included in the construction phase flood risk assessment. [RDWE001]
Surface water	The Contractor would be responsible for designing, constructing and maintaining a surface water drainage system for runoff from site roads, hardstanding areas and buildings. [RDWE002] [RDWE006] Surface water drainage for compounds would be discharged to the local watercourses following appropriate treatment. [RDWE006]
Protection	No flood protection measures are required for construction phase activities in EFR-4.
Temporary works in Flood Zone 3	**Introduction** Temporary works in Catchment EFR-4 that lie in Flood Zone 3 would comprise facilities and structures needed to construct the following: • The two viaducts • Sections of the Project road on embankments • Compensatory flood storage area • Mardyke Wetland **Sequential approach** Determined by the location of the work. The location of temporary works and construction related activities is primarily determined by the alignment of the Project road. The route selection process is further detailed in ES Chapter 3: Assessment of Reasonable Alternatives (Application Document 6.1). Temporary works and construction activities would be undertaken in Flood Zone 1 where possible but due to the alignment of the Project road, working in Flood Zone 3 would be necessary. As working in Flood Zone 3 would be necessary, the Contractor would demonstrate that the site would be safe for the workforce during times of

Parameter	Description
	flooding by preparing a construction phase flood risk assessment. [RDWE001] [RDWE022] The construction phase flood risk assessment would be used to develop safe systems of working in flood risk areas.
	Mitigation Compensatory flood storage would be required to offset any temporary loss of floodplain storage resulting from the construction of the Ground Improvement Tunnel. [RDWE037] The storage would follow the requirements for a conventional CFSA detailed in Section 6.3. The Contractor would develop a construction phase flood risk assessment to demonstrate how the compensation will be provided. [RDWE001] The flood storage areas would be available to function before floodplain storage volume is lost. Upon demobilisation of the temporary works, the land used to form the flood storage areas would be reinstated. [RDWE037]
Resilience	The compensatory flood storage areas and drainage design would make allowances for climate change.
Residual risk	Residual risks in Catchment EFR-4 would include the following: • Inundation of the drainage network caused by an exceptional storm event may lead to surface water flooding. • Excavations may become inundated during a storm event if dewatering operations fail to operate as intended or are undersized. Management of residual flood risk would depend upon the Contractor's preferred method of working. Residual risks would be detailed in the construction phase flood risk assessment along with associated mitigation measures.
Flood compatibility of temporary works	Temporary works in Flood Zone 3 should be limited to the following: • Water-compatible facilities • Site roads • Flood-resilient facilities • Flood repairable facilities
Contractor's personnel	The Contractor would be responsible for establishing emergency response measures for personnel working in areas at risk of flooding. Further information regarding emergency response measures is detailed in Section 16.7.

16.6 M25 and North Section (Catchment EFR-5)

16.6.1 The construction stage activities would include the provision of temporary works including the establishment of haul roads, stockpiling areas and site compounds. There are three compound areas in Catchment EFR-5:

a. M25 compound

b. Ockendon Road compound

c. Warley Street compound

16.6.2 The locations of these compounds are shown on Drawing 00252.

16.6.3 All three compounds would lie in Flood Zone 1 so would be in an area that is at negligible risk of flooding from rivers or the sea.

16.6.4 Elements of the Project in Catchment EFR-5 lie in Flood Zone 3. The temporary works required for these elements would therefore also be in Flood Zone 3.

16.6.5 The parts of the works in Flood Zone 3 would lie in areas of medium and high risk of flooding from rivers or the sea (refer to Section 4 for definitions of flood risk levels).

16.6.6 A summary of flood risk in EFR-5 is presented in Table 16.6.

Table 16.6 Construction phase flood risk in EFR-5

Parameter	Description
Flood risks	The principal construction phase flood risks in EFR-5 are as follows: • Fluvial flooding from the West Mardyke • Localised surface water flooding Refer to Section 12 for further details of site-specific flood risk in EFR-5. In addition to the above, the Contractor would need to make an assessment of potential offsite flood impacts caused by the temporary works. Details of mitigation measures that would be needed to prevent offsite flooding would be included in the construction phase flood risk assessment. [RDWE001]
Surface water	The Contractor would be responsible for designing, constructing and maintaining a surface water drainage system for runoff from site roads, hardstanding areas and buildings. [RDWE002] [RDWE006] Surface water drainage for compounds would be discharged to the network of watercourses to the north of the catchment following appropriate treatment. [RDWE006]
Protection	No flood protection measures are required for construction phase activities in EFR-5.
Temporary works in Flood Zone 3	**Introduction** Temporary works in Catchment EFR-5 that lie in Flood Zone 3 would comprise facilities and structures needed to construct the following: • Widening of the M25 at the point where it crosses the West Mardyke • A new slip road onto the M25 at the point where it crosses the West Mardyke
	Sequential Approach The location of temporary works and construction related activities is primarily determined by the alignment of the Project road. The route selection process is further detailed in ES Chapter 3: Assessment of Reasonable Alternatives (Application Document 6.1). Temporary works and construction activities would be undertaken in Flood Zone 1 where possible but due to the alignment of the Project road, working in Flood Zone 3 would be necessary. As working in Flood Zone 3 would be necessary, the Contractor would demonstrate that the site would be safe for the workforce during times of flooding by preparing a construction phase flood risk assessment. [RDWE001] The construction phase flood risk assessment would be used to develop safe systems of working in flood risk areas.

Parameter	Description
	Mitigation Compensatory flood storage would be required to offset any temporary loss of floodplain storage resulting from the temporary works [RDME037] The storage would follow the requirements for a conventional CFSA detailed in Section 6.3. The Contractor would develop a construction phase flood risk assessment to demonstrate how the compensation will be provided. [RDWE001] The flood storage areas would be available to function before floodplain storage volume is lost. Upon demobilisation of the temporary works, the land used to form the flood storage areas would be reinstated. [RDWE037]
Resilience	The compensatory flood storage areas needed for construction and site drainage design would make allowances for climate change.
Residual risk	Residual risks in Catchment EFR-5 would include the following: • Inundation of the drainage network caused by an exceptional storm event may lead to surface water flooding. • Excavations may become inundated during a storm event if dewatering operations fail to operate as intended or are undersized. Management of residual flood risk would depend upon the Contractor’s preferred method of working. Residual risks would be detailed in the construction phase flood risk assessment along with associated mitigation measures.
Flood compatibility of temporary works	Temporary works located in Flood Zone 3 would be limited to the following: • Water compatible facilities • Site roads • Flood-resilient facilities • Flood repairable facilities
Contractor’s personnel	The Contractor would be responsible for establishing emergency response measures for personnel working in areas at risk of flooding. Further information regarding emergency response measures is detailed in Section 16.7.

Text box 16.1 Construction phase flood risk

- Temporary works are the parts of a construction project that are needed to enable the permanent works to be built. Temporary works for the Project would comprise site facilities, temporary structures for construction of the works and site roads.
- There would be 18 compounds across the Project. In most catchments, the compounds have been located in Flood Zone 1, thereby protecting them from all but exceptional flooding. Most construction work will be located in Flood Zone 1, but by necessity, some will be located in Flood Zone 3.
- Three compounds and construction activities are located in Flood Zone 3. Compensatory flood storage would be provided for any temporary works that displace existing floodplain storage.
- Any temporary works in Flood Zone 3 should be limited to the following:
- Water compatible facilities
- Site roads
- Flood-resilient facilities
- Flood repairable facilities
- Compensatory flood storage and surface water drainage design for temporary works include an uplift of 20% on peak rainfall rates to allow for projected climate change.

16.7 Emergency response measures

Introduction

16.7.1 The Contractor would establish emergency response measures for construction activities in flood risk areas.

16.7.2 These measures would enable the Contractor to protect its workforce and assets in the event of a flood and would facilitate post-flood resumption of construction activities.

16.7.3 Being prepared for the possibility of flooding forms the basis of the emergency response measures. The two key emergency response measures are as follows and as detailed below:

a. Readiness for the possibility of flooding

b. Development of a flood response plan

Readiness for the possibility of flooding

16.7.4 Readiness for the possibility of flooding is a key emergency measure and systems should be put in place to obtain up-to-date flood information, and to act on it as necessary.

16.7.5 There are a number of web-based services that the Contractor could use to be kept informed on weather and flood risk.

16.7.6 Flood information services maintained by the Environment Agency (https://flood-warning-information.service.gov.uk) include the following:

a. Five-day flood risk for England and Wales

b. Flood warnings for England

c. River and sea levels in England

16.7.7 Weather and flood information services available from the Met Office (https://www.metoffice.gov.uk) include the following:

a. Weather forecasts

b. Weather warnings and advice

16.7.8 The Contractor may also sign up to get flood warnings by phone, email or text message (this service is free) (https://www.gov.uk/sign-up-for-flood-warnings).

16.7.9 A targeted flood warning service is also available. This service covers warnings for more than one location but does have an annual charge (https://www.gov.uk/sign-up-for-flood-warnings).

Flood response plan

16.7.10 The flood response plan is another key emergency measure; this plan would set out what the Contractor should do in the event of a flood.

16.7.11 The Contractor would develop a flood response plan for construction activities in areas of flood risk. The plan would typically include, but not be limited to, details of the following:

a. Areas at risk of flooding

b. Nature and direction of flooding

c. Actions to be taken during a flood

d. Warning systems

e. Site evacuation procedures and routes

f. Site reoccupation (address environmental hazards, loss of utilities, etc.)

g. Emergency telephone numbers

h. Dissemination of information and training

16.7.12 The flood plan may be included in the construction phase plan required under the Construction (Design and Management) Regulations 2015.

Text box 16.2 Emergency response measures

The Contractor would establish emergency response measures for construction activities in flood risk areas.

The two key emergency response measures are:

- Readiness for the possibility of flooding
- Development of a flood response plan

17 Summary

17.1 Planning and flood risk

17.1.1 The Project was assessed against the provisions of the National Planning Policy Framework (NPPF) (DLUHC, 2021) and the National Policy Statement for National Networks (NN NPS) (Department for Transport, 2014).

17.2 Sequential Test and Exception Test

17.2.1 The Project would lie primarily in Flood Zone 1 but would include three sections that cross Flood Zones 2, 3a and 3b. The types of flood zone encountered in each catchment are detailed in Table 17.1.

Table 17.1 Flood zones encountered by catchment

Catchment	Section	Flood Zone			
		1	2	3a	3b
EFR-1	South of River Thames	✓	✗	✗	✗
EFR-2	North Portal to Chadwell St Mary	✓	✓	✓	✓
EFR-3	A13 junction	✓	✗	✗	✗
EFR-4	Ockendon Link	✓	✓	✓	✓
EFR-5	North Section	✓	✓	✓	✓

17.2.2 All five catchments have been subject to the Sequential Test. Two catchments would meet the requirements of the Sequential Test but three catchments had to undergo the Exception Test. A summary of the Sequential Test and Exception Test results by catchment is presented in Table 17.2.

Table 17.2 Sequential Test and Exception Test results by catchment

Catchment	Section	Sequential Test	Exception Test
EFR-1	South of River Thames	Pass	N/A
EFR-2	North Portal to Chadwell St Mary	Fail	Pass
EFR-3	A13 junction	Pass	N/A
EFR-4	Ockendon Link	Fail	Pass
EFR-5	North Section	Fail	Pass

17.2.3 The three catchments that needed to be elevated to the Exception Test all have elements of the Project that lie in Flood Zone 3.

17.2.4 These three elements are deemed to have passed the Exception Test because it is considered that the following apply:

a. The Project provides wider sustainability benefits to the community that would outweigh flood risk.

b. The Project would be safe for its lifetime taking account of the vulnerability of its users, without increasing flood risk elsewhere, and would reduce flood risk overall.

17.2.5 It has been demonstrated that the provisions of paragraph 5.109 of the NN NPS, which states that any essential infrastructure project should be designed and constructed to remain operational and safe for users in times of flood, and any project in Flood Zone 3b should result in no net loss of floodplain storage and not impede water flows, have been fulfilled.

17.3 Climate change

17.3.1 Climate change has the potential to increase peak rainfall intensity. This increased peak rainfall intensity results in a corresponding increase in the rate and volume of runoff being discharged to local watercourses and subsequently creates an escalation in flood risk. Furthermore, sea levels are also projected to increase as a result of climate change.

17.3.2 The Environment Agency's current guidance on climate change allowances for flood risk assessments (2022a) has been the primary source of assessing climate change allowances for peak rainfall intensity, peak river flows and sea level rises as applied to the Project.

17.4 Sources of flood risk

17.4.1 All sources of flood risk have been considered. The likelihood of each flood risk in each catchment is presented in Table 17.3.

Table 17.3 Summary of flood risk sources

Catchment	Fluvial	Tidal	Pluvial	Groundwater	Sewers	Reservoirs	Water mains	Water mains
EFR-1	N	N/A	P	N	N	N/A	N	N
EFR-2	P	P	P	N	N	N/A	N	N/A
EFR-3	N	N/A	P	P	N	N/A	N	N/A
EFR-4	P	P	P	N	N	P	N	N/A
EFR-5	P	N/A	P	P	N	N/A	N	N/A

N/A Not Applicable
N Negligible
P Potential

17.5 Flood risk alleviation

17.5.1 The flood risk management strategy considers the suite of flood alleviation measures required to make the Project safe without increasing flood risk elsewhere. Flood alleviation measures for the Project have been divided into three categories:

a. Flood mitigation measures

b. Flood protection measures

c. Flood resilience measures

17.5.2 The types of flood alleviation that would be considered for the Project are presented in Table 17.4.

Table 17.4 Flood alleviation methods considered

Alleviation category	**Alleviation method**	**Alleviation type**
Mitigation	Compensatory flood storage areas	Essential
	Creation and restoration of wetlands	Embedded
	Surface water drainage provisions	Embedded
	Inclusion of flood relief culverts	Essential
	Alterations to watercourse structures	Good practice
	Alterations to watercourse channels	Good practice
	Alteration of the floodplain	Essential
	Reduction of discharge rates from existing flow attenuation structures	Good practice
Protection	Flood bunds	Essential
	Flood walls	Essential
Resilience	Construction of roads on viaducts	Embedded
	Construction of roads on embankments	Embedded
	Change to the road geometry	Embedded
	Inclusion of climate change allowances	Embedded

17.5.3 A summary of the alleviation methods that would be applied to the Project and the means of securing them is detailed by catchment in Table 17.5.

Table 17.5 Summary of mitigation measures applied

Area	Flood alleviation measure						
	CFSA	DR	PRO	BND	FRC	AWC	RFRO
EFR-1	×	DP	×	×	×	×	×
EFR-2	RDWE037	DP	RDWE029	×	×	RDWE046	×
EFR-3	×	DP	×	×	×	×	×
EFR-4	RDWE037	DP	×	RDWE039	RDWE040	×	Potential[(1)]
EFR-5	RDWE037	DP	×	×	×	×	RDWE035

Notes

[(1)] The potential RFRO alleviation in Catchment EFR-4 relates to the catchment wide benefits made possible by inclusion of a wetland. These potential benefits have not been assessed so the effectiveness is unknown.

Legend

CFSA Compensatory flood storage area (altering the floodplain)
DR Highway drainage (surface water drainage provision)
PRO Flood protection measures (bund and walls)
BND Flood bund
FRC Flood relief channel (altering the floodplain)
AWC Alterations to watercourse structures
RFRO Reduce flood risk overall (non-specific additional alleviation measures)
DP Design Principles

17.6 Residual risk

17.6.1 Residual risk is the risk that remains after the flood risk management strategy has been implemented. Although residual flood risks generally have a low probability of occurrence, their impacts can be severe.

17.6.2 A summary of residual risk by catchment is presented in Table 17.6 along with appropriate mitigation measures.

Table 17.6 Residual risk by catchment

Risk	Catchment					Mitigation and Project response
	EFR-1	EFR-2	EFR-3	EFR-4	EFR-5	
Inundation of the highway drainage system	✓	✓	✓	✓	✓	Implementation of an appropriate inspection and maintenance programme
Overtopping of the infiltration basins	✓		✓			Implementation of an appropriate maintenance programme
Overtopping of the retention ponds		✓	✓	✓	✓	Implementation of an appropriate maintenance programme

Risk	Catchment					Mitigation and Project response
	EFR-1	EFR-2	EFR-3	EFR-4	EFR-5	
Inundation of flood storage areas		✓		✓	✓	Implementation of an appropriate maintenance programme
Potential seepage of perched groundwater in cuttings	✓	✓	✓	✓	✓	Inclusion of an appropriate edge of pavement detail
Groundwater mounding	✓		✓			The risk of groundwater mounding to unacceptably shallow depths is negligible.
Breach of tidal defences at Bowaters Sluice		✓				The risk of a breach of River Thames tidal flood defences at Bowaters Sluice is considered to be negligible.
Blockage of Bowaters Sluice		✓				The hydraulic modelling was undertaken on the basis that risk of failure of Bowaters Sluice has been realised.
Cuttings have the potential to alter the groundwater flow regime			✓		✓	The risk that cuttings may alter groundwater flow regime is negligible.
Failure of flow relief channel				✓		Implementation of an appropriate maintenance programme
Reservoir breach				✓		Regulatory inspection requirements
Failure of Mardyke Sluice gate				✓		Flood risk due to failure of Mardyke Sluice would be low.
Breach of tidal flood defences at Mardyke Sluice				✓		Flood flows resulting from a breach would remain in channel at the Project location.
Encountering groundwater in deep cuttings					✓	Inclusion of an appropriate edge of pavement detail

17.7 Combined flood events

17.7.1 The hydraulic modelling undertaken for the FRA considers flood risk for the following flood source combinations:

a. Combined tidal and fluvial events

b. Combined fluvial and urban pluvial events

17.7.2 An assessment of these combined events found the following:

a. Fluvial flooding in the Mardyke floodplain in the vicinity of the Project road is not sensitive to River Thames tide conditions.

b. The West Tilbury Main fluvial modelling assumes that Bowaters Sluice is 100% blocked, so River Thames tide conditions do not influence model results.

c. There is expected to be only a weak dependence between the occurrence of long-duration (fluvial) and short-duration (pluvial) storms in the Mardyke floodplain.

d. West Tilbury Main catchment is Essentially Rural and so urban runoff contributions to fluvial events are insignificant.

17.8 Thames Estuary 2100 Plan

17.8.1 The Thames Estuary 2100 Plan (TE2100) (Environment Agency, 2012) is the Environment Agency's long-term strategy for managing tidal flood risk in the Thames Estuary.

17.8.2 The Project has been reviewed with regard to its potential impact on the TE2100 Plan. The review concluded that the ability to implement the TE2100 Plan would not be affected by the Project. The finding of this review is detailed in Table 17.7.

Table 17.7 Impact of the Project on the TE2100 Plan

Policy unit	Policy
North Kent Marshes (Catchment EFR-1)	The Project road would be in tunnel where it crosses under the existing tidal defences and would not impact any work proposed under the TE2100 Plan.
East Tilbury and Mucking Marshes (Catchment EFR-2)	All Project work would be undertaken to the north of any existing flood defence assets.
Purfleet, Grays and Tilbury (Catchment EFR-2)	There are no existing formal flood defences immediately upstream and downstream of the point where the Project road crosses the Thames Estuary. Existing ground levels adjacent to the estuary are high enough to make it safe from tidal flooding. Any formal defences constructed along this part of the estuary would need to take account of the tunnel if they incorporate deep cut-off walls.
Coalhouse Point Wetland	Coalhouse Point Wetland is not included in the TE2100 Plan and therefore does not have a recommended TE2100 policy.

17.9 Construction phase flood risk

17.9.1 The Project would necessitate construction work being undertaken in Flood Zones 1, 2 and 3. Whilst construction in Flood Zones 2 and 3 would be minimised, it is not possible to avoid it.

17.9.2 Temporary works are the parts of a construction project that are needed to enable the permanent works to be built. Typically, these would comprise site facilities and temporary structures for construction, a network of haul roads, site roads and utilities.

17.9.3 There would be 18 compounds across the Project. In most catchments, the compounds would be located in Flood Zone 1, however, three compounds and construction activities are located in Flood Zone 3. Compensatory flood storage would be provided for any temporary works that displace existing floodplain storage.

17.9.4 Any temporary works in Flood Zone 3 should be limited to the following:

a. Water compatible facilities

b. Flood-resilient facilities

c. Flood repairable facilities

d. Site roads and underground utilities

17.9.5 The Contractor would be responsible for preparing a site-specific flood risk assessment to demonstrate that the site set up and temporary works comply with the requirements of the NPPF (DLUHC, 2021).

17.9.6 The Contractor would establish emergency response measures for construction activities in flood risk areas. The two key emergency response measures are:

a. Readiness for the possibility of flooding

b. Development of a flood response plan

17.10 Register of Environmental Actions and Commitments

17.10.1 The REAC entries (Application Document 6.3, Appendix 2.2) applicable to the Part 6 of the FRA are summarised in Table 17.8

Table 17.8 REAC entries for the drainage strategy

REAC	Name
RDWE001	Construction flood risk
RDWE002	Temporary drainage design
RDWE006	Construction water management
RDWE008	Protection of watercourses during utility works
RDWE012	Operational drainage maintenance
RDWE022	A226 Gravesend Road, Milton, northern tunnel entrance, Station Road and Mardyke compounds. Construction flood risk
RDWE029	Flood protection

REAC	Name
RDWE034	Operational drainage – infiltration basins
RDWE035	Operational drainage – retention ponds
RDWE037	Compensatory flood storage areas
RDWE038	Avoiding impacts on groundwater resources at the Thames Chase Forest Site of Importance for Nature Conservation (SINC), Hall Farm moat, paddock, and St Mary Magdalene Churchyard SINC
RDWE039	Flood bund at Orsett Fen
RDWE040	Maintaining floodplain flow connectivity
RDWE046	Maintaining West Tilbury Main floodplain flow path
RDWE048	Operational drainage – detention basin
RDWE050	Water level control structures at Coalhouse Point and Mardyke wetlands

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Annex A Calculations

A.1 Compensatory flood storage calculations

A.1.1 Calculations associated with CFSAs are presented in this Annex. The calculations, which comprise storage capacities and preliminary earthworks quantities, are listed in Table A.1.

Table A.1 CFSA calculations

Calculation number	Calculation title
0200	Compensatory Flood Storage Area – Summary
0210	Compensatory Flood Storage Area – Tilbury-CFSA-1
0220	Compensatory Flood Storage Area – Mardyke-CFSA-1
0230	Compensatory Flood Storage Area – M25-CFSA-1
0240	Compensatory Flood Storage Area – M25-CFSA-2

LOWER THAMES CROSSING

Calculation	HE540039-CJV-EFR-GEN-CALC-ENV-0200	Version	1.0
		Serial	CALC-001
Subject:	Compensatory Flood Storage Area Summary	Prepared by	ICF
		Prepared by	29-Jul-22
Sub-subject:	Title Sheet	Checked by	RMHB
		Date	26-Aug-22

STATUS	
Preliminary	✓
Tender	
Final	
Construction	
Other (state)	

LEVEL OF VERIFICATION	
Self-check by originator	
Self-check by originator and approval	
Check and approval	✓
Detailed check and approval	
External check and internal approval	

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(yellow)	Manual input
(white)	Calculation

Version	Status	Description	Approved by	Date
1.0	Preliminary	DCO Application	MJW	18/10/2022
			-	-
			-	-
			-	-
			-	-
			-	-
			-	-
			-	-

LOWER THAMES CROSSING

Calculation	HE540039-CJV-EFR-GEN-CALC-ENV-0200	Version	1.0
		Serial	CALC-002
Subject:	Compensatory Flood Storage Area Summary	Prepared by	ICF
		Date	29-Jul-22
Sub-subject:	Quantities	Checked by	RMHB
		Date	26-Aug-22

Source of data

HE540039-CJV-EFR-GEN-CALC-ENV-0210 Tilbury-CFSA-1
HE540039-CJV-EFR-GEN-CALC-ENV-0220 Mardyke-CFSA 1
HE540039-CJV-EFR-GEN-CALC-ENV-0230 M25-CFSA-1
HE540039-CJV-EFR-GEN-CALC-ENV-0240 M25-CFSA-2

Assumptions

Generally, topsoil will be stripped and set aside before excavating for the compensation.
Upon completion of the compensation excavation, the topsoil will be replaced to the same original thickness;
Earthworks for compensatory flood storage incorporated within the Mardyke wetland area are excluded from the figures presented below.

