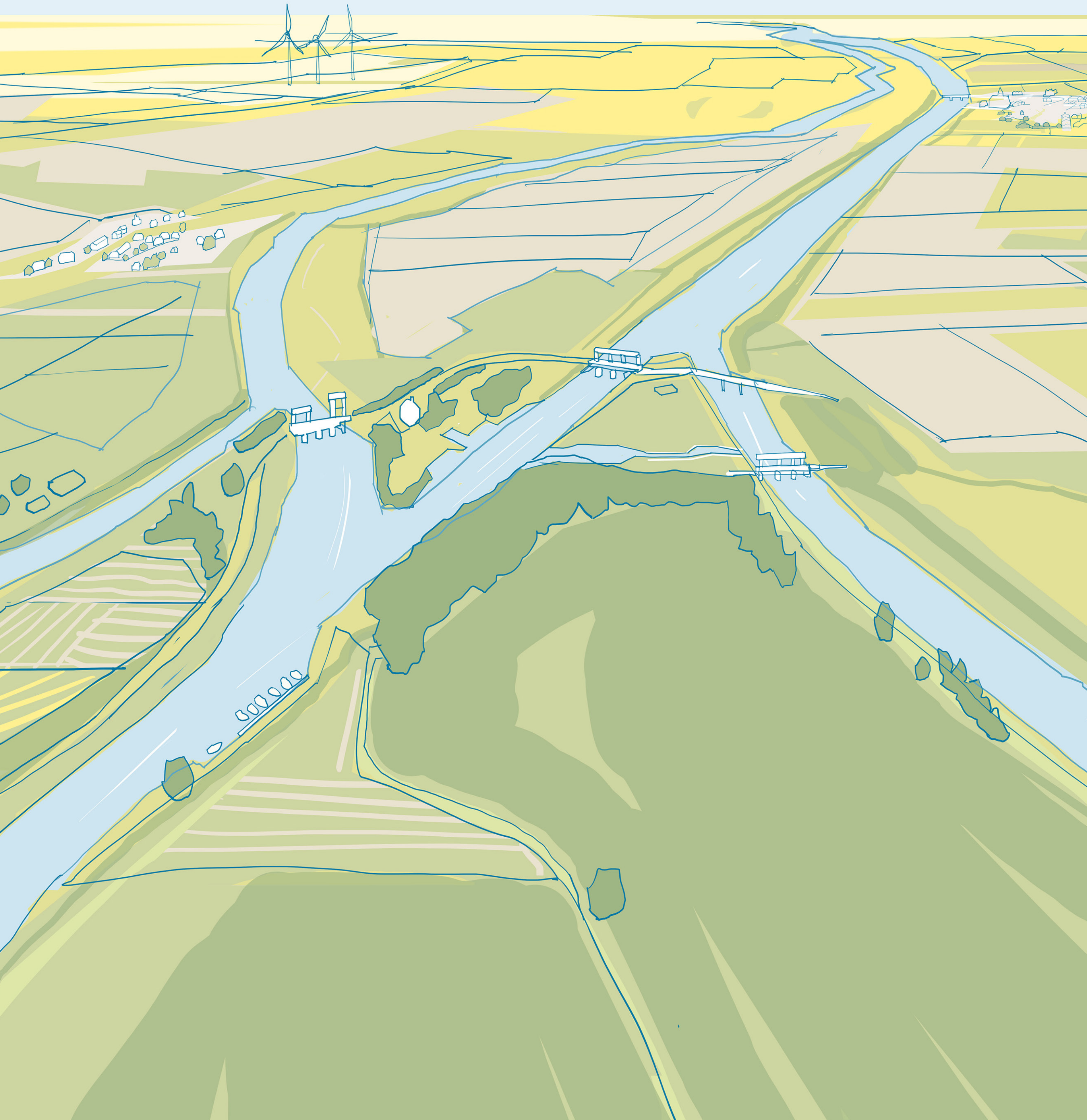
Fens 2100+

Great Ouse

Flood risk baseline

2025



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Glossary of Terms

- **AIMS** – Asset Information System - An Environment Agency hosted database of information on Environment Agency assets, as well as some other key RMA assets.
- **AOD** – Above Ordnance Datum - Referring to an altitude above a localised mean sea level.
- **BRC** - Below Required Condition.
- **Cumecs –** is the SI unit of volumetric flow rate and are equivalent to cubic meters per second (m^3/s).
- **FCERM** – Flood and Coastal Erosion Risk Management.
- **The Fens** – In the context of Fens 2100+, the combined catchments of the Witham, Lower Welland, Lower Nene, Great Ouse and Steeping, including land with an elevation at or below 6m AOD.
- **Flood risk** - A combination of the probability and the potential consequences of flooding. This includes risks from various sources such as rivers, the sea, direct rainfall, rising groundwater, overwhelmed sewers, and reservoirs
- **IDB -** Internal Drainage Board - A public body that manages water levels in an area, known as an internal drainage district.
- **LLFA** – Lead Local Flood Authority, bodies with a statutory responsibility for taking the lead operational role in managing the risk of flooding.
- **MEICA** - Mechanical, Electrical, Instrumentation, Control and Automation assets, in the context of this report relating to flood and coastal risk management (FCRM) assets.
- **NFM** – Natural Flood Management, the practice of using natural processes to reduce the risk of flooding.
- **Resilience**: The capacity of people and places to plan for, protect, respond to, and recover from flooding and coastal change. Resilience has been considered in the context of Fens 2100+ as follows:
    - Anticipate and adapt: Taking action to prepare for and adjust to both the current effects of climate change and the predicted impacts in the future, while responding to local place-based needs and ambitions.
    - Protect: Reducing the risk of flooding and coastal erosion to enhance the safety of communities and places (through investment in physical grey and green infrastructure).
    - Maintain: Co-ordinated activity to realise the whole life value from flood risk infrastructure though inspection, operational management, repair, replacement, renewal and decommissioning.
    - Respond: The ability of places and people to prepare for and react to flooding and coastal erosion in a way that results in minimal impacts to property, the natural environment and health and wellbeing.

    - Recover: The ability of places and people to rebound from flooding and coastal erosion with minimal impacts to property, the natural environment, and health and wellbeing.
    - Transform: To change and improve the way FCERM infrastructure is planned, delivered and operated to be more efficient, sustainable and resilient.
- **RMA** - Risk Management Authority - an organisation responsible by statute for flood and coastal erosion risk management.
- **RNAG** – Reasons for Not Achieving Good.
- **SoP** – Standard of Protection - The severity of flooding that something is designed to withstand, represented by the percentage chance of a certain level of flooding occurring in that year.
- **Telemetry** – is technology that enables an asset to operate without manual interaction.
- **WFD** – Water Framework Directive.
- **WLCS** – Water Level Control Structures.

1. Introduction

1.1 Aim and purpose of this document

This document presents a catchment-scale assessment of current and future flood risk for the Great Ouse catchment. Using the best available data, it presents an overview of current and future flood risk and is intended to support future choices, investments and actions for the Fens 2100+ programme (hereafter referred to as “Fens 2100+”).

1.2 Usage statement

The purpose of the document is to support strategic decision making for the Fens 2100+. This document should be read alongside the Great Ouse baseline evidence report and is intended to provide a strategic current and future flood risk baseline which will inform the development of a future asset management strategy for the Fens 2100+. This document provides a proportionate level of detail required for a strategic catchment-scale baseline. It is anticipated that specific interventions will need to be supported by a more detailed study.

1.3 The Fens 2100+ study area

Fens 2100+ comprises the seven catchments of the Steeping, Lower Welland, South Forty Foot, East and West Fens, Lower Witham Fens, Lower Nene and Great Ouse (see Figure 1).

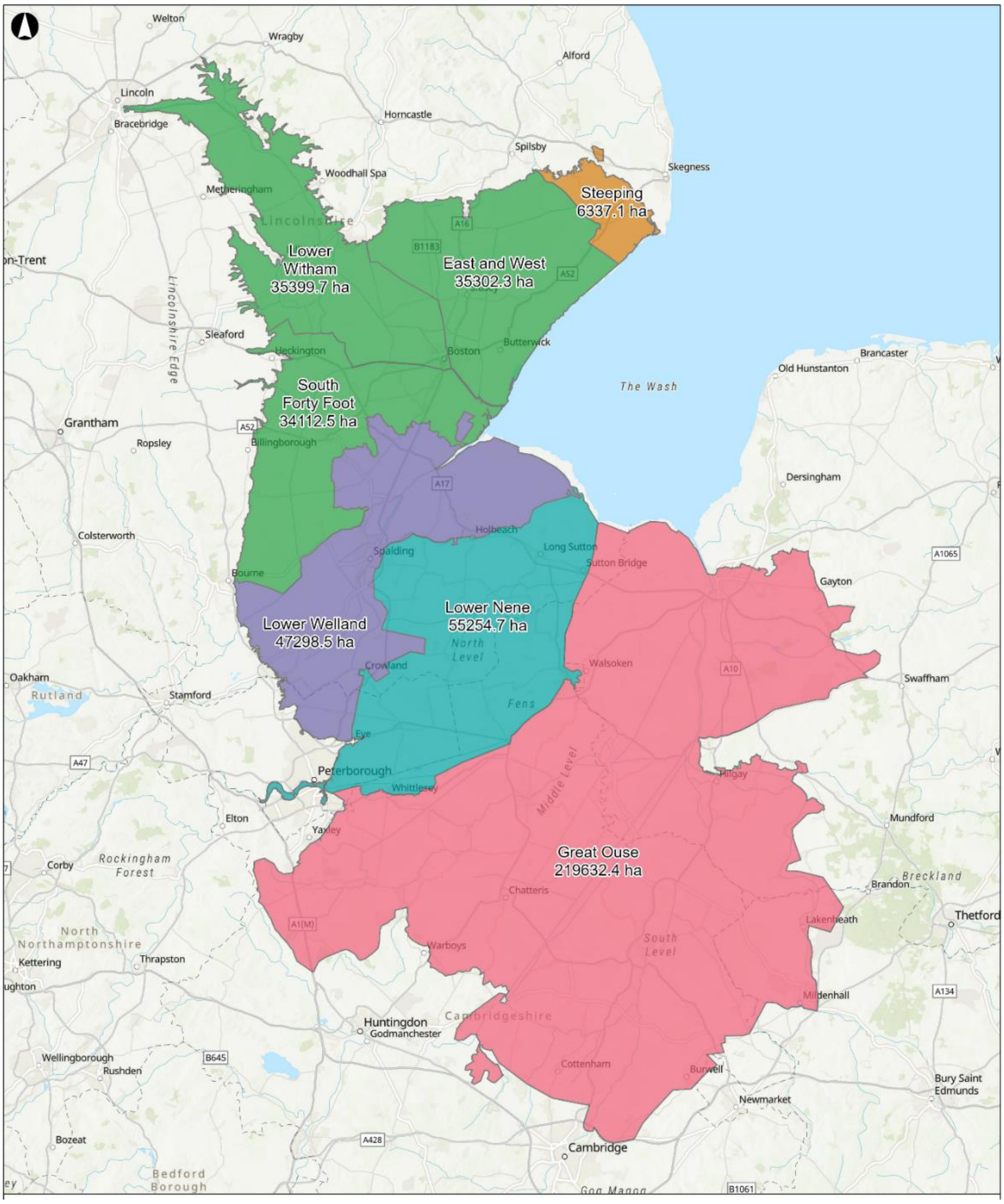

Figure 1: Fens 2100+ study area

1.4 Great Ouse catchment

The Great Ouse catchment (hereafter referred to as "the catchment") covers an area of approximately 2,196km^2 (219,600 ha) across areas of Cambridgeshire, Norfolk, Suffolk, and Lincolnshire. It sits at the south end of the wider Fens 2100+ study area.

The catchment extends along the River Great Ouse from the Earith Sluice to the outfall of the Tidal River Ouse into The Wash at King's Lynn. To the south-west the catchment is bordered by the low clay hills of the Huntingdonshire Uplands. In the north-west the catchment boundary sits along the edge of the Whittlesey Washes and the River Nene in the Lower Nene catchment.

The catchment's topography is flat and low-lying, with almost a third lying below mean sea level. The catchment is predominately artificially drained through a complex network of low-lying drains.

The land use within the catchment is primarily agricultural, with farms covering all sectors of agriculture and horticulture, including arable, livestock, poultry and dairy farming. It is a highly productive agricultural area with approximately 42% of the land classified as Grade 1 agricultural land. Although largely rural, the catchment includes several key urban areas, such as Kings Lynn, Ely and March.

Figure 2 shows a view of the Ouse Washes from Welches Dam.

Figure 2: View of the Ouse Washes from Welches Dam © Arup 2024

It is acknowledged that the catchment is not strictly a hydrological catchment, as there are movements of water both into and out of the area defined, that are not being considered in this report. However, the term 'catchment' has been used throughout the dialogue with the Environment Agency during establishment of the study areas and these areas are being defined for water management purposes. Therefore, the term catchment is used to describe the study area.

1.5 Catchment context

As the River Great Ouse enters the catchment study area at Earith it splits three ways, with much of the flow diverted over 31km through the Old Bedford River (River Delph) and the Ouse Washes, and some directed through the adjacent tidal Hundred Foot (New Bedford) River which runs parallel to the Washes. The third route is the Great Ouse River itself which continues in a wide loop which can be divided into three sections; the Old West River; becoming the Ely Ouse; and then finally the Ten Mile River.

All three routes converge at the Denver Sluice Complex at which point they flow into the tidal River Ouse or the Relief Channel when tide levels are too high. The Tidal River Ouse eventually discharges past King's Lynn into The Wash. The Main Rivers in the catchment are shown in Figure 3.

Other watercourses in the study area include the Hundred Foot River (also known as New Bedford River), the Old Bedford River, Ely Ouse, Wissey, Lark and Cam. Water enters the river network from field ditches which are connected to larger drains managed by Internal Drainage Boards (IDBs).

The catchment is protected from flooding by a network of drains, embankments, pumping stations and sluice gates. The pumping station at St German's is the largest in the UK, with a capacity of $100m^3/s$. It is the only drainage outlet for nearly a third ($700km^2$ or 70,000ha) of land within the catchment. Another of the key assets is the Ouse Washes which provides 90 million m^3 of flood storage and is Britain's largest washland occupying around $25km^2$ (2,500ha).

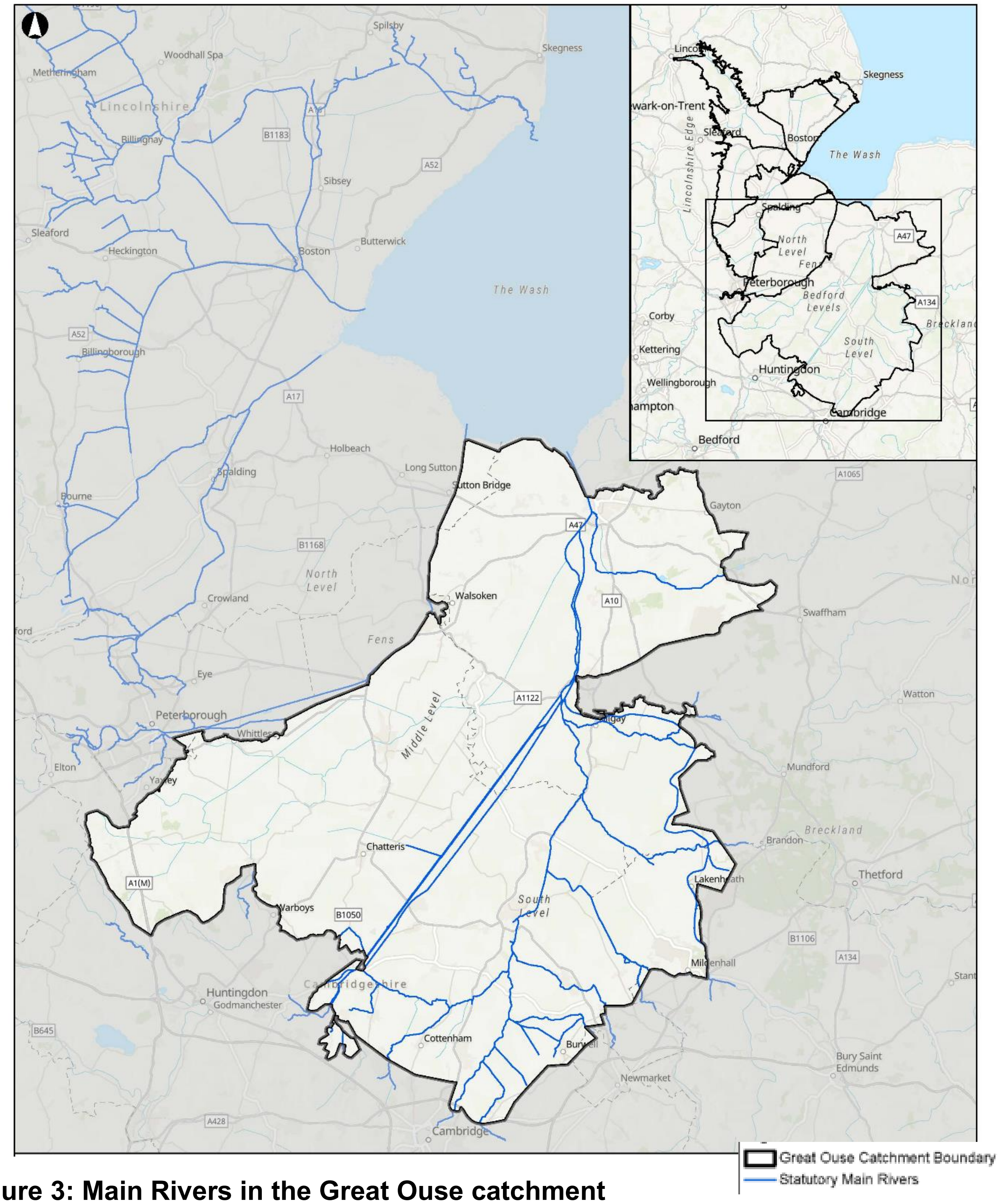

Figure 3: Main Rivers in the Great Ouse catchment

1.6 Key assets

The Great Ouse catchment contains a network of sluices, pumping stations, embankments and flood defences which work together to drain the catchment and prevent flooding.

Error! Reference source not found. Figures 4 - 6 and**Error! Reference source not found.** give an overview of the locations of some of the key assets in the south-east, south-west and north of the catchment respectively. For clarity, not all assets have been included.

The proceeding sections give further details of some of these key assets. Refer to the Assets Technical Baseline Appendix for further information.

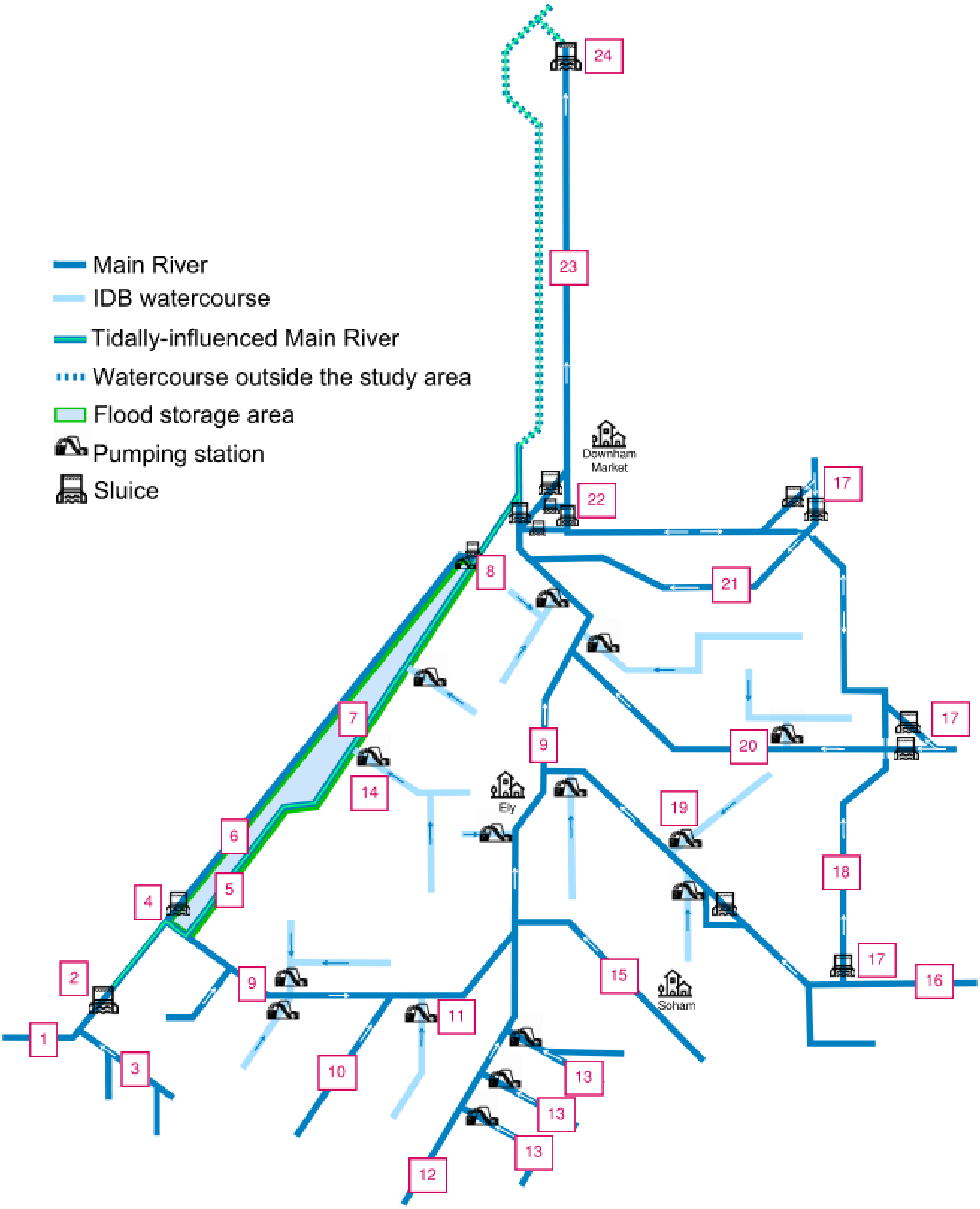

Figure 4: Schematic diagram of assets in the Great Ouse catchment (south-east).

1 **River Great Ouse**
Main River
At 200km long, it is the fourth longest river in England.

2 **Brownshill Staunch**
Environment Agency
The tidal limit on the Great Ouse system, which is tidal on the Hundred Foot River.

3 **Swavesey Drain**
Main River
Drains the area between Swavesy, Over and Longstanton.

4 **Earith Sluice**
Environment Agency
Opens automatically when there are high flows in the Bedford Great Ouse to let some water into the River Delph/ Old Bedford River.

5 **Hundred Foot River/ New Bedford River**
Main River
The usual route for water from the River Great Ouse under normal conditions. It is tidal here and as far inland as Brownshill Staunch.

6 **River Delph/ Old Bedford River**
Main River

7 **Ouse Washes**
Environment Agency & Partners
When Earith Sluice opens, high flows are diverted into the Old Bedford River and once its capacity is exceeded, water spills into the Ouse Washes. Overtopping of the Cradge Bank from the Hundred Foot River may also occur. Water is stored in the Washes until flows subside and it can be discharged through Welmore Lake Sluice.

8 **Welmore Lake Sluice & Pumping Station**
Environment Agency
Used to release water from the Ouse Washes back into the Hundred Foot River.

9 **Old West River / Ely Ouse / Ten Mile River**
Main River
The Great Ouse River is known as the Old West River (between Hermitage Lock and the River Cam), the Ely Ouse (downstream of the River Cam), and the Ten Mile River (downstream of Littleport).

10 **Cottenham Lode**
Main River
A high level carrier with raised embankments on either side.

11 **Chear Fen Pumping Station**
Old West IDB
Pumps water into the Old West River from Chear Fen to the south.

12 **River Cam**
Main River
Brings water from a large upland catchment to its confluence with the Old West River. In the Fens it is a high level carrier with raised embankments on either side.

13 **Cambridgeshire Lodes**
Main Rivers
Bottisham Lode, Swaffham Lode, Reach Lode and Burwell Lode are all high-level carriers with raised embankments on either side. They mostly discharge into the River Cam by gravity but pumping stations can boost the flow of water during periods of high flow.

14 **Oxlode Pumping Station**
Littleport & Downham IDB
Pumps water from the area west of Ely into the Hundred Foot River.