Principal quantities

Parameter	Unit	Tilbury	Mardyke	M25-1	M25-2	Total	
Depth of topsoil	m	0.25	0.25	0.25	0.25	-	Assumed
Plan area of CFSA	m^2	54,485	13,790	375	3,000	71,650	
Volume of compensation provided	m^3	N/A	4,065	225	485	-	
Topsoil - Excavated, stockpiled and replaced	m^3	13,621	3,448	102	750	17,921	Double handling
Topsoil - Disposal or reuse elsewhere	m^3	-	-	-	-	-	
General excavation - Disposal or use elsewhere	m^3	211,095	4,065	225	485	215,870	O/A topsoil
General excavation -Depth band	m	n.e. 6.5m	n.e. 0.6m	n.e. 1.5m	n.e. 0.5m	-	
Surface preparation - Excavation	m^2	54,485	13,790	375	3,000	71,650	
Surface preparation - Fill	m^2	54,485	13,790	375	3,000	71,650	
Net spoil for offsite disposal or reuse elsewhere	m^3	211,095	4,065	225	485	**215,870**	

LOWER THAMES CROSSING

Calculation	HE540039-CJV-EFR-GEN-CALC-ENV-0210	Version	1.0
		Serial	CALC-001
Subject:	Compensatory Flood Storage Area - Tilbury-CFSA-1	Prepared by	ICF
		Prepared by	29-Jul-22
Sub-subject:	Title Sheet	Checked by	RMHB
		Date	26-Aug-22

STATUS	
Preliminary	✓
Tender	
Final	
Construction	
Other (state)	

LEVEL OF VERIFICATION	
Self-check by originator	
Self-check by originator and approval	
Check and approval	✓
Detailed check and approval	
External check and internal approval	

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(yellow)	Manual input
(white)	Calculation

Version	Status	Description	Approved by	Date
1.0	Preliminary	DCO Application	MW	18-Oct-22
			-	-
			-	-
			-	-
			-	-
			-	-
			-	-
			-	-

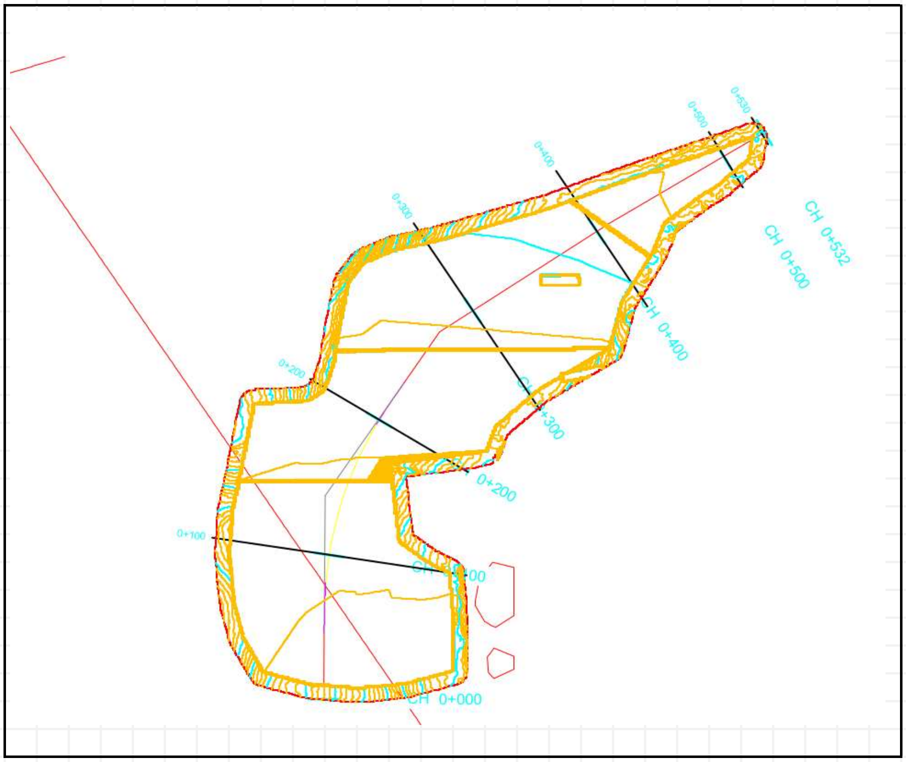
LOWER THAMES CROSSING

Calculation	HE540039-CJV-EFR-GEN-CALC-ENV-0210	Version	1.0
		Serial	CALC-002
Subject:	Compensatory Flood Storage Area - Tilbury-CFSA-1	Prepared by	ICF
		Date	29-Jul-22
Sub-subject:	Excavation volume and Plan Area	Checked by	RMHB
		Date	26-Aug-22

Objective

Calculate excavation volume of CFSA

Source: HE540039-CJV-EFR-S09_EN000000_Z-M3-LX-00012



Excavated Volume

Chainage (m)	Width (m)	Depth (m)	Length (m)	Average width (m)	Average depth (m)	Volume (m^3)
0	127.5	4.25				
			100	138.8	4.25	58,969
100	150	4.25				
			100	132.5	4.50	59,625
200	115	4.75				
			100	121.5	4.31	52,397
300	128	3.88				
			100	100.5	2.94	29,522
400	73	2.00				
			100	46.5	2.13	9,881
500	20	2.25				
			30	17.0	1.38	701
530	14	0.50				
						211,095

Depths and withs taken from the cross sections drawn in the reference drawing.

Red values indicate estimated values.

LOWER THAMES CROSSING

Calculation	HE540039-CJV-EFR-GEN-CALC-ENV-0210	Version	1.0
		Serial	CALC-002
Subject:	Compensatory Flood Storage Area - Tilbury-CFSA-1	Prepared by	ICF
		Date	29-Jul-22
Sub-subject:	Excavation volume and Plan Area	Checked by	RMHB
		Date	26-Aug-22

Plan Area

Chainage (m)	Width (m)	Depth (m)	Length (m)	Average width (m)	Area (m^2)
0	127.5	4.25			
			100	138.8	13,875
100	150	4.25			
			100	132.5	13,250
200	115	4.75			
			100	121.5	12,150
300	128	3.88			
			100	100.5	10,050
400	73	2.00			
			100	46.5	4,650
500	20	2.25			
			30	17.0	510
530	14	0.50			
					54,485

Depths / widths taken from the cross sections drawn in the reference drawing.

Red values indicate estimated values.

LOWER THAMES CROSSING

Calculation	HE540039-CJV-EFR-GEN-CALC-ENV-0210	Version	1.0
		Serial	CALC-003
Subject:	Compensatory Flood Storage Area - Tilbury-CFSA-1	Prepared by	ICF
		Date	29-Jul-22
Sub-subject:	Quantities	Checked by	RMHB
		Date	26-Aug-22

Objective

Calculate principal earthworks quantities forTilbury-CFSA-1

Depth of topsoil	0.25	m	Assumed
Plan area of CFSA	54,485	m^2	CALC-002
Volume of compensation provided	N/A	m^3	Flow retention CFSA

<u>Quantities</u>

Topsoil - Excavated, stockpiled and replaced	13,621	m^3	Double handling
Topsoil - Disposal or reuse elsewhere	0	m^3	
General excavation - Disposal or use elsewhere	211,095	m^3	O/A topsoil
General excavation - Depth band	n.e. 6.5	m	
Surface preparation - Excavation	54,485	m^2	
Surface preparation - Fill	54,485	m^2	
Net spoil for offsite disposal or reuse elsewhere	**211,095**	$\mathbf{m^3}$	

LOWER THAMES CROSSING

Calculation	HE540039-CJV-EFR-GEN-CALC-ENV-0220	Version	1.0
		Serial	CALC-001
Subject:	Compensatory Flood Storage Area - Mardyke-CFSA-1	Prepared by	ICF
		Prepared by	29-Jul-22
Sub-subject:	Title Sheet	Checked by	RMHB
		Date	26-Aug-22

STATUS	
Preliminary	✓
Tender	
Final	
Construction	
Other (state)	

LEVEL OF VERIFICATION	
Self-check by originator	
Self-check by originator and approval	
Check and review	✓
Detailed check and approval	
External check and internal approval	

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Manual input

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1.0	Preliminary	DCO Application	MW	18-Oct-22
			-	-
			-	-
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			-	-
			-	-
			-	-
			-	-

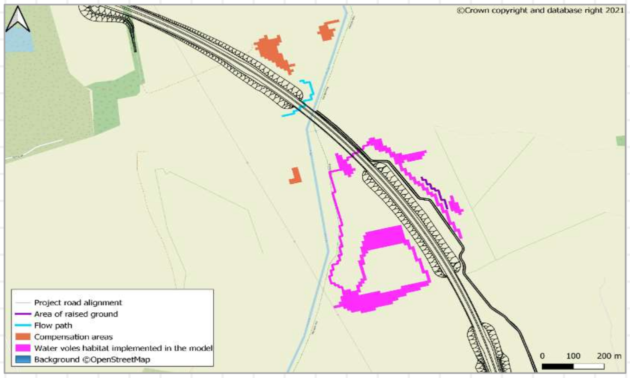
LOWER THAMES CROSSING

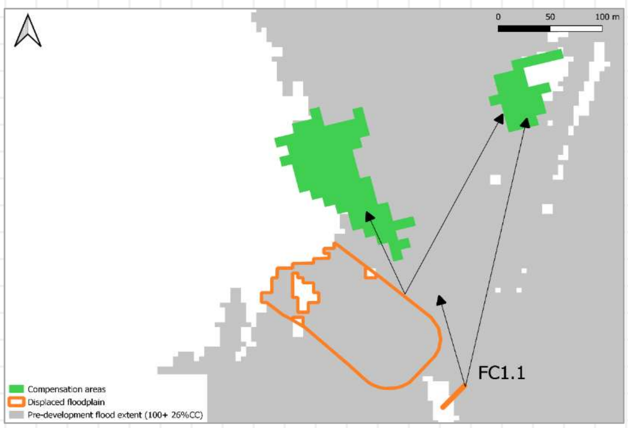
Calculation	HE540039-CJV-EFR-GEN-CALC-ENV-0220	Version	1.0
		Serial	CALC-002
Subject:	Compensatory Flood Storage Area - Mardyke-CFSA-1	Prepared by	ICF
		Date	29-Jul-22
Sub-subject:	Storage volume	Checked by	RMHB
		Date	26-Aug-22

Notes

1 The earthworks calculations presented below are in accordance with Part 4 of the FRA.
2 These calculations exclude earthworks quantities for flood compensation that would be provided by creation of the water vole habitat.
3 Compensatory flood areas have been divided into a number of polygons (see figure).
4 Compensation areas have been calculated on a level for level basis for flood plain storage lost.

Arrangement of CFSA Polygons





Compensation for displaced floodplain areas 1 and FC1.1

Upper limit of level range (mAOD)	Lower limit of level range (mAOD)	Floodplain within level range displaced by the design (without mitigation) (m^3)	Floodplain compensation volume provided within level range (m^3)
3.6	3.5	-	32.08
3.7	3.6	21.32	180.36
3.8	3.7	212.68	486.80
3.9	3.8	575.40	839.15
4	3.9	1,101.19	1,147.31
4.1	4	1,287.48	1,379.00
		3,198.07	**4,064.70**

LOWER THAMES CROSSING

Calculation	HE540039-CJV-EFR-GEN-CALC-ENV-0220	Version	1.0
		Serial	CALC-003
Subject:	Compensatory Flood Storage Area - Mardyke-CFSA-1	Prepared by	ICF
		Date	29-Jul-22
Sub-subject:	Quantities	Checked by	RMHB
		Date	26-Aug-22

Objective

Calculate principal earthworks quantities for Mardyke-CFSA-1

Depth of topsoil	0.25	m	Assumed
Plan area of CFSA	13,790	m^2	CALC-002
Volume of compensation provided	4,065	m^3	CALC-002

<u>Quantities</u>

Topsoil - Excavated, stockpiled and replaced	3,448	m^3	Double handling
Topsoil - Disposal or reuse elsewhere	0	m^3	
General excavation - Disposal or use elsewhere	4,065	m^3	O/A topsoil
General excavation - Depth band	n.e. 0.6m	m	
Surface preparation - Excavation	13,790	m^2	
Surface preparation - Fill	13,790	m^2	
Net spoil for offsite disposal or reuse elsewhere	**4,065**	$\mathbf{m^3}$	

LOWER THAMES CROSSING

Calculation	HE540039-CJV-EFR-GEN-CALC-ENV-0230	Version	1.0
		Serial	CALC-001
Subject:	Compensatory Flood Storage Area - M25-CFSA-1	Prepared by	ICF
		Prepared by	29-Jul-22
Sub-subject:	Title Sheet	Checked by	RMHB
		Date	26-Aug-22

STATUS	
Preliminary	✓
Tender	
Final	
Construction	
Other (state)	

LEVEL OF VERIFICATION	
Self-check by originator	
Self-check by originator and approval	
Check and approval	✓
Detailed check and approval	
External check and internal approval	

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Manual input

Calculation

Version	Status	Description	Approved by	Date
1.0	Preliminary	DCO Application	MW	18-Oct-22
			-	-
			-	-
			-	-
			-	-
			-	-
			-	-
			-	-

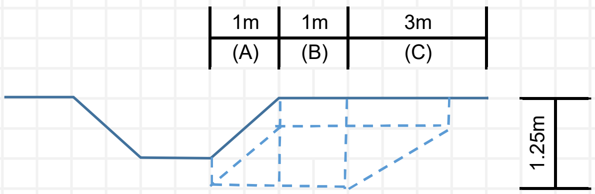
LOWER THAMES CROSSING

Calculation	HE540039-CJV-EFR-GEN-CALC-ENV-0230	Version	1.0
		Serial	CALC-002
Subject:	Compensatory Flood Storage Area - M25-CFSA-1	Prepared by	ICF
		Date	29-Jul-22
Sub-subject:	Storage volume	Checked by	RMHB
		Date	26-Aug-22

Objective: Calculate the volume of storage available in M25 CFSA 1

The Mardyke will be locally widened along a length of 75m, upstream of the M25 crossing.
The dimensions of the Mardyke have been assumed and are shown in the sketch below.
The dashed line on the sketch indicates the revised cross section along the widened length.

Depth oh topsoil	0.25	m	(a)
Length of CFSA	75	m	(b)



		Top soil	Other materials			
Additional cross section	A	0.354	0.500		(c)	
	B	0.250	1.000		(d)	
	C	0.750	1.500		(e)	
	Total CSA	1.354	3.000	m^2	(f)	(c) + (b) + (c)
Length of CFSA		75	75	m	(g)	(b)
Volume		102	225	m^3	(h)	(f) x (b)
Total storage provided			225	m^3	(i)	
Plan area		375 m^2			(j)	(1m + 1m +3m) x (b)

LOWER THAMES CROSSING

Calculation	HE540039-CJV-EFR-GEN-CALC-ENV-0230	Version	1.0
		Serial	CALC-003
Subject:	Compensatory Flood Storage Area - M25-CFSA-1	Prepared by	ICF
		Date	29-Jul-22
Sub-subject:	Quantities	Checked by	RMHB
		Date	26-Aug-22

Objective

Calculate principal earthworks quantities for M25-CFSA-1

Depth of topsoil	0.25	m	Assumed
Plan area of CFSA	375	m^2	CALC-002
Volume of compensation provided	225	m^3	CALC-002

<u>Quantities</u>

Topsoil - Excavated, stockpiled and replaced	102	m^3	Double handling
Topsoil - Disposal or reuse elsewhere	0	m^3	
General excavation - Disposal or use elsewhere	225	m^3	O/A topsoil
General excavation - Depth band	n.e. 1.5m	m	
Surface preparation - Excavation	375	m^2	
Surface preparation - Fill	375	m^2	
Net spoil for offsite disposal or reuse elsewhere	**225**	**m^3**	

LOWER THAMES CROSSING

Calculation	HE540039-CJV-EFR-GEN-CALC-ENV-0240	Version	1.0
		Serial	CALC-001
Subject:	Compensatory Flood Storage Area - M25-CFSA-2	Prepared by	ICF
		Prepared by	29-Jul-22
Sub-subject:	Title Sheet	Checked by	RMHB
		Date	26-Aug-22

STATUS	
Preliminary	✓
Tender	
Final	
Construction	
Other (state)	

LEVEL OF VERIFICATION	
Self-check by originator	
Self-check by originator and approval	
Check and approval	✓
Detailed check and approval	
External check and internal approval	

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(yellow)	Manual input
(white)	Calculation

Version	Status	Description	Approved by	Date
1.0	Preliminary	DCO Application	MW	18-Oct-22
			-	-
			-	-
			-	-
			-	-
			-	-
			-	-
			-	-

Background

A section of the M25 that would be widened to accommodate the Project crosses the West Mardyke. A new slip road onto the M25 would also cross the West Mardyke.

The widened section of the M25 and the slip road would be adjacent to each other at the point where they cross the West Mardyke.

The existing culvert under the M25 would be extended north to accommodate the slip road and south to accommodate the widened section of the M25.

Objective

Calculate the floodplain storage compensation (off site effects) required to offset the volume of storage displaced by the widened section of the M25 and the slip road at the point where they cross the West Mardyke.

Climate change allowances

Methodology

Climate change allowances for peak river flow have been determined in accordance with the provisions of Environment Agency Guidance: *Flood risk assessments: climate change allowances* .

Environment Agency, 2022 (web link)

Determine the management catchment of the West Mardyke

The management catchment has been determined using the Environment Agency's Catchment Data Explorer.

Environment Agency, 2022 (web link)

River Basin District: Thames
Management Catchment: South Essex
Operational Catchment: Mardyke

Determine climate change allowances for peak flow

Peak river flow allowances have been calculated in accordance with the provisions of Environment Agency Guidance*: Flood risk assessments: climate change allowances.*

Environment Agency, 202 (web link)

Peak river flow climate change allowances for Essex South are:

Epoch	2020s	2050s	2080s
Central	0.06	0.05	0.17
Higher	0.11	0.11	0.26
Upper End	0.22	0.27	0.48

Where: The '2020s' epoch is 2015 to 2039
The '2050s' epoch is 2040 to 2069
The '2080s' epoch is 2070 to 2125

As the operation life of the Project is up to 2129, the 2080s epoch has been selected for calculating the compensatory flood storage required. The difference between 2125 and 2130 is assumed to be negligible

LOWER THAMES CROSSING

Calculation	HE540039-CJV-EFR-GEN-CALC-ENV-0240	Version	1.0
		Serial	CALC-002
Subject:	Compensatory Flood Storage Area - M25-CFSA-2	Prepared by	ICF
		Date	29-Jul-22
Sub-subject:	Background and Methodology	Checked by	RMHB
		Date	26-Aug-22

<u>Select the appropriate allowance</u>

The Environments Agency's guidance on climate change allowances for flood risk assessments states: — Environment Agency, 2022 (web link)

The appropriate allowance to assess off-site impacts and calculate floodplain storage compensation depends on land uses in affected areas. Use the:

- *central allowance for most cases*
- *higher central allowance when the affected area contains essential infrastructure*

Although the M25 constitutes essential infrastructure, the level of the M25 is considerably higher than the watercourse at the crossing point (approx. 4m higher). On this basis, the central band allowance for peak river river flows has been adopted for the calculation of compensatory flood storage. — Assumed

EA Product Data - Ref. EAn/2018/76391

Product Data 4 was obtained for the Project from the Environment Agency data is presented in Annex A.

The flood level data presented in EAn/2018/76391 pertinent to this calculation is:

Node at upstream end of culvert:	MTRB08_2283	
Storm event considered:	1 in 100 year event+ 20% CC	
Flood level at node for event considered:	8.26	mAOD

Node at upstream end of culvert:	MTRB08_2238	
Storm event considered:	1 in 100 year event+ 20% CC	
Flood level at node for event considered:	8.23	mAOD

The flood levels presented in EAn/2018/76391 is assumed to be the base line data and is valid for use in this calculation.

Summary

The peak river flow allowance for the this calculation is **17%**

Based on:	Management catchment	Essex South
	Epoch	2080s
	Allowance	Central
	Storm event	1 in 100 year

For the purposes of this calculation, the 1 in 100 year event with 20% climate charge allowance rom EAn/2018/76391 has been adopted. This represents a slightly precautionary approach when compared with the 17% stated above.

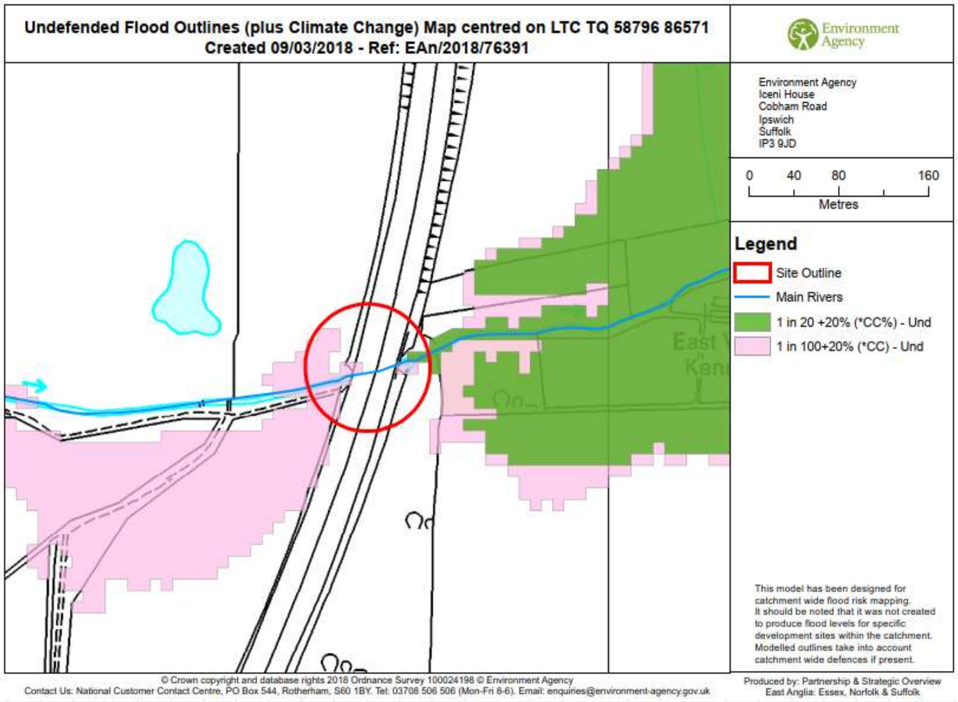
Peak river level used in this calculation:	Upstream of culvert	8.26	mAOD
	Downstream of culvert	8.23	mAOD

LOWER THAMES CROSSING

Calculation	HE540039-CJV-EFR-GEN-CALC-ENV-0240	Version	1.0
		Serial	CALC-003
Subject:	Compensatory Flood Storage Area - M25-CFSA-2	Prepared by	ICF
		Date	29-Jul-22
Sub-subject:	Floodplain storage displaced	Checked by	RMHB
		Date	26-Aug-22

Fluvial flooding extents

The drawing below is taken from EAn/2018/76391. It shows fluvial flood limits for a 1 in 100 year storm event with a 20% allowance for climate change.



Width of flood plain affected by the works	To south	110	m	Scaled from drawing
	To north	25	m	Scaled from drawing

Area to the west of the culvert under the M25 - Slip road

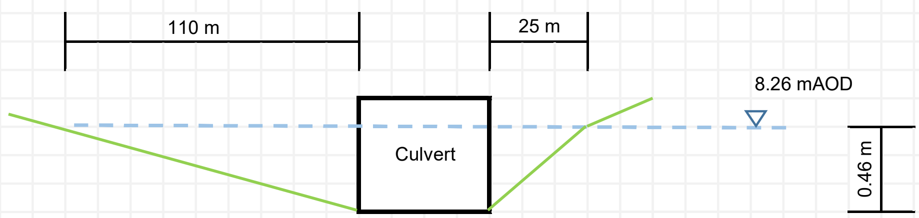
Extents of displaced water

The above drawing has been used as to determine the extents of the flooding to the west of the culvert.

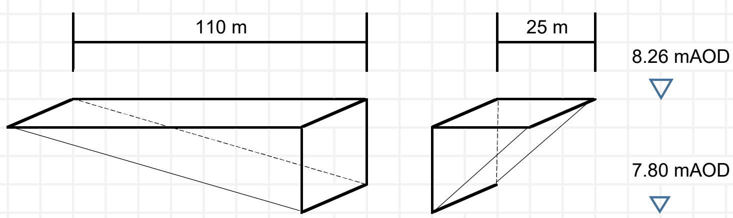
Dimensional data

Flood level	8.26	mAOD	(c)	CALC-002
Ground level	7.80	mAOD	(d)	Survey data
Flood depth	0.46	mAOD	(e)	(c) - (d)

Width increase due to slip road	15	m	(f)	Displacement width



Displacement of flood plain



Assumptions: Ground rises uniformly from the culvert until it reaches the flood level.
Displaced flood storage has a wedge shaped cross section.
It is assumed that the cross section is uniform over the width of displacement — Precautionary

Displacement	South	379.5	m^3	(g)	(a) x (e) x (f) x 0.5
	North	86.3	m^3	(h)	(b) x (e) x (f) x 0.5

LOWER THAMES CROSSING

Calculation	HE540039-CJV-EFR-GEN-CALC-ENV-0240	Version	1.0
		Serial	CALC-003
Subject:	Compensatory Flood Storage Area - M25-CFSA-2	Prepared by	ICF
		Date	29-Jul-22
Sub-subject:	Floodplain storage displaced	Checked by	RMHB
		Date	26-Aug-22

Displacement - South west quadrant

For analysis purposes, the volume of flood plain storage displaced to the west of the culvert has been split into nine depth bands, eight of which are 0.05m deep and one 0f 0.06m deep .

Level (mAOD)	Length (m)	Depth (m)	Width (m)	Volume (m^3)	Σ Volume (m^3)
8.26	110.00				
		0.05	15.0	77.9	379.5
8.21	97.78				
		0.05	15.0	68.8	301.6
8.16	85.56				
		0.05	15	59.6	232.8
8.11	73.33				
		0.05	15	50.4	173.3
8.06	61.11				
		0.06	15	49.5	122.8
8.00	48.89				
		0.05	15	32.1	73.3
7.95	36.67				
		0.05	15	22.9	41.3
7.90	24.44				
		0.05	15	13.8	18.3
7.85	12.22				
		0.05	15	4.6	4.6
7.80	0.00				
Totals		**0.46**		**379.5**	

Cumulative volume bottom up

The 0.06m depth has been been included so that the total depth matches the flood depth.

LOWER THAMES CROSSING

Calculation	HE540039-CJV-EFR-GEN-CALC-ENV-0240	Version	1.0
		Serial	CALC-003
Subject:	Compensatory Flood Storage Area - M25-CFSA-2	Prepared by	ICF
		Date	29-Jul-22
Sub-subject:	Floodplain storage displaced	Checked by	RMHB
		Date	26-Aug-22

Displacement -North west quadrant

For analysis purposes, the volume of flood plain storage displaced to the west of the culvert has been split into nine depth bands, eight of which are 0.05m deep and one of 0.06m deep .

Level (mAOD)	Length (m)	Depth (m)	Width (m)	Volume (m^3)
8.26	25.00			
		0.05	15.0	17.7
8.21	22.22			
		0.05	15.0	15.6
8.16	19.44			
		0.05	15	13.5
8.11	16.67			
		0.05	15	11.5
8.06	13.89			
		0.06	15	11.3
8.00	11.11			
		0.05	15	7.3
7.95	8.33			
		0.05	15	5.2
7.90	5.56			
		0.05	15	3.1
7.85	2.78			
		0.05	15	1.0
7.80	0.00			
Totals		**0.46**		**86.3**

The 0.06m depth has been included so that the total depth matches the flood depth.

LOWER THAMES CROSSING

Calculation	HE540039-CJV-EFR-GEN-CALC-ENV-0240	Version	1.0
		Serial	CALC-003
Subject:	Compensatory Flood Storage Area - M25-CFSA-2	Prepared by	ICF
		Date	29-Jul-22
Sub-subject:	Floodplain storage displaced	Checked by	RMHB
		Date	26-Aug-22

Total displacement - West

Level (mAOD)	Volume (m^3)	Volume (m^3)
8.26		
	95.6	465.8
8.21		
	84.4	370.1
8.16		
	73.1	285.8
8.11		
	61.9	212.6
8.06		
	60.8	150.8
8.00		
	39.4	90.0
7.95		
	28.1	50.6
7.90		
	16.9	22.5
7.85		
	5.6	5.6
7.80		
Totals	**465.8**	

Area to the east of the culvert under the M25 - Widening

The width of the M25 will increase by approximately 7m eastwards at the point where it crosses the West Mardyke.

The drawing above indicates that there is some flooding near the downstream end of the culvert but it would be in-channel over the widened section of the M25. As the widening g of the M25 would not impact the channel, there will be no off-site impacts to consider and no need for compensatory flood storage.

There is more flooding downstream of the culvert but this would not be impacted by the Project.

Summary

The total volume of displaced floodplain storage to the west of the culvert is 465.8 m^3

The total volume of displaced floodplain storage to the east of the culvert is 0.0 m^3

465.8 **m^3**

LOWER THAMES CROSSING

Calculation	HE540039-CJV-EFR-GEN-CALC-ENV-0240	Version	1.0
		Serial	CALC-004
Subject:	Compensatory Flood Storage Area - M25-CFSA-2	Prepared by	ICF
		Date	29-Jul-22
Sub-subject:	Compensatory flood storage provided	Checked by	RMHB
		Date	26-Aug-22

Compensatory Flood Storage Area

For the purposes of this analysis:

(i) The footprint of the CFSA is assumed to be straight sided polygon.
(ii) The CFSA is assumed to be outside the 1 in 100 year + 20% fluvial flood limits.
(iii) Ground level at the southern extent of the CFSA will be set at 7.8 mAOD.
(iv) Ground levels rise uniformly from the southern boundary of the CFSA to its northern boundary.
(v) The approximate footprint is shown on the extracts from Google Earth.

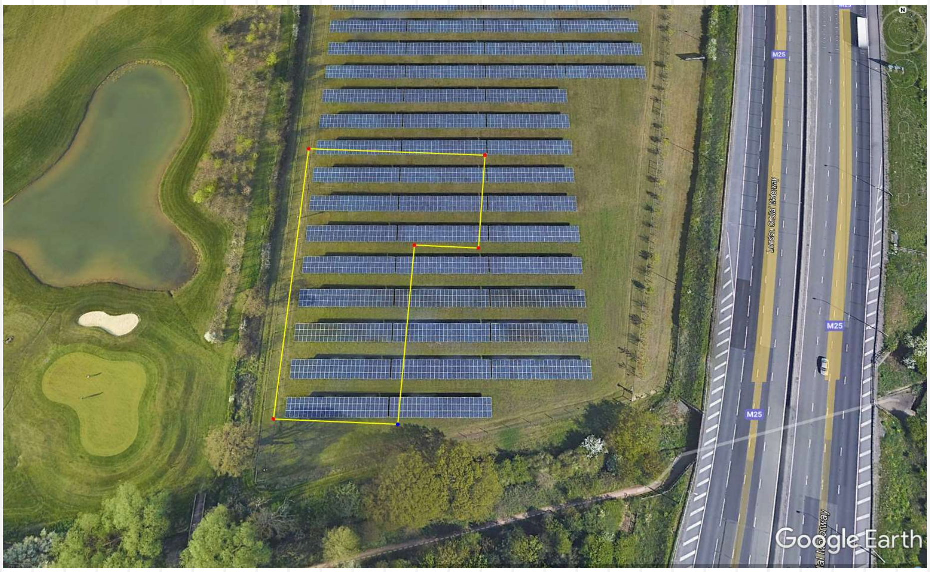
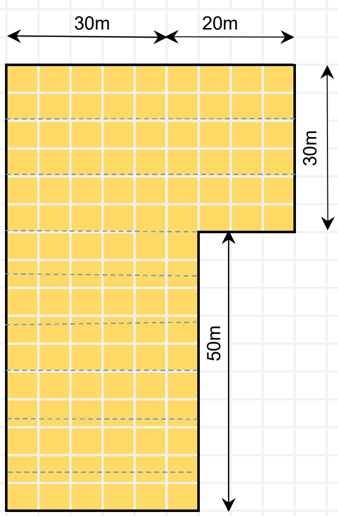


Image from Google Earth



Plan area 3000 m^2 (a)

LOWER THAMES CROSSING			
Calculation	HE540039-CJV-EFR-GEN-CALC-ENV-0240	Version	1.0
		Serial	CALC-004
Subject:	Compensatory Flood Storage Area - M25-CFSA-2	Prepared by	ICF
		Date	29-Jul-22
Sub-subject:	Compensatory flood storage provided	Checked by	RMHB
		Date	26-Aug-22

For analysis purposes, the volume of flood created to the north east of the culvert has been split into nine depth bands.

The depth bands have been estimated set with lower depth at the southern (bottom) and higher depth at the northern end.

The depth of cut at each level is set so that the compensation volume provided is to be equal, or slightly greater than, the volume of compensation required on a level for level basis..

In the table below, the requirements are condition noted in the above paragraph is checked and the volume provided to volume required ratio is precented as a percentage.

Level (mAOD)	Length (m)	Depth (m)	Width (m)	Volume provided (m^3)	Σ Volume provided (m^3)	Σ Volume required (m^3)		
8.26								
	10	0.20	45	90.0	485.0	465.8	OK	104%
8.21								
	10	0.20	45	90.0	395.0	370.1	OK	107%
8.16								
	10	0.20	45	90.0	305.0	285.8	OK	107%
8.11								
	8.33	0.21	30	52.5	215.0	212.6	OK	101%
8.06								
	8.33	0.20	30	50.0	162.5	150.8	OK	108%
8.01								
	8.33	0.20	30	50.0	112.5	90.0	OK	125%
7.96								
	8.33	0.15	30	37.5	62.5	50.6	OK	123%
7.91								
	8.33	0.05	30	12.5	25.0	22.5	OK	111%
7.86								
	8.33	0.05	30	12.5	12.5	5.6	OK	222%
7.81								
Totals				**485.00**				

Cumulative volume bottom up

Cumulative volume bottom up CALC-003

Summary

The total volume of displaced	465.8	m^3	CALC-003
Total compensation available	485.0	m^3	
			OK

LOWER THAMES CROSSING

Calculation	HE540039-CJV-EFR-GEN-CALC-ENV-0240	Version	1.0
		Serial	CALC-005
Subject:	Compensatory Flood Storage Area - M25-CFSA-2	Prepared by	ICF
		Date	29-Jul-22
Sub-subject:	Quantities	Checked by	RMHB
		Date	26-Aug-22

Objective

Calculate principal earthworks quantities for M25-CFSA-2

Depth of topsoil	0.25	m	Assumed
Plan area of CFSA	3000	m^2	CALC-004
Volume of compensation provided	485	m^3	CALC-004

Quantities

Topsoil - Excavated, stockpiled and replaced	750	m^3	Double handling
Topsoil - Disposal or reuse elsewhere	0	m^3	
General excavation - Disposal or use elsewhere	485	m^3	O/A topsoil
General excavation - Depth band	n.e. 0.5m	m	
Surface preparation - Excavation	3000	m^2	
Surface preparation - Fill	3000	m^2	
Net spoil for offsite disposal or reuse elsewhere	**485**	**m^3**	

LOWER THAMES CROSSING

Calculation	HE540039-CJV-EFR-GEN-CALC-ENV-0240	Version	1.0
		Serial	CALC-006
Subject:	Compensatory Flood Storage Area - M25-CFSA-2	Prepared by	ICF
		Date	29-Jul-22
Sub-subject:	Summary	Checked by	RMHB
		Date	26-Aug-22

Methodology and base data

Two elements of Project cross the West Mardyke floodplain (Flood Zone 3). These elements are:
- A new slip road on to the M25
- A widened section of the M25

The objective of this calculation is to determine the compensatory storage required to offset the floodplain storage displaced by these elements of the project.

Information from EAn/2018/76391 was used to determine the extents of fluvial flooding in the vicinity of the crossing.

Flood level data in EAn/2018/76391 was used as the baseline flooding for the calculation.

The calculation was undertaken in accordance with the following:
- Environment Agency, G*uidance - Flood risk assessments: climate change allowances* , 2021

The calculation was informed by the following documents:
- Environment Agency, *Catchment management explorer* , 2021
- Environment Agency, *Guidance -Peak river flow climate change allowances by management catchment* , 2021

Peak flow climate change allowance

The peak river flow climate change allowances calculated using the above data is **17%** — CALC-002

As EAn/2018/76391 includes flood levels for the 100 year storm with a 20% allowance for climate change, this flood level was used in the calculation.

Volume of floodplain displaced by the Project

The volume of water displaced by the Project was divided in to the west (upstream end) and east (downstream end) of the culvert under the M25.

The total volume of displaced floodplain storage to the west of the culvert is **466** m^3 — CALC-003

There is no displacement of floodplain storage to the east of the culvert to the east of the culvert. — CALC-003

Compensatory flood storage area

An area for providing compensatory flood storage has been identified. This area lies to the north west of the upstream end of the culvert under the M25.

The area of the compensatory flood storage area would be approximately **3000** m^2 — CALC-004

The total volume of compensation provided is **485** m^3 — CALC-004

The compensation is provided on a level for level basis with slightly more storage available at all levels across the compensation area. — CALC-004

LOWER THAMES CROSSING

Calculation	HE540039-CJV-EFR-GEN-CALC-ENV-0240	Version	1.0
		Serial	CALC-006
Subject:	Compensatory Flood Storage Area - M25-CFSA-2	Prepared by	ICF
		Date	29-Jul-22
Sub-subject:	Summary	Checked by	RMHB
		Date	26-Aug-22

Disposal

Total volume of spoil for off-site disposal 485 m^3 CALC-005

Comments

- This calculation is an example of how the compensatory flood storage could be provided; the contractor may offer a different solution.
- The area to be made available to the contractor for provision of compensatory storage is larger than the flood compensation area occupied by the solution presented this calculation
- Some assumptions have had to be made on interpretation of ground level data.
- A more detailed ground map may enable a more efficient solution to be developed
- Some remodelling of existing ground levels along the southern edge of the compensation area presented in this solution would be required to ensure connectivity with the West Mardyke.

Annex B Environment Agency – EAn/2018/76391ERF

Reference: EAn/2018/76391
Site Address: LTC TQ 578796 86571
Date: 09/03/2018

Included:

- Flood Map
- Undefended Key Outlines – 20, 100 & 1000 Map
- Undefended Key Outlines – *CC 20 & 100Map
- 1D Levels & Flows Nodes Map
- 1D (In-channel) Undefended Levels & Flows Table
- Historic Flood Outlines Map

Important information to note with your Product:

Flood Risk Assessments (FRAs)

If you are obtaining this information for use within a Flood Risk Assessment (FRA) required for a planning application, please include our unaltered Product 4 data within an appendix of your FRA.

Flood Zones

Please see the attached map showing the Flood Zones (outlines) for the area of the site. Our maps show the site is located in fluvial Flood Zone 3.

Climate Change (Fluvial Only)

Flood risk data requests including an allowance for climate change will be based on the 1% annual probability flood including an additional 20% increase on peak flows to account for climate change impacts, unless otherwise stated. You should refer to 'Flood risk assessments: climate change allowances' to check if this allowance is still appropriate for the type of development you are proposing and its location. You may need to undertake further assessment of future flood risk using different allowances to ensure your assessment of future flood risk is based on best available evidence.

The flow data for this model has been provided.

For further guidance on fluvial climate change please contact the Partnership and Strategic Overview Team at: PSOENS@environment-agency.gov.uk

Historic Flood Events

Examinations of our records of historic flooding show that the general area has previously flooded. Please note that these records show flooding to the land and do not necessarily indicate that properties within the historic flood events were flooded internally. It is also possible that the pattern of flooding in this area has changed and that this area would now flood under different circumstances. Please see the attached PDF for flood history information.

Surface Water

Please be aware that in recent years, there has been an increase in flood damage caused by surface water flooding or drainage systems that have been overwhelmed. We have worked with Lead local Flood Authorities (LLFAs) to develop a map which incorporates the best local and national scale information on surface water flood risk. These maps can be viewed on our website at the following:-

https://flood-warning-information.service.gov.uk/long-term-flood-risk/map?easting=623702&northing=309258&address=10024022371&map=SurfaceWater

Reservoir Flooding

You can obtain a map which shows the extent of flooding if a reservoir was to fail and release the water that it holds. The map shows the worst case scenario. These maps can be viewed on our website at the following:-

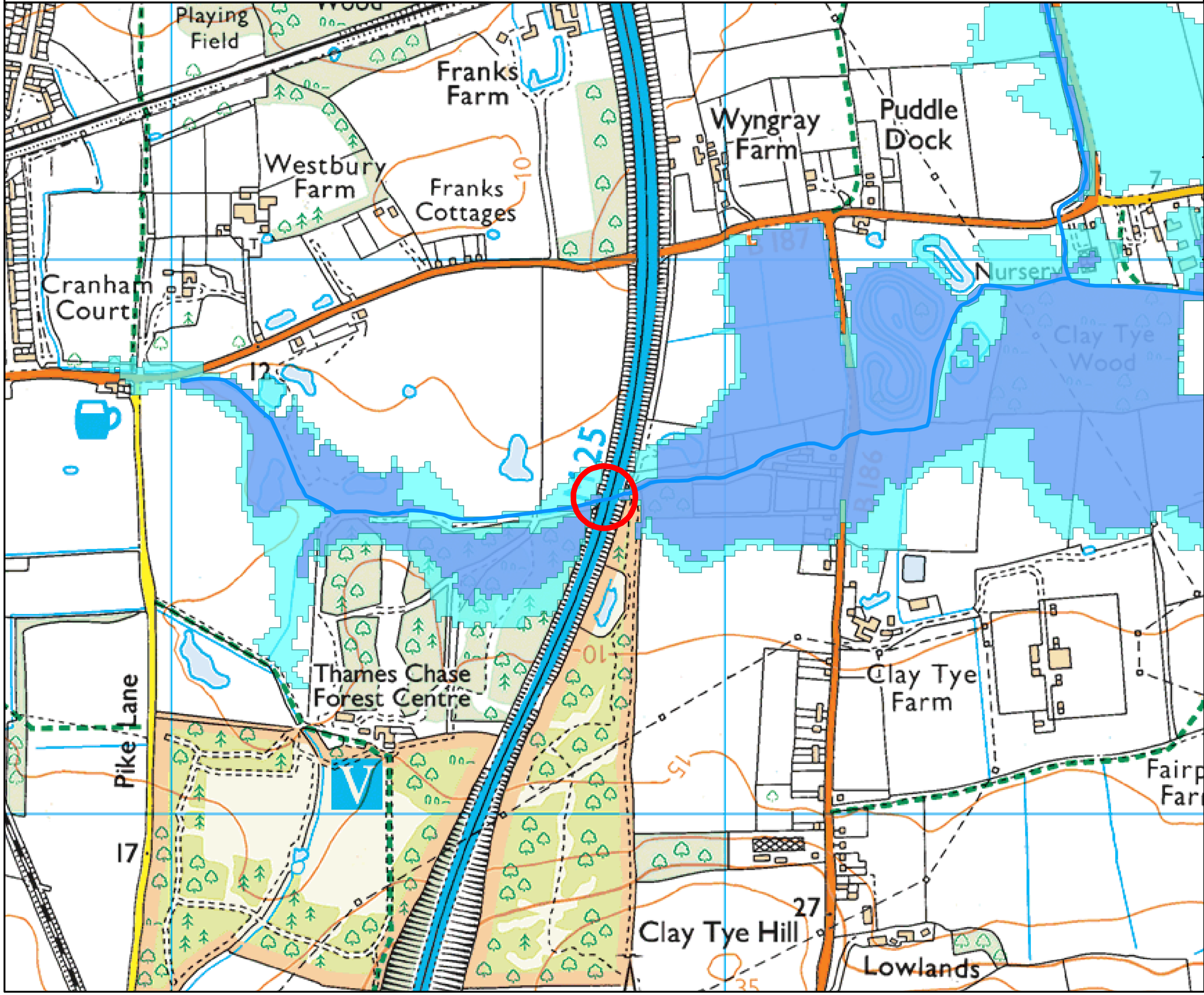
https://flood-warning-information.service.gov.uk/long-term-flood-risk/map?easting=623702&northing=309258&address=10024022371&map=SurfaceWater

Flood Map for Planning centred on LTC TQ 58796 86571
Created 09/03/2018 - Ref: EAn/2018/76391

Environment Agency

Environment Agency
Iceni House
Cobham Road
Ipswich
Suffolk
IP3 9JD

0 135 270 540
Metres



Legend

- Site Outline
- Main Rivers
- Areas Benefiting from Defence
- Flood Zone 3
- Flood Zone 2
- Flood Storage Area

Flood Map for Planning (assuming no defences)

Flood Zone 3 shows the area that could be affected by flooding:
- from the sea with a 1 in 200 or greater chance of happening each year
- or from a river with a 1 in 100 or greater chance of happening each year.

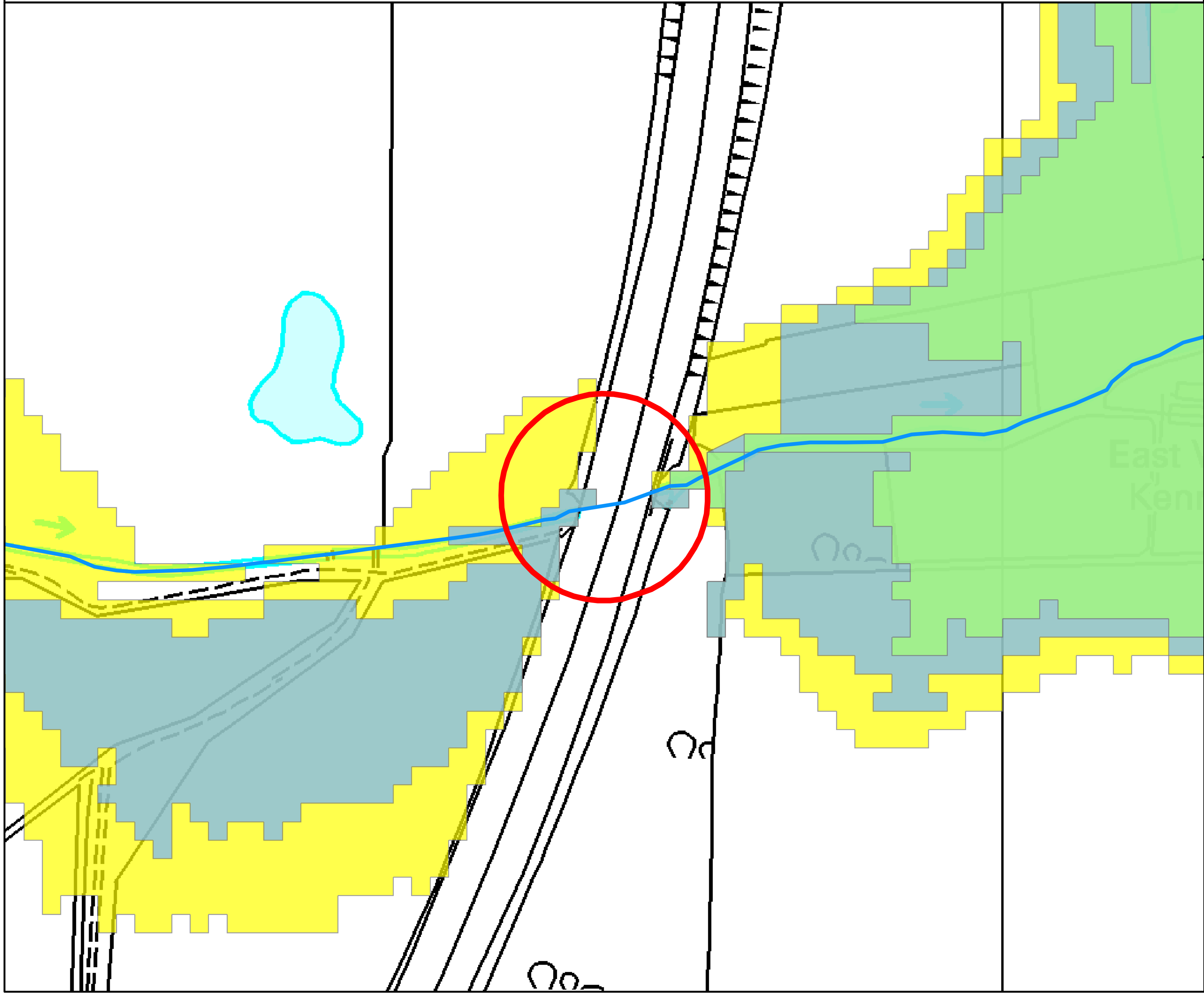
Flood Zone 2 shows the extent of an extreme flood from rivers or the sea with up to a 1 in 1000 chance of occurring each year.

Contact Us: National Customer Contact Centre, PO Box 544, Rotherham, S60 1BY. Tel: 03708 506 506 (Mon-Fri 8-6). Email: enquiries@environment-agency.gov.uk

Produced by: Partnership & Strategic Overview
East Anglia: Essex, Norfolk & Suffolk

Undefended Flood Outlines Map centred on LTC TQ 58796 86571
Created 09/03/2018 - Ref: EAn/2018/76391

Environment Agency



Environment Agency
Iceni House
Cobham Road
Ipswich
Suffolk
IP3 9JD

0 40 80 160
Metres

Legend

- Site Outline
- Main Rivers
- 1 in 20 (5%) - Und
- 1 in 100 (1%) - Und
- 1 in 1000 (0.1%) - Und

This model has been designed for catchment wide flood risk mapping.
It should be noted that it was not created to produce flood levels for specific development sites within the catchment.
Modelled outlines take into account catchment wide defences if present.