15 **Soham Lode**
Main River
Beginning north of Newmarket, it carries water from Soham to the Ely Ouse.

16 **River Lark**
Main River
Rising south of Bury St Edmunds it is one of several tributaries of the Ely Ouse.

17 **Diversion Sluices**
Environment Agency
The Lark Head Sluice (on the River Lark), the Hockwold Diversion Sluices (on the Little Ouse River) and the Stoke Ferry Diversion Sluices (on the River Wissey) allow water to be diverted from these watercourses into the Cut-Off Channel. This relieves pressure on the Ten Mile River. Syphons allow the Cut-Off Channel to flow beneath the Wissey and Little Ouse.

18 **Cut-Off Channel**
Main River
Under flood conditions, water from the River Lark, Wissey and Little Ouse can be diverted into the Cut-Off Channel to relieve pressure on the rest of the South Level system. When required, the Cut-Off Channel's flow can be reversed (via sluices at Denver) to transfer excess water to the Blackdyke Intake north of Hockwold, where it can be transferred to reservoirs in Essex.

19 **Lark Pumping Station**
Burnt Fen IDB
Pumps water from the area between the Little Ouse River and the River Lark.

20 **Little Ouse River**
Main River
Downstream of the Hockwold Diversion Sluices, the river is a high-level carrier with raised embankments on either side of the channel.

21 **River Wissey**
Main River
Joins the Ten Mile River just south of Denver.

22 **Denver Sluice Complex**
Environment Agency
The system of sluices here hold water levels throughout the South Level system and release flows into the River Great Ouse.

23 **Great Ouse Relief Channel**
Main River
Can be used to store more than 9.5 million cubic metres of water arriving from the South Level, to reduce flood risk to King's Lynn.

24 **Tail Sluice**
Environment Agency
Opened in 1959, it sets the tidal limit of the Great Ouse Relief Channel. It is formed of seven sluices, each 9m wide.

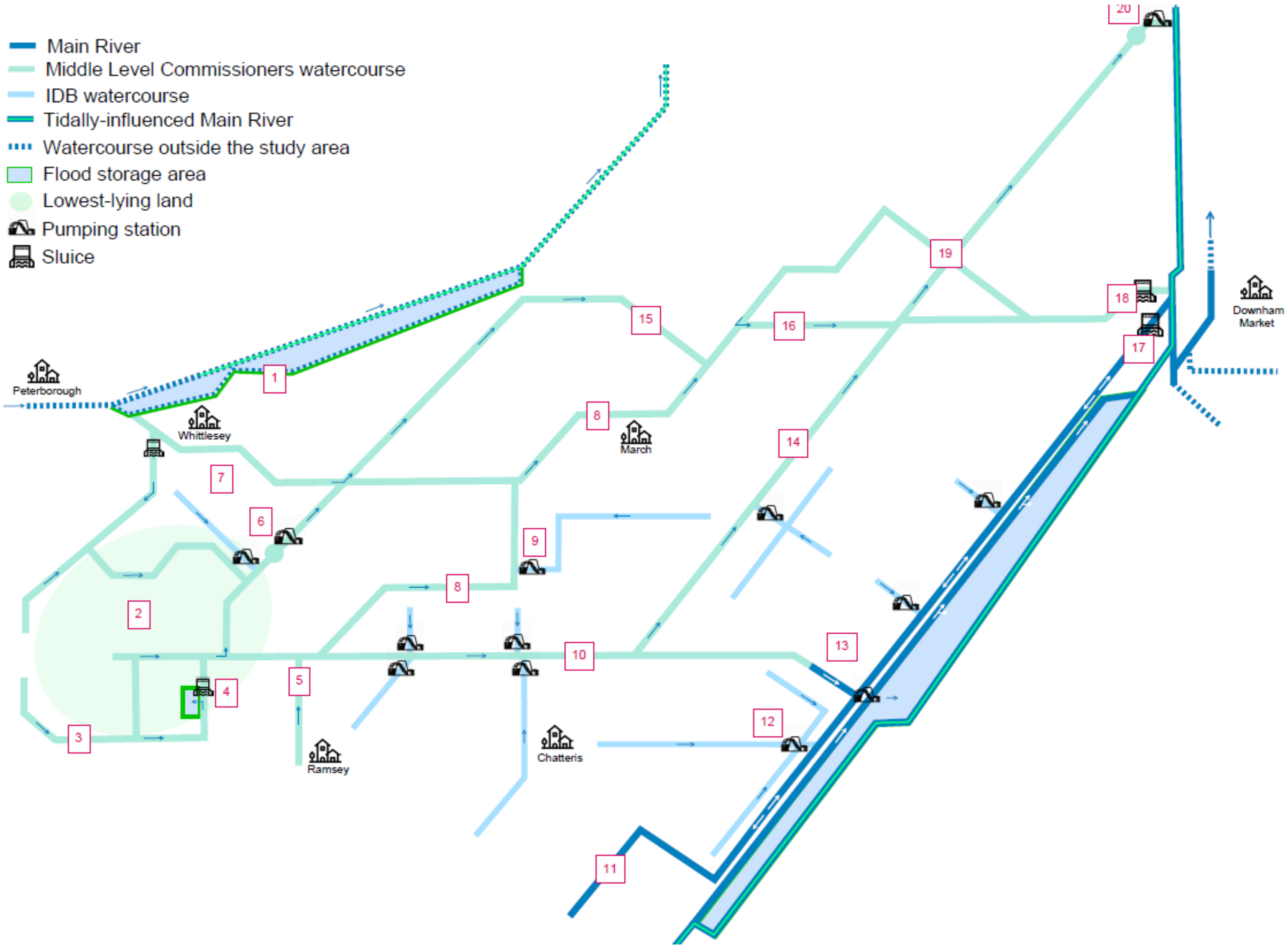

Figure 5: Schematic diagram of assets in the Great Ouse catchment (south-west).

1 **South Barrier Bank**
Environment Agency
As undertaker of the Whittlesey (Nene) Washes flood storage area, the Environment Agency are responsible for maintaining the South Barrier Bank which prevents water from spilling into the Middle Level.

2 **Triple pumping**
Middle Level Commissioners
The south-western area of the Middle Level contains the lowest land levels and the deepest peat, which will continue to shrink into the future. The area is vulnerable, being the first area to receive flood water from the higher ground to the south, whilst being located furthest from St. German's Pumping Station. Water in this area is pumped three times to reach the North Sea: at an IDB 'booster' pump, then at Bevills Leam, and finally at St. German's.

3 **Middle Level Catchwater Drain**
Middle Level Commissioners
Designed to minimise the amount of water entering the low-lying Middle Level district, it intercepts run-off from higher ground to the south and directing it to Bevills Leam.

4 **Control Sluice & Woodwalton Fen Flood Storage Area**
Middle Level Commissioners
In times of high flows from the catchwater drain, the control sluice can be closed to divert water into Woodwalton Fen National Nature Reserve, as a back-up measure. Water can be stored here and discharged into the river system at a controlled rate.

5 **Ramsey High Lode**
Middle Level Commissioners
Ramsey High Lode receives and conveys water towards St Germans Pumping Station from the Bury Brook sub-catchment. This sub-catchment is within the Middle Level Commissioners' highland area - which although lying mostly beyond the Fens 2100+ study area boundary, accounts for 10% of the Commissioners' overall catchment.

6 **Bevills Leam Pumping Station**
Middle Level Commissioners
Constructed to boost the flow from the lowest lying area of the Middle Level into Bevills Leam, to flow northwards to St. German's. Bevills Leam pond upstream of the pumping station provides temporary storage of flood water from the Catchwater Drain.

7 **Whittlesey Dyke**
Middle Level Commissioners
Known as King's Dyke upstream of Whittlesey, it carries water eastwards to the Twenty Foot River and the Old River Nene.

8 **Old River Nene**
Middle Level Commissioners
The previous meandering course of the River Nene before the new straightened channel was dug.

9 **Ransonmoor Pumping Station**
Ransonmoor District Drainage Commissioners
One of the 56 IDB pumping stations which outfall directly into the Middle Level Commissioners' watercourses.

10 **Forty Foot Drain**
Middle Level Commissioners
A straightened channel which links the Old River Nene with the Main River system via Horseway Lock.

11 **Ouse Washes Counter Drain**
Main River
Normally discharges water into the River Great Ouse through the Old Bedford Sluice, but also pumps backwards to maintain water resources in Summer.

12 **Mepal Pumping Station**
Sutton & Mepal IDB
Originally built in 1840, it is typical of many fenland pumping stations which started out with coal fired steam operated pumps, then diesel and eventually electric. It discharges water into the Ouse Washes Counter Drain.

13 **Welches Dam Pumping Station**
Environment Agency
Moves water from the Ouse Washes Counter Drain into the Ouse Washes flood storage area.

14 **Sixteen Foot Drain**
Middle Level Commissioners
IDB pumping stations pump water from surrounding land into the channel.

15 **Twenty Foot River**
Middle Level Commissioners
A continuation of Bevills Leam after its junction with Whittlesey Dyke, it eventually connects to the Old River Nene north-east of March.

16 **New Popham's Eau**
Middle Level Commissioners
Water in this drain is pulled eastwards by St German's Pumping Station.

17 **Old Bedford Sluice & Lock**
Environment Agency
Used to release water from the River Delph/ Old Bedford River into the River Great Ouse.

18 **Salters Lode Lock**
Middle Level Commissioners
The guillotine gate at Salters Lode form part of the Great Ouse Tidal Defences. The guillotine gate and the lock gate enables access for watercraft between the Great Ouse and the MLC systems, which connects to the River Nene near Peterborough at Stanground Lock.

19 **Middle Level Main Drain**
Middle Level Commissioners
Brings water northwards from the Middle Level area and discharges it to the tidal reach of the River Great Ouse through St German's Pumping Station.

20 **St German's Pumping Station**
Middle Level Commissioners
The largest pumping station in Britain, it is the primary outlet for water from the Middle Level system, and pumps water from an area of 700km² into the tidal stretch of the River Great Ouse. A 'pond' or widened section of the channel upstream can store additional water before it is pumped.

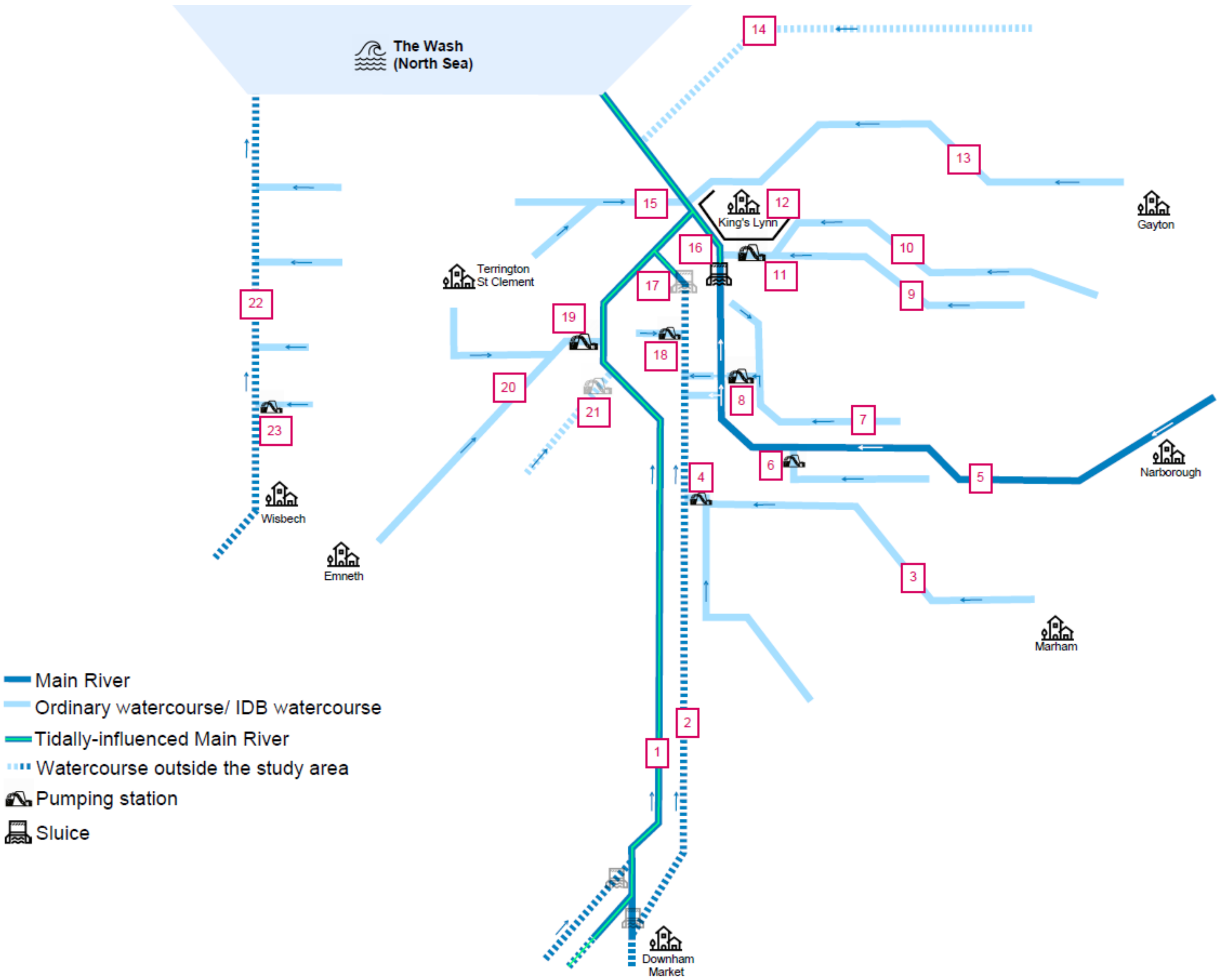

Figure 6: Schematic diagram of assets in the Great Ouse catchment (north).

1 **River Great Ouse**
Main River
Downstream of Denver Sluice it is tidal, and is a high-level carrier with raised embankments up to 6m above the surrounding land. Significant lengths of the embankments have erosion protection on the channel sides such as concrete block work.

2 **Great Ouse Relief Channel**
Main River
Part of the South Level System.

3 **Polver Drain/Sandy Drain/Fourteeen Foot Drain**
East of Ouse, Polver and Nar IDB
Moves water from Marham Fen to the Great Ouse Relief Channel.

4 **Polver Pumping Station**
East of Ouse, Polver and Nar IDB
Pumps water from the Polver Drain into the Great Ouse Relief Channel.

5 **River Nar**
Main River
The river is a biological Site of Special Scientific Interest. As Main River, the Nar is maintained by the Environment Agency and downstream of Narborough is a high-level carrier.

6 **Mill Fen Pumping Station**
East of Ouse, Polver and Nar IDB
Pumps water from the Mill Fen Drain into the River Nar.

7 **Puny Drain**
East of Ouse, Polver and Nar IDB
Carries water in the Nar Valley towards Puny Pumping Station.

8 **Puny Pumping Station**
East of Ouse, Polver and Nar IDB
Located on a diversion channel, it can pump water out to the Great Ouse Relief Channel during high flows in the Puny Drain, to protect King's Lynn from additional water. There is a similar diversion channel between the River Nar and the Great Ouse Relief Channel for the same purpose.

9 **Pierrepoint Drain**
King's Lynn IDB
Carries water to Pierrepoint Pumping Station.

10 **Middleton Stop Drain**
King's Lynn IDB
Carries water to the Pierrepoint Drain.

11 **Pierrepoint Pumping Station**
King's Lynn IDB
Pumps water out of Pierpoint Drain into the River Nar.

12 **King's Lynn defences**
Environment Agency
The 'hard defences' comprise flood walls and 61 sets of flood gates which can be closed to protect King's Lynn from tidal flooding.

13 **Gaywood River**
King's Lynn IDB
Flows by gravity into the River Great Ouse.

14 **River Babingley**
King's Lynn IDB
Drains the coastal area north of the catchment boundary into the River Great Ouse by gravity.

15 **West Lynn Drain**
King's Lynn IDB
Drains the land west of King's Lynn into the River Great Ouse via gravity.

16 **Old Nar Tidal Sluice**
Environment Agency
Sets the tidal limit of the River Nar.

17 **Tail Sluice**
Environment Agency
Part of the South Level system.

18 **Saddlebow Pumping Station**
East of Ouse, Polver and Nar IDB
Pumps out the area between the River Great Ouse and the Great Ouse Relief Channel.

19 **Islington Pumping Station**
King's Lynn IDB
Replaced in 2022, this is the largest pumping station owned by King's Lynn IDB. It drains approximately 65km^2 of land south-west of King's Lynn.

20 **Smeeth Lode**
King's Lynn IDB
Collects water from a network of smaller channels between Emneth and Terrington St Clement.

21 **St German's Pumping Station**
Middle Level Commissioners
Part of the Middle Level system.

22 **River Nene**
Main River
Forms the western boundary of the Great Ouse catchment. The western part of the King's Lynn IDB district discharges into the River Nene.

23 **Ingleborough Pumping Station**
King's Lynn IDB
Most of the King's Lynn IDB outfalls into the Nene drain by gravity, but the Inglebrough catchment is pumped. Ingleborough pumping station is King's Lynn IDB's oldest pumping station, commissioned in 1965.

1.6.1 Sluices

Brownshill Staunch (Figure 7) sits at the upstream end of the catchment and marks the tidal limit on the Great Ouse system, which is tidal on the Hundred Foot and Bedford Ouse Rivers downstream. It consists of three sluice gates alongside a lock gate. The gates are in poor condition and two have been closed to avoid the risk of becoming stuck open, which means the water level can't be maintained for navigation. The Environment Agency are currently carrying out investigations to identify the full scope of works required to restore the asset to its required condition.[1]

Figure 7: Brownshill Staunch Sluice looking South (upstream) © Michael Trolove and licensed for re-use under the Creative Commons Licence.

Earith Sluice is located downstream of Brownshill Staunch and opens automatically when there are high flows in the Bedford Ouse River to let some water into the Old Bedford River. It consists of three radial gates and was built in 1954 to replace the previous Seven Holes Sluice structure. Some refurbishment work was carried out by the Environment Agency around 2009-2012.[2]

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[1] EA@ St Ives and Brownshill Staunch Sluices Information Page (2025) Available at: https://consult.environment-agency.gov.uk/east-anglia-c-e/st-ives-and-brownshill-staunch-sluices-information/ Accessed: April 2025

[2] The Ouse Washes Website: Earith Sluice, Old Bedford River, Earith. Available at: https://www.ousewashes.info/sluices/earith-sluice.htm Accessed: April 2025

Figure 8: Earith Sluice looking South (upstream) © ousewashes.info

Hermitage Lock is just downstream of Earith Sluice and allows navigation between the New Bedford River system and the Ely Ouse via the Old West River. There has been a lock at this location since 1651. The current iteration was constructed in 1968 and refurbished in 1997.[3]

Welches Dam Lock is used to transfer water from the Forty Foot Drain into the Old Bedford River but is not currently operational. A 1996 report by the National Rivers Authority states that it was impractical to keep the channel open for navigation due to high seepage losses in the Forty Foot River. It was still navigable with difficulty in 2001 but was sealed off a few years later with steel piles.[4] There are plans to reopen it under the new Fens Reservoir scheme to transfer water from the Counter Drain to the new reservoir.

[3] The Ouse Washes Website: Hermitage Lock, Earith. Available at: https://www.ousewashes.info/sluices/hermitage-lock.htm Accessed: April 2025

[4] The Ouse Washes Website: Welches Dam. Available at: https://www.ousewashes.info/welchesdam/wd.htm Accessed: April 2025

Figure 9: Welches Dam Lock looking West (upstream) (April 2011) © ousewashes.info

Isleham Lock and Weir is a navigational lock on the main channel of the river Lark and can also act as a flood risk management sluice. A drop leaf weir gate on the back channel is used to maintain upstream water levels under normal flow conditions.

Just downstream of the Ouse Washes, **Welmore Lake Sluice & Pumping Station** is used to release water from the Washes back in the Hundred Foot River. The first sluice was built in this location in 1825 and was replaced in 1933, then again in 1999 with the current iteration. It has three sets of gates, and a capacity 50% great than the previous sluice. When the Ouse Washes are in use, the floodwaters block the A1101 (also known as the Welney Wash Road or Welney Causeway). The purpose of the capacity increase was to allow quicker discharge of flood waters and so reduce the time that the A1101 is impassable.[5]

[5] The Ouse Washes Website: Welmore Lake Sluice - the end of the Ouse Washes floodwater reservoir Available at: https://www.ousewashes.info/sluices/welmore-lake-sluice.htm Accessed: April 2025

Figure 10: Welmore Lake Sluice looking North-East (downstream) © ousewashes.info

Denver Sluice Complex (Figure 11) sits roughly in the middle of the catchment and sets the tidal limit of the River Great Ouse. It is positioned at the confluence of five different watercourses including the Old and New Bedford Rivers, and the Ely Ouse system which flows in the tidal River Great Ouse at this location.

The Complex consists of five components. It started with the Denver sluice which was built in conjunction with the Ouse Washes in 1651 to drain the marshes. The A.G. Wright Sluice was added in 1957 to connect the new Relief Channel constructed as part of the Ely Ouse Flood Protection Scheme in response to the flooding of 1947. The Diversion Sluice, Impounding Sluice and Residual Flow Sluice were added in 1971 to divert water via the Cut-Off Channel to Essex which regularly suffered from droughts.

Further details of the five components are set out below.