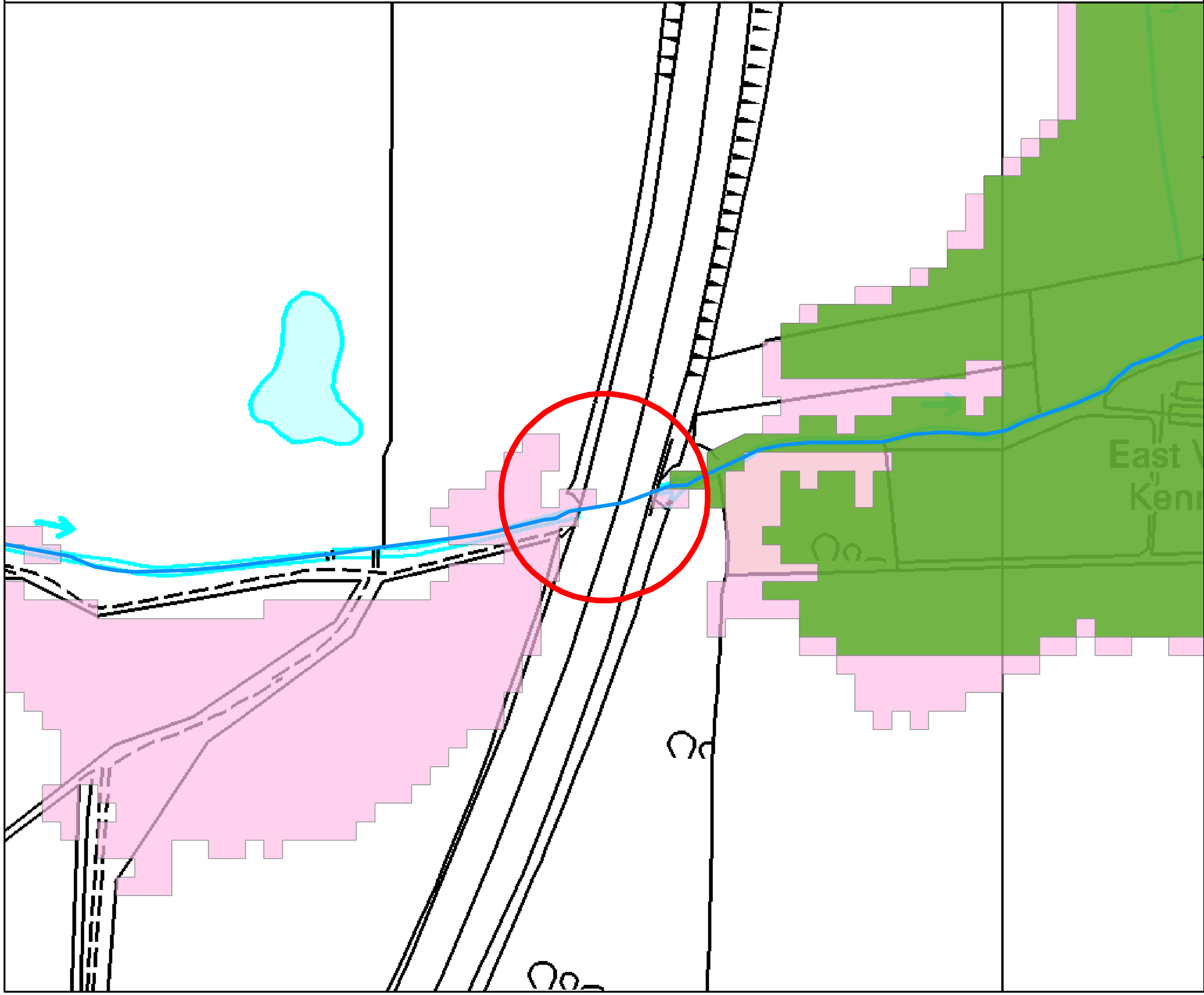
Contact Us: National Customer Contact Centre, PO Box 544, Rotherham, S60 1BY. Tel: 03708 506 506 (Mon-Fri 8-6). Email: enquiries@environment-agency.gov.uk

Produced by: Partnership & Strategic Overview
East Anglia: Essex, Norfolk & Suffolk

Undefended Flood Outlines (plus Climate Change) Map centred on LTC TQ 58796 86571
Created 09/03/2018 - Ref: EAn/2018/76391

Environment Agency

Environment Agency
Iceni House
Cobham Road
Ipswich
Suffolk
IP3 9JD



Legend

- Site Outline
- Main Rivers
- 1 in 20 +20% (*CC%) - Und
- 1 in 100+20% (*CC) - Und

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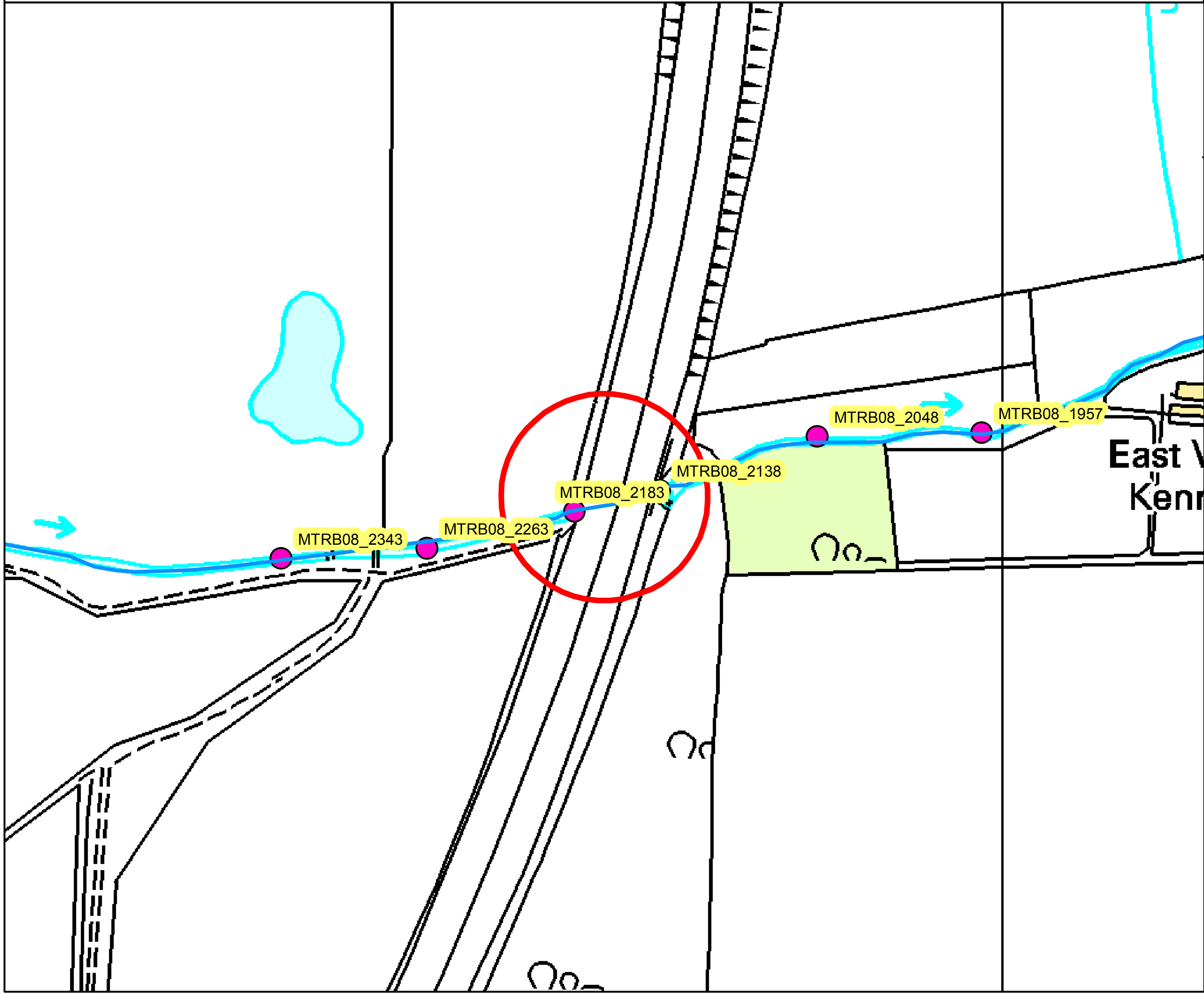
Produced by: Partnership & Strategic Overview
East Anglia: Essex, Norfolk & Suffolk

Modelled Level Location Map centred on LTC TQ 58796 86571
Created 09/03/2018 - Ref: EAn/2018/76391



Environment Agency

Environment Agency
Iceni House
Cobham Road
Ipswich
Suffolk
IP3 9JD

0 40 80 160
Metres

Legend

- Site Outline
- Main Rivers
- Modelled Data Node Point

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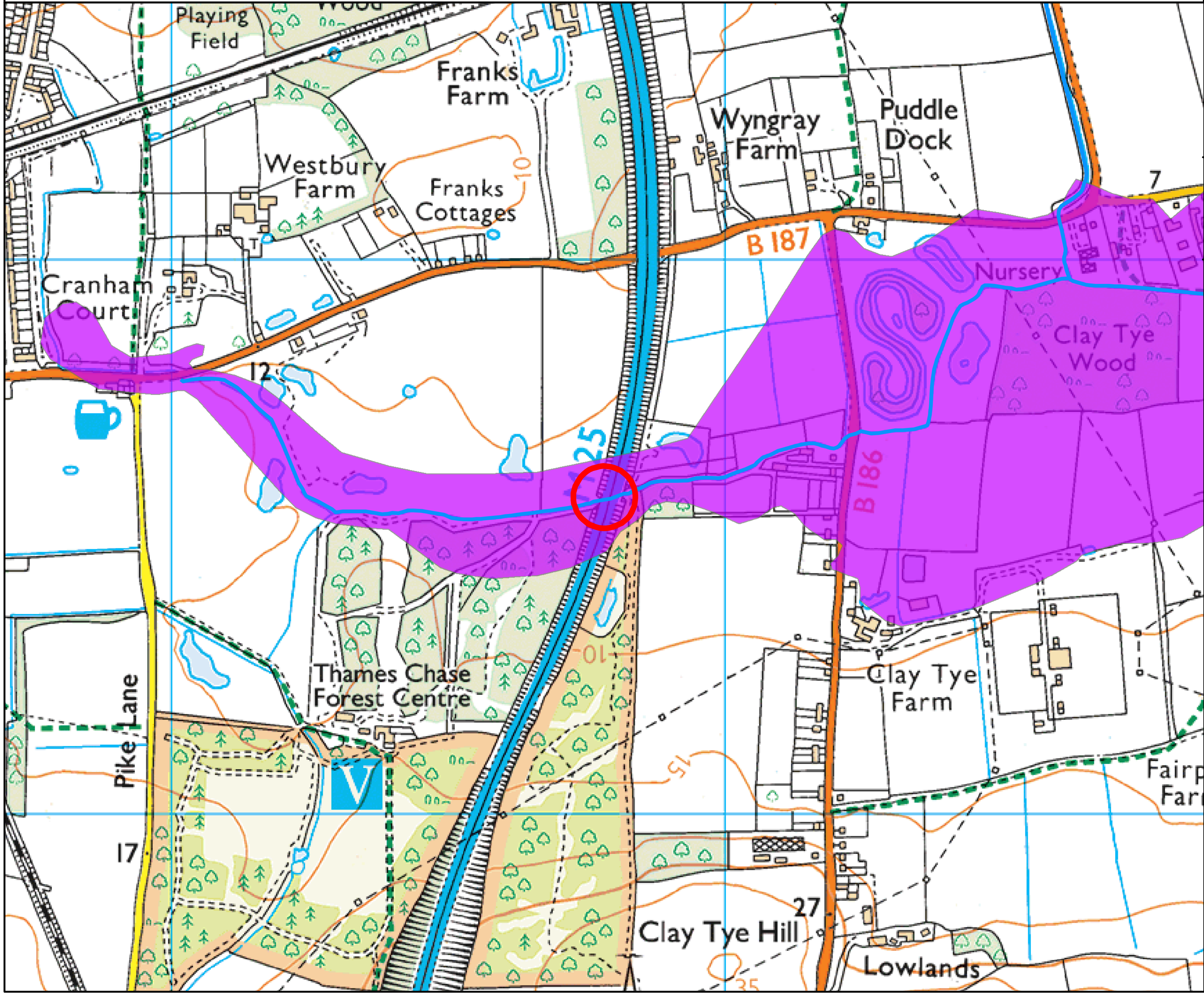
Produced by: Partnership & Strategic Overview
East Anglia: Essex, Norfolk & Suffolk

Recorded Flood Events Outlines Map centred on LTC TQ 58796 86571
Created 09/03/2018 - Ref: EAn/2018/76391

Environment Agency



Environment Agency
Iceni House
Cobham Road
Ipswich
Suffolk
IP3 9JD

0 135 270 540
Metres

Legend

- Site Outline
- Main Rivers
- 1968 Flood Outline

The historic flood event outlines are based on a combination of anecdotal evidence, Environment Agency staff observations and survey.
Our historic flood event outlines do not provide a definitive record of flooding.
It is possible that there will be an absence of datain places where we have not been able to record the extent of flooding.
It is also possible for errors occur in the digitisation of historic records of flooding.

Contact Us: National Customer Contact Centre, PO Box 544, Rotherham, S60 1BY. Tel: 03708 506 506 (Mon-Fri 8-6). Email: enquiries@environment-agency.gov.uk

Produced by: Partnership & Strategic Overview
East Anglia: Essex, Norfolk & Suffolk

Reference: **EAn/2018/76391**
Site Address: **LTC TQ 62042 83753**
Date: **09/03/2018**

Included:

- Flood Map
- Undefended Key Outlines – 20, 100 & 1000 Map
- Undefended Key Outlines – *CC 20 & 100Map
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- 1D (In-channel) Undefended Levels & Flows Table
- Historic Flood Outlines Map

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Please see the attached map showing the Flood Zones (outlines) for the area of the site. Our maps show the site is located in fluvial Flood Zone 3.

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The flow data for this model has been provided.

For further guidance on fluvial climate change please contact the Partnership and Strategic Overview Team at: PSOENS@environment-agency.gov.uk

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Please be aware that in recent years, there has been an increase in flood damage caused by surface water flooding or drainage systems that have been overwhelmed. We have worked with Lead local Flood Authorities (LLFAs) to develop a map which incorporates the best local and national scale information on surface water flood risk. These maps can be viewed on our website at the following:-

https://flood-warning-information.service.gov.uk/long-term-flood-risk/map?easting=623702&northing=309258&address=10024022371&map=SurfaceWater

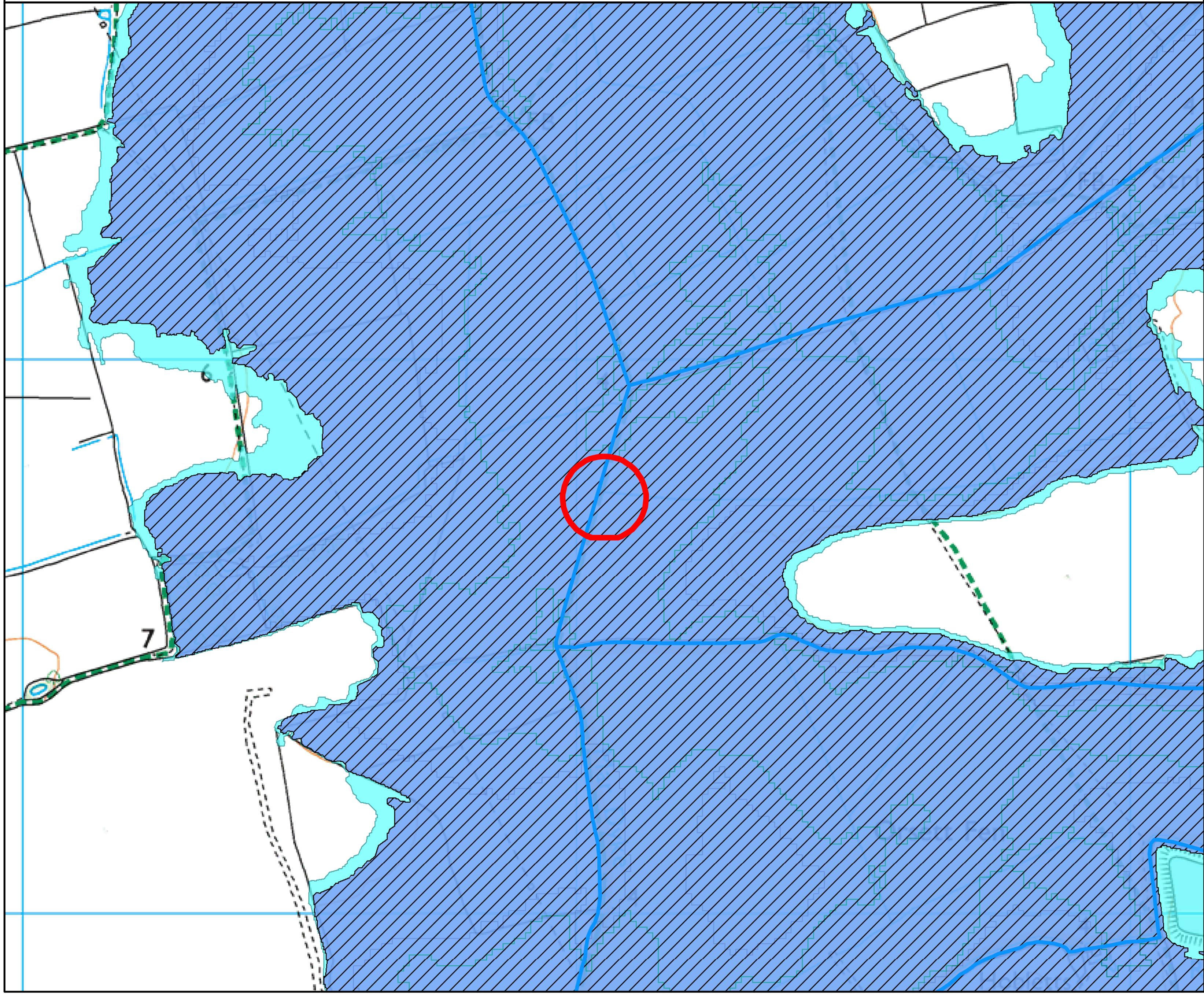
Reservoir Flooding

You can obtain a map which shows the extent of flooding if a reservoir was to fail and release the water that it holds. The map shows the worst case scenario. These maps can be viewed on our website at the following:-
https://flood-warning-information.service.gov.uk/long-term-flood-risk/map?easting=623702&northing=309258&address=10024022371&map=SurfaceWater

Flood Map for Planning centred on LTC TQ 62042 83753
Created 09/03/2018 - Ref: EAn/2018/76391

Environment Agency

Environment Agency
Iceni House
Cobham Road
Ipswich
Suffolk
IP3 9JD



0 137.5 275 550
Metres

Legend

- Site Outline
- Main Rivers
- Areas Benefiting from Defence
- Flood Zone 3
- Flood Zone 2
- Flood Storage Area

Flood Map for Planning (assuming no defences)

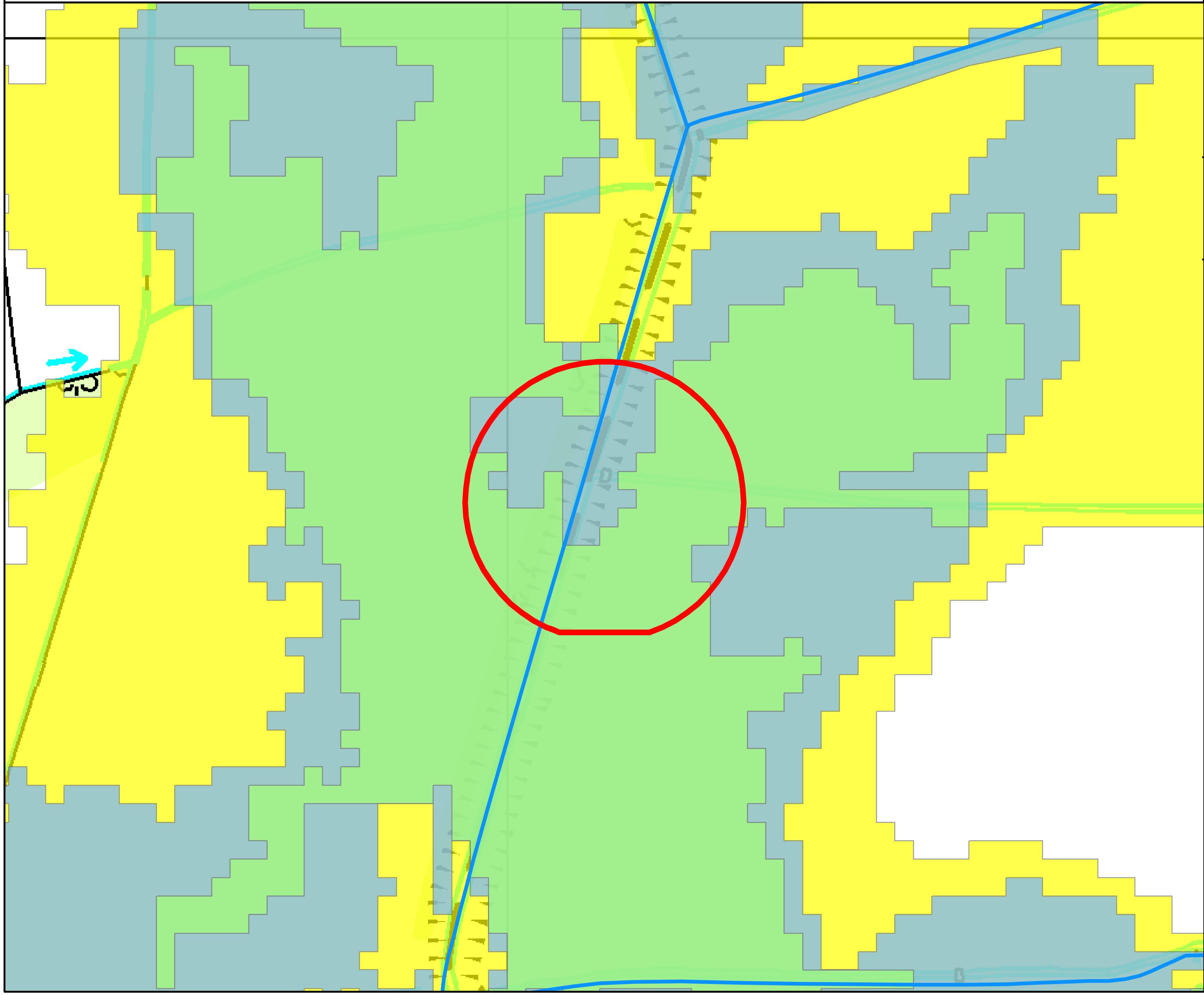
Flood Zone 3 shows the area that could be affected by flooding:
- from the sea with a 1 in 200 or greater chance of happening each year
- or from a river with a 1 in 100 or greater chance of happening each year.

Flood Zone 2 shows the extent of an extreme flood from rivers or the sea with up to a 1 in 1000 chance of occurring each year.

Contact Us: National Customer Contact Centre, PO Box 544, Rotherham, S60 1BY. Tel: 03708 506 506 (Mon-Fri 8-6). Email: enquiries@environment-agency.gov.uk

Produced by: Partnership & Strategic Overview
East Anglia: Essex, Norfolk & Suffolk

Undefended Flood Outlines Map centred on LTC TQ 62042 83753
Created 09/03/2018 - Ref: EAn/2018/76391



Environment Agency

Environment Agency
Iceni House
Cobham Road
Ipswich
Suffolk
IP3 9JD

0 40 80 160
Metres

Legend

- Site Outline
- Main Rivers
- 1 in 20 (5%) - Und
- 1 in 100 (1%) - Und
- 1 in 1000 (0.1%) - Und

This model has been designed for catchment wide flood risk mapping. It should be noted that it was not created to produce flood levels for specific development sites within the catchment. Modelled outlines take into account catchment wide defences if present.

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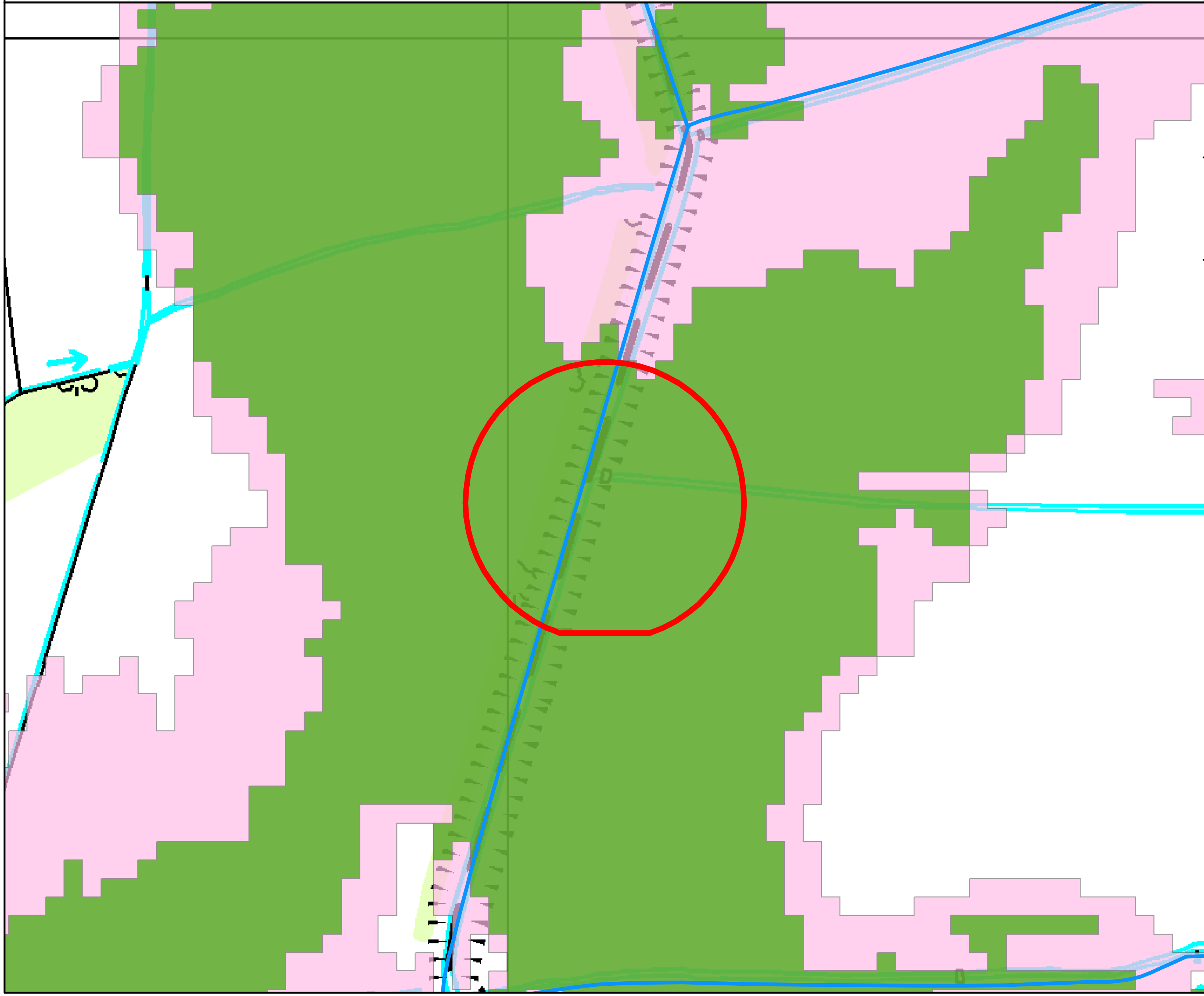
Produced by: Partnership & Strategic Overview
East Anglia: Essex, Norfolk & Suffolk

Undefended Flood Outlines (plus Climate Change) Map centred on LTC TQ 62042 83753
Created 09/03/2018 - Ref: EAn/2018/76391