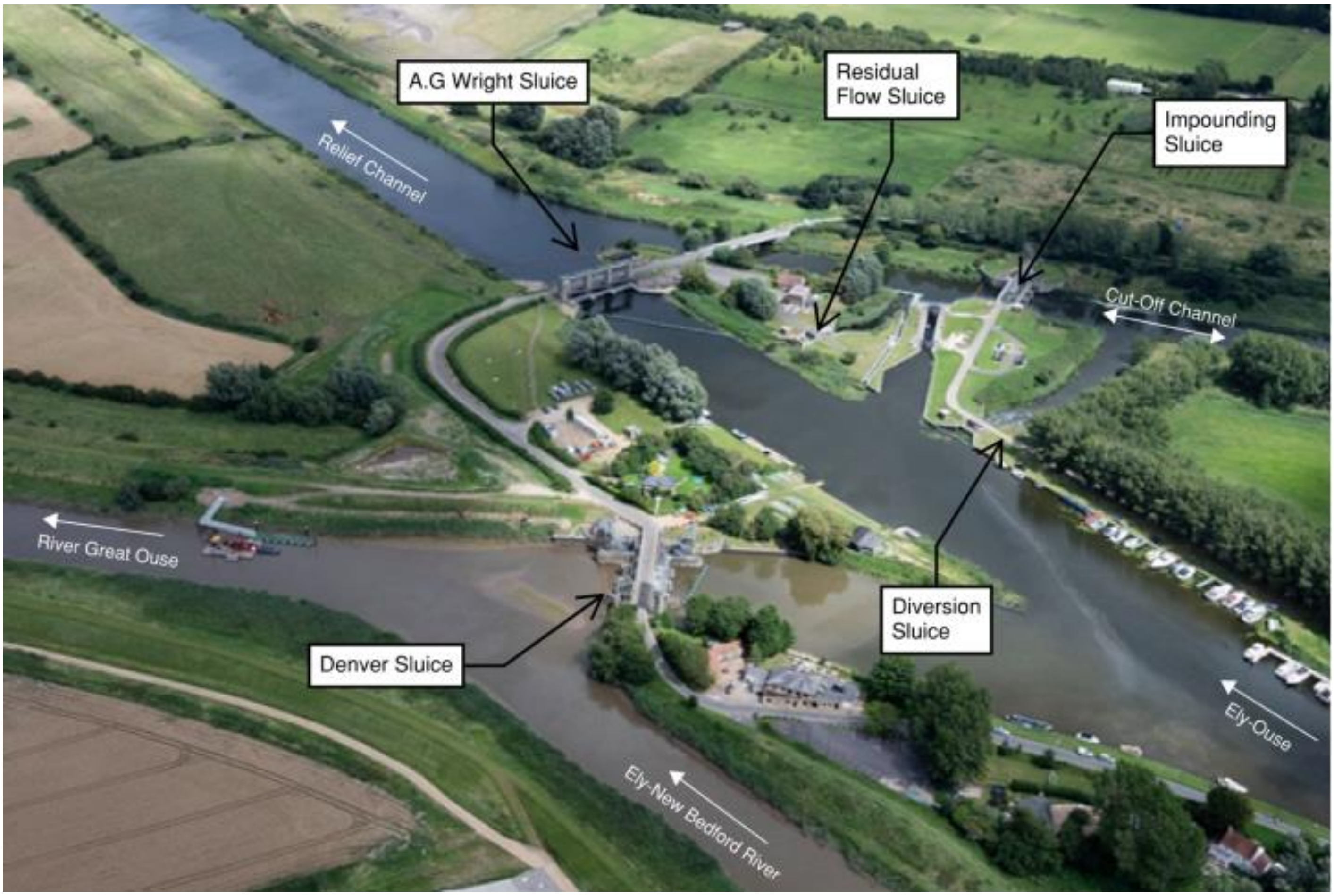

Figure 11: Denver Sluice Complex looking East[6]

1. **Denver Sluice** acts as the tidal limit on the River Great Ouse, protecting the Ely Ouse from tidal waters. There has been a sluice at this site since 1651 when the Ouse Washes were constructed. It has been rebuilt and refurbished numerous times over the centuries. The current structure was built in 1834 and enlarged in the 1920's[7]. It consists of two lift gates (one of which is now blocked off with a concrete slab), and three outlets known as "little eyes".[8]

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[6] Flickr: Rowing club at the Denver Sluice Complex aerial image - part of the Great Ouse River System in Norfolk UK Available at: https://www.flickr.com/photos/john_fielding/50222344876/ Accessed: April 2025

[7] Explore West Norfolk: Denver Sluice, Great River Ouse walk FRW Available at: https://www.explorewestnorfolk.co.uk/trails/denver-sluice-great-river-ouse-walk-frw-26/ Accessed: April 2025

[8] The Ouse Washes Website: Denver Sluice and Navigation Lock, Ely Ouse/ Ten Mile River. Available at: https://www.ousewashes.info/sluices/denver-sluice.htm Accessed: April 2025

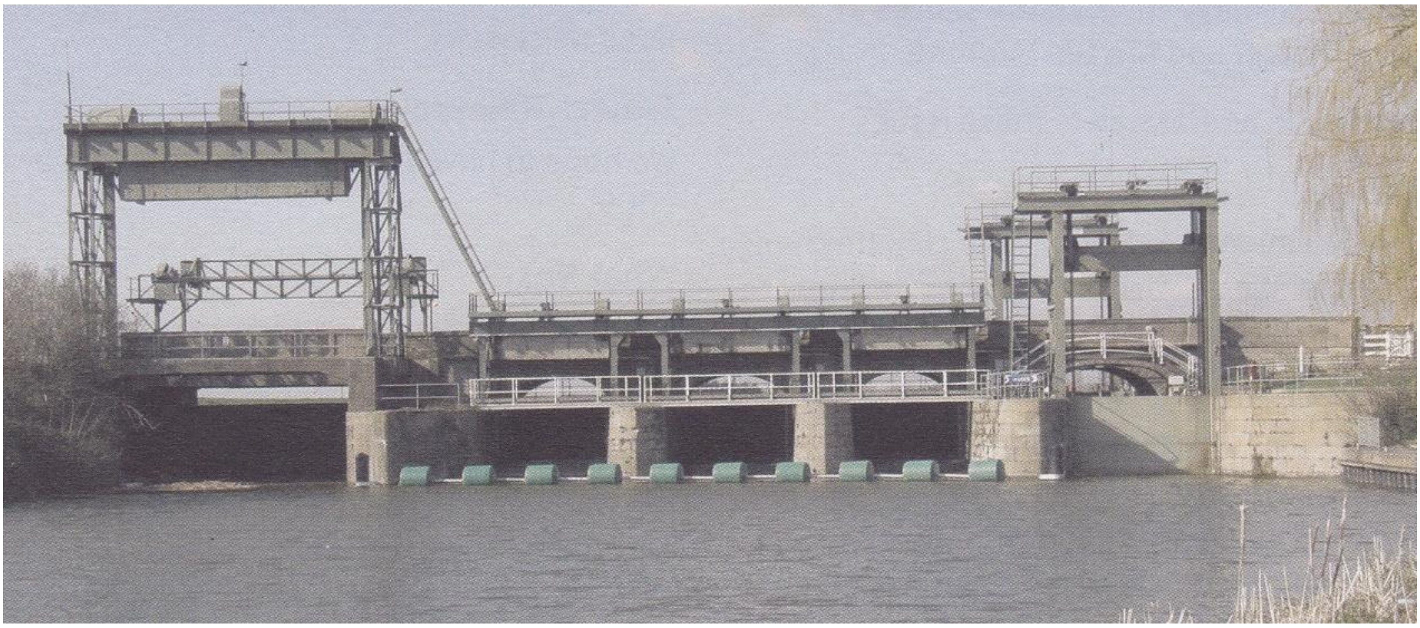

Figure 12: Denver Sluice looking North (downstream)[9]

2. **A.G. Wright Sluice** is an inlet sluice for flood water from the River Cam and the other rivers of the South Level to the Relief Channel, which discharges into the River Great Ouse further north. It was built in 1957 after the flooding of 1947 and 1953.[10]

[9] The Ouse Washes Website: Denver Sluice and Navigation Lock, Ely Ouse/ Ten Mile River. Available at: https://www.ousewashes.info/sluices/denver-sluice.htm Accessed: April 2025

[10] Geograph: TG5801 – The A G Wright Sluice (2014) Available at: https://www.geograph.org.uk/photo/3973843 Accessed: April 2025

Figure 13: A.G Wright Sluice looking South (upstream)[11]

3. **Diversion Sluice** was built as part of the water transfer scheme to Essex. It allows water from the Ely Ouse to be diverted into the Cut-Off Channel when the Impounding Sluice is closed. The water travels onwards via pumping stations and an underground pipeline to be stored in Essex reservoirs.[12]

4. **Impounding Sluice** was also built in 1969 as part of the water transfer scheme to Essex. It reverses the flow in the Cut-Off Channel.

[11] Geograph: TG5801 – The A G Wright Sluice (2014) Available at: https://www.geograph.org.uk/photo/3973843 Accessed: April 2025

[12] The East Anglian Waterways Association: Denver "Complex" Available at: https://eawa.co.uk/waterways.html Accessed: April 2025

Figure 14: Impounding Sluice looking North (downstream)[13]

5. **Residual Flow Sluice** is a small sluice which can be opened to allow enough flow in the Relief Channel to maintain the river water quality at King’s Lynn, whenever most of the flow is being diverted down the Cut-off Channel to Essex.

Head Sluice controls flow into the Cut-off Channel upstream of the Denver Complex and can be opened to allow water from the Lark to enter the Cut-off Channel during high flows. It consists of four weirs to manage the considerable difference in water level.[14]

Hockwold Diversion Sluices sit along the Cut-off Channel between Head Sluice and the Denver Complex. They consist of two sluice gates across the Little Ouse to divert the water into the Cut-off Channel, and a syphon to allow the Cut-off Channel to flow under the Little Ouse.

[13] Geograph: TF5900 - Flood Relief Cut Off Channel Impounding Sluice (2015) Available at: https://www.geograph.org.uk/photo/4673209 Accessed: April 2025

[14] Ouse Washes - The Heart of the Fens: Ely Dry – Essex Wet: the Great Ouse Cut Off Channel (2013) Available at: https://ousewasheslps.wordpress.com/2013/12/19/ely-dry-essex-wet-the-great-ouse-cut-off-channel/ Accessed: April 2025

Figure 15: One of the two sluice gates at Hockwold looking South (upstream) (© Arup 2024)

Nearby the Denver Complex, the **Old Bedford Sluice** is used to release water from the Old Bedford River (known as the Counter Drain upstream) into the tidal River Great Ouse. A sluice was first built here in 1630. The current gate was installed in 1995 by the National Rivers Authority (the Environment Agency's predecessor). In summer, when salinity is below an acceptable level, it can provide irrigation for the Ouse Washes and adjacent Fens.[15]

[15] The Ouse Washes Website: Old Bedford Sluice/Lock, Salters Lode. Available at: https://www.ousewashes.info/sluices/old-bedford-sluice.htm Accessed: April 2025

Figure 16: Old Bedford Sluice looking North-East (downstream)[16]

Tail Sluice sets the tidal limit of the Relief Channel. It was opened in 1959 and is formed of seven sluices, each 9m wide. The Ely Ouse can either be discharged into the tidal River Great Ouse via Denver Sluice or diverted into the Relief Channel and held until tides allow discharge via the Tail Sluice.[17] The Environment Agency is planning to spend £1.3m refurbishing the sluice to keep it fit for purpose for the next 18 years.[18]

[16] The Ouse Washes Website: Old Bedford Sluice/Lock, Salters Lode. Available at: https://www.ousewashes.info/sluices/old-bedford-sluice.htm Accessed: April 2025

[17] The Ouse Wash Website: Denver Sluice and Navigation Lock, Ely Ouse/ Ten Mile River. Available at: https://www.ousewashes.info/sluices/denver-sluice.htm Accessed: April 2025

[18] BBC: Environment Agency gives £68m for flood protection (2025) Available at: https://www.bbc.co.uk/news/articles/c0l1ly56112o Accessed: April 2025

Figure 17: Tail Sluice looking North (downstream) (Environment Agency)

Figure 18: Tail Sluice looking South (upstream) (Environment Agency)

Old Nar Tidal Sluice sets the tidal limit of the River Nar. In 1884, trade on the River Nar was declining due to the construction of a nearby trainline. An act of parliament removed the need to keep the Nar navigable, and the subsequent construction of the sluice gate prevented boats from accessing the river[19].

1.6.2 Pumping stations

Alder Pumping Station discharges water from a network of around 50km of drains into the River Lark.[20] It is owned by Mildenhall IDB and has a capacity of 4 cumecs.

Located on a diversion channel, **Puny Drain Pumping Station** can pump water out to the Relief Channel during high flows in the Puny Drain, protecting Kings Lynn from additional water. This pumping station has a capacity of 4 cumecs. It was built around 20 years ago and is owned by the East of Ouse, Polver and Nar IDB.

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[19] Kiddle: River Nar facts for kids. Available at: https://kids.kiddle.co/River_Nar Accessed: April 2025

[20] Ely Group of Internal Drainage Boards: Mildenhall. Available at: https://www.elydrainageboards.gov.uk/internal-drainage-boards/mildenhall/ Accessed: May 2025

Cawdle Fen Pumping Station discharges water from a network of around 4km of drains into the Ely Ouse River.[21] It drains a small but major urban area which includes a railway station, a large supermarket site and business parks in Ely. It is owned by Cawdle Fen IDB and has a capacity of 0.9 cumecs.

Bevill's Leam Pumping Station was constructed to boost the flow from the lowest lying area of the Middle Level into the Bevill's Leam, to flow northward to St.Germans. It also provides temporary controlled storage of flood water from the Catchwater Drain. It is owned by the Middle Level Commissioners.

Chear Fen Pumping Station is situated on the Old West River and serves a major landfill site, a business park and the A10. It is owned by the Old West IDB and has a capacity of 2.6 cumecs.

At Upware, there are two pumping stations, one owned by the EA and one by the IDB. The **IDB Upware Pumping Station** controls water levels in an 80km network of drains, discharging into the River Cam.[22] The **EA Upware Pumping Station** drains a large area and is critical as if it were to fail there would be significant consequences to the surrounding area.

Welches Dam Pumping Station moves water arriving from the Middle Level via the Ouse Washes Counter Drain into the Ouse Washes. It was built in the 1940s and refurbished in 1998. In 2009 it was again refurbished and upgraded from diesel to electric to give the station another 25 years of life.[23]

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[21] Ely Group of Internal Drainage Boards: Cawdle Fen Conservation Statement. Available at: https://www.elydrainageboards.gov.uk/internal-drainage-boards/cawdle-fen/cawdle-fen-conservation-statement/ Accessed: May 2025

[22] Ely Group of Internal Drainage Boards: Swaffham. Available at: https://www.elydrainageboards.gov.uk/internal-drainage-boards/swaffham/ Accessed: May 2025

[23] The Ouse Washes Website: Welches Dam Pumping Station. Available at: https://www.ousewashes.info/pumpingstations/welches-dam.htm Accessed: April 2025

Figure 19: Welches Dam Pumping Station looking North-East (downstream) (© Arup 2024).

Welmore Lake Sluice & Pumping Station is used to release water from the Ouse Washes back int the Hundred Foot River. A pumping station was first installed as part of the new sluice gate installation in 1999. It proved increasingly insufficient and was replaced in 2010 with a new electrically powered pumping station.[24]

Figure 20: Welmore Lake Pumping Station looking West (2017) © ousewashes.info

St Germans Pumping Station was built in 1936 to discharge water from the Fens that could no longer flow under gravity due to peat shrinkage lowering ground levels. It started with three diesel pumps with a capacity of 40 cumecs. In 1951, the capacity was increased to 70 cumecs by adding a fourth diesel pump and converting two pumps to electric motors. In 2010 a brand-new pumping station was constructed just downstream of the original facility which has six pumps with a total capacity of 100 cumecs. It is the responsibility of the Middle Level Commissioners and is the largest pumping station in Great Britain.[25]

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[24] The Ouse Washes Website: Welmore Lake Sluice - the end of the Ouse Washes floodwater reservoir Available at: https://www.ousewashes.info/sluices/welmore-lake-sluice.htm Accessed: April 2025

[25] Middle Level Commissioners: History of the Middle Level Commissioners. Available at: https://middlelevel.gov.uk/education/ Accessed: April 2025

Figure 21: St Germans Pumping Station looking North (upstream) © Environment Agency

1.6.3 Embankments

Embankments are constructed features designed to contain water and are ideally constructed of a solid clay core surrounded by piled material, and finally a layer of grass/vegetation.

In the Great Ouse catchment, there are 95km of coastal embankments and 405km of fluvial embankments as shown in Figure 22. A significant portion of this infrastructure will soon require investment as it is nearing the end of its design life.[26]

[26] EA: Future Fens Flood Risk Management. Available at: https://www.ada.org.uk/wp-content/uploads/2021/05/Future-Fens-Flood-Risk-Management-SUMMARY-DOC-Final_web.pdf Accessed: April 2025

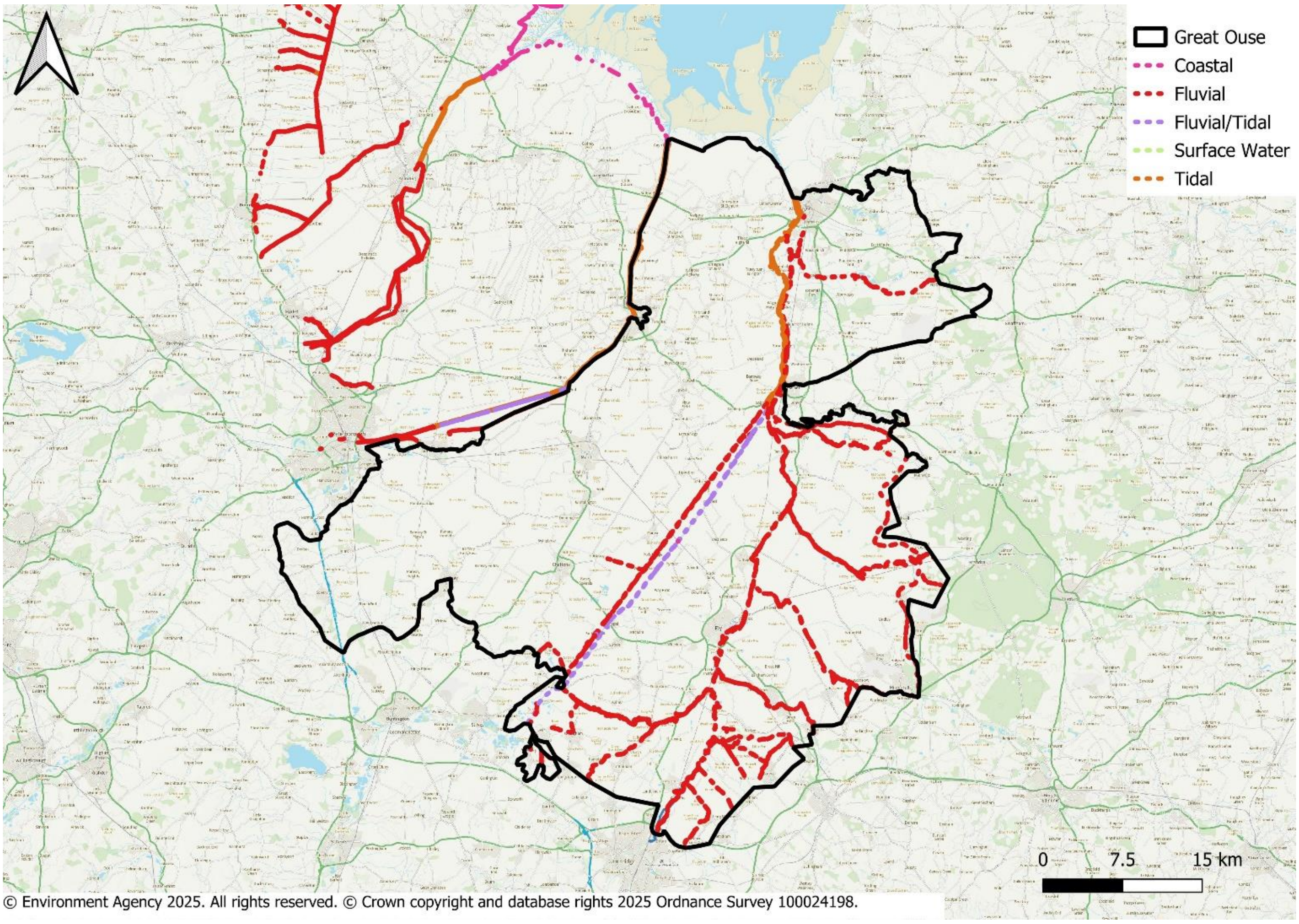

Figure 22: Environment Agency embankments in the Great Ouse catchment.

The **Ouse Washes** (also known as the Hundred Foot Washes) was constructed in 1653 is the largest area of washland in the UK. It is approximately 19 miles long and half a mile wide providing 90 million m^3 of flood water storage. During high flows in the Hundred Foot and Old Bedford Rivers, water is designed to overtop the embankments and spill into the Ouse Washes. It is stored there until flows subside and it can be discharged through Welmore Lake Sluice at the northern end. Although it is dry for much of the time, the Ouse Washes is classified as a reservoir under the Reservoirs Act (1975) and is managed by the Environment Agency.[27]

There are three roads that cross the Ouse Washes which can often become flooded when the Washes is in use, including the A1101 (also known as the Welney Wash Road or Welney Causeway) which has been dubbed the "UK's most flooded road".

In 2022, the Environment Agency completed a 6-year £40m project to raise the Middle Level Barrier Bank, which forms the West bank of the Washes (left as you look downstream), to maintain the standard of flood protection for local properties and agricultural land. They also installed a demountable flood barrier outside Welney to prevent water spilling from the Ouse Washes into Welney Village.[28]

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[27] EA: Ouse Washes Section 10 Works information page. Available at: https://consult.environment-agency.gov.uk/east-anglia-c-e/ouse-washes-section-10-works/ Accessed: April 2025

[28] GOV.UK: Work completed on Ouse Washes protects thousands of homes (2022) Available at: https://www.gov.uk/government/news/work-completed-on-ouse-washes-protects-thousands-of-homes Accessed: May 2025

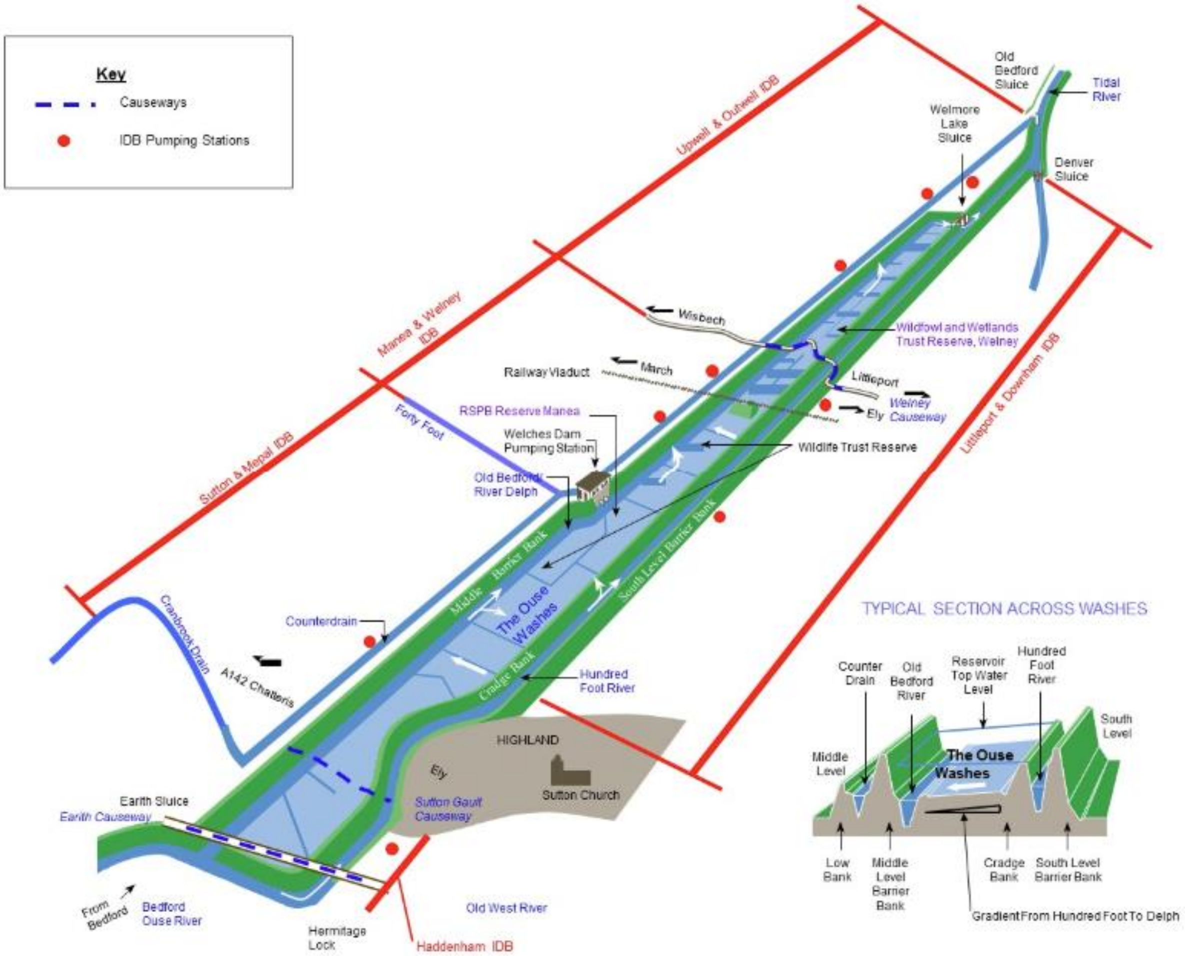

Figure 23: The Ouse Washes[29]

The **Relief Channel** (or Flood Relief Channel) and **Cut-off Channel** (see Figure 24) were first suggested in 1639 and again in 1810, but they were too expensive. A cheaper option with just the Relief Channel was proposed again in 1940 in response to flooding in the 1930s but was put on hold due to World War II. Following severe flooding in 1947, both channels were finally constructed in 1950s and 1960s as part of the Ely Ouse Flood Protection Scheme.

[29] EA: Ouse Washes Section 10 Works information page. Available at: https://consult.environment-agency.gov.uk/east-anglia-c-e/ouse-washes-section-10-works/ Accessed: April 2025

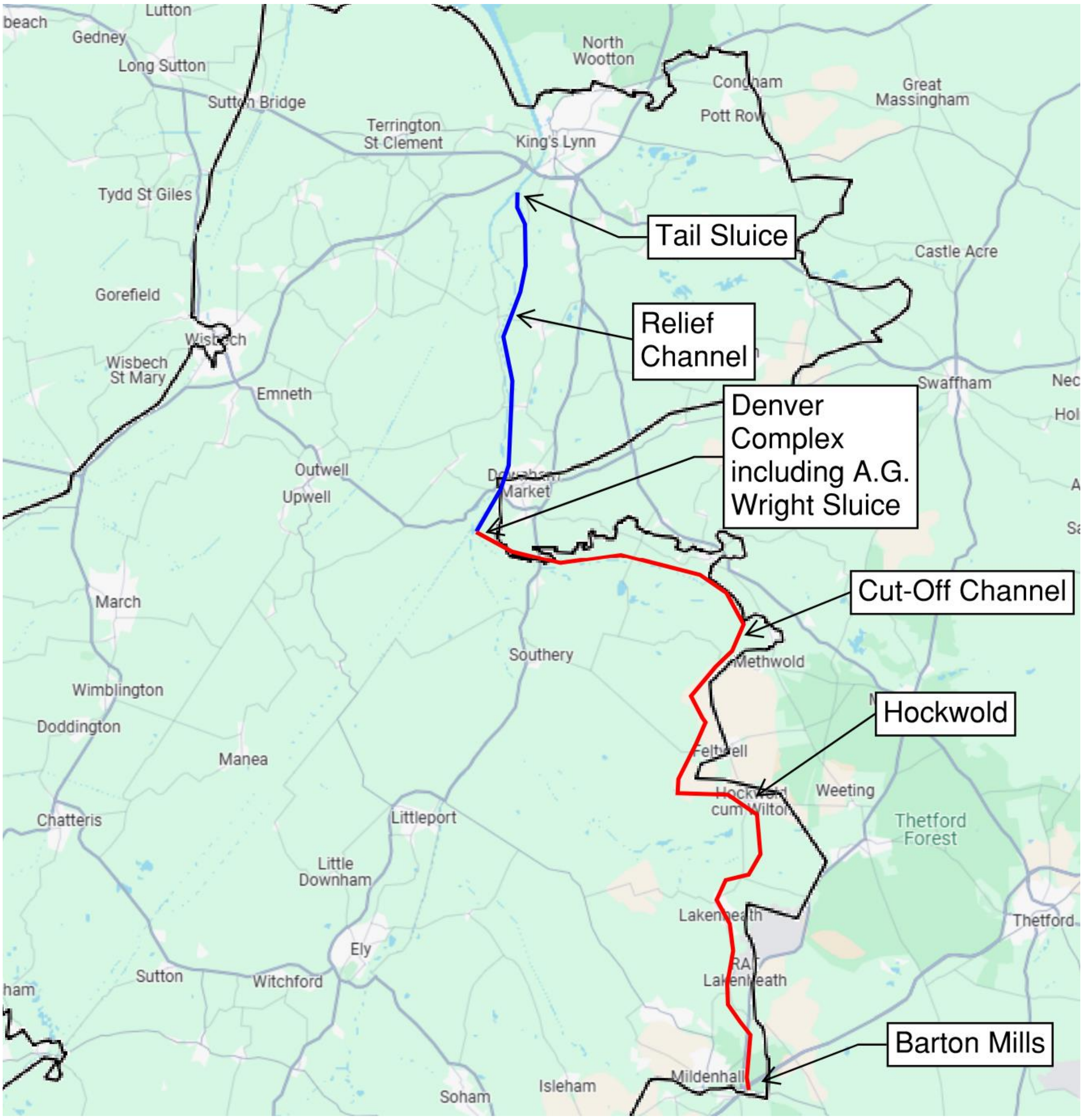

Figure 24: Diagram of Relief Channel & Cut-off Channel

When tides are high, water can be diverted from the Ely Ouse via the A.G. Wright Sluice at the Denver Complex into the Relief Channel and held until tides allow discharge at Tail Sluice.[30] This channel can store more than 9.5 million cubic meters of water reducing the flood risk to King's Lynn downstream.

The Cut-off Channel was completed in 1964 and provides a similar form of flood water storage, collecting water from the Lark, Little Ouse and Wissey. It starts at the Lark Head Sluice on the River Lark at Barton Mills and discharges at Denver Sluice reducing flood risk in Mildenhall and the washlands around the Great Ouse. On the way it intersects the Little Ouse and Wissey. At each intersection it passes under the rivers via a syphon and

[30] The Ouse Washes Website: Denver Sluice and Navigation Lock, Ely Ouse/ Ten Mile River. Available at: https://www.ousewashes.info/sluices/denver-sluice.htm Accessed: April 2025

can draw water from these rivers when the appropriate sluice gates are opened[31]. The syphons allow the Cut-off channel to serve a second purpose. In the summer, when flows are generally much lower, the flow in the Cut-off Channel can be reversed to move excess water south as part of the Ely Ouse-Essex water transfer scheme. The water flows as far as Hockwold where it enters the Blackdyke tunnel below the River Lark to the Kennet Pumping Station and a system of rivers and tunnels carries it over 140km southwards to reservoirs in Essex[32].

1.6.4 Flood Defences

The **King's Lynn Flood Defences** comprise flood walls and 61 sets of flood gates which can be closed to protect King's Lynn from tidal flooding. The embankments protecting King's Lynn from the tide were raised following the 1953 North Sea tidal surge which swept along the west coast of England and killed 15 people in King's Lynn.

The flood gates were installed following another North Sea storm surge in 1978. They were tested in 2013 when a further storm surge nearly over-topped them. Even with a last-minute drop in the wind, the tide was within four or five inches of the tops of all the gates[33]. An Environment Agency refurbishment programme was established to defend against future flooding[34]. The refurbishment programme consisted of a number of elements:

- 30 existing gates were refurbished, refitting with seals and hinge mechanisms as required, then rehung and tested;
- 15 new vehicle flood gates were installed; and
- 15 new demountable flood barriers were installed.

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[31] Ouse Washes: The Heart of the Fens: Ely Dry – Essex Wet: the Great Ouse Cut Off Channel (2013) Available at: https://ousewasheslps.wordpress.com/tag/little-ouse/#:~:text=At%20each%20of%20these%20intersections%2C%20the%20Cut%20Off,the%20appropriate%20sluice%20gates%20are%20opened%20and%20closed. Accessed: April 2025

[32] St Edmundsbury: The River Lark After the year 1600. Available at: www.stedmundsburychronicle.co.uk/riverlark/larkafter1600.htm Accessed: April 2025

[33] Eastern Daily Press: Logs reveal how close King's Lynn came to flooding during December storm surge (2014). Available at: https://www.edp24.co.uk/news/weather/21024812.logs-reveal-close-kings-lynn-came-flooding-durign-december-storm-surge/ Accessed: April 2025

[34] Flood control International: Kings Lynn Case Study. Available at: https://floodcontrolinternational.com/case-studies/kings-lynn/ Accessed: April 2025

Figure 25: Flood Barriers at King's Lynn[35]

[35] Flood control International: Kings Lynn Case Study. Available at: https://floodcontrolinternational.com/case-studies/kings-lynn/ Accessed: April 2025

2. Notable flood history

A number of flood events have impacted the Great Ouse catchment. These events have been summarised in the proceeding sections.

Information on flood history has come from various sources, in the form of:

- Flood outlines (GIS files) recorded by the Environment Agency;
- Environment Agency: Future Fens Flood Risk Management – Baseline Report (2020)
- News articles from reputable news organisations, such as the BBC and local newspapers.

2.1 1930s

A number of fluvial flooding incidents occurred in the Great Ouse catchment throughout the 1930s. The most notable in 1937 resulted in flooded farmland, closed schools and communities were cut off.

This led to the Sir Murdoch MacDonald Report on Flood Protection published in 1940 which proposed a cut off channel to collect flood water from three rivers and divert them via a relief channel to the Denver Sluice. However, investment was put but on hold due to World War II[36].

2.2 March 1947

On March 13th 1947, a combination of rapidly thawing snow, rain and high spring tides lead to widespread flooding across the Fens. High winds created waves against the banks of the watercourses causing breaches in the Ouse at Ely, Over, Little Thetford and Hockwold. The flooding including around 15,000 hectares of extremely valuable agricultural land as shown in Figure 26. Much of the South Level was under water for around two weeks with some areas remaining underwater for over two months.

This led to the reactivation of the Sir Murdoch MacDonald Report and the passing of the Great Ouse Flood Protection Act in 1949. After years of negotiations, an agreement was reached in 1953 and works for the Murdoch MacDonald scheme started in 1954 (also known as the Ely Ouse Flood Protection Scheme). The works included the construction of the Relief Channel, Cut-off Channel, and bank improvement works to the Ten Mile and Ely Ouse rivers. These works cost approximately £150 million in today's money[37] and were completed in 1970.

The recorded flood outline for this event is shown in Figure 27 and Figure 28.

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[36] Ouse Washes: The Heart of the Fens: Ely Dry – Essex Wet: the Great Ouse Cut Off Channel (2013) Available at: https://ousewasheslps.wordpress.com/tag/1947-flood/#:~:text=A%20detailed%20study%20of%20drainage%20problems%20and%20ongoing,MacDonald%20Report%20on%20Flood%20Protection%20published%20in%201940. Accessed: April 2025

[37] EA: Future Fens Flood Risk Management – Baseline Report (2020) Available at: https://www.ada.org.uk/wp-content/uploads/2021/05/Future-Fens-Flood-Risk-Management-Baseline-Report-Final_web.pdf Accessed: April 2025

Figure 26: Flooding of the River Great Ouse at Ely Dock Junction, Cawdle Fen, from the looking West, 1947 © Britain from Above

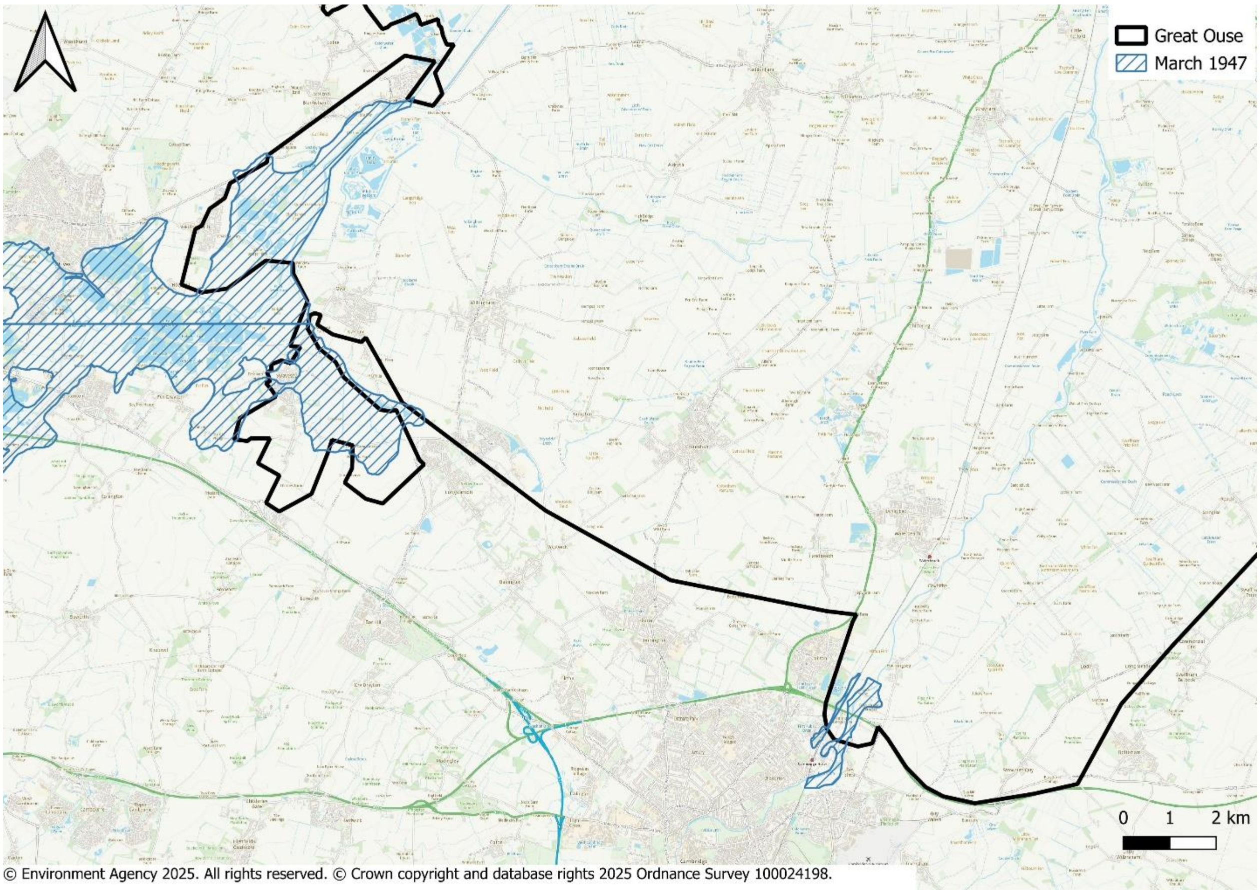

Figure 27: 1947 Environment Agency Recorded Flood Outline near Cambridge

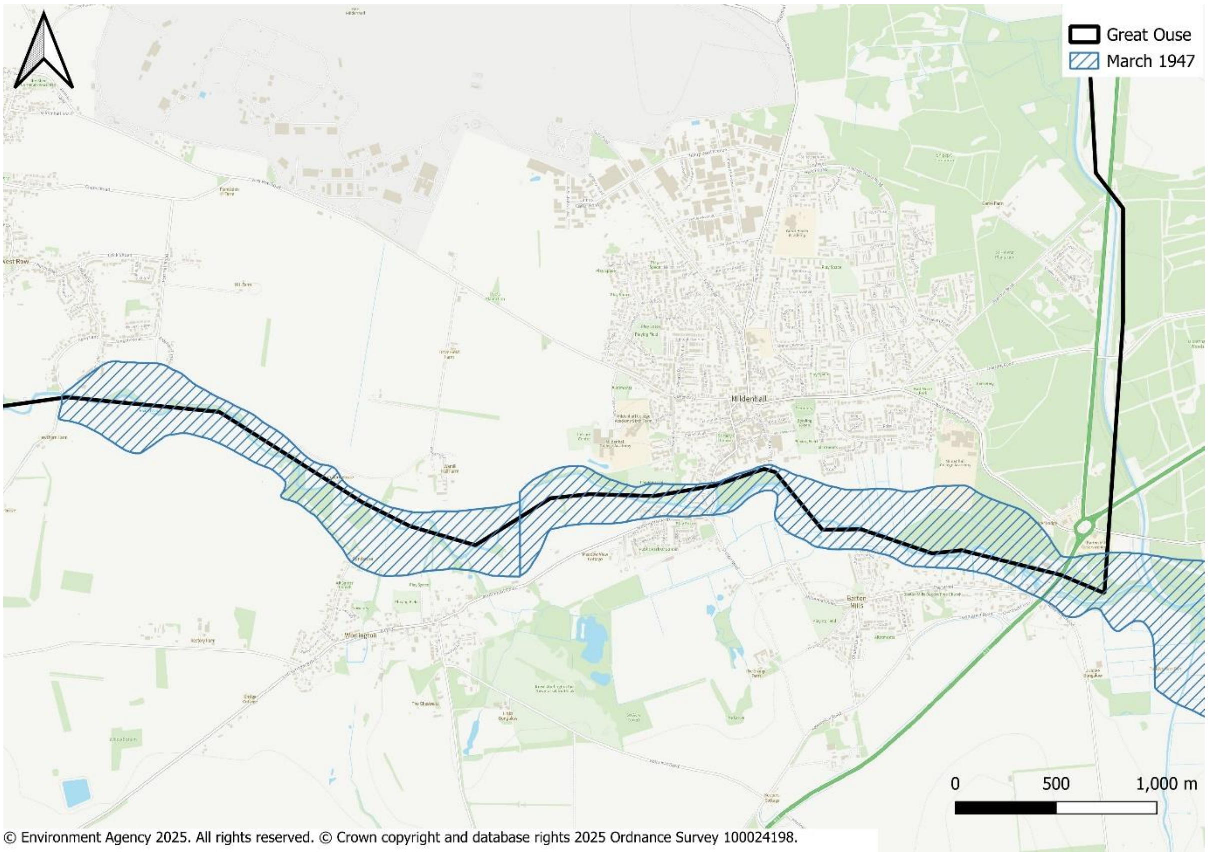

Figure 28: 1947 Environment Agency Recorded Flood Outline in Mildenhall

2.3 1951

Environment Agency records, as shown in Figure 29, show flooding of agricultural land near Isleham in 1951. The source was fluvial flooding from the River Lark.

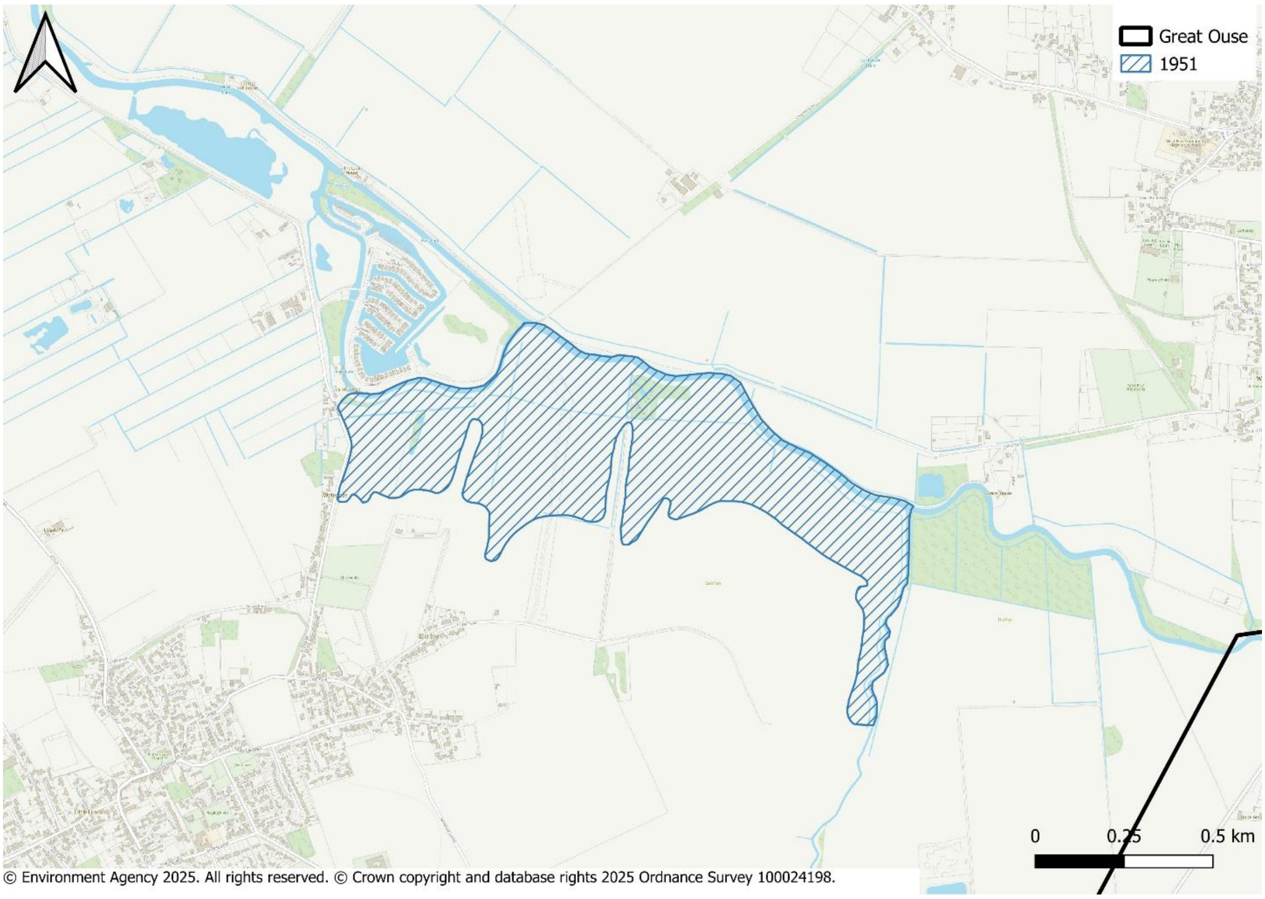

Figure 29: 1951 Environment Agency Recorded Flood Outline near Isleham

2.4 January 1953

In January 1953 a combination of a high spring tide and severe wind storm over the North Sea caused a storm surge which struck the east coast of England and Scotland as well as the Netherlands and North-West Belgium. In some places the sea level was more than 5.6 metres above mean sea level[38]. In the UK 307 people died, 15 of them in King's Lynn where water broke through the medieval port and flooded most of South Lynn, as shown in Figure 30, resulting in a fifth of the town being underwater[39]. Many homes were destroyed and thousands were left homeless[40].

This led to an agreement to increase the height of the banks of the Great Ouse Tidal River as part of the Ely Ouse Flood Protection Scheme.

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[38] EA, Future Fens Flood Risk Management, Baseline Report (2020)

[39] Eastern Daily Press: Remembering when the 1953 floods hit the Norfolk coast (2023) Available at: https://www.edp24.co.uk/news/23269770.remembering-1953-floods-hit-norfolk-coast/ Accessed: April 2025

[40] EA, Future Fens Flood Risk Management, Baseline Report (2020)

Figure 30: King's Lynn flooding in 1953[41]

2.5 January 1978

On the 11th of January 1978, a North Sea storm surge caused extensive flooding in King's Lynn. The Ouse overflowed into the town centre causing millions of pounds worth of damage[42], including St Margrets Church (Figure 32). Following this event, sixty flood gates and barriers were installed around the town.

There was also extensive flooding at Wisbech, and the hospital was closed for a number of weeks[43], though this was caused by flooding from the River Nene which sits just outside the catchment boundary. For further details of the River Nene, see the Lower Nene report.

The Environment Agency's recorded flood outline for this event is shown in Figure 31 and Figure 33.