Environment Agency



Environment Agency
Iceni House
Cobham Road
Ipswich
Suffolk
IP3 9JD

0 40 80 160
Metres

Legend

Site Outline
Main Rivers
1 in 20 +20% (*CC%) - Und
1 in 100+20% (*CC) - Und

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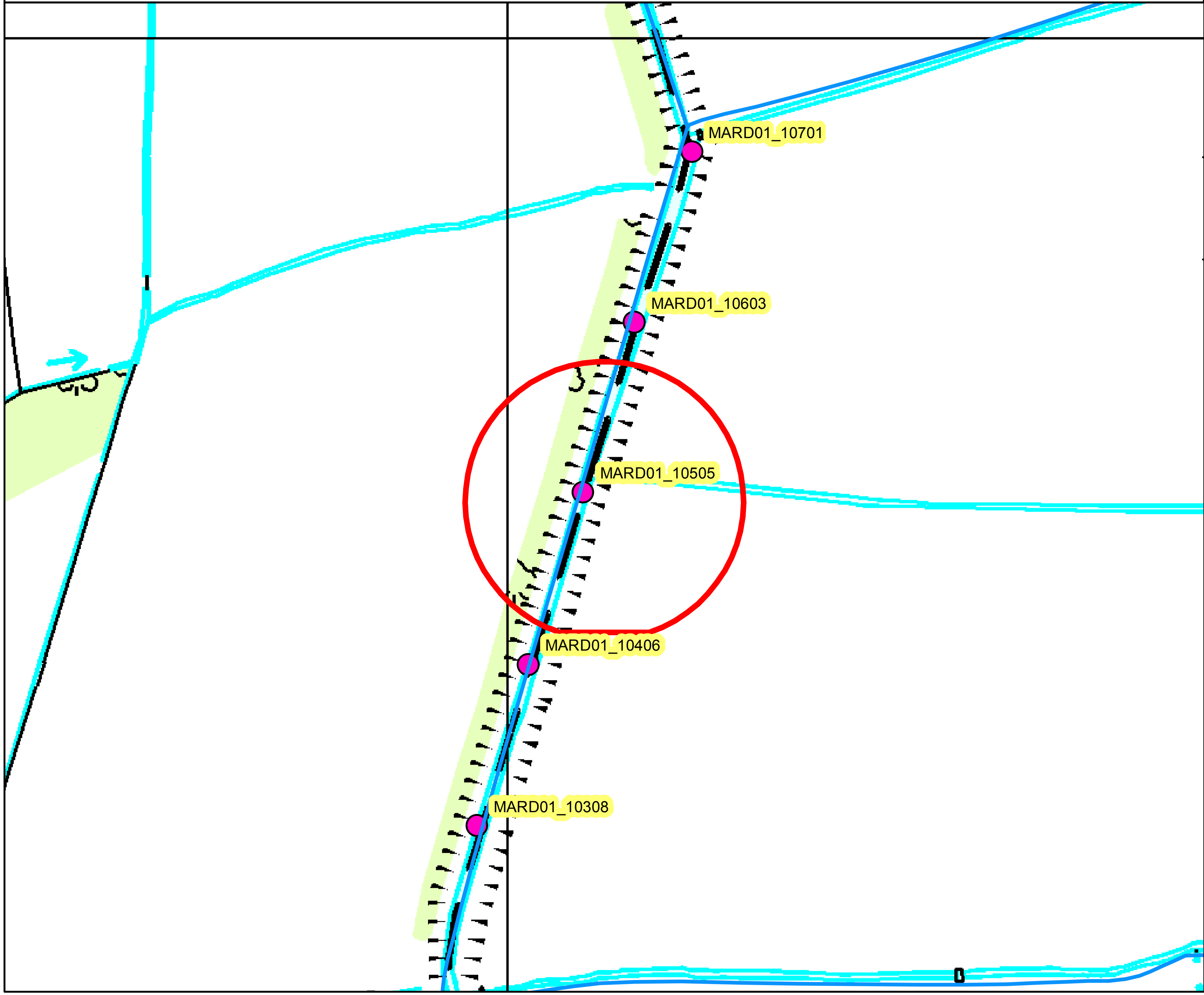
Produced by: Partnership & Strategic Overview
East Anglia: Essex, Norfolk & Suffolk

Modelled Level Location Map centred on LTC TQ 62042 83753
Created 09/03/2018 - Ref: EAn/2018/76391



Environment Agency

Environment Agency
Iceni House
Cobham Road
Ipswich
Suffolk
IP3 9JD

0 40 80 160
Metres

Legend

- Site Outline
- Main Rivers
- Modelled Data Node Point

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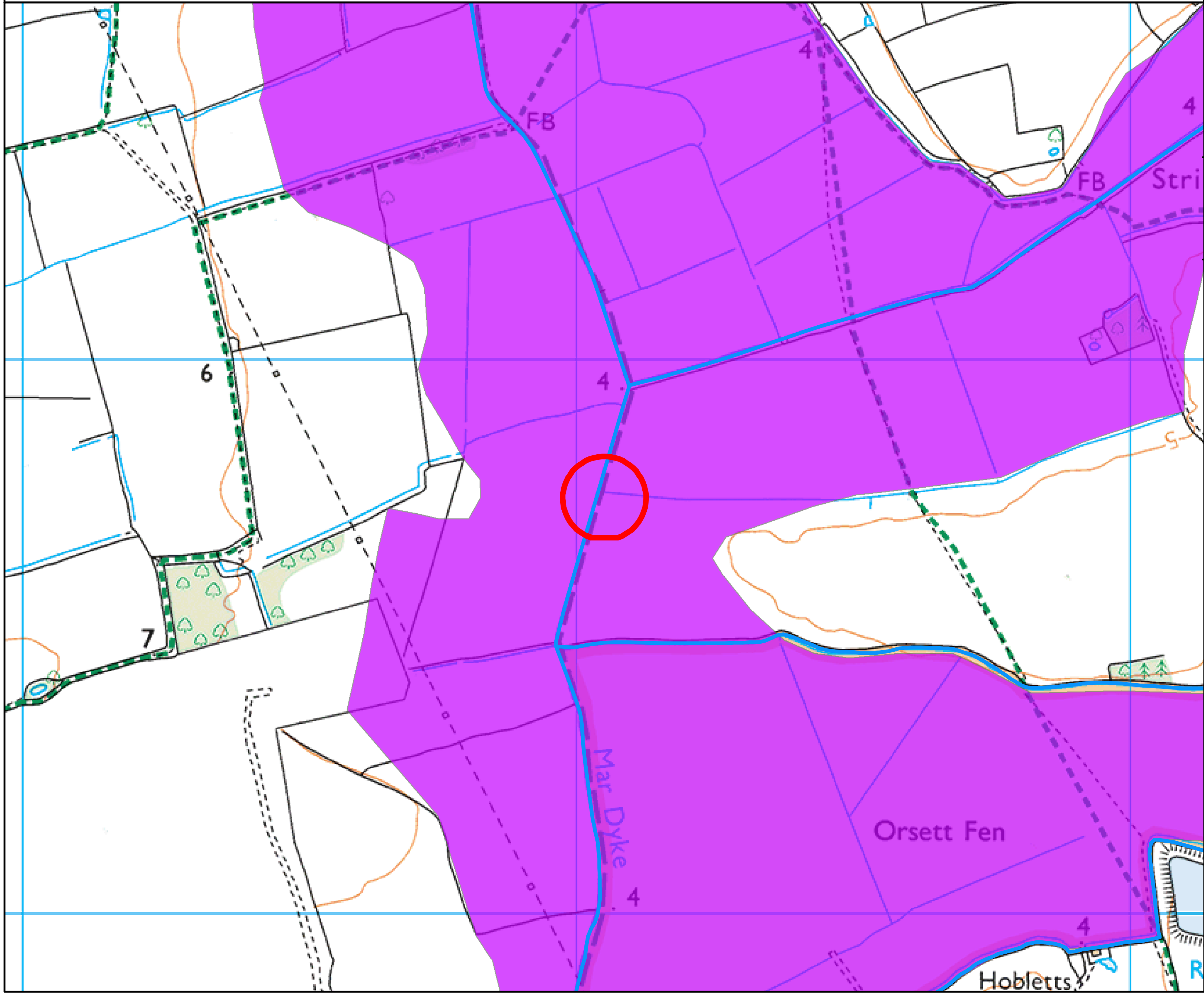
Produced by: Partnership & Strategic Overview
East Anglia: Essex, Norfolk & Suffolk

Recorded Flood Events Outlines Map centred on LTC TQ 62042 83753
Created 09/03/2018 - Ref: EAn/2018/76391



Environment Agency

Environment Agency
Iceni House
Cobham Road
Ipswich
Suffolk
IP3 9JD

0 135 270 540
Metres

Legend

- Site Outline
- Main Rivers
- 1968 Flood Outline

The historic flood event outlines are based on a combination of anecdotal evidence, Environment Agency staff observations and survey.
Our historic flood event outlines do not provide a definitive record of flooding.
It is possible that there will be an absence of datain places where we have not been able to record the extent of flooding.
It is also possible for errors occur in the digitisation of historic records of flooding.

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Produced by: Partnership & Strategic Overview
East Anglia: Essex, Norfolk & Suffolk

Reference: EAn/2018/76391
Site Address: LTC TQ 62371 83505
Date: 09/03/2018

Included:

- Flood Map
- Undefended Key Outlines – 20, 100 & 1000 Map
- Undefended Key Outlines – *CC 20 & 100Map
- 1D Levels & Flows Nodes Map
- 1D (In-channel) Undefended Levels & Flows Table
- Historic Flood Outlines Map

Important information to note with your Product:

Flood Risk Assessments (FRAs)
If you are obtaining this information for use within a Flood Risk Assessment (FRA) required for a planning application, please include our unaltered Product 4 data within an appendix of your FRA.

Flood Zones
Please see the attached map showing the Flood Zones (outlines) for the area of the site. Our maps show the site is located in fluvial Flood Zone 3.

Climate Change (Fluvial Only)
Flood risk data requests including an allowance for climate change will be based on the 1% annual probability flood including an additional 20% increase on peak flows to account for climate change impacts, unless otherwise stated. You should refer to 'Flood risk assessments: climate change allowances' to check if this allowance is still appropriate for the type of development you are proposing and its location. You may need to undertake further assessment of future flood risk using different allowances to ensure your assessment of future flood risk is based on best available evidence.

The flow data for this model has been provided.

For further guidance on fluvial climate change please contact the Partnership and Strategic Overview Team at: PSOENS@environment-agency.gov.uk

Historic Flood Events
Examinations of our records of historic flooding show that the general area has previously flooded. Please note that these records show flooding to the land and do not necessarily indicate that properties within the historic flood events were flooded internally. It is also possible that the pattern of flooding in this area has changed and that this area would now flood under different circumstances. Please see the attached PDF for flood history information.

Surface Water
Please be aware that in recent years, there has been an increase in flood damage caused by surface water flooding or drainage systems that have been overwhelmed. We have worked with Lead local Flood Authorities (LLFAs) to develop a map which incorporates the best local and national scale information on surface water flood risk. These maps can be viewed on our website at the following:-

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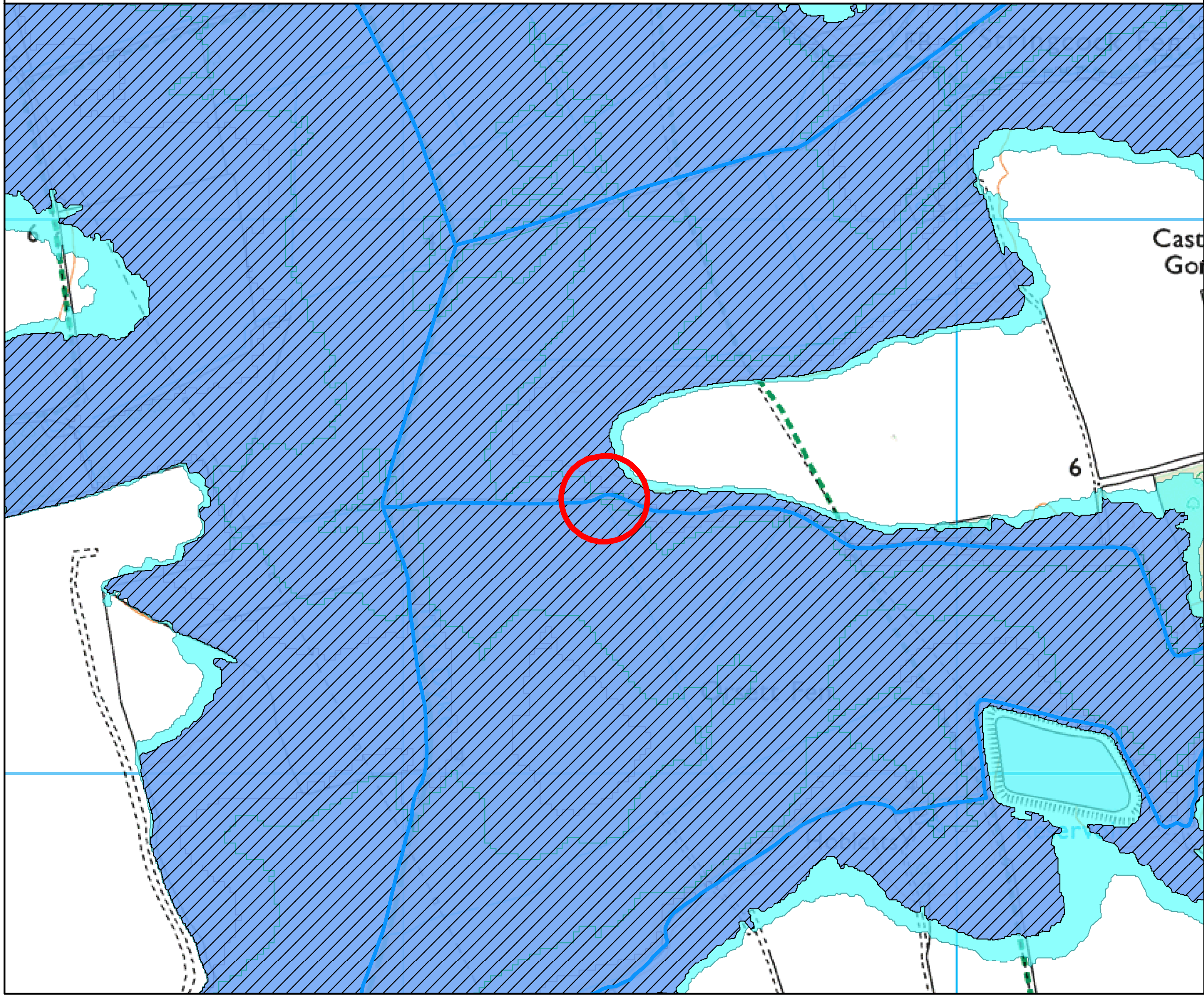
Flood Map for Planning centred on LTC TQ 62371 83505
Created 09/03/2018 - Ref: EAn/2018/76391



Environment Agency

Environment Agency
Iceni House
Cobham Road
Ipswich
Suffolk
IP3 9JD

0 135 270 540
Metres

Legend

- Site Outline
- Main Rivers
- Areas Benefiting from Defence
- Flood Zone 3
- Flood Zone 2
- Flood Storage Area

Flood Map for Planning (assuming no defences)

Flood Zone 3 shows the area that could be affected by flooding:
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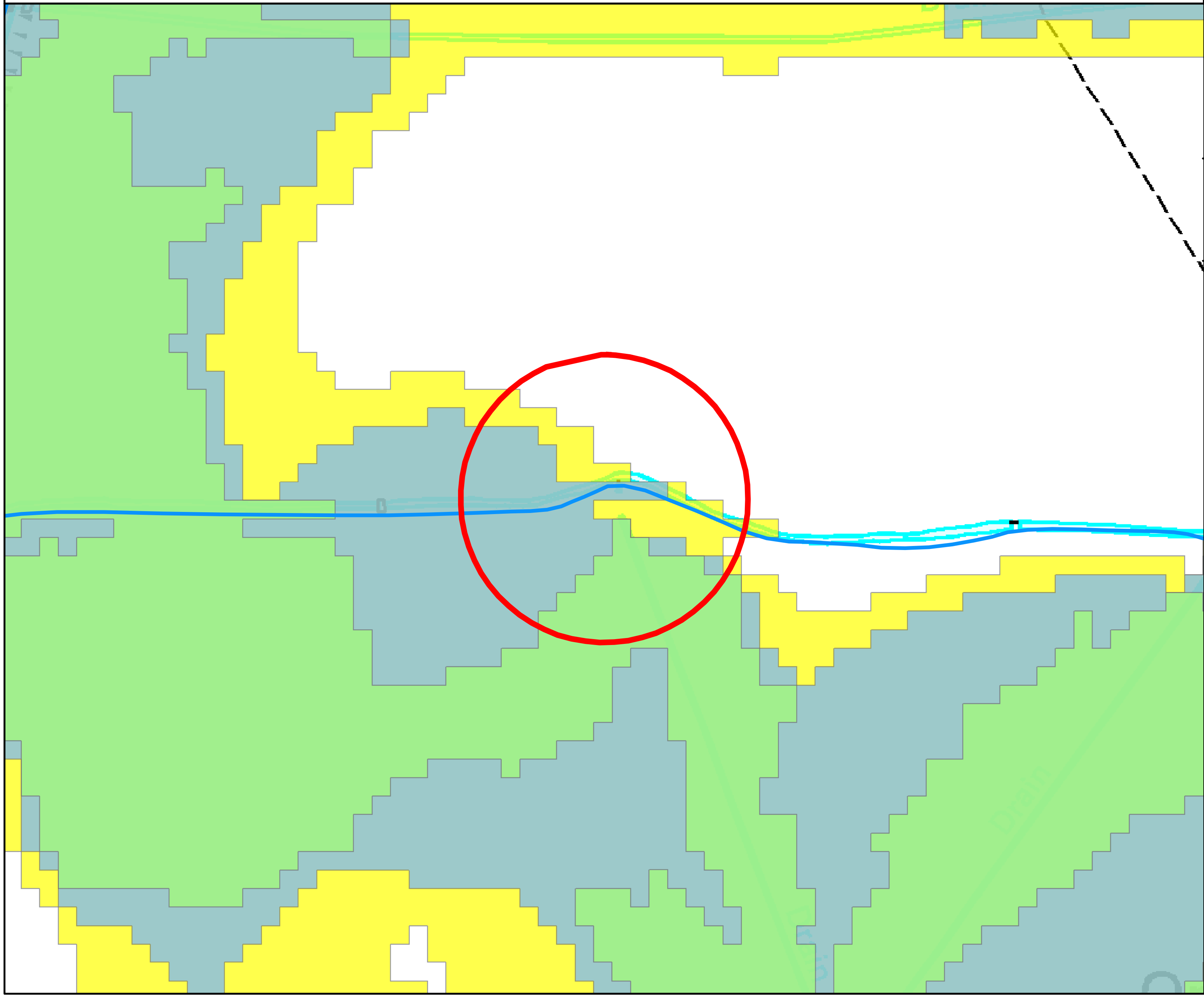
Produced by: Partnership & Strategic Overview
East Anglia: Essex, Norfolk & Suffolk

Undefended Flood Outlines Map centred on LTC TQ 62371 83505
Created 09/03/2018 - Ref: EAn/2018/76391



Environment Agency

Environment Agency
Iceni House
Cobham Road
Ipswich
Suffolk
IP3 9JD

0 40 80 160
Metres

Legend

- Site Outline
- Main Rivers
- 1 in 20 (5%) - Und
- 1 in 100 (1%) - Und
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This model has been designed for catchment wide flood risk mapping. It should be noted that it was not created to produce flood levels for specific development sites within the catchment. Modelled outlines take into account catchment wide defences if present.

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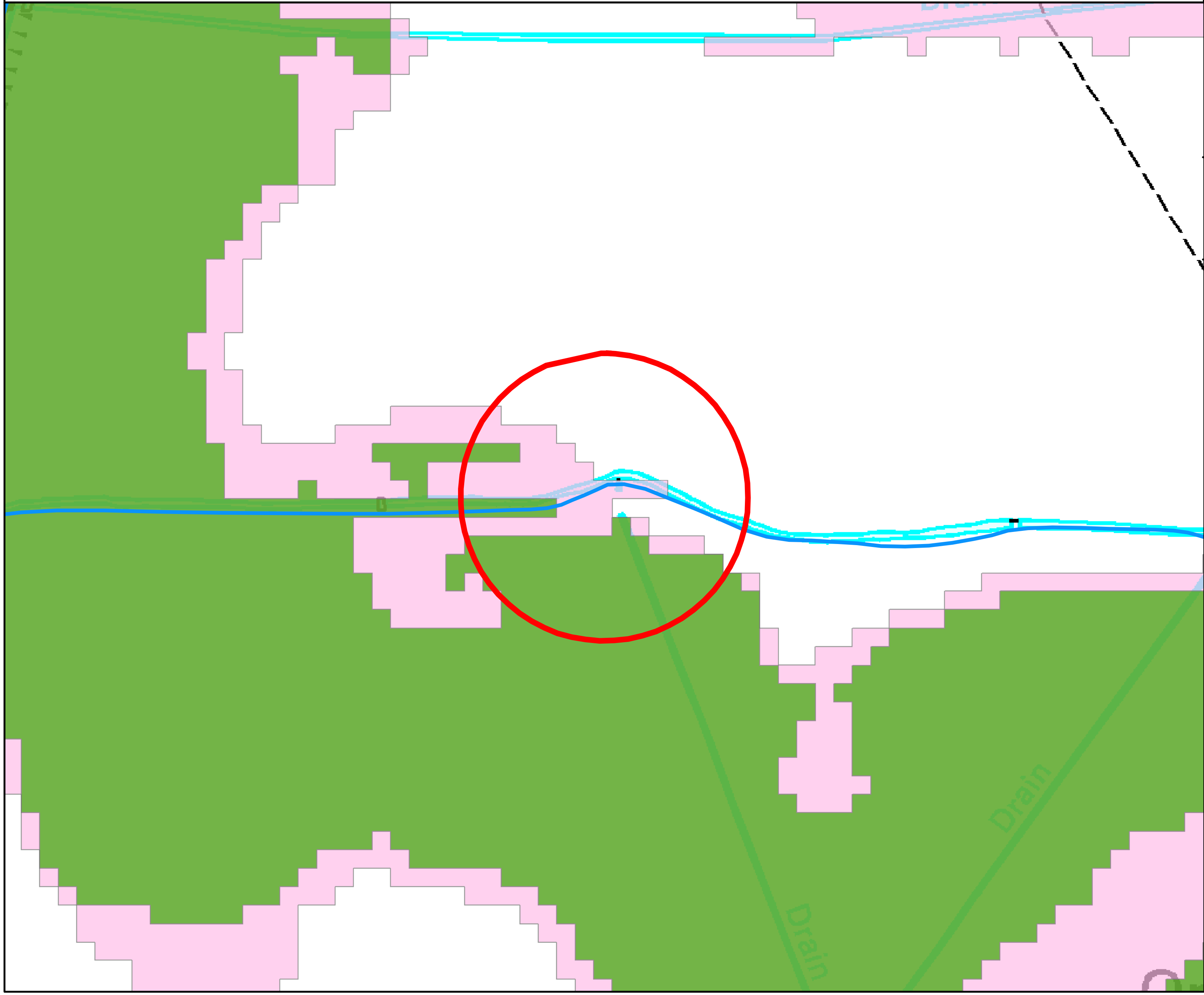
Produced by: Partnership & Strategic Overview
East Anglia: Essex, Norfolk & Suffolk

Undefended Flood Outlines (plus Climate Change) Map centred on LTC TQ 62371 83505
Created 09/03/2018 - Ref: EAn/2018/76391



Environment Agency

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Suffolk
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0 40 80 160
Metres

Legend

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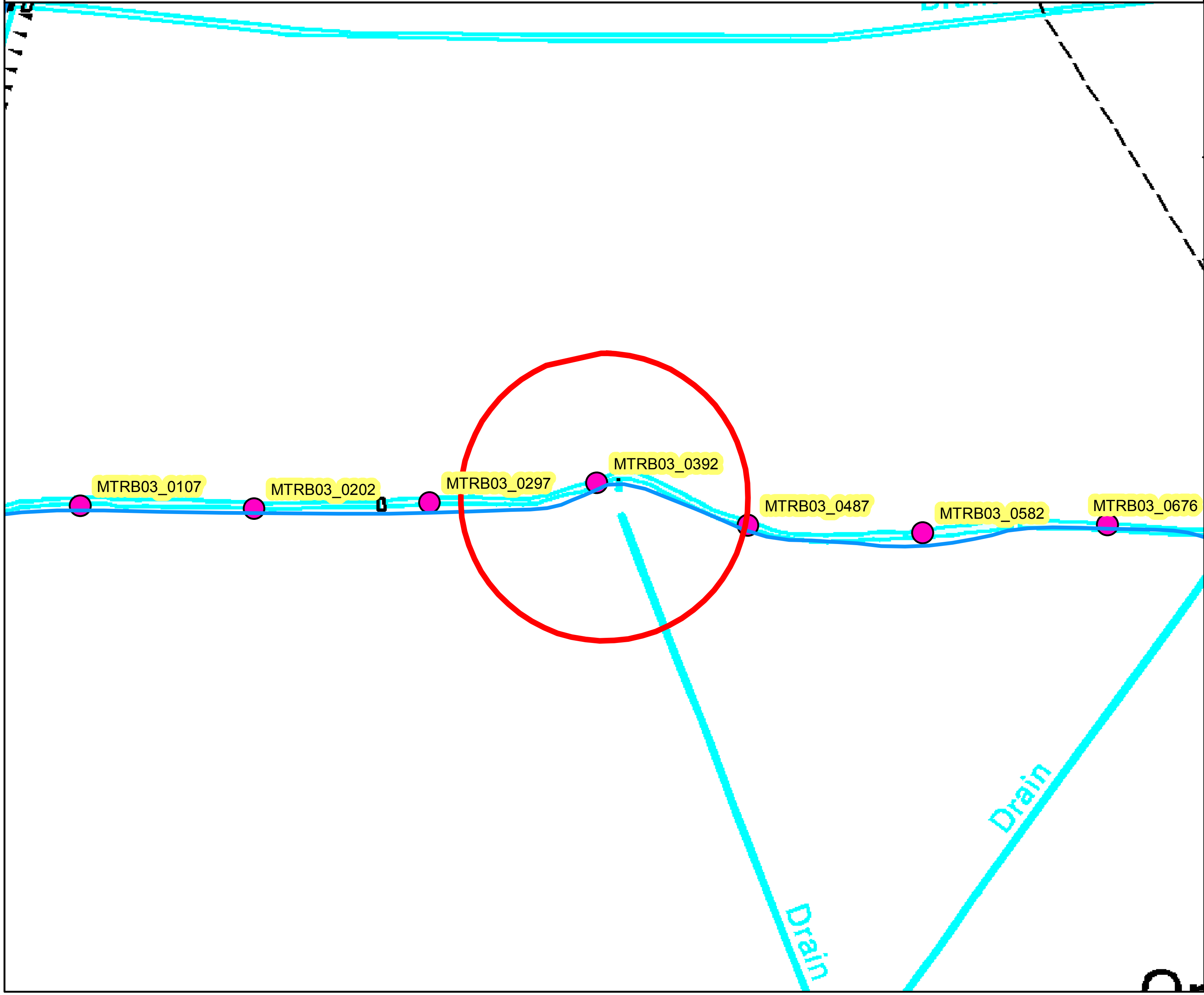
Produced by: Partnership & Strategic Overview
East Anglia: Essex, Norfolk & Suffolk

Modelled Level Location Map centred on LTC TQ 62371 83505
Created 09/03/2018 - Ref: EAn/2018/76391



Environment Agency
Iceni House
Cobham Road
Ipswich
Suffolk
IP3 9JD

0 40 80 160
Metres

Legend

- Site Outline
- Main Rivers
- Modelled Data Node Point

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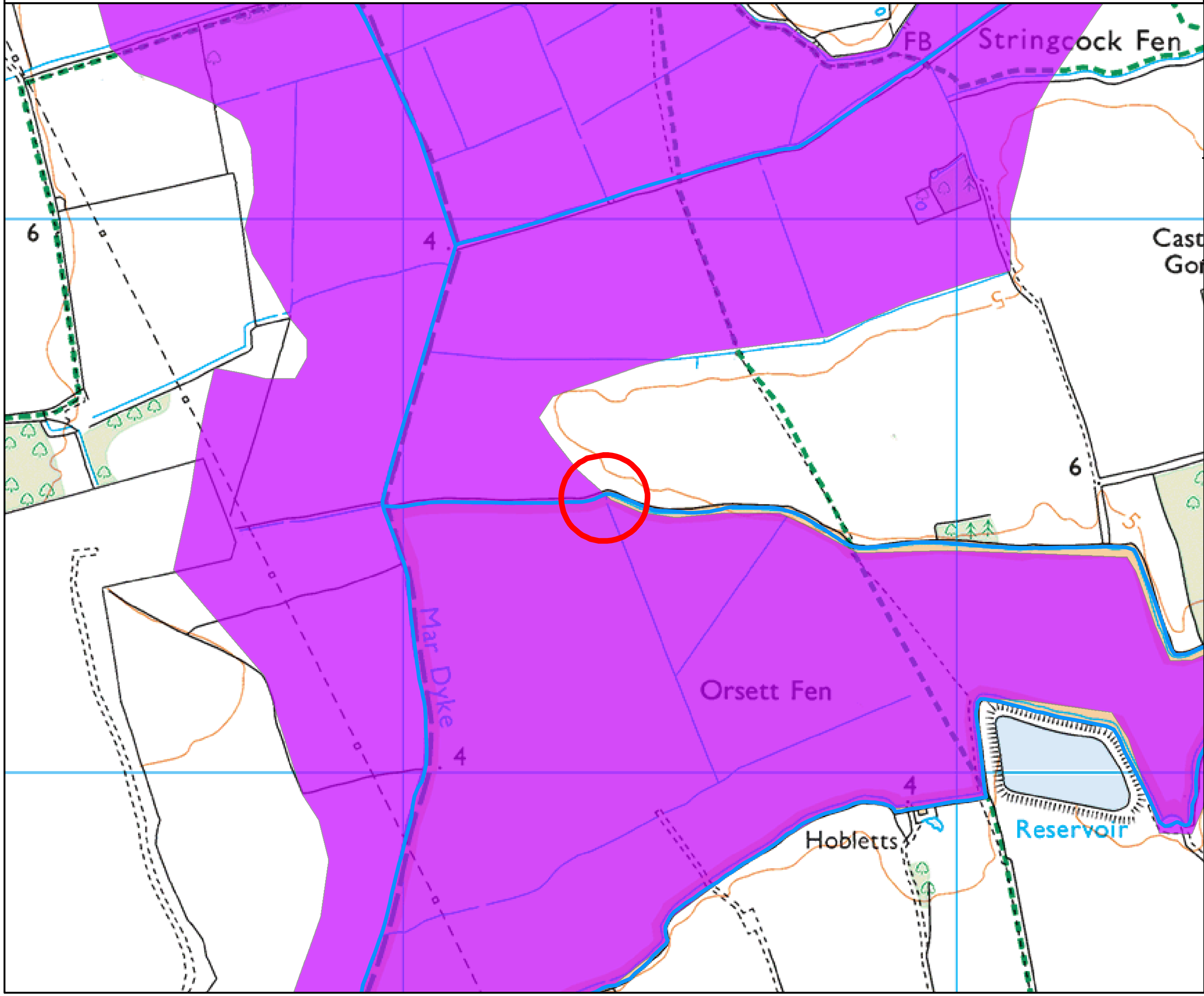
Produced by: Partnership & Strategic Overview
East Anglia: Essex, Norfolk & Suffolk

Recorded Flood Events Outlines Map centred on LTC TQ 62371 83505
Created 09/03/2018 - Ref: EAn/2018/76391



Environment Agency

Environment Agency
Iceni House
Cobham Road
Ipswich
Suffolk
IP3 9JD

0 135 270 540
Metres

Legend

Site Outline

Main Rivers

1968 Flood Outline

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Produced by: Partnership & Strategic Overview
East Anglia: Essex, Norfolk & Suffolk

Reference: EAn/2018/76391
Site Address: LTC TQ 62630 82854
Date: 09/03/2018

Included:

- Flood Map
- Undefended Key Outlines – 20, 100 & 1000 Map
- Undefended Key Outlines – *CC 20 & 100Map
- 1D Levels & Flows Nodes Map
- 1D (In-channel) Undefended Levels & Flows Table
- Historic Flood Outlines Map

Important information to note with your Product:

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Flood Zones
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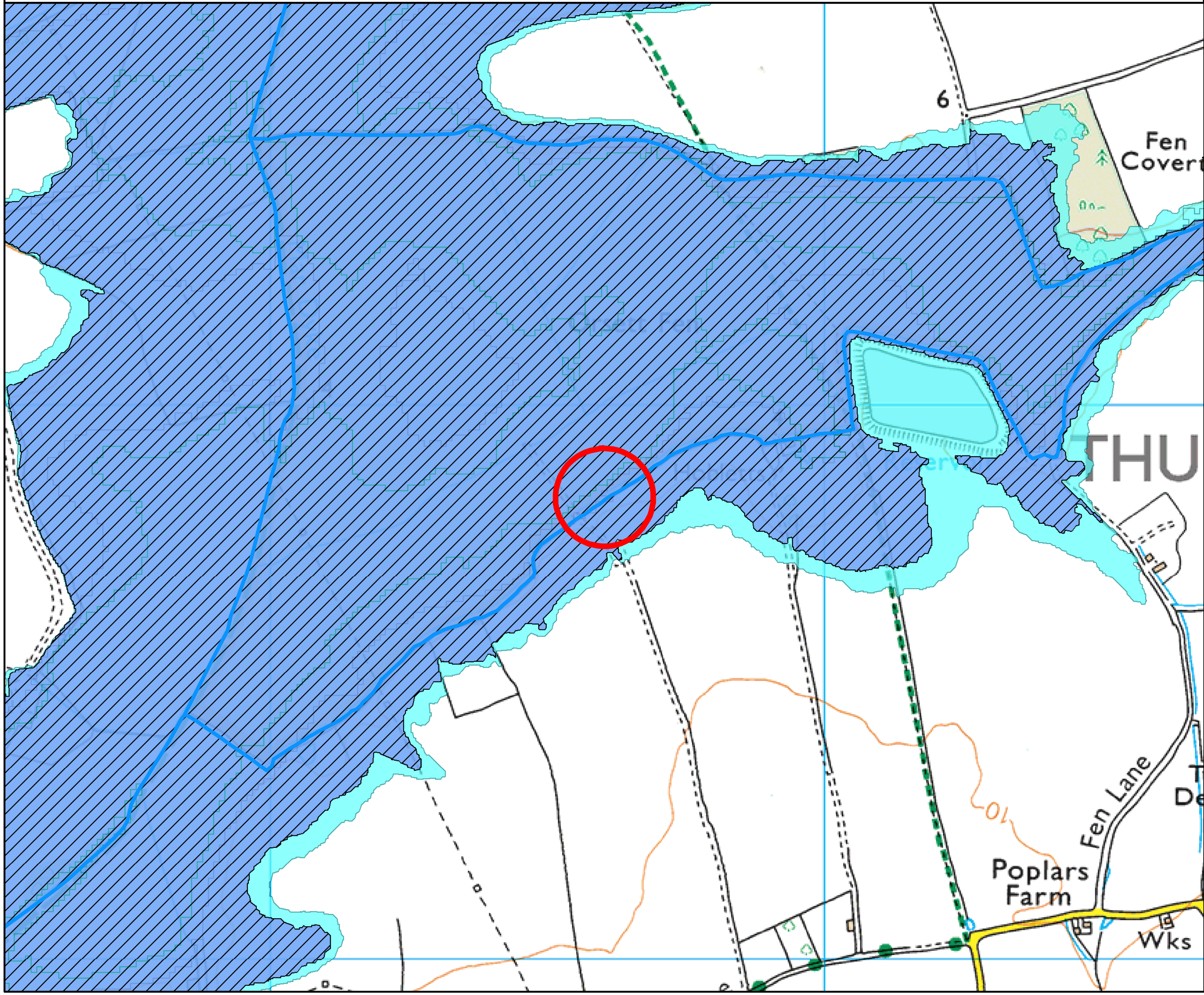
Flood Map for Planning centred on LTC TQ 62630 82854
Created 09/03/2018 - Ref: EAn/2018/76391

Environment Agency



Environment Agency
Iceni House
Cobham Road
Ipswich
Suffolk
IP3 9JD

0 135 270 540
Metres

Legend

- Site Outline
- Main Rivers
- Areas Benefiting from Defence
- Flood Zone 3
- Flood Zone 2
- Flood Storage Area

Flood Map for Planning (assuming no defences)

Flood Zone 3 shows the area that could be affected by flooding:
- from the sea with a 1 in 200 or greater chance of happening each year
- or from a river with a 1 in 100 or greater chance of happening each year.

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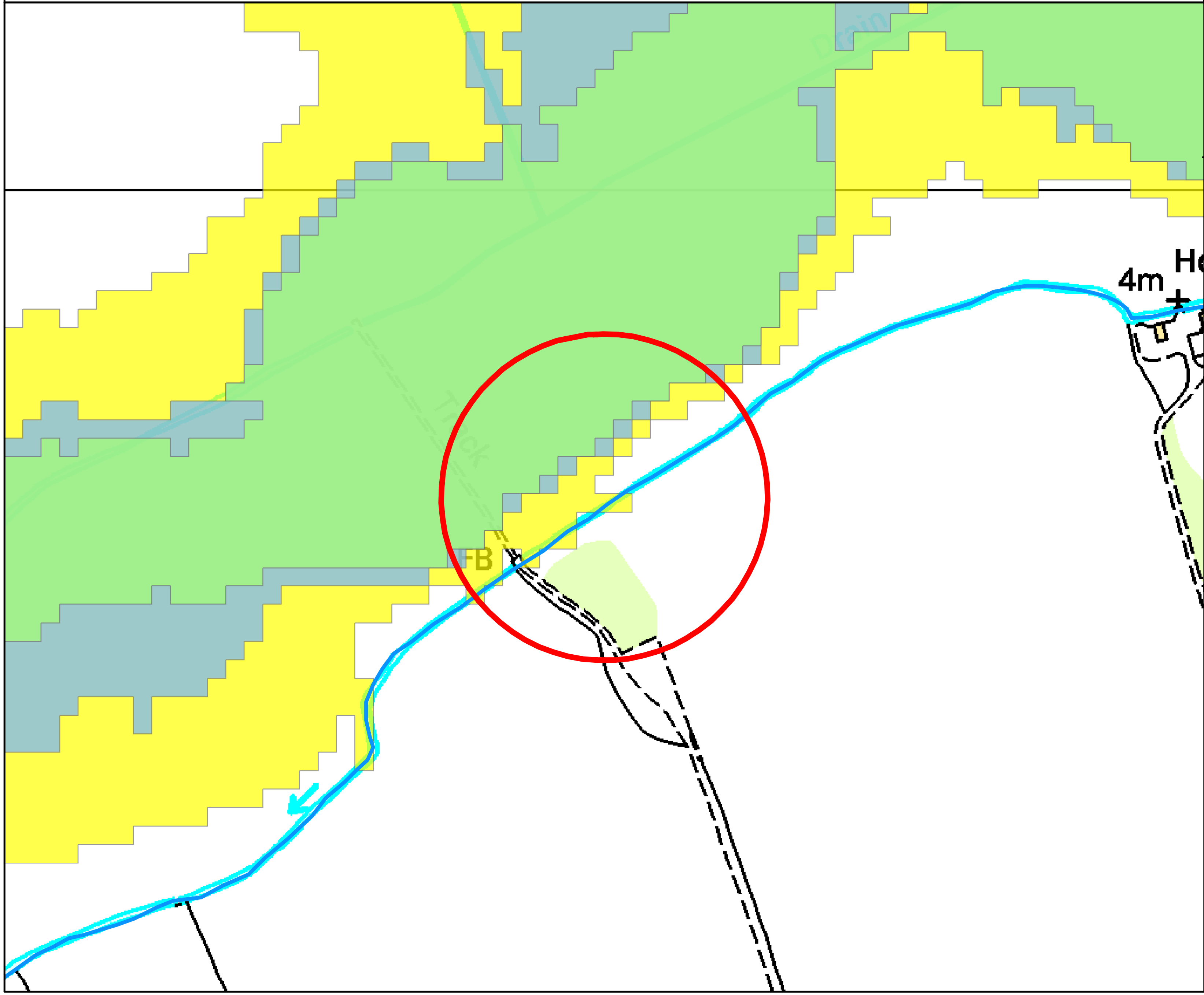
Produced by: Partnership & Strategic Overview
East Anglia: Essex, Norfolk & Suffolk

Undefended Flood Outlines Map centred on LTC TQ 62630 82854
Created 09/03/2018 - Ref: EAn/2018/76391

Environment Agency

Environment Agency
Iceni House
Cobham Road
Ipswich
Suffolk
IP3 9JD



0 40 80 160
Metres

Legend

- Site Outline
- Main Rivers
- 1 in 20 (5%) - Und
- 1 in 100 (1%) - Und
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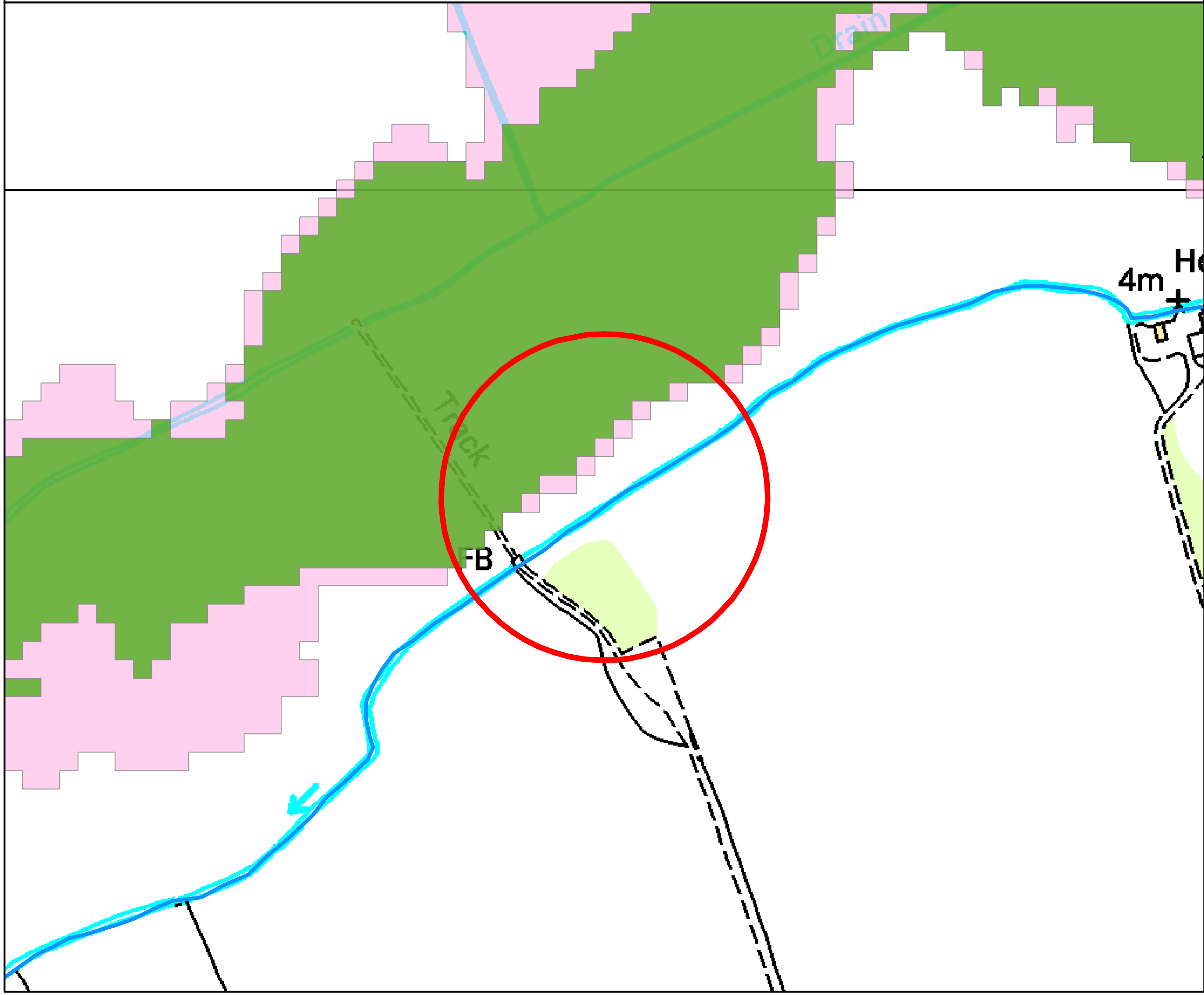
Produced by: Partnership & Strategic Overview
East Anglia: Essex, Norfolk & Suffolk

Undefended Flood Outlines (plus Climate Change) Map centred on LTC TQ 62630 82854
Created 09/03/2018 - Ref: EAn/2018/76391

Environment Agency

Environment Agency
Iceni House
Cobham Road
Ipswich
Suffolk
IP3 9JD



0 40 80 160
Metres

Legend

- Site Outline
- Main Rivers
- 1 in 20 +20% (*CC%) - Und
- 1 in 100+20% (*CC) - Und

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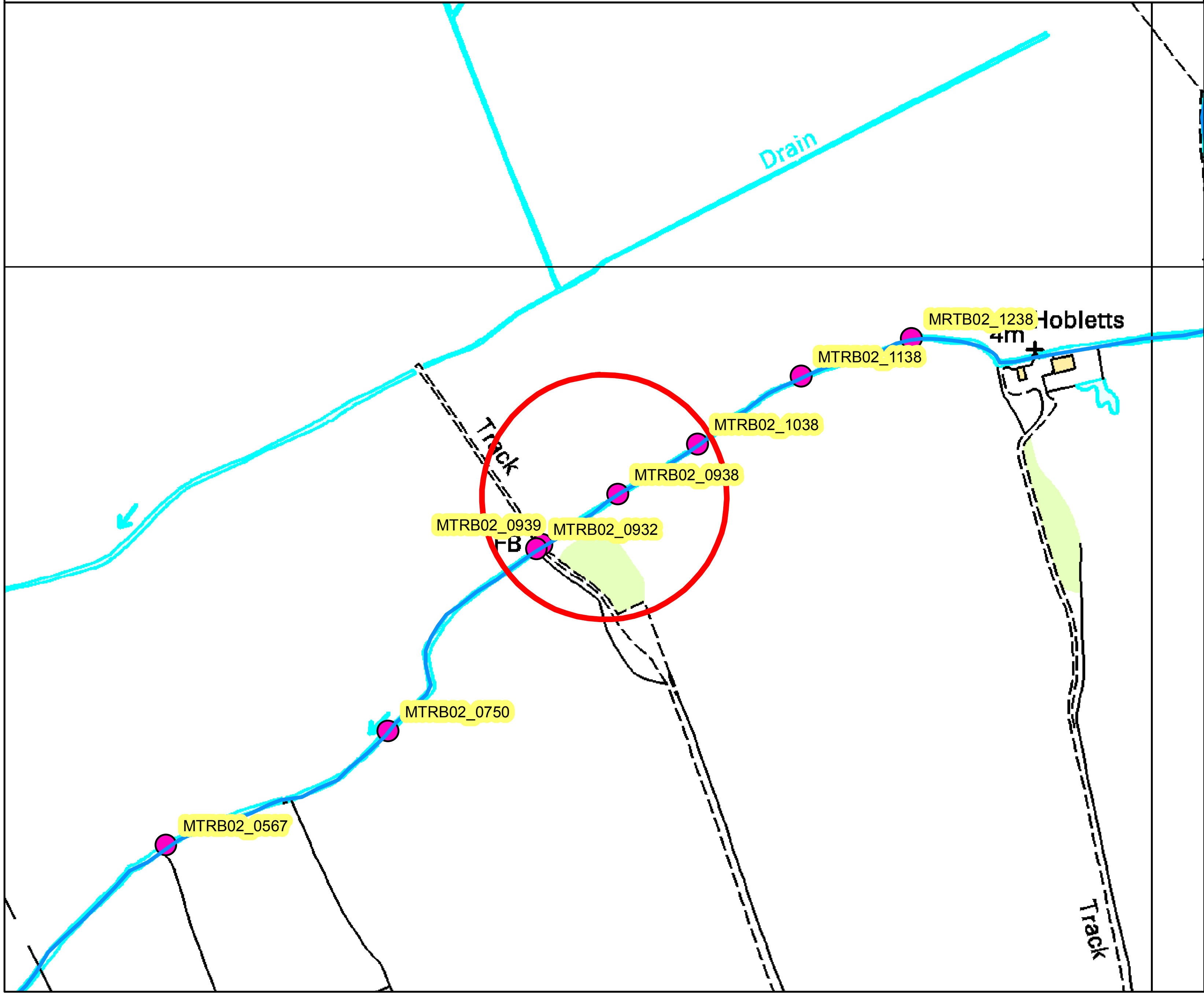
Produced by: Partnership & Strategic Overview
East Anglia: Essex, Norfolk & Suffolk

Modelled Level Location Map centred on LTC TQ 62630 82854
Created 09/03/2018 - Ref: EAn/2018/76391

Environment Agency

Environment Agency
Iceni House
Cobham Road
Ipswich
Suffolk
IP3 9JD

0 55 110 220
Metres



Legend

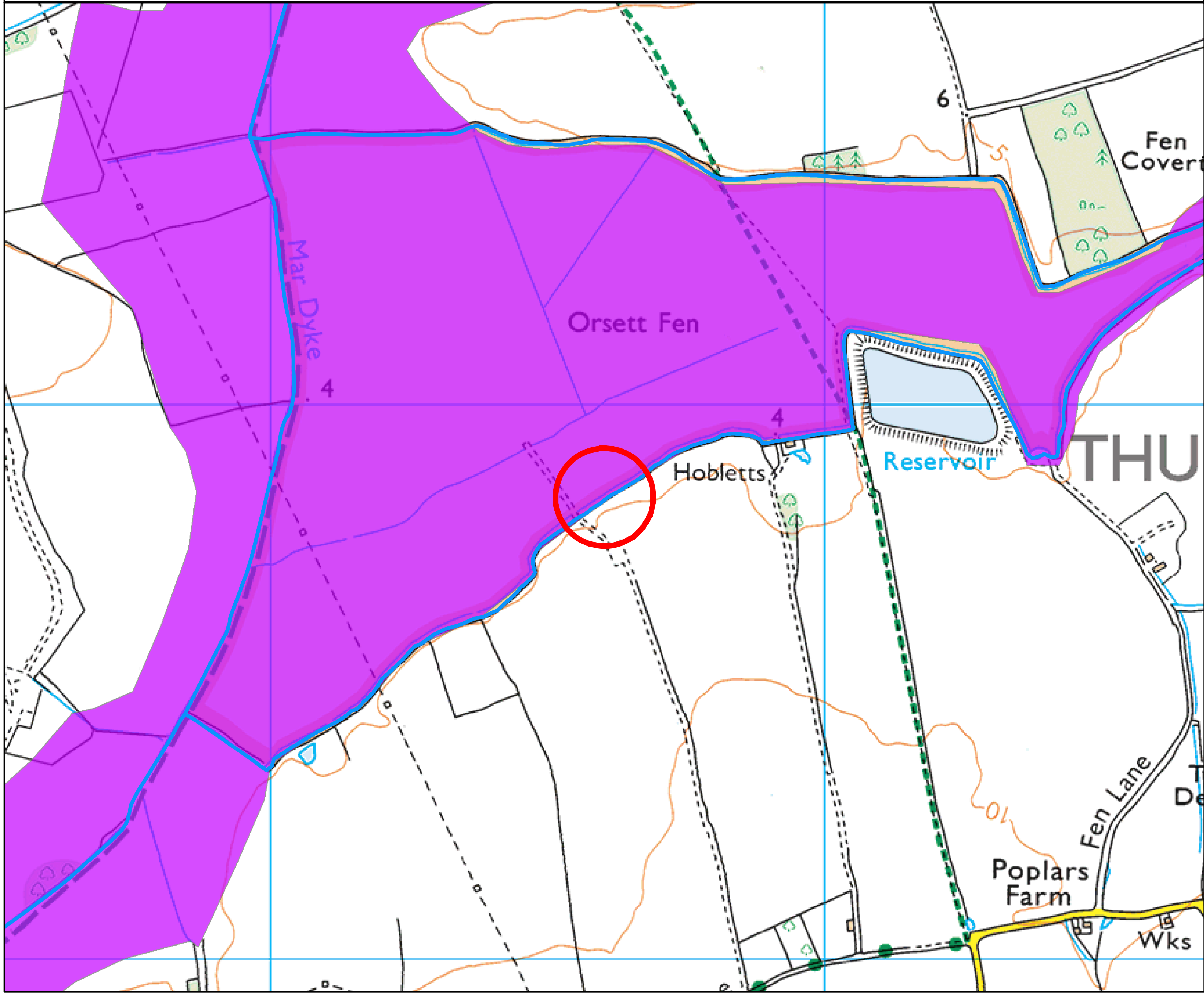
- Site Outline
- Main Rivers
- Modelled Data Node Point

This model has been designed for catchment wide flood risk mapping. It should be noted that it was not created to produce flood levels for specific development sites within the catchment. Modelled outlines take into account catchment wide defences if present.