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[41] Eastern Daily Press: The Floods of 1953: Village and towns struck by tragedy (2013) Available at: https://www.edp24.co.uk/lifestyle/21095340.floods-1953-village-towns-struck-tragedy/ Accessed: April 2025

[42] Flood control International: Kings Lynn Case Study. Available at: https://floodcontrolinternational.com/case-studies/kings-lynn/ Accessed: April 2025

[43] Eastern Daily Press: The day the water struck (2008) Available at: https://www.edp24.co.uk/news/20686885.day-water-struck/ Accessed: April 2025

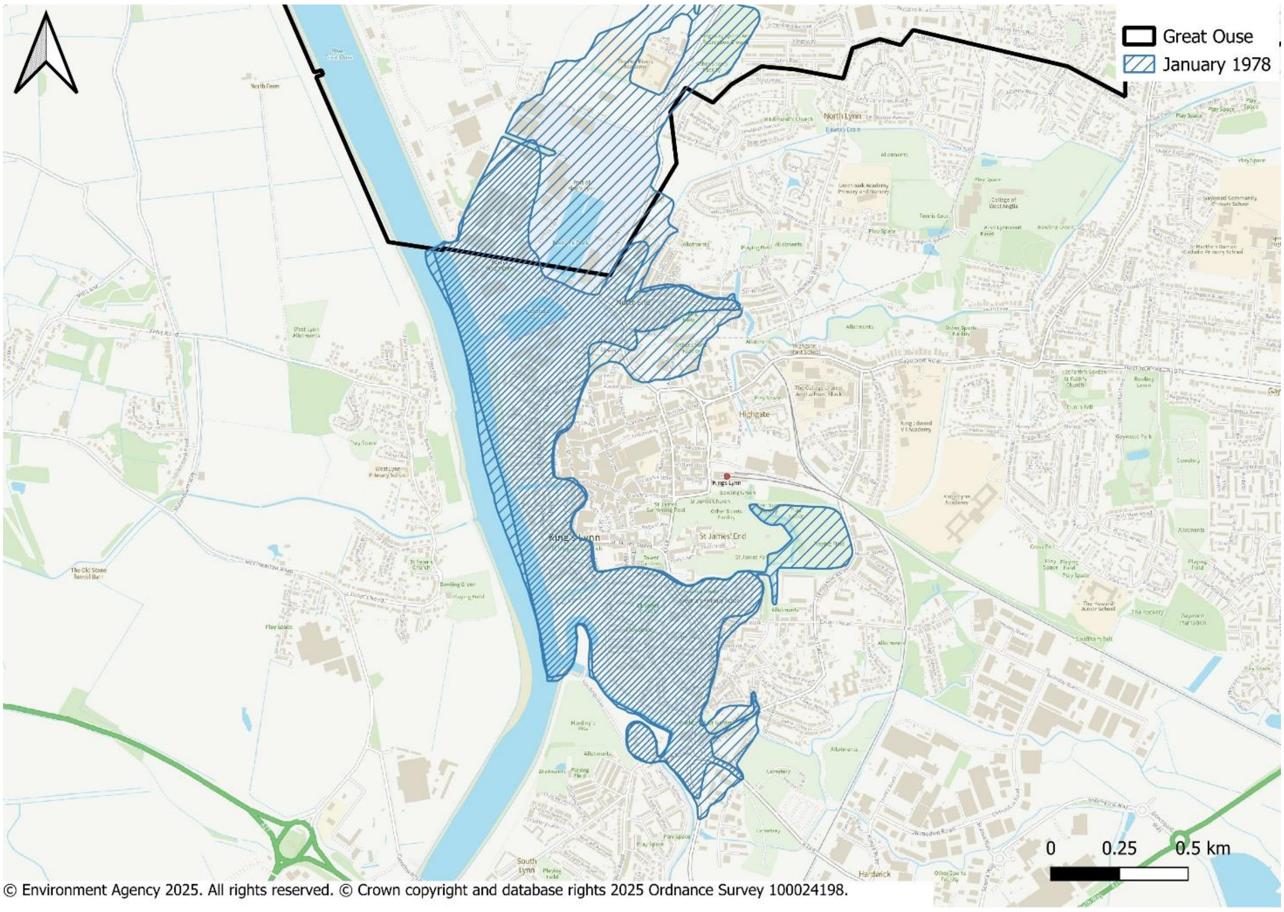

Figure 31: January 1978 Environment Agency Recorded Flood Outline in King's Lynn

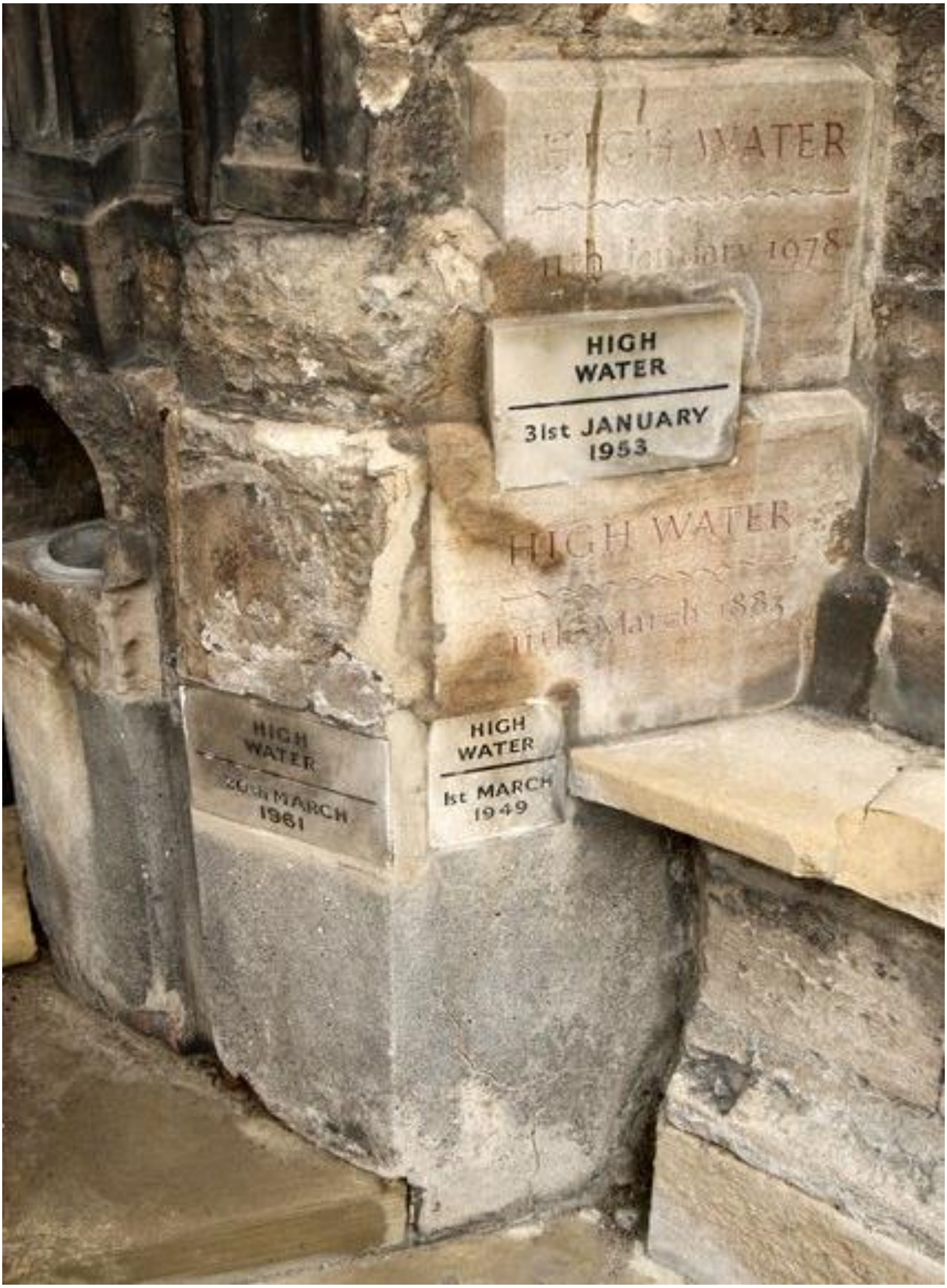

Figure 32: Flood markers on the door of St Margaret's church in King's Lynn, showing the 1978 flood level as the highest recorded © Dave Hitchborne and licensed for re-use under the Creative Commons Licence.

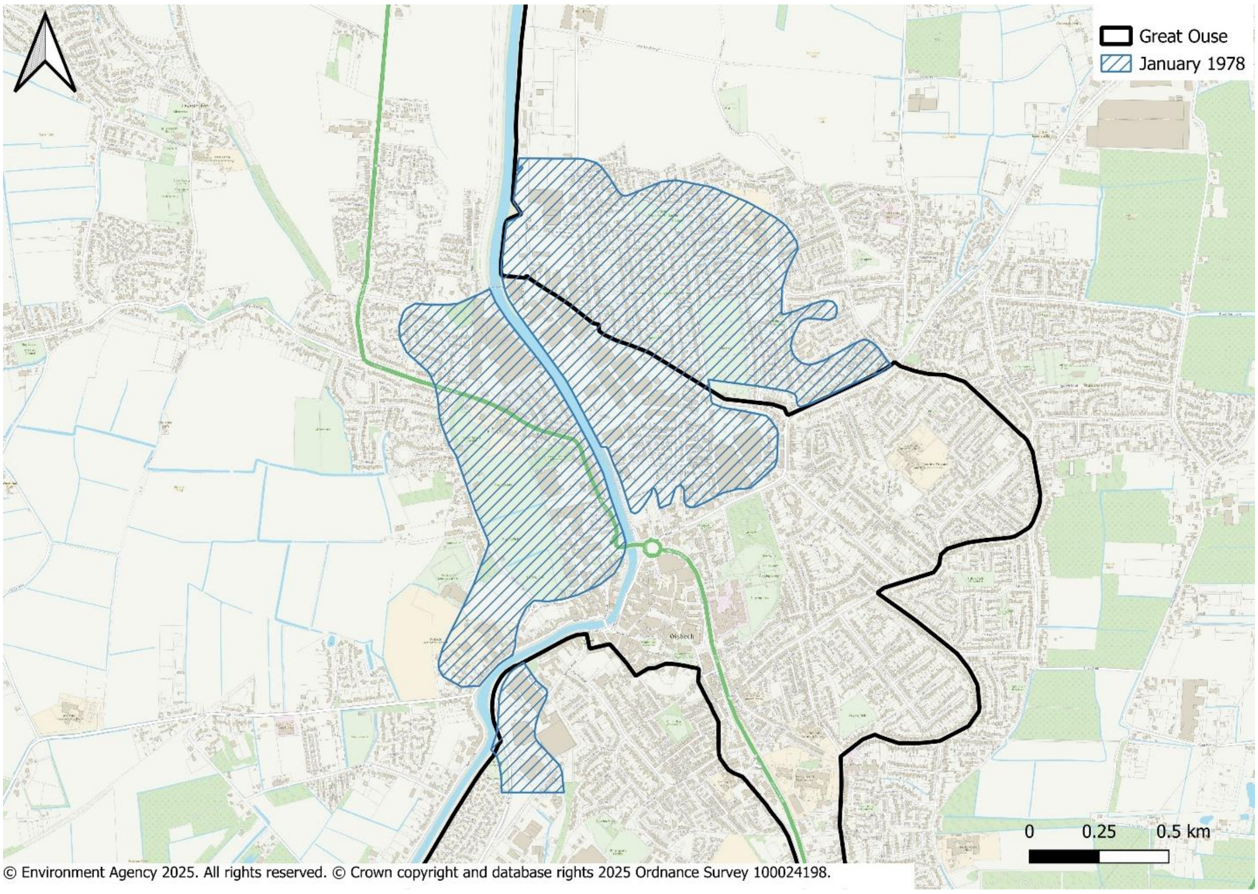

Figure 33: January 1978 Environment Agency Recorded Flood Outline in Wisbech from the River Nene

2.1 May 1978

In May 1978, agricultural land was flooded near Northstowe, as shown in Figure 34**Error! Reference source not found.**. The source of the flooding is fluvial from the Beck Brook and the River Great Ouse.

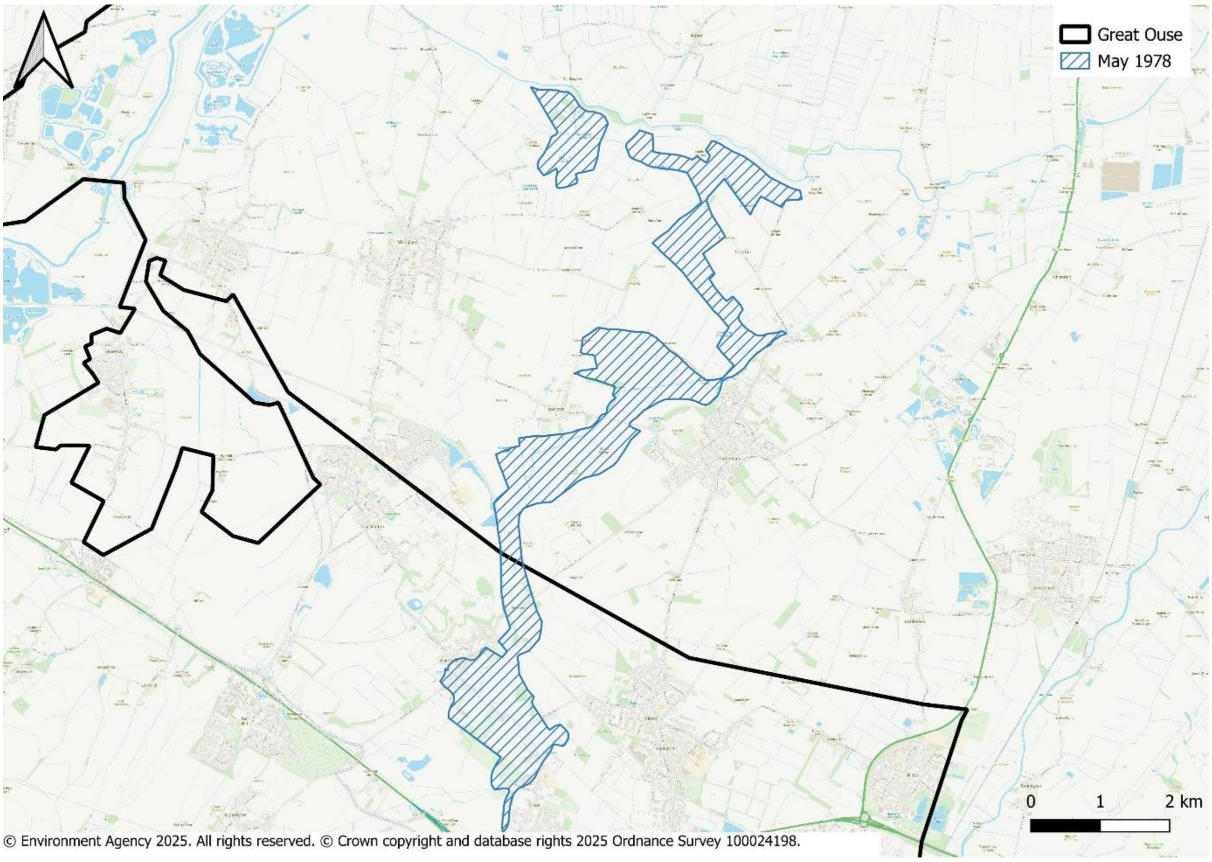

Figure 34: May 1978 Environment Agency Recorded Flood Outline near Northstowe

2.2 Autumn 1993

In October 1993, heavy rain fell for three days (11th, 12th and 13th) on an already saturated catchment. Return periods were estimated at 8 years for the Great Ouse and Earith and 17 years for the Great Ouse at Denver. Flooding was reported around the eastern and southern tributaries of the Great Ouse.[44] On the 12th of November the River Nar breached causing flooding between Lynn Road and New Road, as shown in Figure 35.

[44] EA & Mott Macdonald, Fenland Flood Risk Mapping: Final modelling Report (2016)

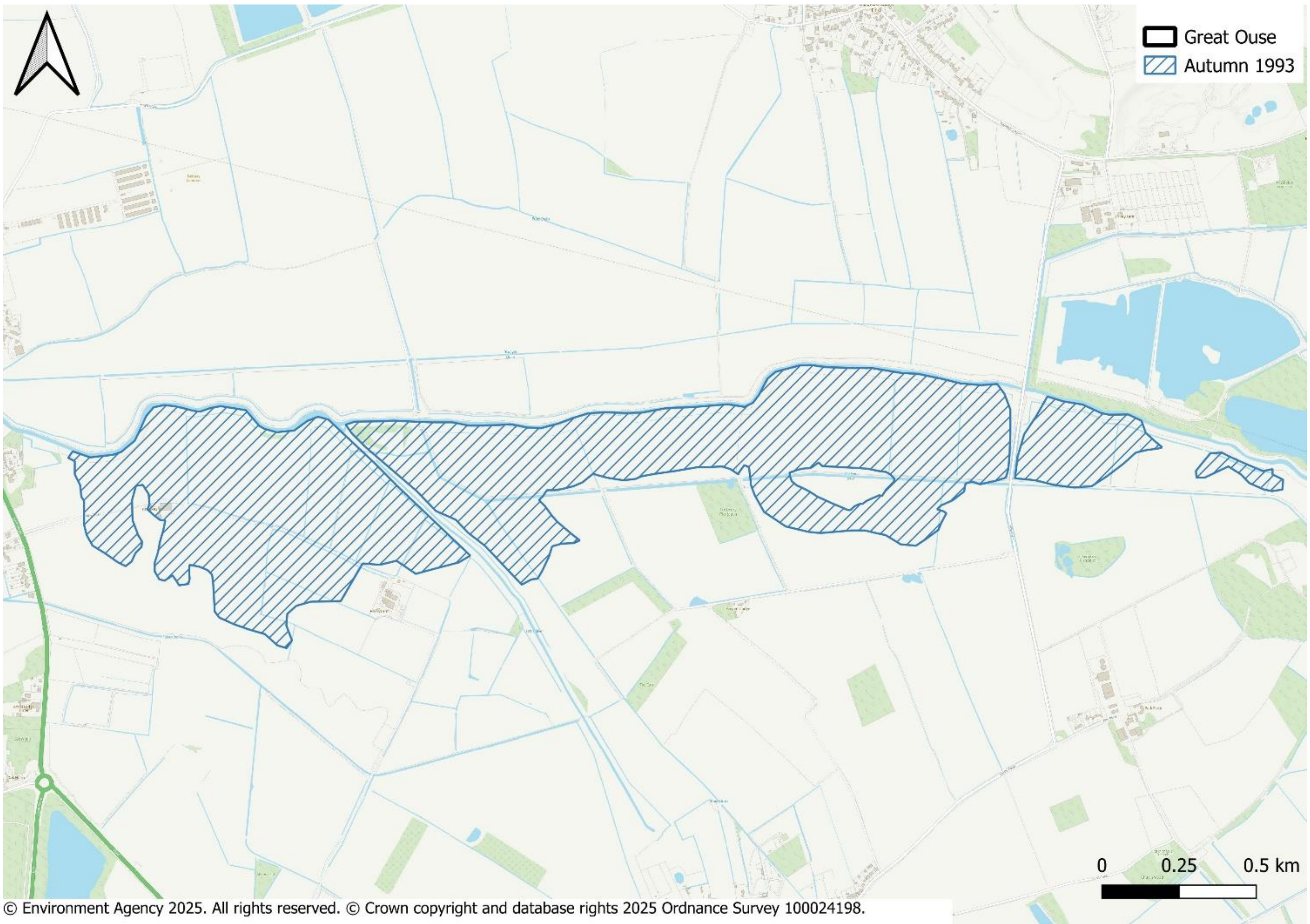

Figure 35: 1993 Environment Agency Recorded Flood Outline near Watlington along the River Nar

2.3 Easter 1998

On 9-10th April 1998, heavy rain fell on already saturated ground in the Midlands (see Figure 37) causing excessive surface run-off and flooding.[45] The River Great Ouse burst its banks near St Ives as shown in Figure 37.

[45] Hydro-GIS Ltd: 25 years ago, the Easter floods of 1998 caused devastation in the Midlands (2023) Available at: https://hydro-gis.co.uk/25-years-ago-the-easter-floods-of-1998-caused-devastation-in-the-midlands/ Accessed: April 2025

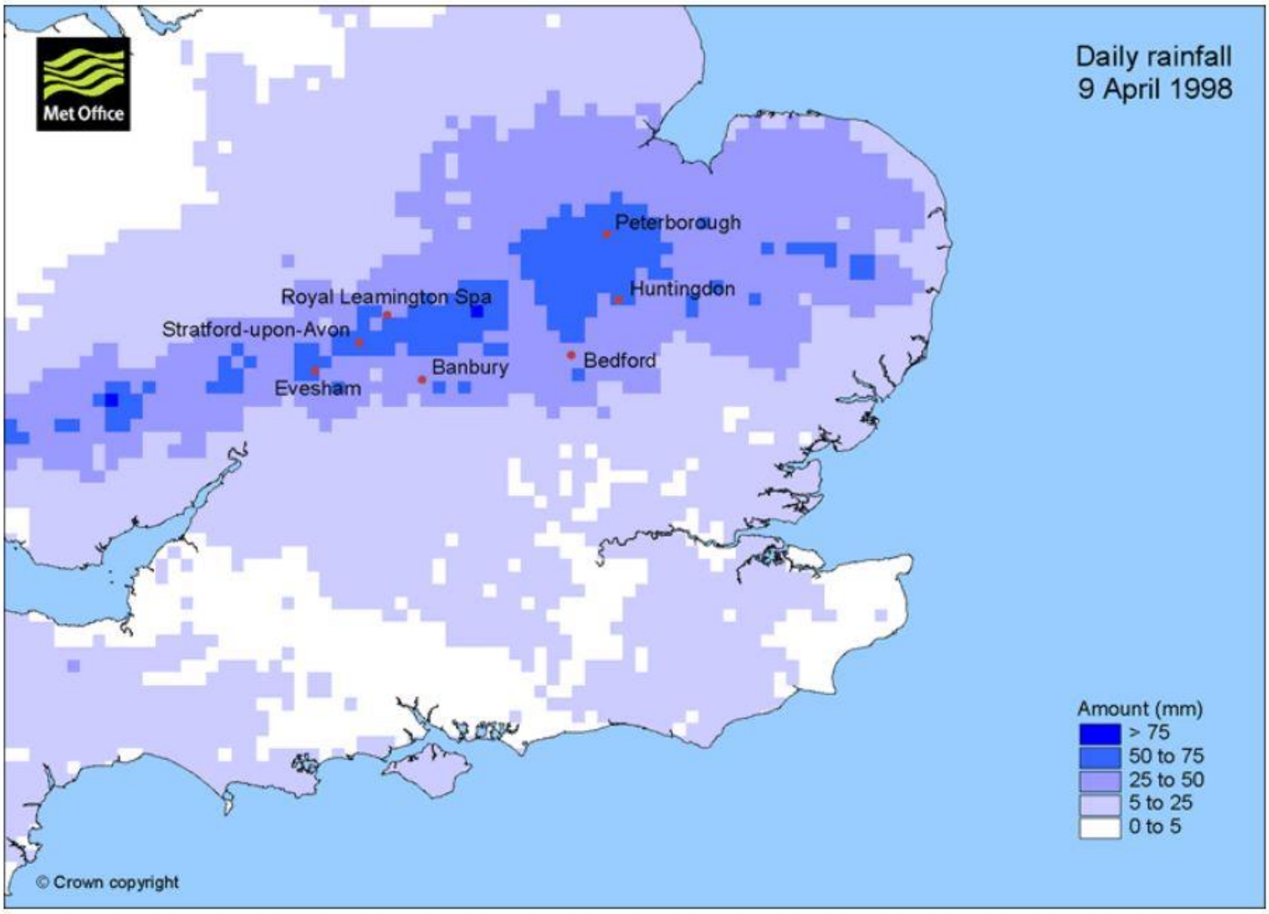

Figure 36: 24 hour recorded rainfall on 9th April 1998 © Met Office

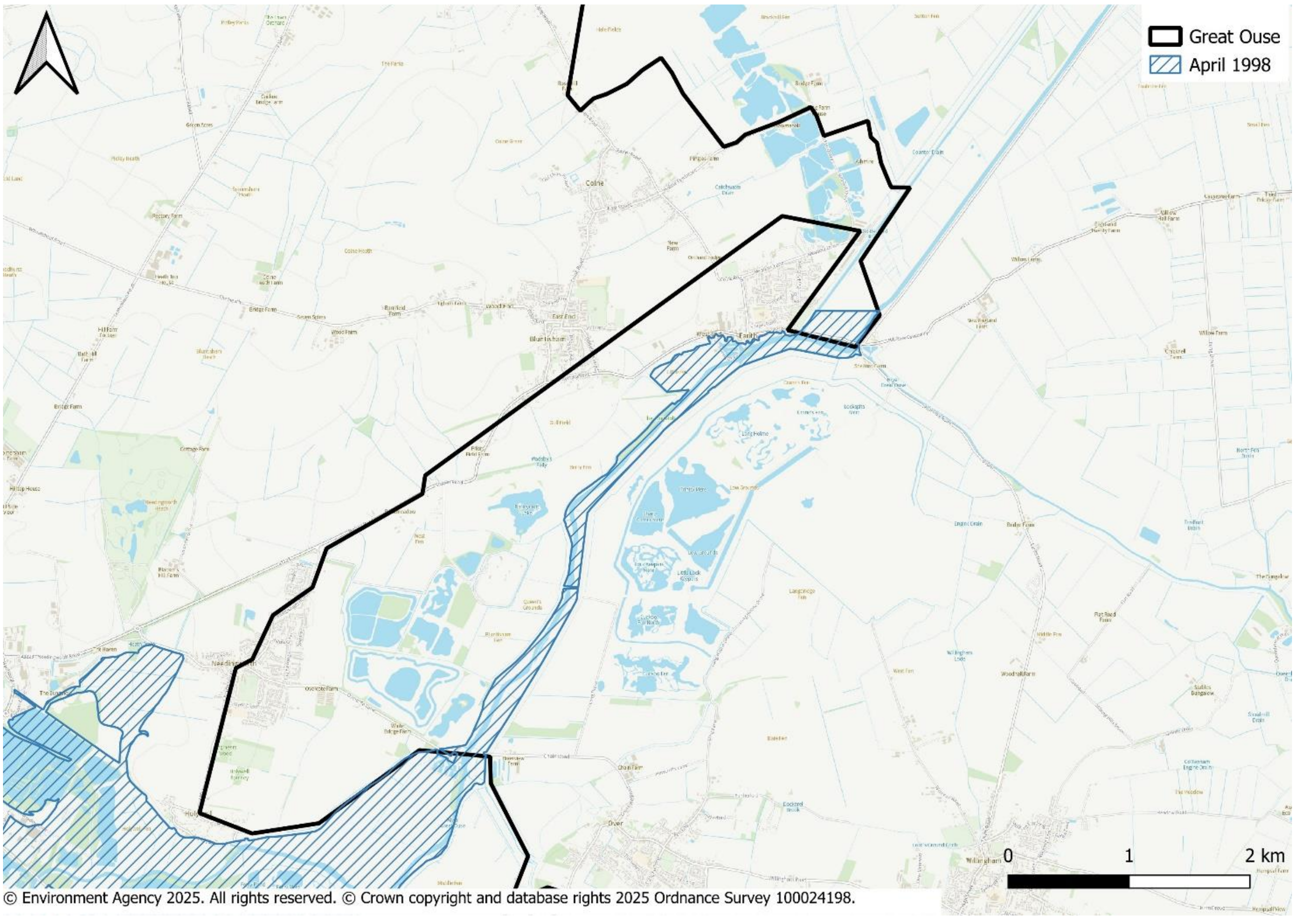

Figure 37: 1998 Environment Agency Recorded Flood Outline near St Ives

2.4 October 2001

On the 20th and 21st October 2001, torrential rain fell on Cambridgeshire and Essex leading to the worst floods in 20 years[46]. Within the catchment, there was some flooding around the Cambridge area as shown in Figure 38, due to the River Great Ouse, Beck Brook and River Cam bursting their banks.