Contact Us: National Customer Contact Centre, PO Box 544, Rotherham, S60 1BY. Tel: 03708 506 506 (Mon-Fri 8-6). Email: enquiries@environment-agency.gov.uk

Produced by: Partnership & Strategic Overview
East Anglia: Essex, Norfolk & Suffolk

Recorded Flood Events Outlines Map centred on LTC TQ 62630 82854
Created 09/03/2018 - Ref: EAn/2018/76391



Environment Agency

Environment Agency
Iceni House
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IP3 9JD

0 135 270 540
Metres

Legend

- Site Outline
- Main Rivers
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Produced by: Partnership & Strategic Overview
East Anglia: Essex, Norfolk & Suffolk

Reference: EAn/2018/76391
Site Address: LTC TQ 67350 75582
Date: 09/03/2018

Included:

- Flood Map
- 1D Levels Map
- 1D (In-channel) Defended Levels Table
- Historic Flood Outlines Map

Important information to note with your Product:

Flood Risk Assessments (FRAs)

If you are obtaining this information for use within a Flood Risk Assessment (FRA) required for a planning application, please include our unaltered Product 4 data within an appendix of your FRA.

Flood Zones

Please see the attached map showing the Flood Zones (outlines) for the area of the site. Our maps show the site is located in tidal Flood Zone 3.

Un-Modelled Watercourses

Our maps show the site is located in tidal Flood Zone 3, the high probability zone. However, we have not undertaken any detailed modelling for the nearby West Tilbury Main, so this source of flood risk has not been assessed for the purpose of the flood map. This will need to be investigated further in any FRA.

Normally, in these circumstances, an FRA will need to undertake a modelling exercise in order to derive flood levels and extents, both with and without allowances for climate change, for the watercourse, in order to inform the design for the site. Without this information, the risk to the development from fluvial flooding associated with the main watercourse is unknown.

Climate Change (Tidal Only)

There is no change to the way we respond to sites affected solely by tidal flood risk as the sea level allowances are unchanged. Please use the "Table 3 sea level allowance for each epoch in millimetres (mm) per year with cumulative sea level rise for each epoch in brackets (use 2008 baseline)" found at:
https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances#table-3

Historic Flood Events

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Surface Water

Please be aware that in recent years, there has been an increase in flood damage caused by surface water flooding or drainage systems that have been overwhelmed.

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http://maps.environment-agency.gov.uk/wiyby/wiybyController?ep=maptopics&lang=_e

Reservoir Flooding

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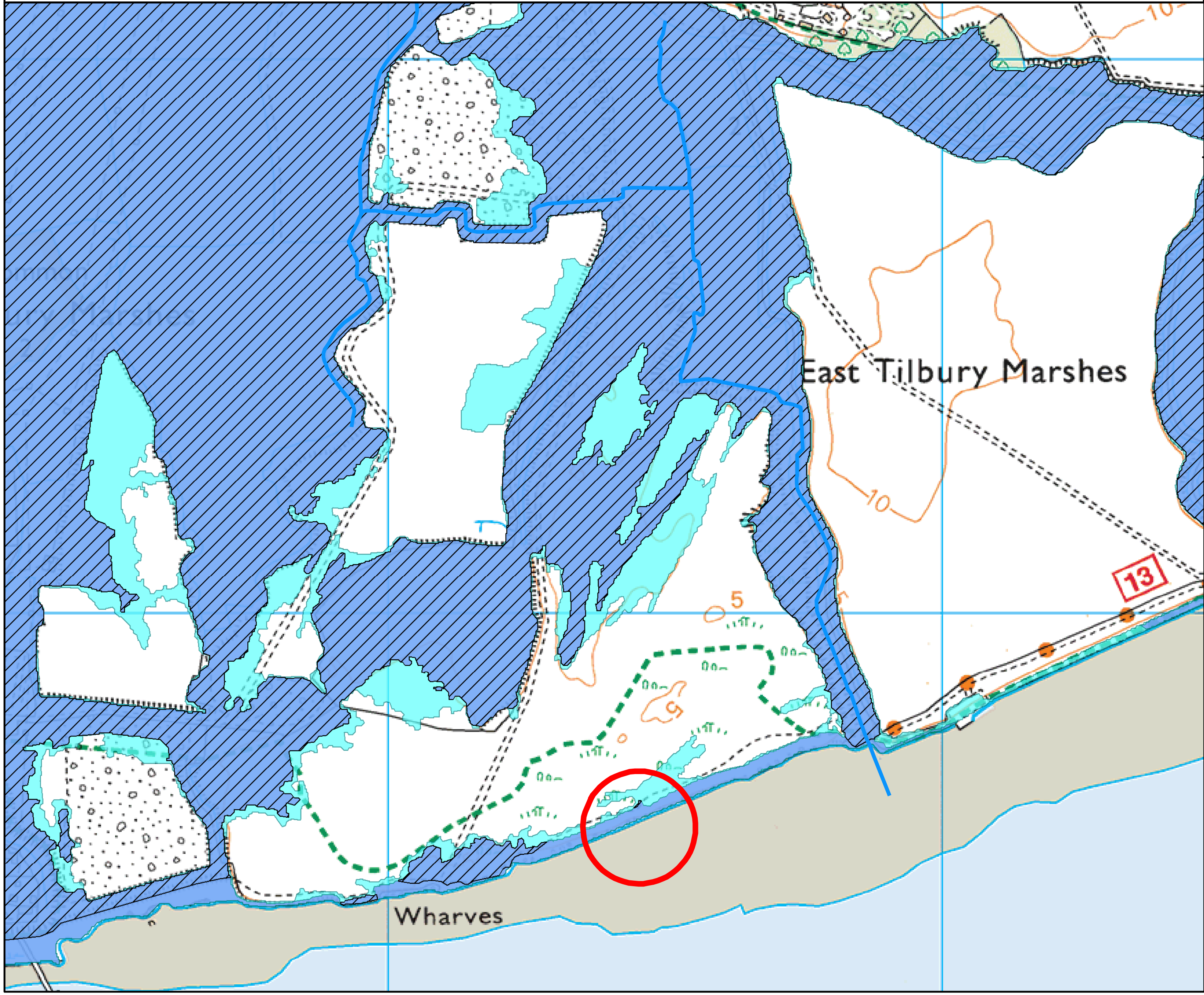
Flood Map for Planning centred on LTC TQ 67350 75582
Created 09/03/2018 - Ref: EAn/2018/76391

Environment Agency



Environment Agency
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Ipswich
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0 135 270 540
Metres

Legend

- Site Outline
- Main Rivers
- Areas Benefiting from Defence
- Flood Zone 3
- Flood Zone 2
- Flood Storage Area

Flood Map for Planning (assuming no defences)

Flood Zone 3 shows the area that could be affected by flooding:
- from the sea with a 1 in 200 or greater chance of happening each year
- or from a river with a 1 in 100 or greater chance of happening each year.

Flood Zone 2 shows the extent of an extreme flood from rivers or the sea with up to a 1 in 1000 chance of occurring each year.

Contact Us: National Customer Contact Centre, PO Box 544, Rotherham, S60 1BY. Tel: 03708 506 506 (Mon-Fri 8-6). Email: enquiries@environment-agency.gov.uk

Produced by: Partnership & Strategic Overview
East Anglia: Essex, Norfolk & Suffolk

Modelled Level Location Map centred on LTC TQ 67350 75582
Created 09/03/2018 - Ref: EAn/2018/76391

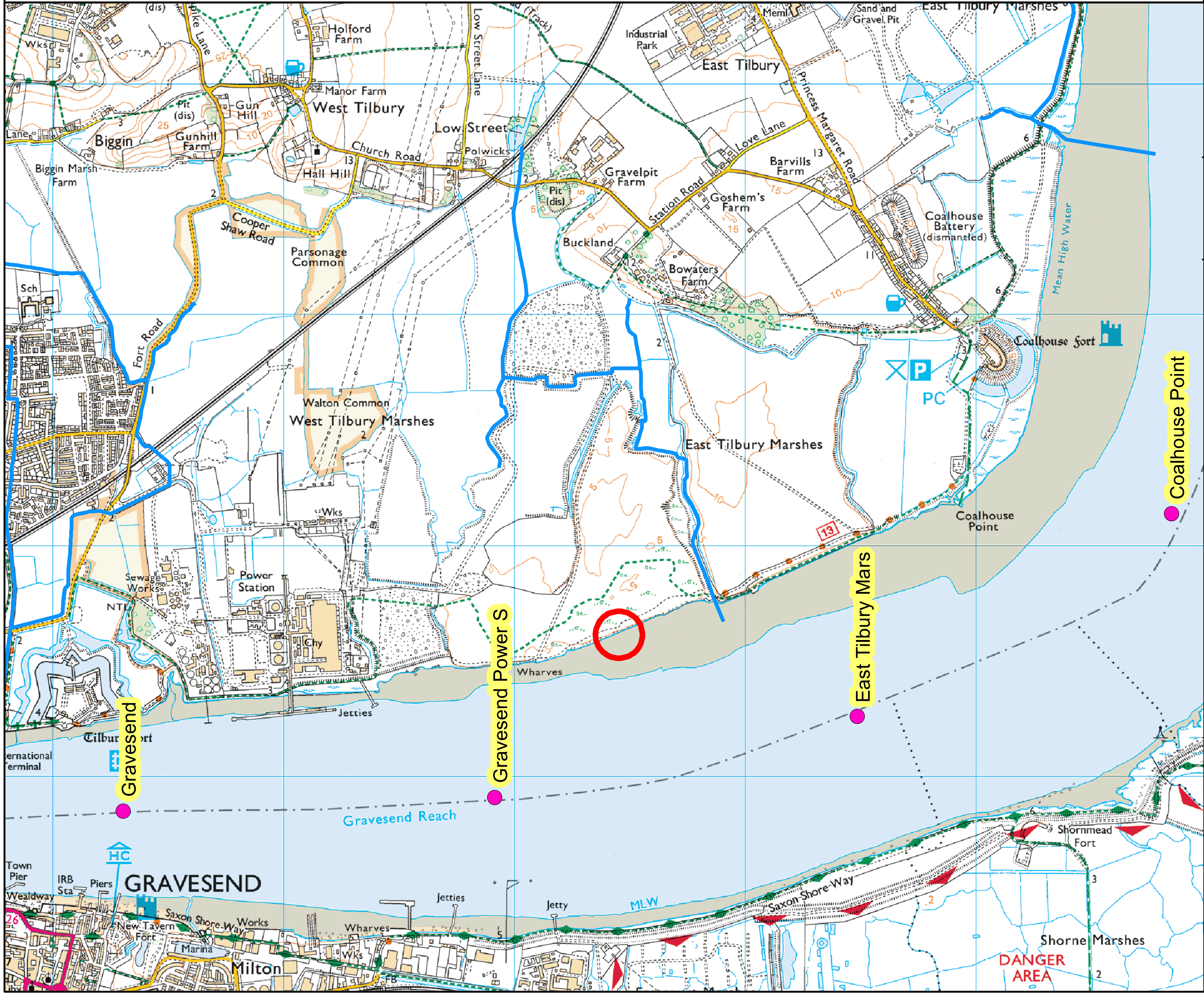
Environment Agency

Environment Agency
Iceni House
Cobham Road
Ipswich
Suffolk
IP3 9JD

0 320 640 1,280
Metres

Legend

- Site Outline
- Main Rivers
- Modelled Data Node Point



This model has been designed for catchment wide flood risk mapping.
It should be noted that it was not created to produce flood levels for specific development sites within the catchment.
Modelled outlines take into account catchment wide defences if present.

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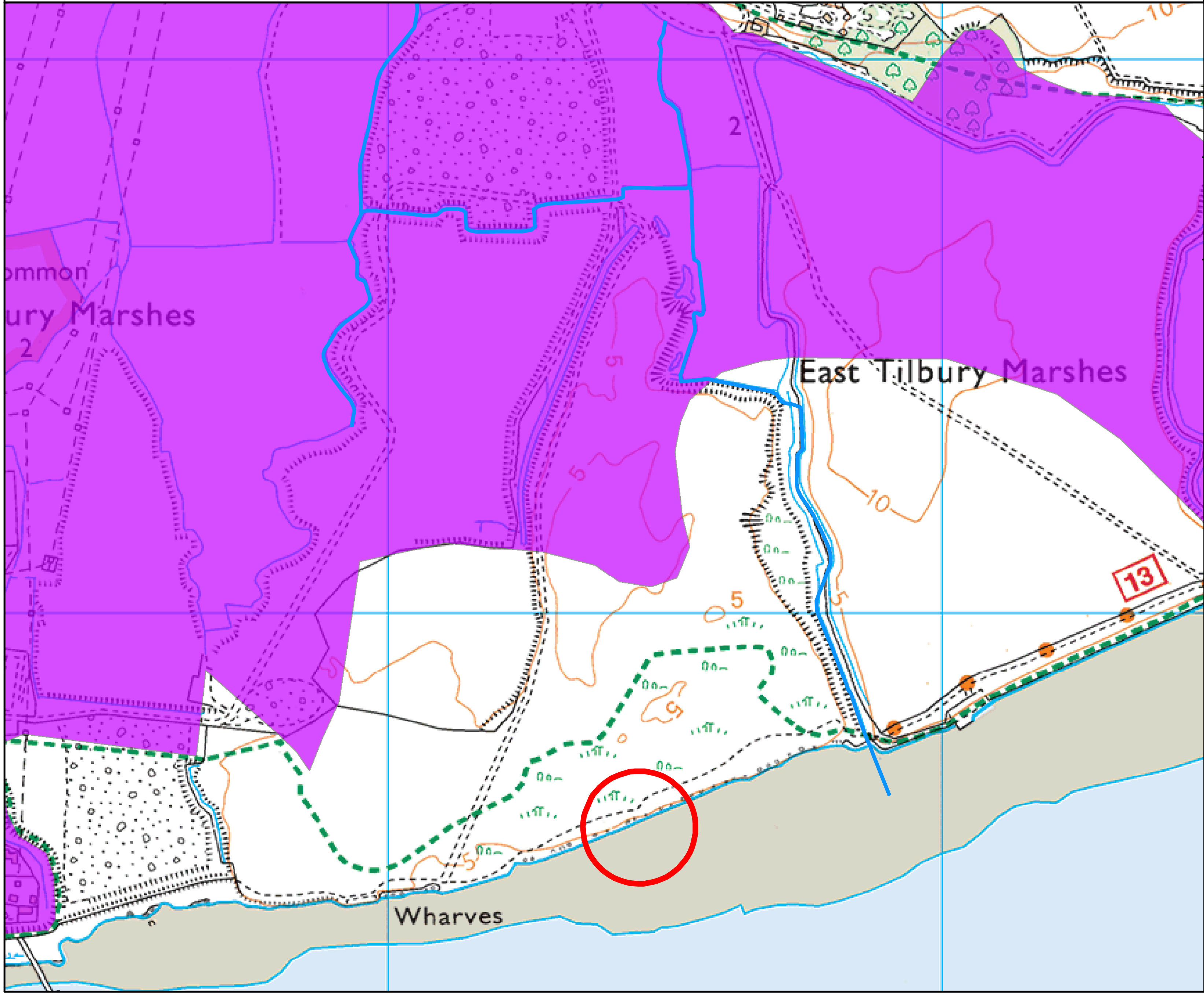
Produced by: Partnership & Strategic Overview
East Anglia: Essex, Norfolk & Suffolk

Recorded Flood Events Outlines Map centred on LTC TQ 67350 75582
Created 09/03/2018 - Ref: EAn/2018/76391

Environment Agency



Environment Agency
Iceni House
Cobham Road
Ipswich
Suffolk
IP3 9JD

0 135 270 540
Metres

Legend

- Site Outline
- Main Rivers
- 1953 Outline

The historic flood event outlines are based on a combination of anecdotal evidence, Environment Agency staff observations and survey.
Our historic flood event outlines do not provide a definitive record of flooding.
It is possible that there will be an absence of datain places where we have not been able to record the extent of flooding.
It is also possible for errors occur in the digitisation of historic records of flooding.

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Produced by: Partnership & Strategic Overview
East Anglia: Essex, Norfolk & Suffolk

Datasheet Reference:	EAn/2018/76391
Source of information:	Mardyke Flood Risk Study (2011) JBA for the Environment Agency
Source of Flooding	Fluvial
Flood Levels Provided	In-Channel

Key

CC	Climate Change
AEP	Annual Exceedance Probability
mAODN	Metres Above Ordnance Datum Newlyn
m^3s^{-1}	Cubic Metres Per Second (Cumecs)

Undefended

Levels (mAODN) **AEP**

Node	5% (1:20)	5% (1:20) +20%CC	1.33% (1:75)	1% (1:100)	1% (1:100) +20%CC	0.1% (1:1,000)
MTRB08_2183	8.05	8.12	8.18	8.20	8.26	8.48
MTRB08_2138	8.04	8.11	8.17	8.19	8.23	8.41
MTRB08_2263	8.07	8.14	8.21	8.24	8.30	8.65
MTRB08_2343	8.12	8.18	8.27	8.30	8.37	8.72
MTRB08_1957	8.01	8.07	8.10	8.12	8.14	8.25
MTRB08_2048	8.02	8.09	8.14	8.15	8.19	8.31
MARD01_10701	3.83	3.91	3.98	4.01	4.11	4.47
MARD01_10603	3.79	3.87	3.94	3.97	4.07	4.46
MARD01_10505	3.76	3.84	3.91	3.94	4.05	4.45
MARD01_10406	3.74	3.81	3.89	3.92	4.04	4.44
MARD01_10308	3.72	3.80	3.87	3.91	4.02	4.43
MTRB03_0107	3.71	3.79	3.86	3.90	4.02	4.42
MTRB03_0202	3.71	3.79	3.86	3.90	4.01	4.40
MTRB03_0297	3.72	3.79	3.86	3.90	4.02	4.39
MTRB03_0392	3.73	3.80	3.87	3.91	4.02	4.39
MTRB03_0487	3.74	3.81	3.88	3.91	4.02	4.39
MTRB03_0582	3.76	3.82	3.89	3.92	4.02	4.39
MTRB03_0676	3.79	3.84	3.90	3.93	4.02	4.38
MTRB02_0939	3.88	3.91	3.94	3.96	4.03	4.34
MTRB02_0932	3.85	3.88	3.91	3.93	4.01	4.34
MTRB02_0750	3.66	3.73	3.79	3.83	3.94	4.33
MTRB02_0567	3.60	3.68	3.76	3.80	3.92	4.32
MRTB02_1238	4.25	4.26	4.27	4.28	4.29	4.43
MTRB02_1138	4.16	4.18	4.19	4.19	4.21	4.40
MTRB02_1038	4.08	4.10	4.11	4.12	4.15	4.38

Flows (m^3s^{-1}) **AEP**

Node	5% (1:20)	5% (1:20) +20%CC	1.33% (1:75)	1% (1:100)	1% (1:100) +20%CC	0.1% (1:1,000)
MTRB08_2183	5.74	6.57	8.10	8.63	10.45	21.76
MTRB08_2138	5.72	6.57	8.08	8.63	10.42	21.72
MTRB08_2263	5.72	6.57	8.10	8.65	9.79	14.62
MTRB08_2343	5.72	6.58	8.11	8.65	9.80	14.89
MTRB08_1957	5.72	6.58	8.05	8.59	9.51	13.39
MTRB08_2048	5.71	6.57	8.07	8.61	9.86	17.65
MARD01_10701	23.21	24.79	25.75	26.16	28.13	35.73
MARD01_10603	23.69	25.31	26.34	26.82	28.80	36.77
MARD01_10505	23.65	25.38	26.77	27.39	29.47	35.76
MARD01_10406	23.63	25.73	27.60	28.35	29.65	36.29
MARD01_10308	23.58	25.76	27.68	28.39	29.44	37.38
MTRB03_0107	2.02	1.95	2.00	2.03	2.09	2.41
MTRB03_0202	2.28	2.32	2.35	2.36	2.40	2.70
MTRB03_0297	2.28	2.34	2.36	2.37	2.41	2.72
MTRB03_0392	2.29	2.35	2.38	2.39	2.43	2.70
MTRB03_0487	2.30	2.36	2.39	2.41	2.45	2.71
MTRB03_0582	2.30	2.37	2.40	2.42	2.46	2.72
MTRB03_0676	2.31	2.38	2.42	2.43	2.46	2.73
MTRB02_0939	1.36	1.40	1.42	1.43	1.44	1.66
MTRB02_0932	1.36	1.40	1.42	1.43	1.44	1.66
MTRB02_0750	1.36	1.40	1.41	1.42	1.43	1.64
MTRB02_0567	1.35	1.38	1.40	1.40	1.41	1.61
MRTB02_1238	1.36	1.41	1.43	1.43	1.44	1.67
MTRB02_1138	1.36	1.41	1.43	1.43	1.44	1.67
MTRB02_1038	1.36	1.40	1.42	1.43	1.44	1.67

Datasheet Reference: EAn/2018/76391
Source of information: Thames Estuary 2100 (2008)
HR Wallingford for the Environment Agency
Source of Flooding Tidal
Flood Levels Provided In-Channel

Key
CC Climate Change
AEP Annual Exceedance Probability
mAODN Metres Above Ordnance Datum Newlyn
m^3s^{-1} Cubic Metres Per Second (Cumecs)

Defended

Location	Node Ref	Easting	Northing	2005		2040		2070		2100		2120		2070 Defence Crest Levels	
				1 in 200 (0.5% AEP)	1 in 1000 (0.1% AEP)	1 in 200 (0.5% AEP)	1 in 1000 (0.1% AEP)	1 in 200 (0.5% AEP)	1 in 1000 (0.1% AEP)	1 in 200 (0.5% AEP)	1 in 1000 (0.1% AEP)	1 in 200 (0.5% AEP)	1 in 1000 (0.1% AEP)	Existing Barrier	New Barrier
Dartford	3.15	554397	178402	5.64	5.97	5.85	6.18	6.00	6.33	6.32	6.65	6.52	6.85	7.60	6.10
Dartford Marshes	3.16	555012	177896	5.62	5.95	5.83	6.16	5.98	6.31	6.30	6.63	6.49	6.82	7.60	6.10
Long Reach	3.17	555831	177179	5.61	5.94	5.82	6.15	5.97	6.30	6.29	6.62	6.48	6.81	7.60	8.50
Dartford Tunnel	3.18	557090	176390	5.61	5.94	5.82	6.15	5.96	6.29	6.27	6.60	6.46	6.79	7.50	8.50
Stone Ness	3.19	558175	175703	5.59	5.92	5.80	6.13	5.95	6.28	6.27	6.60	6.45	6.78	7.50	8.50
West Thurrock	3.20	559355	176131	5.57	5.90	5.78	6.11	5.94	6.27	6.25	6.58	6.43	6.76	7.50	8.50
Swanscombe	3.21	560139	177011	5.56	5.89	5.77	6.10	5.91	6.24	6.22	6.55	6.41	6.74	7.50	8.50
Grays	3.22	561470	176679	5.53	5.86	5.74	6.07	5.91	6.24	6.21	6.54	6.40	6.73	7.50	8.00
Tilbury	3.23	562066	175589	5.52	5.85	5.73	6.06	5.89	6.22	6.19	6.52	6.38	6.71	7.50	8.00
Northfleet	3.24	562675	174950	5.50	5.83	5.71	6.04	5.86	6.19	6.16	6.49	6.36	6.69	7.40	8.00
Tilbury Ferry	3.25	564109	174800	5.48	5.81	5.69	6.02	5.84	6.17	6.14	6.47	6.34	6.67	7.40	8.00
Gravesend	3.26	565307	174848	5.45	5.78	5.66	5.99	5.81	6.14	6.11	6.44	6.32	6.65	7.40	8.00
Gravesend Power S	3.27	566916	174908	5.38	5.71	5.59	5.92	5.75	6.08	6.05	6.38	6.28	6.61	7.40	8.00
East Tilbury Mars	3.28	568488	175258	5.31	5.64	5.52	5.85	5.68	6.01	5.99	6.32	6.23	6.56	7.00	7.00
Coalhouse Point	3.29	569850	176137	5.25	5.58	5.46	5.79	5.60	5.93	5.92	6.25	6.18	6.51	6.48	6.48
Coastguard Cottag	3.30	570320	178011	5.21	5.54	5.42	5.75	5.56	5.89	5.86	6.19	6.13	6.46	6.75	6.75
Mucking Flats	3.31	571235	179824	5.16	5.49	5.37	5.70	5.53	5.86	5.85	6.18	6.12	6.45	7.50	8.10
Corringham Marshe	3.32	573440	180782	5.08	5.41	5.29	5.62	5.48	5.81	5.83	6.16	6.10	6.43	7.50	8.10
Blythe Sands	3.33	575633	181137	5.00	5.33	5.21	5.54	5.43	5.76	5.81	6.14	6.08	6.41	7.50	8.10
Halstow Marshes	3.34	577953	181149	4.95	5.28	5.16	5.49	5.37	5.70	5.76	6.09	6.04	6.37	7.40	8.10
West Point	3.35	579995	181222	4.89	5.22	5.10	5.43	5.33	5.66	5.72	6.05	6.01	6.34	7.40	8.10
East Canvey Point	3.36	583007	181318	4.81	5.14	5.02	5.35	5.30	5.63	5.69	6.02	5.98	6.31	7.40	8.10
Leigh	3.37	585820	181583	4.73	5.06	4.94	5.27	5.27	5.60	5.66	5.99	5.95	6.28	6.70	7.40
Southend	3.38	588653	181517	4.70	5.03	4.91	5.24	5.22	5.55	5.62	5.95	5.92	6.25	6.70	7.40

Thames Estuary 2100 (TE2100)
You have requested in-channel flood levels for the tidal river Thames. These have been taken from the Thames Estuary 2100 study completed by HR Wallingford in 2008.

Details about the TE2100 plan
The TE2100 plan is now live and within it are a set of levels on which the flood risk management strategy is based. The plan is the overarching flood management strategy for the Thames Estuary and therefore

Details about the TE2100 in-channel levels
The TE2100 in-channel levels take into account operation of the Thames Barrier when considering future levels.

Fluvial Return Periods	
50% (1:2)	1 in 2
20% (1:5)	1 in 5
10% (1:10)	1 in 10
5% (1:20)	1 in 20
5% (1:20) +20%CC	1 in 20 + CC
2% (1:50)	1 in 50
1.33% (1:75)	1 in 75
1% (1:100)	1 in 100
1% (1:100) +20%CC	1 in 100 + 20%CC
1% (1:100) +25%CC	1 in 100+ 25%CC
1% (1:100) +35%CC	1 in 100+ 35%CC
1% (1:100) +65%CC	1 in 100+ 65%CC
0.66% (1:150)	1 in 150
0.5% (1:200)	1 in 200
0.5% (1:200) +CC	1 in 200 + CC
0.33% (1:300)	1 in 300
0.1% (1:1,000)	1 in 1,000
0.1% (1:1000) +20%CC	1 in 1000 + 20%CC
0.1% (1:1000) +25%CC	1 in 1000 + 25% CC

Tidal Return Periods	
50% (1:2)	1 in 2
20% (1:5)	1 in 5
10% (1:10)	1 in 10
5% (1:20)	1 in 20
5% (1:20) + CC	1 in 20 + CC
2% (1:50)	1 in 50
1.33% (1:75)	1 in 75
1% (1:100)	1 in 100
1% (1:100) + CC	1 in 100 + CC
0.66% (1:150)	1 in 150
0.5% (1:200)	1 in 200
0.5% (1:200) + CC	1 in 200 + CC
0.33% (1:300)	1 in 300
0.1% (1:1,000)	1 in 1,000
0.1% (1:1000) + CC	1 in 1000 + CC

Annex C Breach modelling: Considering TE2100 future barrier options

Lower Thames Crossing

Flood Risk Assessment

Breach modelling: Considering TE2100 future barrier options

DATE: October 2022 | HE540039-CJV-EFR-GEN-TNT-ENV-00012 | VERSION: 1.0

Lower Thames Crossing

Flood Risk Assessment

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1 Introduction

1.1 Background

1.1.1 The Lower Thames Crossing breach assessment, undertaken to inform the Flood Risk Assessment (the FRA) (Application Document 6.3, Appendix 14.6), includes breach simulations for the present day (2030) and future (2130) for return periods 200 years (0.5% AEP) and 1000 years (0.1% AEP). Breaches were simulated at the following TE2100 model nodes:

a. 3.15 (Mardyke Sluice breach location)

b. 3.26 (TIL005 breach location)

c. 3.28 (TIL006 breach location)

1.1.2 Further details of the breach modelling undertaken are in Part 5 of the FRA, Annex E.

1.1.3 The FRA breach simulations did not consider the future Thames barrier options, as set out in the TE2100 plan (TE2100 Phase 3 Topic 1.5 Set 2 Estuary Wide Options - Hydraulic Modelling, Environment Agency (December 2008) and TE2100: Design Water Levels and Future Defence Crest Levels, Environment Agency, (May 2015)). Following consultation with the Environment Agency, this technical note extends the FRA breach assessment to also consider breaches assuming the following TE2100 future Thames barrier (and flood defences) options:

a. Option 1.4 (barrier at Woolwich)

b. Option 3.2 (barrier at Long Reach)

c. Option 3.1 (barrier at Gravesend Reach)

1.1.4 The breach modelling undertaken to date for the FRA assumes that during a simulated breach of the River Thames tidal defences, flood water is conveyed into the tidal floodplain only through the breach opening (i.e. no overflow of tidal flood defences), as the simulated Extreme Water Levels (EWLs) for all breaches simulated are below flood defence levels. This assumption remains valid when considering the TE2100 future Thames barrier Options 1.4, 3.2 and 3.1, as these options specify that the flood defence heights would be upgraded when required for each option to provide the required standard of service specified by the TE2100 plan (which is greater than or equal to 1000 years at the breach locations, and so above the 1000 year return period EWL applied in the breach simulations).

1.2 Potential for TE2100 future barrier options to influence the FRA breach assessment

1.2.1 Results of a simulated breach assuming the future barrier Options 1.4, 3.2 and 3.1 in 2130 may differ to results of the FRA breach simulations already undertaken, since:

a. Future barrier options may result in different River Thames design EWLs compared to those applied in the FRA breach modelling.

b. Future barrier options may specify different future tidal flood defence levels (in 2130) compared to those applied in the FRA breach modelling. The FRA breach simulations undertaken and the future barrier options both assume that the 1000 year return period River Thames EWLs in 2130 would be below the River Thames tidal flood defence levels in 2130 at the FRA breach locations. However, the specification of simulated breach start and end times is influenced by flood defence heights (Breach of Defences Guidance, Environment Agency, 2018), and so a change in flood defence levels (in the barrier options) results in a change in specified breach start and end times.

2 Assessment of TE2100 future barrier options

2.1 Comparison of EWLs for TE2100 future barrier options with those applied in the FRA breach modelling

2.1.1 The FRA breach modelling applied EWLs derived from TE2100 EWLs, adjusted to account for the more recent Environment Agency Coastal Flood Boundary dataset 2018 (CFB2018) and UKCP18 projected sea level rise allowances.

2.1.2 The TE2100 simulated EWLs for Option 1.4 (TE2100: Design Water Levels and Future Defence Crest Levels, Environment Agency (May 2015)) are the same as the TE2100 EWLs from which the FRA breach modelling EWLs were derived, as this option assumes no change to the tidal barrier location in the future.

2.1.3 The TE2100 simulated EWLs for TE2100 Options 3.2 and 3.1 differ from those of Option 1.4 as Options 3.2 and 3.1 represent a change in tidal flood barrier location (with future barriers at Long Reach and Gravesend Reach respectively).

2.1.4 Table 1 compares EWLs applied in the FRA breach modelling (including the TE2100 EWLs provided by the Environment Agency and adjusted values accounting for CFB2018 and UKCP18) with those simulated for the TE2100 Options 1.4, 3,2 and 3.1, at breach locations Mardyke Sluice, TIL005 and TIL006.

2.1.5 A comparison of EWLs applied in the FRA with those simulated for the TE2100 Options 1.4, 3,2 and 3.1 should be based on the TE2100 EWLs provided for use in the FRA rather than the adjusted EWLs. This provides a “like-for-like” comparison, as all values compared are then based on the TE2100 modelling and boundary conditions.

Table 1: Mardyke Sluice: EWLs applied in the FRA breach modelling and EWLs simulated for the TE2100 Options 1.4, 3,2 and 3.1

Year	1000 year (0.1% AEP) Extreme Water level values (mAOD)				
	TE2100 EWLs provided for FRA	*Applied in breach modelling	[1]TE2100 Option 1.4	[2]TE2100 Option 3.2	[3]TE2100 Option 3.1
TE2100 model node 3.15 (Mardyke Sluice breach location)					
2120	6.85		6.85		
2130	6.95**	7.08			
2140	7.04**			5.40	5.40
2170	7.33		7.33	5.40	5.40
TE2100 model node 3.26 (TIL005 breach location)					
2120	6.65		6.65		
2130	6.76**	6.89			
2140	6.87**			6.88	5.18
2170	7.19		7.19	7.24	5.18
TE2100 model node 3.28 (TIL006 breach location)					
2120	6.56		6.56		
2130	6.68**	6.83			
2140	6.80**			6.83	6.61
2170	7.17		7.17	7.21	7.06

** The EWLs adjust TE2100 values according to the latest Environment Agency Coastal Flood Boundary dataset 2018 and UKCP18 sea level rise values. Full details of this adjustment are in the FRA breach modelling appendix (FRA Part 5).*

*** Interpolated values to aid comparison with values applied in the breach modelling and other TE2100 options:*

1 – Source: Table A.5 in TE2100: Design Water Levels and Future Defence Crest Levels, Environment Agency (May 2015)

2 – Source: TE2100 Phase 3 Topic 1.5 Set 2 Estuary Wide Options - Hydraulic Modelling, Environment Agency (December 2008). 2140 EWLs taken from Table 4.8, 2170 EWLs taken from Table 4.10

3 – Source: TE2100 Phase 3 Topic 1.5 Set 2 Estuary Wide Options - Hydraulic Modelling, Environment Agency (December 2008). 2140 EWLs taken from Table 4.7, 2170 EWLs taken from Table 4.9

2.1.6 Table 1 indicates:

a. Option 1.4 EWLs are the same as the TE2100 EWLs provided for use in the FRA breach modelling at all FRA breach locations.

b. Option 3.2 EWLs are;

   i. lower than the TE2100 EWLs provided for use in the FRA breach modelling at the Mardyke Sluice breach location.

   ii. slightly higher than the TE2100 EWLs provided for use in the FRA breach modelling at TIL005 and TIL006 breach locations by approximately 0.01m and 0.03m respectively (based on values for 2140, highlighted orange in Table 1).

c. Option 3.1 EWLs are lower than the TE2100 EWLs provided for use in the FRA breach modelling at all FRA breach locations.

2.1.7 In summary, the EWLs presented in Table 1 indicate the TE2100 future barrier Options 1.4, 3.2 and 3.1 would not result in a significant increase in EWLs at the FRA breach locations in 2130, with increases only for Option 3.2 by up to 0.03m (based on values for 2140).

2.1.8 An increase in EWLs by up to 0.03m is considered insignificant compared to other assumptions and uncertainties in assessing breach impacts in 2130. Other assumptions and uncertainties include:

a. The CFB2018 stated 2.5% and 97.5% confidence intervals in the 1000 year return period EWL at Southend in the CFB2018 base year (2017) are -0.49m and +0.60m respectively (and these confidence intervals only account for statistical uncertainty).

b. There is significant uncertainty in estimating future sea level rise due to climate change.

c. There is uncertainty in the TE2100 hydraulic modelling.

d. The breach modelling guidance applies assumptions (e.g. breach width, start time and duration) which may or may not be representative of an actual breach, should one occur in the future.

e. There is uncertainty in the hydraulic modelling of breach propagation inland.

2.1.9 The increase in EWLs by up to 0.03m is therefore considered insignificant in the context of the wider assumptions and uncertainties in assessing breach impacts in 2130, and, with respect to the EWLs applied, the FRA breach simulations results are considered an appropriate assessment of future breach flood risk i.e. the FRA assessment of the impact of the Project on breach flood risk elsewhere, and the impact of a breach on the Project, is considered robust in this regard.

2.2 Comparison of flood defence levels for TE2100 future barrier options with those applied in FRA breach modelling

2.2.1 The Environment Agency breach simulation guidance specifies a simulated breach start time to be when flood levels reach ¾ of the flood defence height. For a given EWL, a change in flood defence levels at a simulated breach location therefore has potential to impact on the simulated breach impacts. The TE2100 future Options 1.4, 3.2 and 3.1 require changes in flood defence levels at the FRA breach locations, as detailed in Table 2 which lists:

a. Existing flood defence levels at the FRA breach locations as applied in the breach modelling and as reported in TE2100 reports (report references are in Table 2).

b. Required future flood defence levels for the TE2100 Options 1.4, 3.2 and 3.1 at the FRA breach locations, as reported in TE2100 reports (report references are in Table 2).

Table 2: Existing and future flood defence levels at FRA simulated breach locations

				Required future defence level in 2130 (mAOD)		
FRA breach location	**TE2100 model node**	**FRA breach modelling assumed defence level (mAOD)**	**Existing defence level (according to TE2100 reporting) (mAOD)**	**Option 1.4**	**Option 3.2**	**Option 3.1**
Mardyke Sluice	3.15	7.16[1]	7.05[4]	8.10[4]	6.10[4]	6.90[5]
TIL005	3.26	6.48[2]	6.65[4]	7.90[4]	8.00[4]	6.63[5]
TIL006	3.28	4.99[3]	7.00[4]	7.00[4]	7.00[4]	6.63[5]

1 – Source: Lower Thames Crossing channel topographic survey, undertaken for this study – Storm Geomatics (November/December 2018)

2 – Source: Information received from Environment Agency for Asset Number 152988 (Datasheet reference EAN/2018/76391, 2018)

3 – Source: Environment Agency Bowaters Sluice "as built" drawing

4 – Source: Table 7.1 in TE2100: Design Water Levels and Future Defence Crest Levels, Environment Agency (May 2015)

5 – Source: Table 4.9 in TE2100 Phase 3 Topic 1.5 Set 2 Estuary Wide Options - Hydraulic Modelling, Environment Agency (December 2008)

2.2.2 Where Table 2 indicates a required future flood defence level is lower than the existing flood defence level:

a. It is assumed the level of the existing flood defence would not actually be lowered in the future.

b. The requirement for a lower flood defence level arises from a lower design EWL (for that future barrier option and location) than the equivalent TE2100 EWL provided for use in the FRA. The simulated impacts of a breach for these options would therefore be lower than the FRA simulations.

2.2.3 Therefore only the future barrier options with increased EWLs compared to the TE2100 EWLs provided for use in the FRA, and/or increased flood defence levels if required, have potential to result in increased simulated breach impacts. As discussed earlier, the impact of increased EWLs by up to 0.03m is considered insignificant, and so the following considers the influence on simulated breach events of increasing flood defence levels.

2.2.4 Figures 1 to 3 show the influence of increasing flood defence levels on breach start and end times for the FRA breach simulations. The change in breach start and end times is shown for the highest required future defence levels (i.e. the future defence levels that are most different to those assumed in the FRA breach simulations, highlighted in orange in Table 2).

Figure 1: Impact of increased defence levels on breach start and end times at Mardyke Sluice breach (based on future level for Option 1.4 in 2130)

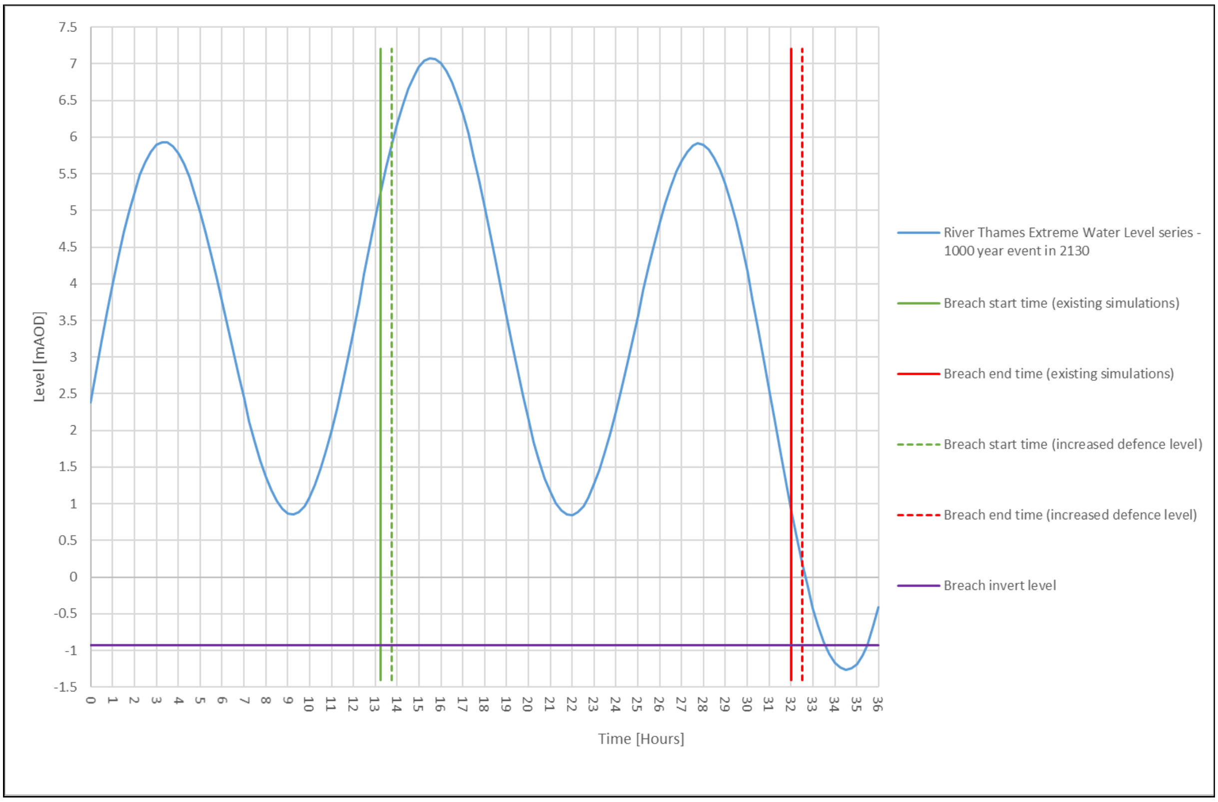


Figure 2: Impact of increased defence levels on breach start and end times at TIL005 breach (based on future level for Option 3.2 in 2130)

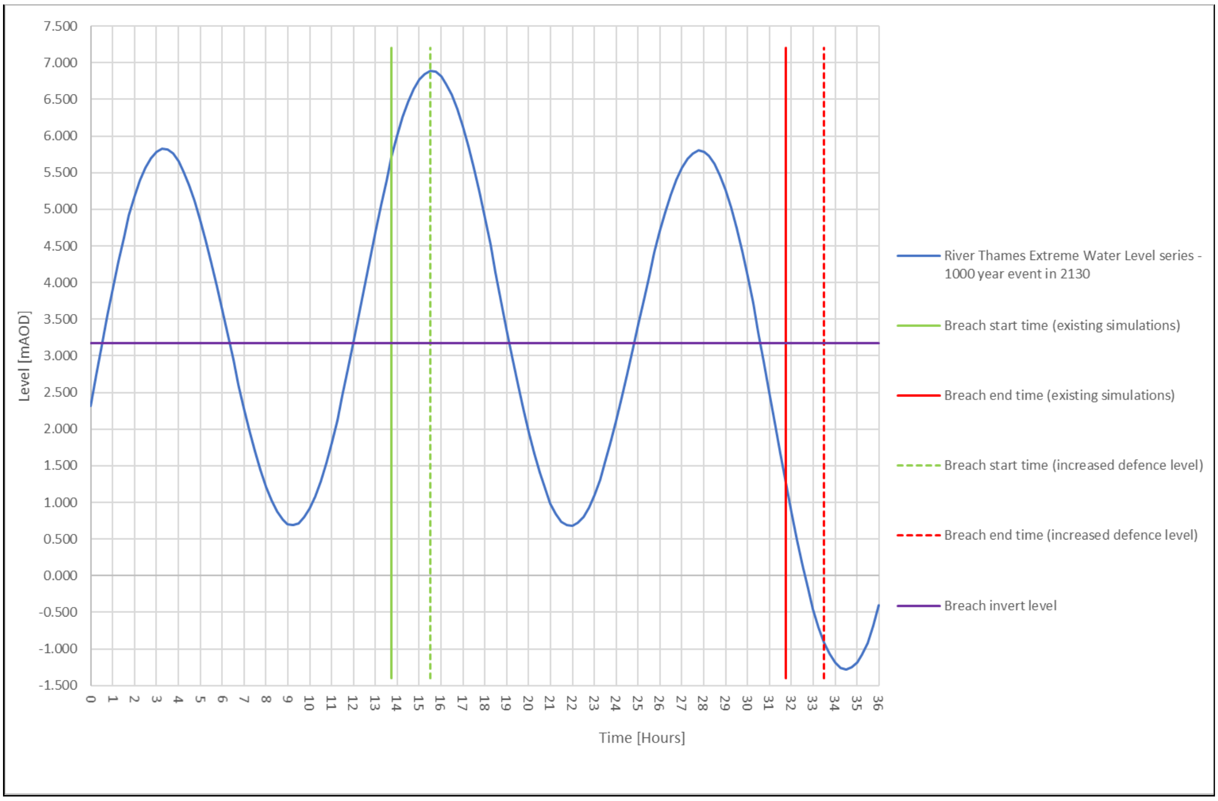
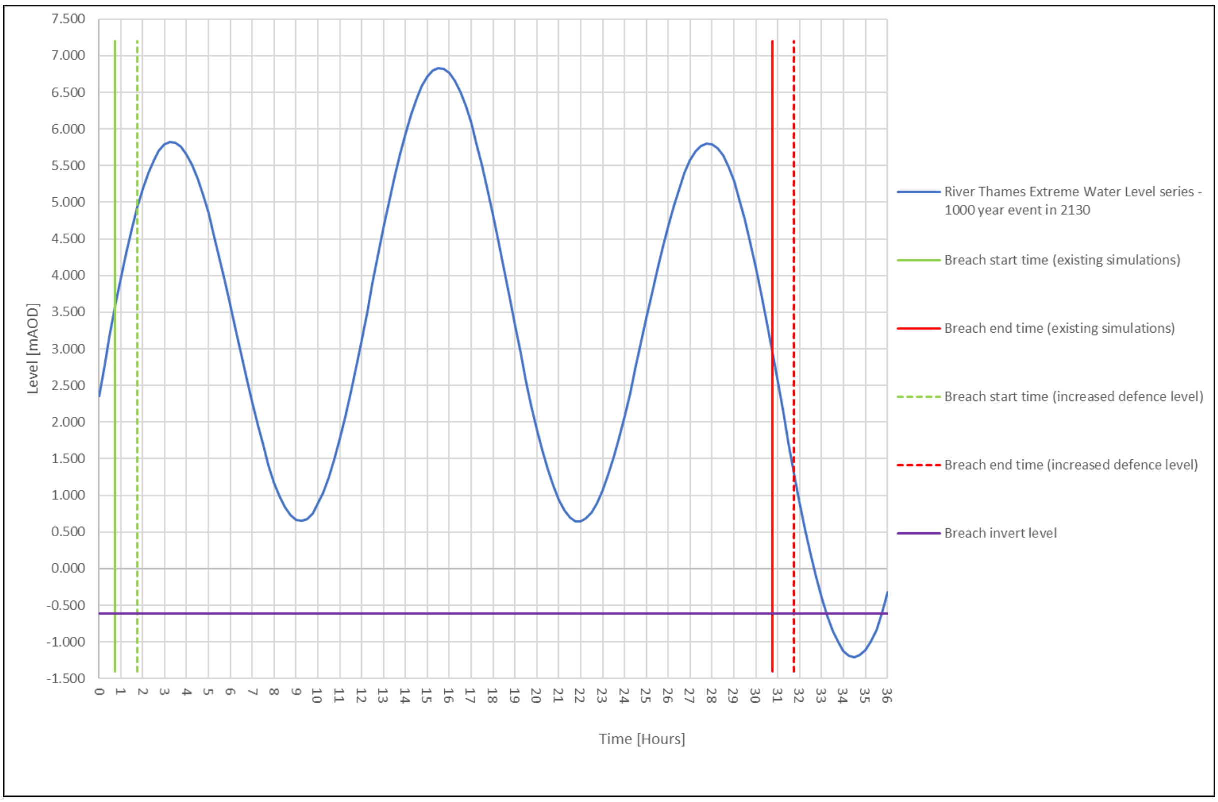


Figure 3: Impact of increased defence levels on breach start and end times at TIL006 breach (based on future level for Option 3.2 in 2130)



2.2.5 Figures 1 to 3 show that for all FRA breach locations, applying higher flood defence levels results in a delay in the start and end times of simulated breaches. An inspection of Figures 1 to 3 indicates that the reduction in initial breach flows resulting from increased defence levels (due to a delayed start) would exceed the gain in breach flows at the end of the simulated breach event, as River Thames flood levels are higher at the start of simulated breach events than at the end of the events (and for TIL005 there would be no gain in breach flows at the end of the simulated breach event, as River Thames levels would be below the TIL005 breach invert level at the end of the simulated beach). There would therefore be an overall reduction in simulated breach flood volume as a result of increasing flood defence levels.

2.2.6 The FRA breach simulation results show the nearest parts of the Project within TIL005 and TIL006 breach event flood extents are approximately 2km and 0.8km respectively from the breach locations, with simulated peak velocities significantly lower than at the breach locations. The influence of an increase in flood defence levels on breach impacts at the Project would therefore be dominated by total breach volume (i.e. breach flood extent and level).

2.2.7 Simulating increased flood defence levels would therefore be expected to reduce breach event peak flood levels and extents slightly in the vicinity of the Project (and a breach of Mardyke Sluice would remain in-channel at the Project location, as is the case for the breach simulations undertaken for the FRA), such that the FRA breach simulations already undertaken portray a slightly more conservative case in the future (2130) than the alternative future barrier options.

2.2.8 The slight reduction in breach flood volumes as a result of increased flood defence levels is considered insignificant in the context of the wider assumptions and uncertainties in assessing breach impacts in 2130 listed in paragraph 2.1.8. The FRA breach simulations results are therefore considered an appropriate assessment of future breach flood risk i.e. the FRA assessment of the impact of the Project on breach flood risk elsewhere, and the impact of a breach on the Project, is considered robust in this regard.

3 Conclusions

3.1.1 This technical note:

a. Extends the breach assessment to also consider breaches assuming the following TE2100 future Thames barrier (and flood defences) options:

   i. Option 1.4 (barrier at Woolwich)

   ii. Option 3.2 (barrier at Long Reach)

   iii. Option 3.1 (barrier at Gravesend Reach)

b. Considers the potential for changes in River Thames EWLs and required flood defence levels in the future, as a result of implementing any of the future barrier Options 1.4, 3.2 and 3.1, to influence future breach flood risk.

c. Concludes that the FRA breach simulation results provide an appropriate assessment of future breach flood risk i.e. the FRA assessment of the impact of the Project on breach flood risk elsewhere, and the impact of a breach on the Project, is considered robust. Therefore no further breach simulations are required to account for TE2100 future barrier options 1.4, 3.2 and 3.1.

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