[46] BBC:2001: UK braced for more flooding (2001) Available at: http://news.bbc.co.uk/onthisday/hi/dates/stories/october/22/newsid_2489000/2489289.stm Accessed: April 2025

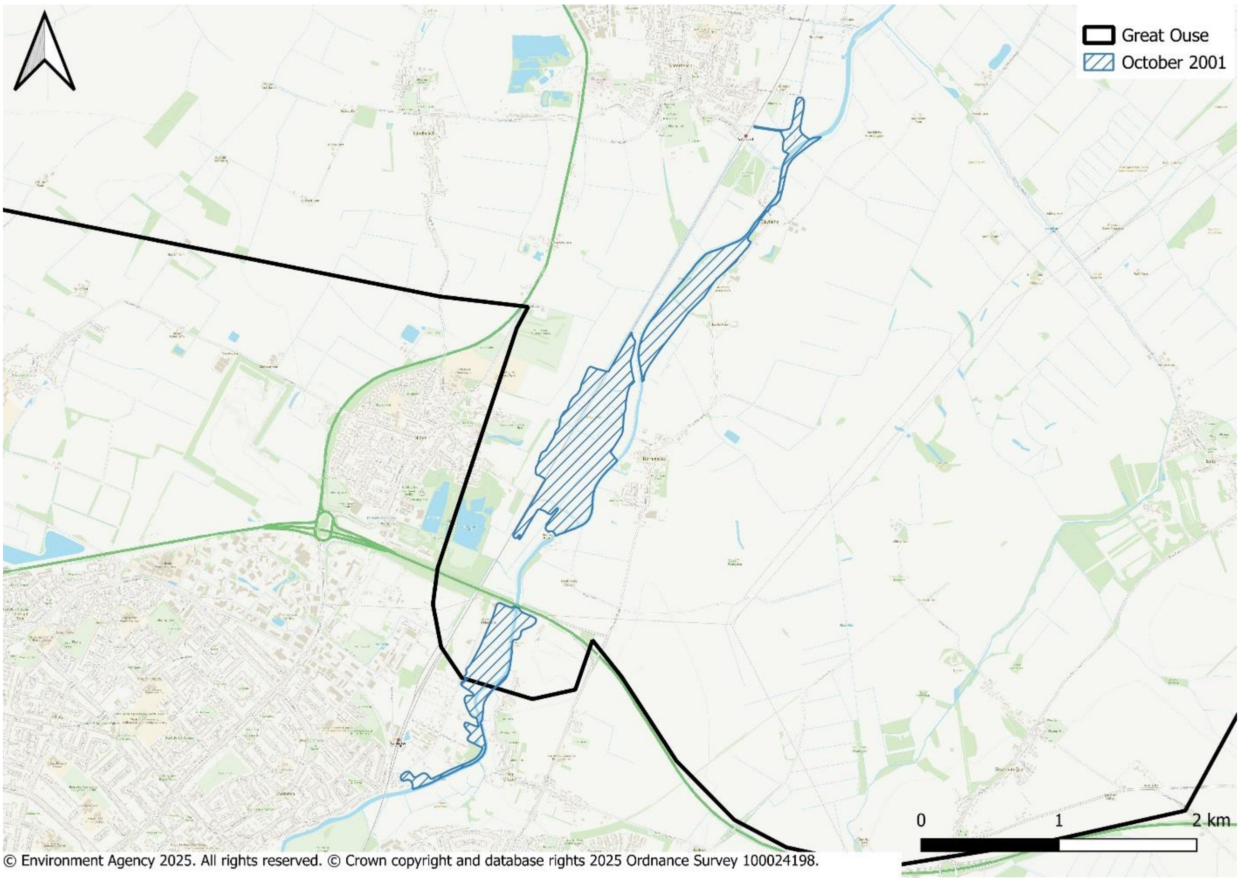

Figure 38: 2001 Environment Agency Recorded Flood Outline near Cambridge

2.5 December 2013

On 5th December 2013, a combination of high tide, a North-Westerly gale and low-pressure weather system lead to a storm surge all along the Norfolk coast. The River Ouse overtopped its banks flooding South Quay and Purfleet Quay[47] in King's Lynn as shown in Figure 39.

Environment Agency logs show that a wind change was all that prevented the water from overtopping the King's Lynn tidal defences[48] (described in Section 1.6.4). Even with the drop in the wind levels, the tide was within four or five inches of the tops of all the gates. The water level was higher even than the levels seen in the 1953 flood[49].

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[47] Eastern Daily Press: WEST NORFOLK AREA: Photo gallery, video, see how the storm surge left parts of King's Lynn and Hunstanton flooded. Available at: https://www.edp24.co.uk/news/weather/21065725.west-norfolk-area-photo-gallery-video-see-storm-surge-left-parts-kings-lynn-hunstanton-flooded/ Accessed: April 2025

[48] Eastern Daily Press: Logs reveal how close King's Lynn came to flooding during December storm surge (2014). Available at: https://www.edp24.co.uk/news/weather/21024812.logs-reveal-close-kings-lynn-came-flooding-durign-december-storm-surge/ Accessed: April 2025

[49] ITV News: Storm surge: Looking back at a dramatic 24 hours in the East (2013) Available at: https://www.itv.com/news/anglia/update/2013-12-06/storm-surge-looking-back-at-a-dramatic-24-hours-in-the-east/ Accessed: April 2025

Whilst the flood gates installed following the 1978 did their job, an Environment Agency refurbishment programme was established to defend against future flooding[50] costing around £1.2 million[51] (see Section 1.6.4 for further details).

Figure 39: King's Lynn Custom House surrounded by water[52]

2.6 December 2020

On December 23rd 2020, heavy rainfall fell on already saturated ground. At its peak, the St German's pumping station was pumping 70 tonnes of water each second, equivalent to emptying two Olympic swimming pools a minute[53]. Middle Level Commissioners described it as "*the largest and most challenging event…since Easter 1998"[54].*

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[50] Flood control International: Kings Lynn Case Study. Available at: https://floodcontrolinternational.com/case-studies/kings-lynn/ Accessed: April 2025

[51] Lynn News: Growing calls for tidal barrage move in King's Lynn (2019) Available at: https://www.lynnnews.co.uk/news/growing-calls-for-river-great-ouse-flood-defence-move-in-kings-lynn-9076528/ Accessed: April 2025

[52] Eastern Daily Press: WEST NORFOLK AREA: Photo gallery, video, see how the storm surge left parts of King's Lynn and Hunstanton flooded. Available at: https://www.edp24.co.uk/news/weather/21065725.west-norfolk-area-photo-gallery-video-see-storm-surge-left-parts-kings-lynn-hunstanton-flooded/ Accessed: April 2025

[53] Ely Standard: 'The largest and most challenging event we have faced since 1998' (2020) Available at: https://www.elystandard.co.uk/news/22753996.the-largest-challenging-event-faced-since-1998/ Accessed: April 2025

[54] Wisbech Standard: 'The largest and most challenging event we have faced since 1998' (2020) Available at: https://www.wisbechstandard.co.uk/news/22650041.the-largest-challenging-event-faced-since-1998/ Accessed: May 2025

Several homes in March, Wisbech and Doddington were flooded. Flooding in March was in part blamed on the fact that "*March is a low-lying island of clay and till surrounded by reclaimed marsh/fen. This makes managing excessive rainfall and the resulting surface water a major challenge*"[55].

2.7 2021-2025 A1101 Flooding

The A1101 (also known as Welney Wash Road or the Welney Causeway) crosses the Ouse Washes basin. The basin is designed to act as flood water storage and regularly floods when the Old Bedford River overflows. When this happens, the A1101 is also flooded and has become known as the "*UK's most-flooded road"*[56], often stranding vehicles who try to drive through the flood water. These flood incidents also inundate the Grade 4 farmland within the Ouse Washes. A list of recent events is included below:

- February 2021 stranding a vehicle[57] (Figure 40);
- March 2023[58] (Figure 41);
- January 2024 (Storm Henk), stranding an HGV[59](Figure 42). The road remained submerged for 3 months;
- December 2024[60]; and
- January 2025.[61]

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[55] Cambs Times: March could be the key focus of major flood prevention project (2021) Available at: https://www.cambstimes.co.uk/news/22843669.march-key-focus-major-flood-prevention-project/ Accessed: April 2025

[56] Insight: UK's 'most-flooded road' breaks record after being submerged for 3 months (2024) Available at: https://www.saferhighways.co.uk/post/uk-s-most-flooded-road-breaks-record-after-being-submerged-for-3-months Accessed: April 2025

[57] Ely Standard: 'Find another route or buy a boat,' say Welney Flood Watch volunteers (2021) Available at: https://www.elystandard.co.uk/news/22753723.find-another-route-buy-boat--say-welney-flood-watch-volunteers/ Accessed: April 2025

[58] Ely Standard: A1101 Welney: Motorists still defy Wash Road flooding (2023) Available at: https://www.elystandard.co.uk/news/23391621.a1101-welney-motorists-still-defy-wash-road-flooding/ Accessed: April 2025

[59] Cambs News: VIDEO: Stricken HGV rescued from flooded A1101 Welney Wash Road (2024) Available at: https://www.cambsnews.co.uk/news/video-stricken-hgv-rescued-from-flooded-a1101-welney-wash-road/20692/ Accessed: April 2025

[60] Eastern Daily Press: Welney Wash submerged under a 1ft of water amid flood alert (2024) Available at: https://www.edp24.co.uk/news/24773535.welney-wash-submerged-1ft-water-amid-flood-alert/?ref=yahoo Accessed: May 2025

[61] Eastern Daily Press: Welney Wash Road has begun flooding after rising tides (2025) Available at: https://www.edp24.co.uk/news/24850405.welney-wash-road-begun-flooding-rising-tides/ Accessed: April 2025

Figure 40: Flooded A1101 February 2021 © BBC

Figure 41: Flooded A1101 March 2023 [62]

[62] Ely Standard: A1101 Welney: Motorists still defy Wash Road flooding (2023) Available at: https://www.elystandard.co.uk/news/23391621.a1101-welney-motorists-still-defy-wash-road-flooding/ Accessed: April 2025

Figure 42: Flooded A1101 January 2024 [63]

2.8 Other events

The flood events detailed in the preceding sections detail the flood history of the catchment where records have been found. Recorded flood history is likely to be biased towards flooding that impacts properties.

It is expected that there will be more instances of flooding of agricultural land that have not been recorded.

2.9 Discussion

The flood history indicates that King's Lynn is at risk of tidal flooding. The 1953 tidal event killed 15 people and despite the subsequent raising of embankments, it was flooded again in the 1978 tidal event. Following this event, sixty flood gates and barriers were installed. However, the most recent storm surge in 2013 was within only four or five inches of the tops of all the gates. Refurbishments have since been made to these defences, though it's not clear whether they have been raised. With climate change bringing ever more extreme weather events, it is likely these defences will be insufficient in the near future.

In terms of fluvial flooding, the Great Ouse catchment experienced a number of extreme events in the 1930s and then again in 1947 when the Ouse burst its banks at Ely, leading to the activation of the Murdoch MacDonald scheme and the construction of the Relief Channel, Cut-off Channel, and bank improvement works to the Ten Mile and Ely Ouse rivers. Since these works were completed, flooding has been on a smaller scale, caused by surface water runoff and swelling rivers, rather than embankment breaches. The main towns affected include Ely, March and Wisbech. Transport networks have also been affected, in particular the regularly flooded A1101.

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[63] Cambs News: VIDEO: Stricken HGV rescued from flooded A1101 Welney Wash Road (2024) Available at: https://www.cambsnews.co.uk/news/video-stricken-hgv-rescued-from-flooded-a1101-welney-wash-road/20692/ Accessed: April 2025

3. Methodology and data review

3.1 2020 Great Ouse Baseline Report

This study builds in the work undertaken in 2020 to develop a baseline report for the Great Ouse as part of the Environment Agency's 'Flood Risk Management for the Fens' project. That project (2020) provided a narrative-based assessment of flood risk from all sources, however this (2025) report seeks to use best available modelling data to provide an improved understanding of the risk posed from tidal and fluvial flooding. This methodology is detailed in the proceeding sections.

3.2 Methodology

The methodology used in this assessment is to use best available information (i.e. no new modelling work has been undertaken for this study) to document both current and future flood risk and has been agreed with the Environment Agency. This assessment has been informed by a review of the existing hydraulic modelling and engagement with the relevant Environment Agency teams.

The proceeding sections detail the existing datasets used to determine the baseline flood risk in the Great Ouse catchment.

3.3 Detailed hydraulic modelling

A review of all detailed models in the Fens 2100+ study area was undertaken. The review found that in the Great Ouse catchment, there were four suitable models that could be used to describe flood risk and which number of metrics could be extracted from:

- 2015 River Nar – part of the Eastern Rivers Modelling Study.
- 2015 River Snail – part of the Eastern Rivers Modelling Study.
- 2016 Fenland Flood Risk model.
- 2018 Wash model – part of the East Anglian Coastal Modelling Study.

These models are described in more detail in the proceeding sections.

3.3.1 2015 River Nar model

In 2015 JBA Consulting was commissioned by the Environment Agency to carry out hydraulic modelling of the Eastern Rivers to understand flood risk. This work was subdivided into a number of packages, of which the River Nar was one. The River Nar model is a 1D-2D ISIS-TUFLOW fluvial-only model. The model extent is shown in Figure 43.

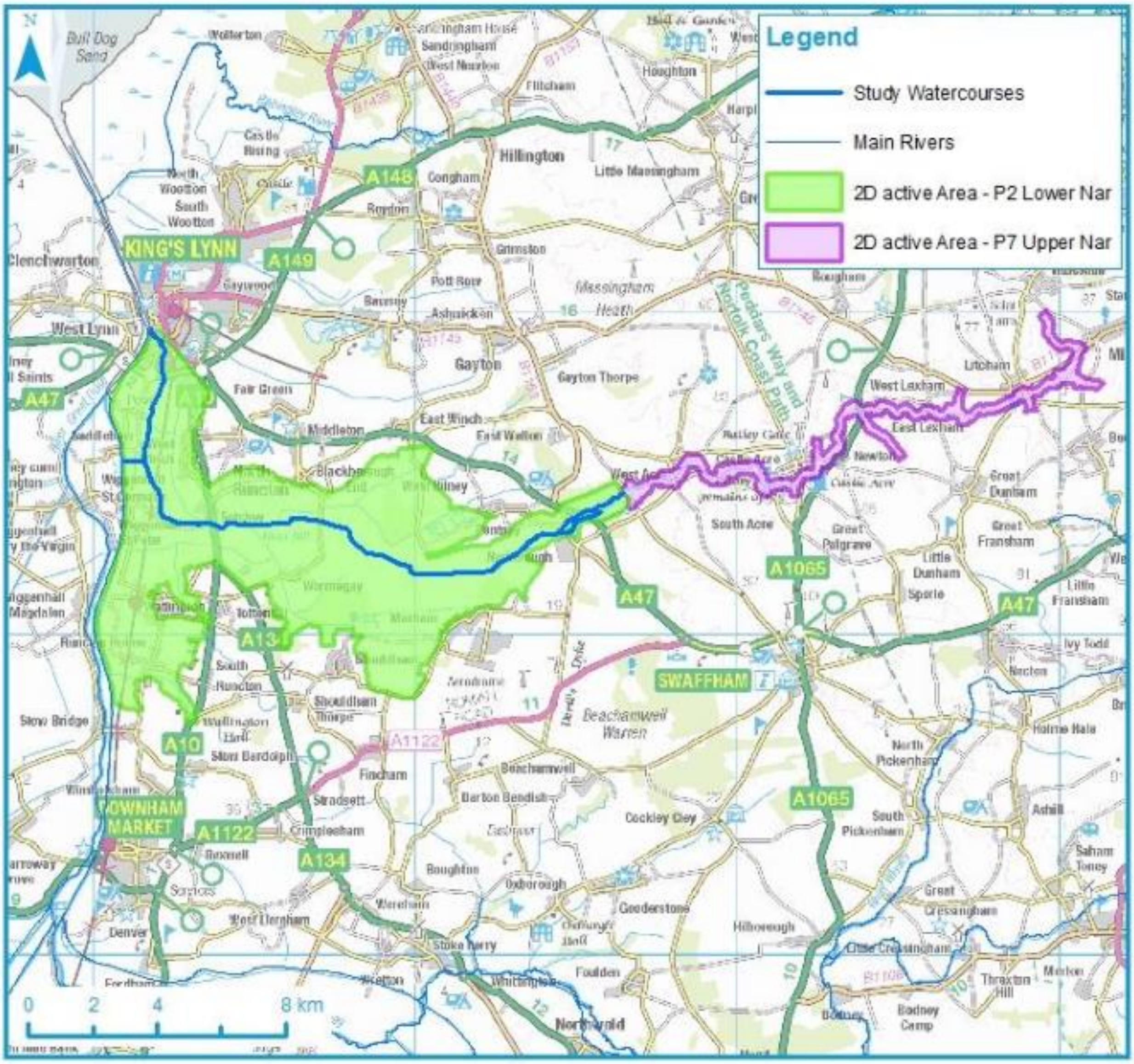

Figure 43: 2015 River Nar model extent © Environment Agency

The present-day flood scenarios in the model include 50, 20, 10, 5, 3.33, 2,1.33, 1, 0.5 & 0.1% AEP events. Climate change flood risk was modelled for the 1 and 0.1% AEP events, using a 20% uplift on inflows. Defended and undefended scenarios as well as blockage scenarios were also modelled.

3.3.2 2015 River Snail model

The River Snail model was initially developed for the EA in in 2011 by Hyder Consulting. In 2013 Capita updated the hydrological estimates, then finally in 2015 JBA carried out a further review and updates as part of the Environment Agency commissioned Eastern Rivers Modelling Study.

The River Snail model is a 1D-2D ISIS-ESTRY-TUFLOW fluvial-only model. The model extent is shown in Figure 44.

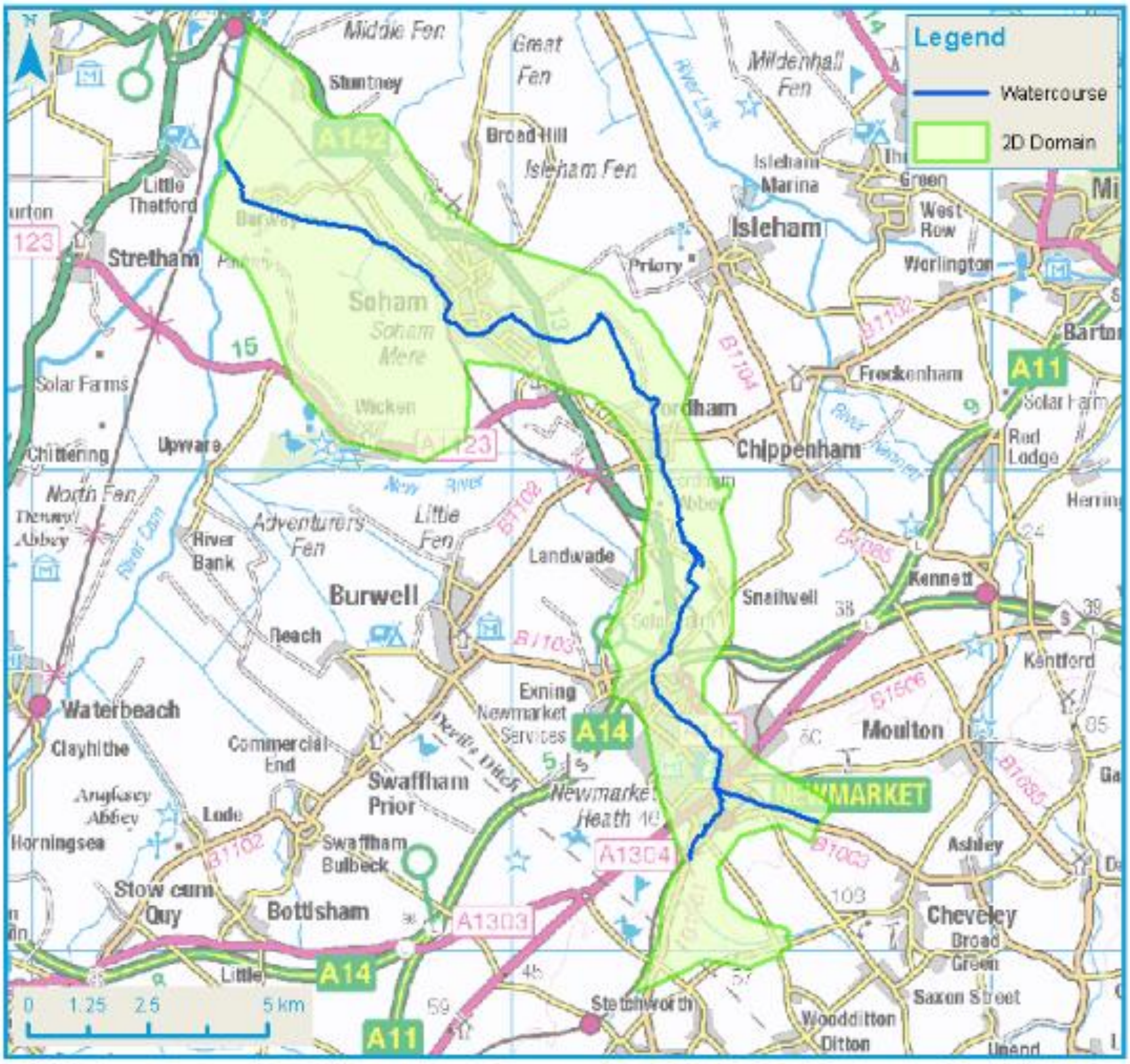

Figure 44: 2015 River Snail model extent © Environment Agency

The present-day flood scenarios in the model include 50, 20, 10, 5, 3.33, 2,1.33, 1, 0.5 & 0.1% AEP events. Climate change flood risk was modelled for the 1 and 0.1% AEP events, using a 20% uplift on inflows. Defended and undefended scenarios as well as blockage scenarios were also modelled.

3.3.3 2016 Fenland Flood Risk model

In 2011, the Environment Agency commissioned Mott MacDonald to carry out a flood mapping study of the Fenland catchment, delays meant the final report was issued in 2016. The study undertook hydraulic modelling of the following:

- Ely Ouse;
- Beford Ouse;
- Tidal Great Ouse;
- Relief Channel; and
- The Bury Brook.

The model extent is shown in Figure 45.

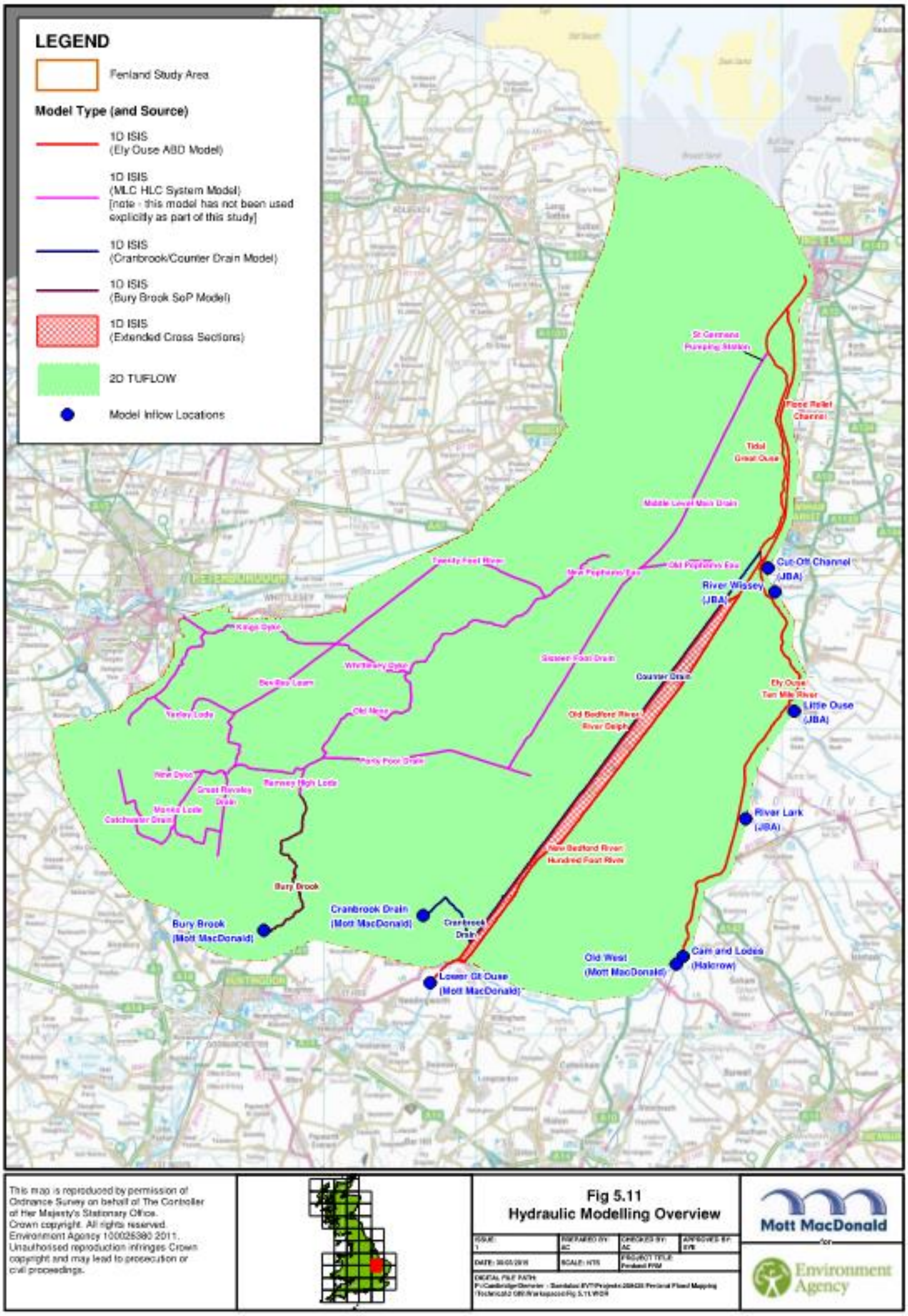

Figure 45: Fenland Flood Risk model extent © Environment Agency

Due to the size of the study area a two-tiered approach to modelling was used;

- An ISIS (now Flood Modeller) 1D model with coarser resolution 2D modelling (with a 50m grid) for the Ely Ouse and Bedford Ouse systems, the Tidal great Ouse and the Relief Channel to achieve reasonable run times;
- An ISIS 1D model with refined 2D modelling to provide more detailed flood mapping for the Bury Brook.

The model captures fluvial flooding only, using estimated flood tidal water levels at King's Lynn for a 1 in 1 year return period[64]. The present-day flood scenarios in the model include 20, 10, 5, 4, 2,1.33, 1, 0.5 & 0.1% AEP events. Climate change flood risk was modelled for the 5, 0.5 and 0.1% AEP events, using a 20% uplift on inflows. The model includes only defended scenarios as it was agreed with the Environment Agency that a scenario with removal or complete deterioration of defences would not be considered.

3.3.4 2018 Wash model

In 2018 JBA Consulting were commissioned by the Environment Agency to assess coastal flood risk along the East Anglian coastline. 18 hydrodynamic models were developed, including The Wash model which extends from Hunstanton to the River Nene (see Figure 46). The study was focussed on tidal flood risk and doesn't include fluvial, surface water or groundwater flooding.

[64] This equates to a 100% AEP - it is the flood event that can be expected to occur, on average, every year.

Figure 46: 2018 Wash model extent © Environment Agency

The present-day flood scenarios in the model include 10, 5, 3.33, 1.33, 1, 0.5, 0.2 and 0.1% AEP events. Climate change flood risk was modelled for the 5, 0.5 and 0.1% AEP events, using sea-level rises projected to the year 2115 by the National Planning Policy Framework (NPPF). Defended and undefended scenarios have been undertaken.

3.3.5 Limitations

All the models are Environment Agency – therefore are primarily interested in flooding from tidal and Main Rivers, as such the representation of flooding from drainage ditches is likely to be simplistic of not represented at all.

3.3.5.1 2015 River Snail and River Nar models

- Hydrology derived as part of these studies are now over 10 years old and will not reflect changes in methods and data.
- The River Nar model channel surveys is now over 30 years old and unknown in origin.
- The River Snail model channel surveys are now at least over 10 years old.
- The LIDAR data in the models will have since been superseded by finer resolution data.

3.3.5.2 2016 Fenland Flood Risk model

- Hydrology derived as part of this studies is now over 10 years old and will not reflect changes in methods and data.
- The LIDAR data in the model will have since been superseded by finer resolution data.
- The 2016 Fenland fluvial model only considers an sea level of a 1 in 1 year return period. Neither this model, nor the 2018 Wash model include an assessment of Joint Probability for fluvial and tidal variables;
- Channel survey used to define the 1D model will now be over 10 years old, and will no reflect recent changes in the channel (i.e. sedimentation).

3.3.5.3 2018 Wash model

- The 2018 Wash model did not include an assessment of Joint Probability for fluvial and tidal variables;
- The LIDAR data in the model will have since been superseded by finer resolution data.
- The 2018 model uses tidal boundary data that is now 7 years old – these levels will certainly have changed, although the level of change is not known.

3.4 Other data Sources

3.4.1 National Flood Risk Assessment

The National Flood Risk Assessment (NaFRA) consists of a number of different products, including:

Risk of Flooding from Rivers and Sea (RoFRS) - A geospatial dataset the floodplain split into 50m x 50m cells and each allocated one of four flood risk likelihood categories.

Reduction in Risk of Flooding from Rivers and Sea Due to Defences (RRFRSDD)– Produced using the defended scenario of flood risk in the Risk of Flooding from Rivers and Sea dataset and an undefended scenario of flood risk from rivers and sea.

Risk of Flooding from Surface Water (RoFSW) - A geospatial dataset the floodplain split into 2m x 2m cells and each allocated one of four flood risk likelihood categories.

Risk of Flooding from Multiple Sources (RoFMS) - A geospatial dataset combining data from RoFRS & RoFSW. The RoFMS inherits the appearance of the input datasets. When both RoFRS and RoFSW indicate a risk in the same area, the RoFSW (surface water flood risk) will be the more prominent feature, indicating the potential for flooding from surface water in that specific location (see Figure 47).

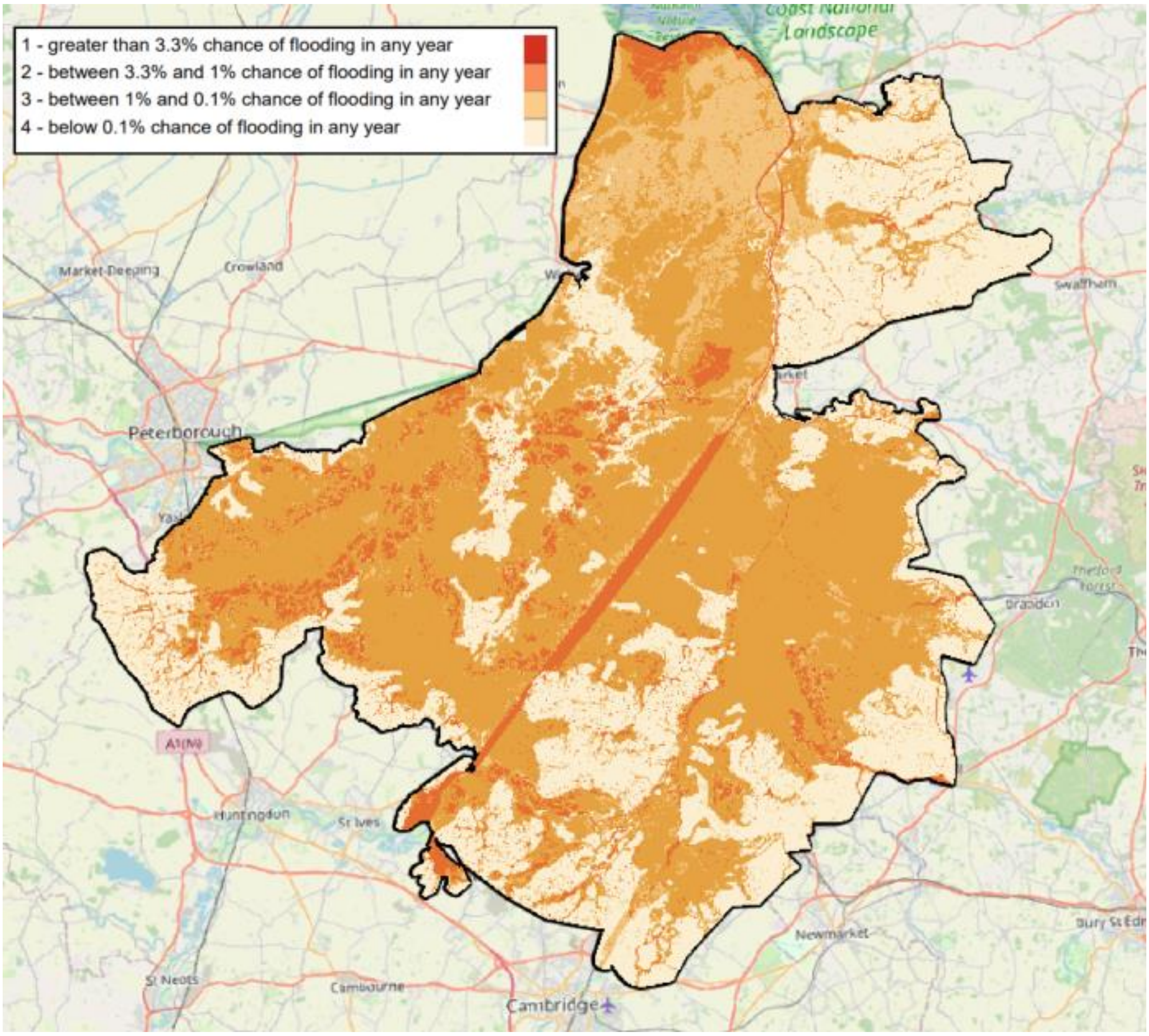

Figure 47: Risk of flooding from multiple sources © Environment Agency

Reduction in Risk of Flooding from Rivers and Sea Due to Defences - Produced using the defended scenario of flood risk in the Risk of Flooding from Rivers and Sea dataset and an undefended scenario of flood risk from rivers and sea.

Flood Zone 2 - It is the best estimate of the areas of land at risk of flooding, when the presence of flood defences is ignored and covers land between Flood Zone 3 and the extent of the flooding from rivers or the sea with a 0.1% AEP of flooding each year.

Flood Zone 3 - It is the best estimate of the areas of land at risk of flooding, when the presence of flood defences is ignored and covers land with a 1% AEP or greater chance of flooding each year from Rivers; or with a 0.5% AEP or greater chance of flooding each year from the Sea.

The datasets listed above, have been developed using an ‘undefended’ approach – i.e. the tidal and fluvial flood defences have been removed. Given the low-lying nature of the majority of the catchment, this will inevitably result in an over-prediction of current flood risk. The dataset does not include any allowance for climate change. It would also not represent flood risk accurately in a heavily pumped catchment such as the Great Ouse catchment.

As this catchment has detailed models for both fluvial and tidal flood risk, NaFRA has not been used in this assessment.

3.4.2 National Flood Risk Assessment 2

National Flood Risk Assessment 2 (NaFRA2) includes:

- NaFRA2 software system: a web-based IT solution for Environment Agency staff; and
- New National Modelling (NNM): provides hazard outputs for rivers, sea, and surface water for various scenarios.
- For NaFRA2, the focus is on using local modelling, though limited detailed local models are available within the catchment. The NNM will be used throughout most of the catchment and features:
- Models using JFlow GPU software;
- A 2m model grid based on the Environment Agency’s Integrated Height Model 2019 and Defra Marine DEM;
- Outputs including maximum depth, level, etc.; and
- Present day and climate change scenarios.

However, the specific Fens model developed for NaFRA2 is not available for this project, as it is not currently approved for use locally.

3.4.3 Internal drainage board models

We have not been made aware of any models produced by the Internal Drainage Boards for this catchment. Although there are Environment Agency models for both fluvial and tidal flood risk, as detailed in Section 3.2, these models would be of limited use when trying to understand the wider drainage network.

3.5 Other sources of information

3.5.1 Anglian River Basin District Flood Risk Management Plan (2021-2027)

This plan encourages a partnership to explore the resilience measures that will help the basin district be more resilient and informs the delivery of existing flood programmes.

3.5.2 Cambridgeshire Flood Risk Management Strategy (2021-2027)

This management strategy (approved in 2022) is a revision of the existing Local Flood Risk Management Strategy created in 2015.

3.5.3 Anglican Water: draft Water Resources Management Plan 2024

This plan sets out how water resources will be managed to ensure a sustainable and secure supply of clean drinking water for Anglican Water customers from 2025 to 2050.

3.5.4 Regional Water Resources Plan for Eastern England (December 2023)

This plan sets out details for the proposed management of water supplies while outlining the needs of different sectors for water in the region, now and in the future.

3.5.5 Borough Council of King's Lynn & West Norfolk Level 2 Strategic Flood Risk Assessment (2019)

This SFRA provides a community-based assessment of flood risk across identified communities in the borough, considering the detailed nature of the flood risk within a flood zone, and assessing other sources of flooding.

3.6 Key receptors

3.6.1 Settlements

March, Chatteris, Soham, Downham Market, Ely and King’s Lynn are the main centers of population in the catchment. Wisbech lies just outside the catchment boundary to the west, and Cambridge and Huntingdon are large settlements located close to the catchment to the south. Due to the low-lying wetlands which dominated much of the catchment in the past, these urban areas and villages generally developed on isolated ‘islands’ which are higher than the surrounding floodplain. Connectivity within the catchment is supported by key transport routes, such as the A17, A47, A10, A141 and A142, and the railway station at King’s Lynn which links to Ely and on to Cambridge.

3.6.2 Agriculture

The Fens is an area of national agricultural importance due to its rich peaty soils. Farms across the catchment are mainly focused on the production of arable and grassland crops.

Across the catchment, around 1580km2 (72%) of land is classified as ALC Grade 1 and 2 land, with the largest majority being classified as Grade 1 land. Table 1 and Figure 48 present an overview of ALC classification in the catchment.

Table 1: Land classification within the catchment

	Grade 1	Grade 2	Grade 3	Grade 4	Non-agricultural
Area (km^2)	919.1 (91,910ha)	660.7 (66,070ha)	403.2 (40,320ha)	110.8 (11,080ha)	62.3 (6,230ha)
Percentage of catchment (%)	41.8%	30.1%	18.4%	5%	2.8%

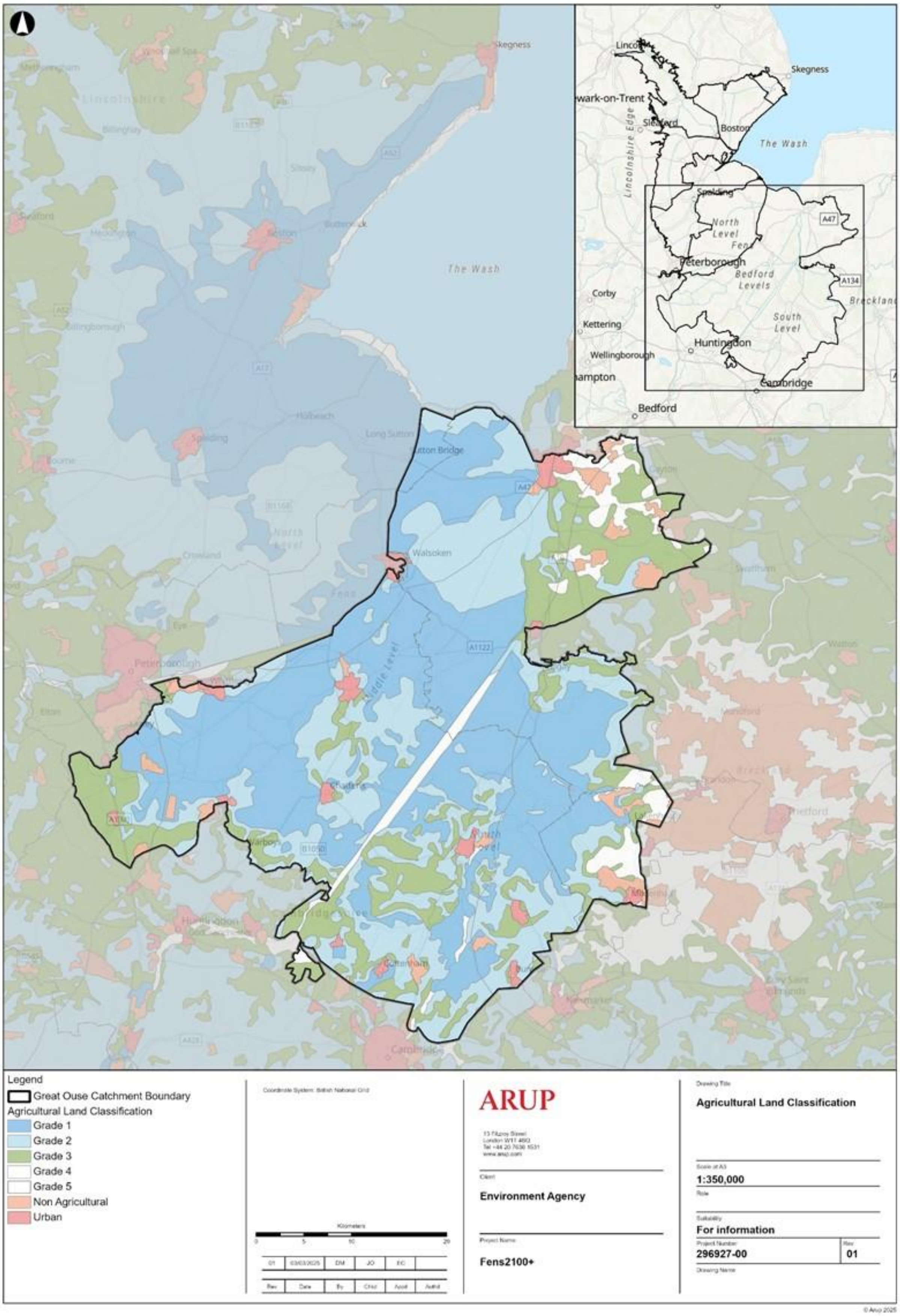

Figure 48: Land classification across the catchment

Approximately 1717km^2 (78%) of land across the catchment is currently farmed.

It is estimated that the agricultural value of the crops grown on this land (based on 2023 data) is as follows:

- Cereal production – c.£120.8 million;
- Other arable – c. £97.3 million; and
- Fruit and vegetables – c.£124.8 million.

Grassland does not directly create economic value but instead supports the grazing of sheep and cattle, or the production of livestock feed. The estimated overall economic output of crops and livestock is in the region of £520.8 million, highlighting the importance of the agricultural sector.

4. Climate change

The impact of climate change has been represented in all of the models used in this assessment to understand future tidal and fluvial impacts. The approach to climate change in each of the models is described in the proceeding sections.

4.1 Tidal climate change

Climate change (CC) has been assessed as part of the Wash Model up to 2115, calculated rates of sea level rise used in this study are shown in Table 2.

Table 2: NPPF sea-level rise calculations

Region	Net sea-level rise (mm/yr) NPPF			
	2015-2025	**2025-2055**	**2055-2085**	**2085-2115**
East and south-east	4	8.5	12	15
Number of years	10	30	30	30
Total (m)	0.04	0.26	0.36	0.45
Overall sea-level rise (m)	1.11			

The sea level rise applied to the design peak water levels generates a level of **6.08mAOD** at King's Lynn for the 0.5% AEP event.

Since the study was completed in 2018, sea level rise estimates have been revised. Current Environment Agency recommends assessing against two scenarios; Higher Central and Upper End. The allowances for sea level rise are shown in Table 3.

Table 3: Sea level allowances for each epoch

Area of England	Allowance	2000 to 2035 (mm)	2036 to 2065 (mm)	2066 to 2095 (mm)	2096 to 2125 (mm)	Cumulative rise 2000 to 2125 (metres)
2025 Anglian	Higher central	5.8	8.7	11.6	13	1.20
	Upper end	7	11.3	15.8	18.1	1.60

For flood risk assessments and strategic flood risk assessments both the higher central and upper end allowances will need to be assessed.

Flood and Coastal Erosion Risk Management (FCERM) schemes are typically assessed against the higher central. Given the long-term nature of the Fens 2100+ project, the 2080s epoch with the higher central allowance is most applicable to this study.

These estimates have been compared to those applied in the 2018 modelling, shown in Table 2 and Figure 49. This shows that the estimates used in the 2018 study are higher than the Higher Central and Upper End.

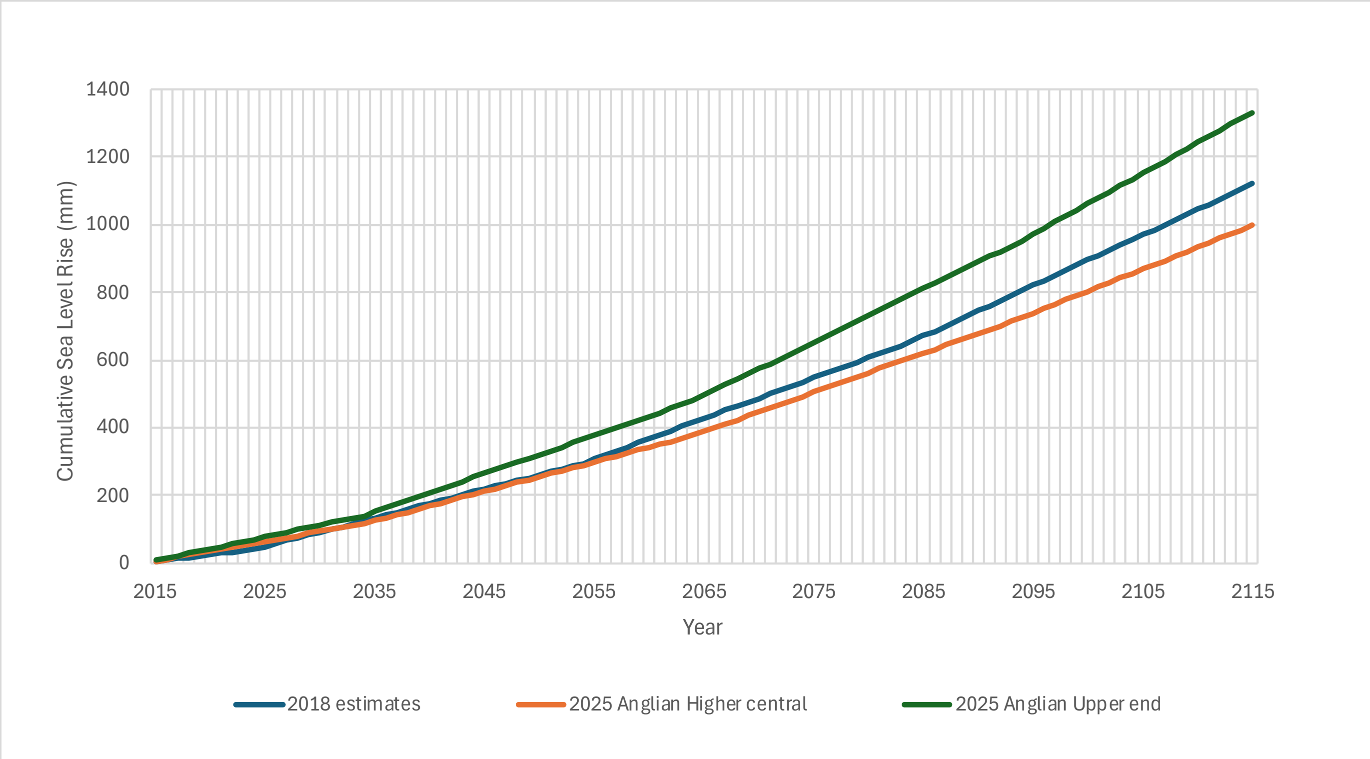

Figure 49: Comparison of sea level rise estimates

4.2 H++ scenario

The Fens 2100+ project is a long-term adaptive plan for the landscape as such the H++ is a useful sensitivity test. Current Environment Agency guidance states that a value of 1.9m up to 2100 should be used (There is no H++ value for sea level rise beyond 2100).

None of the available modelling for the Great Ouse catchment includes an assessment of the H++ scenario. The most extreme value for climate change used within the 2018 modelling (as detailed in Table 2) is 1.11m – this is considerably smaller than the value of 1.9m. We can therefore infer that the H++ scenario would show significantly more flooding (depth and extent) than the results presented in the proceeding sections.

It is recommended that in future phases of Fens 2100+, when assets and systems are being assessed that a stress test using the upper end or H++ is used to inform long term decision making.

4.3 Fluvial climate change

4.3.1 2015 River Nar Model

The 2015 River Nar model has applied climate change uplifts to the 1% and 0.1% AEP events. The model uses climate change allowances in accordance with NPPF guidance which was current at the time of the model build which was plus 20% to model inflows.

4.3.2 2015 River Snail Model

The 2015 River Snail model also has applied climate change uplifts to the 1% and 0.1% AEP events. The model similarly uses climate change allowances in accordance with NPPF guidance which was current at the time of the model build which was plus 20% to model inflows.

4.3.3 2016 Fenland Flood Risk Model

The 2016 Fenland Flood Risk model has applied a climate change uplift to the 1% AEP event only. The model uses climate change allowances in accordance with NPPF guidance which was current at the time of the model build which was plus 20% to model inflows.

4.3.4 Current Guidance

The latest climate change guidance for peak river flows is provided for Management Catchments. The Great Ouse catchment sits across three of these Management Catchments; The North West Norfolk Management Catchment (Table 4), the Old Bedford and Middle Level Management Catchment (Table 5) and the Cam and Ely Ouse Management Catchment (Table 6). These tables have a range of uplifts for the Central estimate for the 2080's epoch. The worst case is the North West Norfolk Management Catchment with an increase of fluvial flows by 23% which is similar to the 20% uplift applied to all the fluvial models.

Table 4: North West Norfolk Management Catchment peak river flow allowances

	Central	Higher	Upper
2020s	13%	18%	30%
2050s	11%	18%	34%
2080s	23%	33%	57%

Table 5: Old Bedford and Middle Level Management Catchment peak river flow allowances

	Central	Higher	Upper
2020s	3%	9%	23%
2050s	-3%	4%	22%
2080s	6%	15%	39%

Table 6: Cam and Ely Ouse Management Catchment peak river flow allowances

	Central	Higher	Upper
2020s	2%	7%	21%
2050s	-2%	5%	22%
2080s	9%	19%	45%

For Flood Risk Assessments and Strategic Flood Risk Assessments the following are used:

- Flood zones 2 or 3a:

  essential infrastructure – higher central allowance;

  highly vulnerable – central allowance (development should not be permitted in flood zone 3a);

more vulnerable – the central allowance;

less vulnerable – the central allowance;

water compatible – the central allowance;

- Flood zone 3b:

  essential infrastructure – use the higher central allowance;

  highly vulnerable – development should not be permitted;

  more vulnerable – development should not be permitted;

  less vulnerable – development should not be permitted;

  water compatible – use the central allowance.

- For FCERM schemes, the following are used:

  Central allowance as the design allowance;

  Higher central allowance to test the impacts of higher scenarios of climate change and any extra mitigation;

  Extreme allowance to test the option under more extreme climate change and exceedance events; and

  2080s epoch allowances for changes beyond the 2080s epoch and up to 2115.

This guidance suggests that the climate change uplift applied to the three fluvial models is similar to that required for FCERM schemes, and for more vulnerable, less vulnerable and water compatible development (central allowance) in Flood Zone 3a.

However, in future phases of Fens 2100+, it is recommended that stress testing is carried out at more extreme climate change scenarios to ensure that the future climate is considered within the long term decision making.

5. Tidal flood risk

5.1 Current tidal flood risk

The Great Ouse catchment is protected by significant tidal defences along the coast (as shown in Figure 22), these provide a high level of protection and are only overtopped during an extreme flood event.

The 2018 Tidal Wash model shows that the tidal flood risk in the catchment is located along the Ouse River. It suggests that there are no properties at risk from tidal flooding from the 0.5% and the 0.1% tidal event.

The majority of flooding is to Grade 4 Agricultural land in the Ouse Washes as shown in Figure 50.

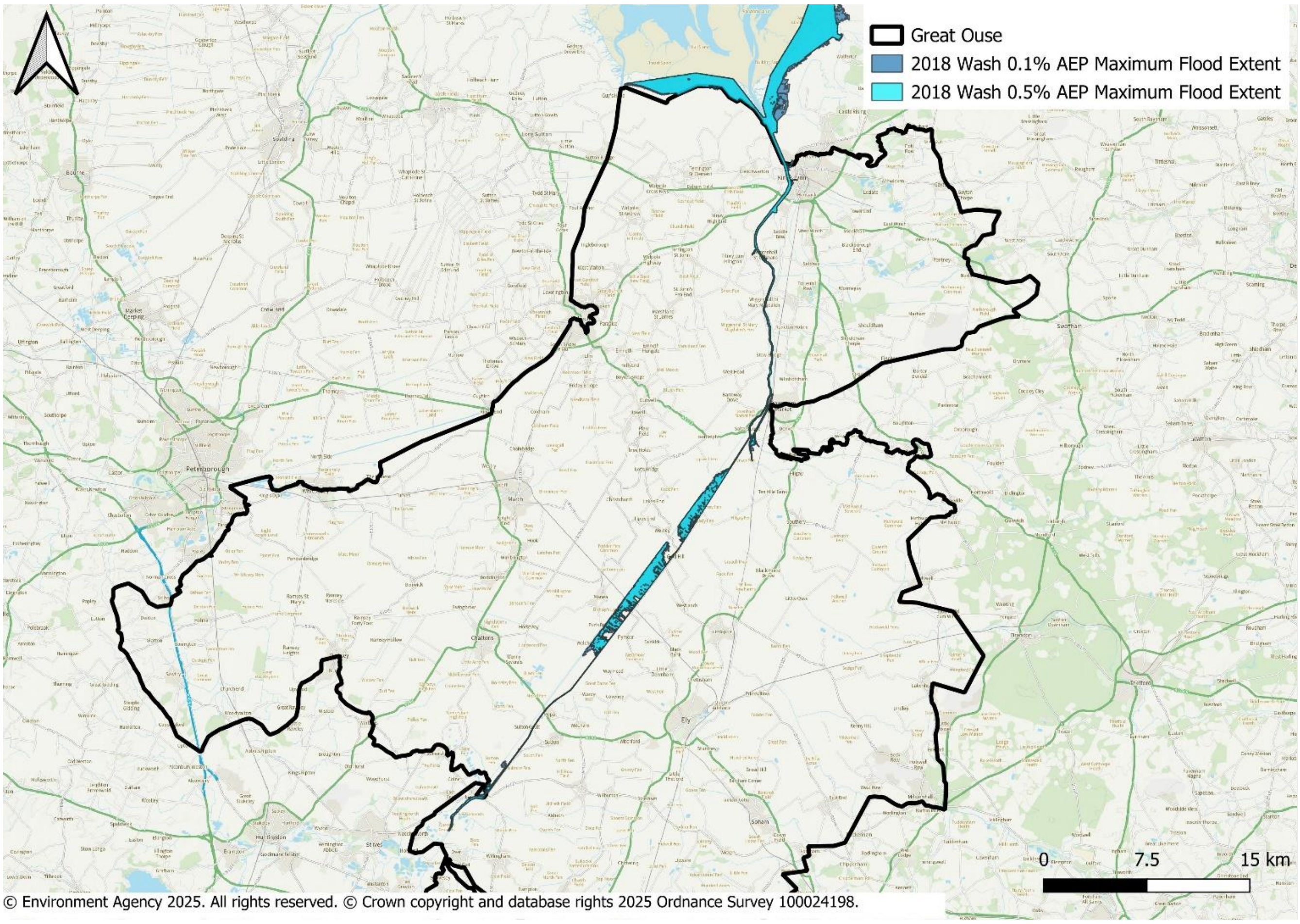

Figure 50: 0.5% AEP event and 0.1% AEP event current tidal flood risk in the catchment

5.2 Future tidal flood risk

Tidal climate change has been assessed using the 2018 Tidal Wash Model modelling for the 0.5% AEP event up to 2115.

Results from the modelling show a significant increase in flood risk in comparison to the present day with large areas of King's Lynn predicted to inundate, as shown in Figure 51. The flooding comes from overtopping of flood defences in King's Lynn.

The majority of flooding to agricultural land is still predominantly to Grade 4 land within the Ouse Washes.

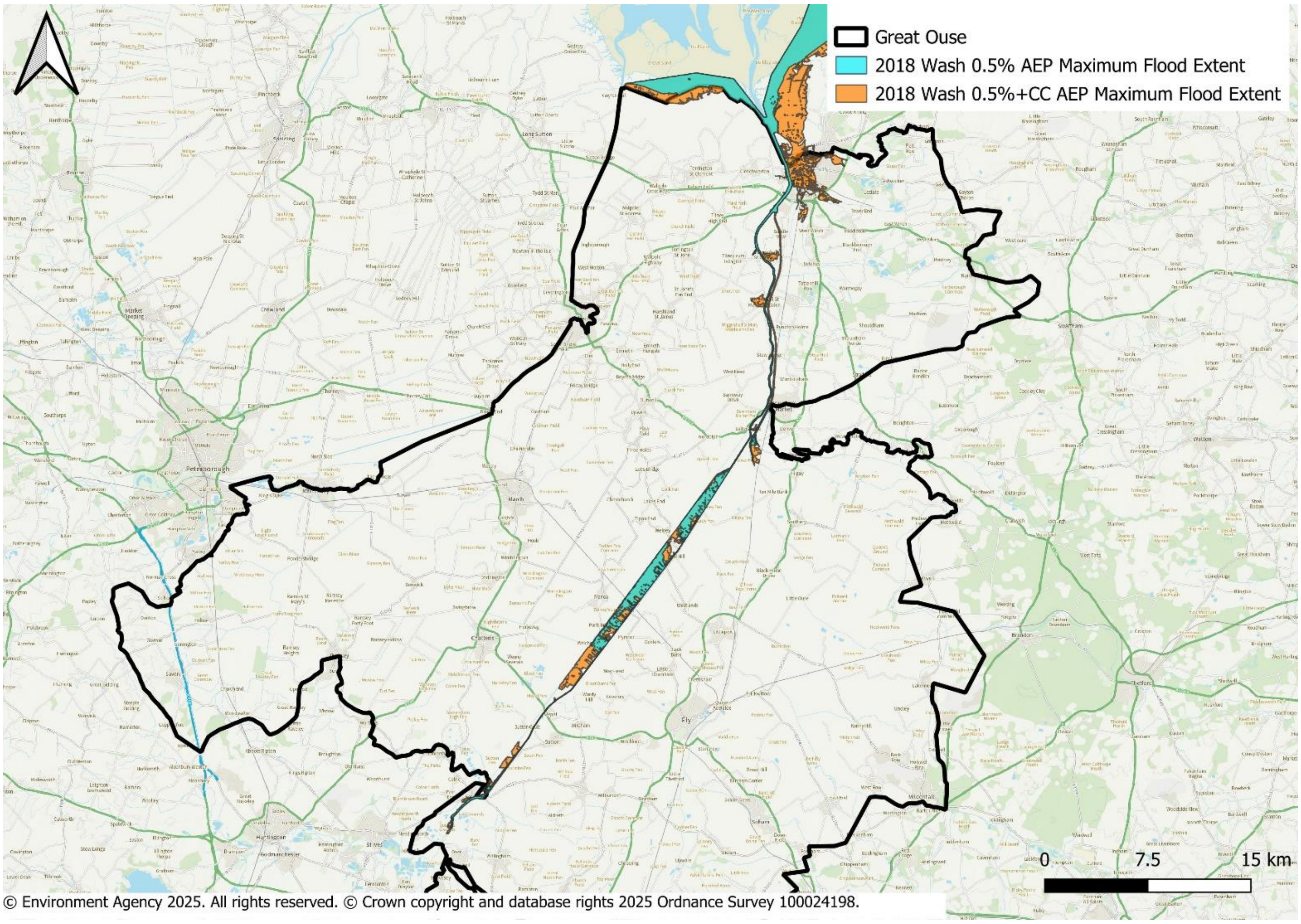

Figure 51: Comparison between 0.5% present day and 0.5% with climate change applied up to 2115

5.3 Key metrics

5.3.1 Total area

The total area modelled to be at risk of tidal flood risk in the 2018 Tidal Wash model within the Great Ouse catchment was:

- Current 0.5% AEP (1 in 200-year) event – 14.56km^2 (1,456ha) – 0.66% of total catchment area;
- Future 0.5% AEP (1 in 200-year) event with allowance for climate change – 31.27km^2 (3,127ha) – 1.42% of total catchment area;
- Current 0.1% AEP (1 in 1000-year) event – 16.39km^2 (1,639ha) – 0.75% of total catchment area.

5.3.2 Grades of agricultural land

The agricultural land within the Great Ouse catchment area is assessed for tidal flood risk based on different grades, this has been summarised in Table 7.

Table 7: Agricultural land grading at risk of tidal flooding

Agricultural Grade	0.5% AEP (km^2)	0.5% with an allowance for climate change AEP (km^2)	0.1% AEP (km^2)
Grade 1	0.59km^2 (59ha)	1.24km^2 (124ha)	0.67km^2 (67ha)
Grade 2	1.50km^2 (150ha)	5.59km^2 (559ha)	1.66km^2 (166ha)
Grade 3	0	0	0
Grade 4	11.16km^2 (1,116ha)	18.40km^2 (1,840ha)	12.65km^2 (1,265ha)
Grade 5	0	0	0
Total	**13.78km^2 (1,378ha)**	**25.23km^2 (2,523ha)**	**15.59km^2 (1,559ha)**

5.3.3 Percentage area over 30cm flood depth

The area that floods over 30cm for each event is as follows:

- Current 0.5% AEP event – 8.6km^2 (860 ha) – 0.39% of total catchment area.
- Future 0.5% AEP event with allowance for climate change – 18.8km^2 (1,880ha) – 0.86**%** of total catchment area.
- Current 0.1% AEP event – 10.25km^2 (1,025ha) – 0.47% of total catchment area.

5.3.4 Discussion

Current flood risk from tidal sources is generally low, with the majority of flooding to Grade 4 agricultural land situated within the Ouse Washes. Even the 0.1% event only results in 0.75% of the catchment flooding.

When climate change up to 2115 is applied to the 0.5% AEP event, there is still very limited flooding to agricultural land, however, a large part of King’s Lynn is predicted to inundate, highlighting the vulnerability of the Great Ouse catchment to climate change.

6. Fluvial flood risk

6.1 Current fluvial flood risk

6.1.1 Defended

The flood history suggests fluvial flood risk in the Great Ouse catchment is relatively low. This is due to the large network of flood defences throughout the catchment including embankments, sluice gates and pumping stations. The majority of fluvial flooding is contained within the Ouse Washes flood storage reservoir, which affects low grade agricultural land and restricts use of the A1101. Fluvial flooding outside of the Ouse Washes tends to be localised and affect only small numbers of properties.

Results from the three fluvial models combined similarly show that in the 1% AEP event, it is primarily the Ouse Washes that are flooded, as intended, as well as a number of relatively small areas of agricultural land. However, in the 0.1% AEP event, there is more extensive fluvial flooding of higher grade agricultural land as flood water breach the embankments that form the Ouse Washes basin (Figure 52), though there is still minimal impact on properties.

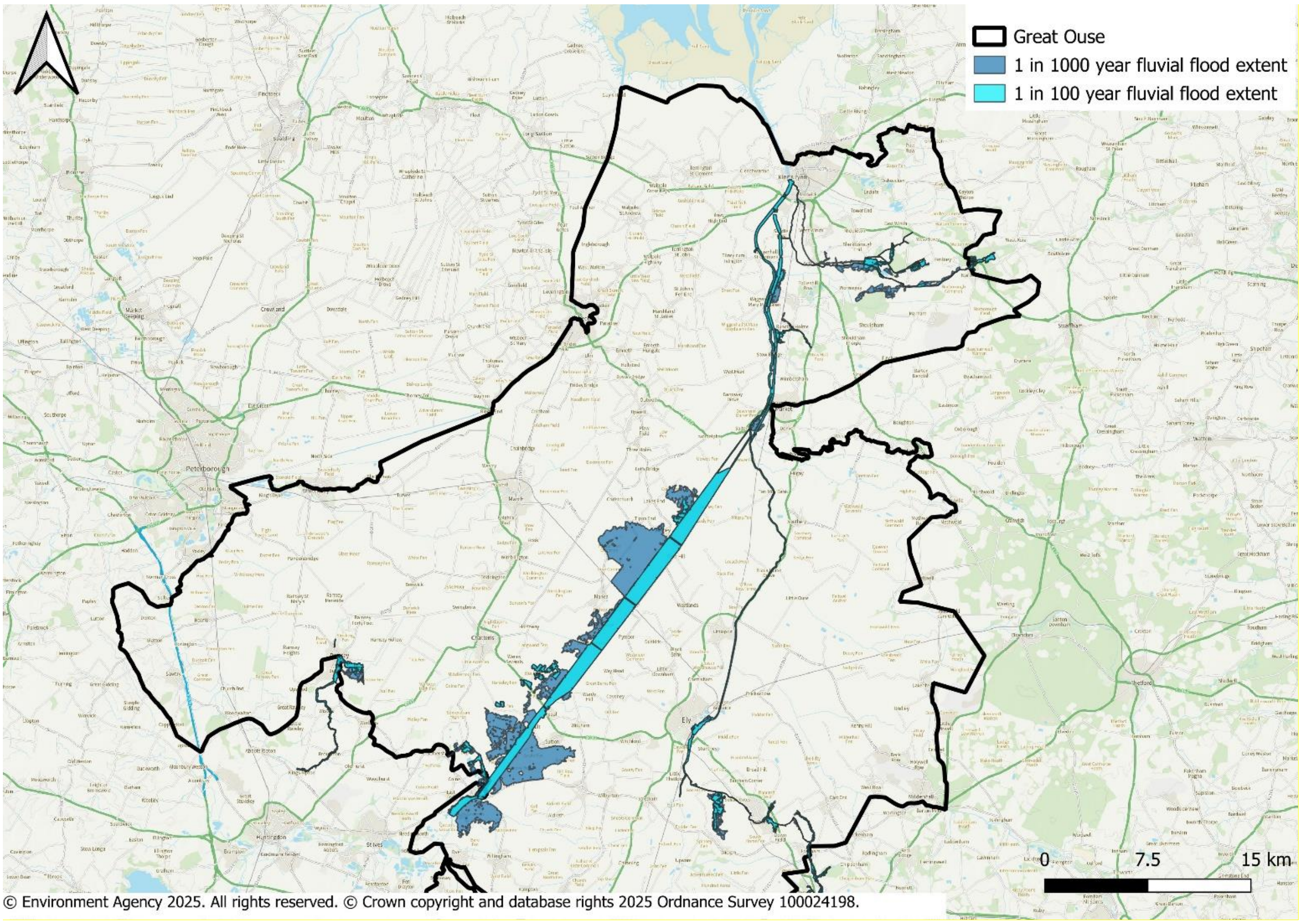

Figure 52: The 1% AEP event and the 0.1% AEP event current fluvial flood risk in the catchment[65]

6.1.2 Undefended

To understand the importance of the network of flood defences in the Great Ouse catchment, ideally the "defended" scenario would be compared to an equivalent "undefended" scenario, in which the flood defences are removed. However, the Fenland fluvial model which covers the majority of the catchment, does not consider an undefended scenario.

Instead, it is possible to get an indication of the scale of flooding that would occur if the defences were removed, by looking at the Environment Agency river and sea flood maps. They are based on an undefended scenario; however, it should be noted that these maps are based on relatively high level, broadscale modelling and will not be as accurate at the fluvial model results for the defended scenario.

As can be seen from Figure 53, without defences, the vast majority of the catchment is at either low or medium risk of fluvial and tidal flooding every year.

[65] Combined results of three fluvial models: 2015 River Nar model, 2015 River Snail model & 2016 Fenland Flood Risk model

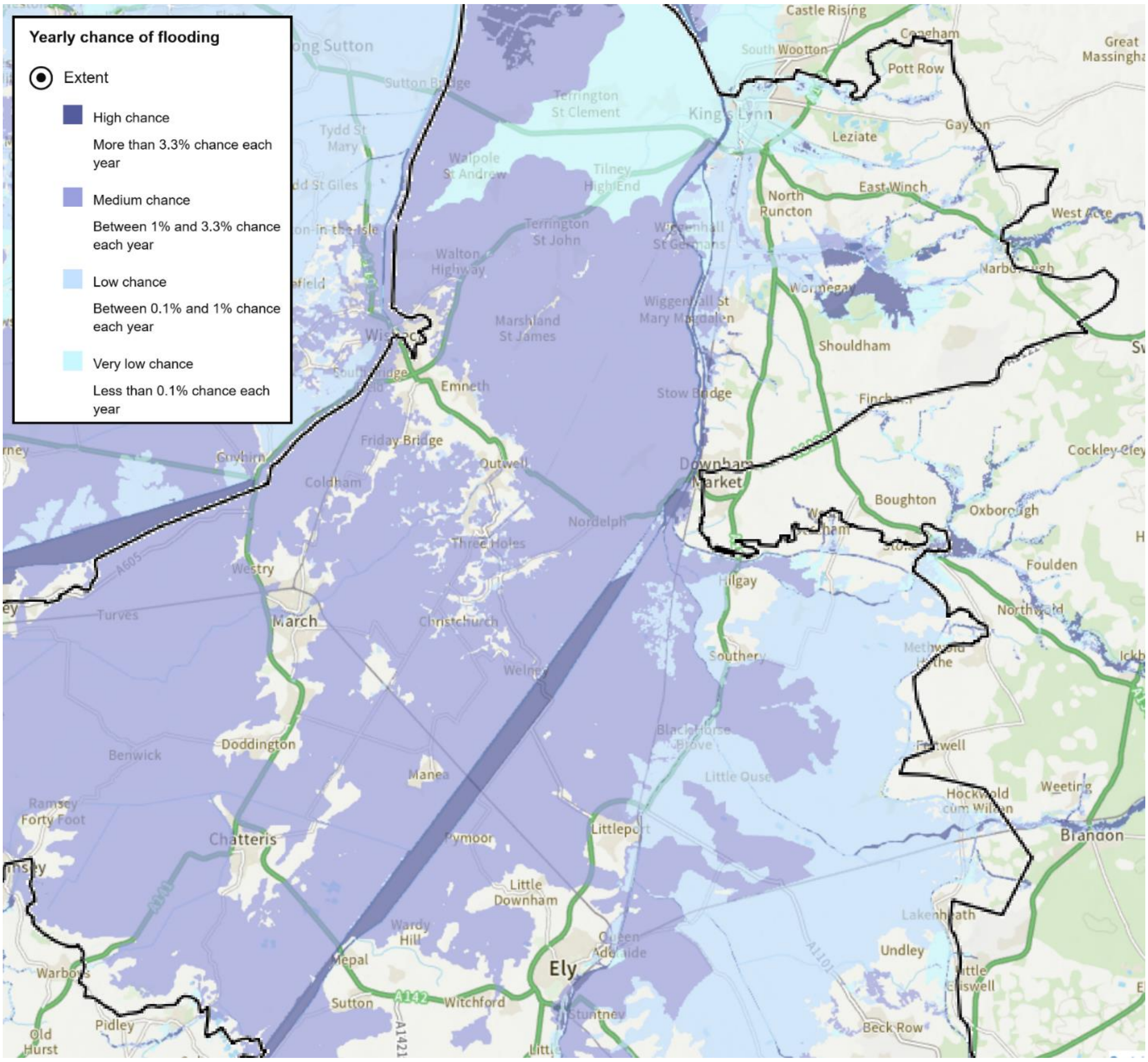

Figure 53: Yearly chance of flooding from rivers and sea[66] © Environment Agency

6.2 Future fluvial flood risk

The three models apply a climate change scenario using a flow uplift of +20%, this is close to the Central allowance in the 2080s epoch.

Despite fluvial flows being increased by 20% and existing defences in place, there is only a small increase in fluvial flood risk predicted by the three fluvial models, as shown in Figure 54.

66 EA, Yearly chance of flooding, Rivers and sea map. Available at: ttps://check-long-term-flood-risk.service.gov.uk/map, Accessed: May 2025

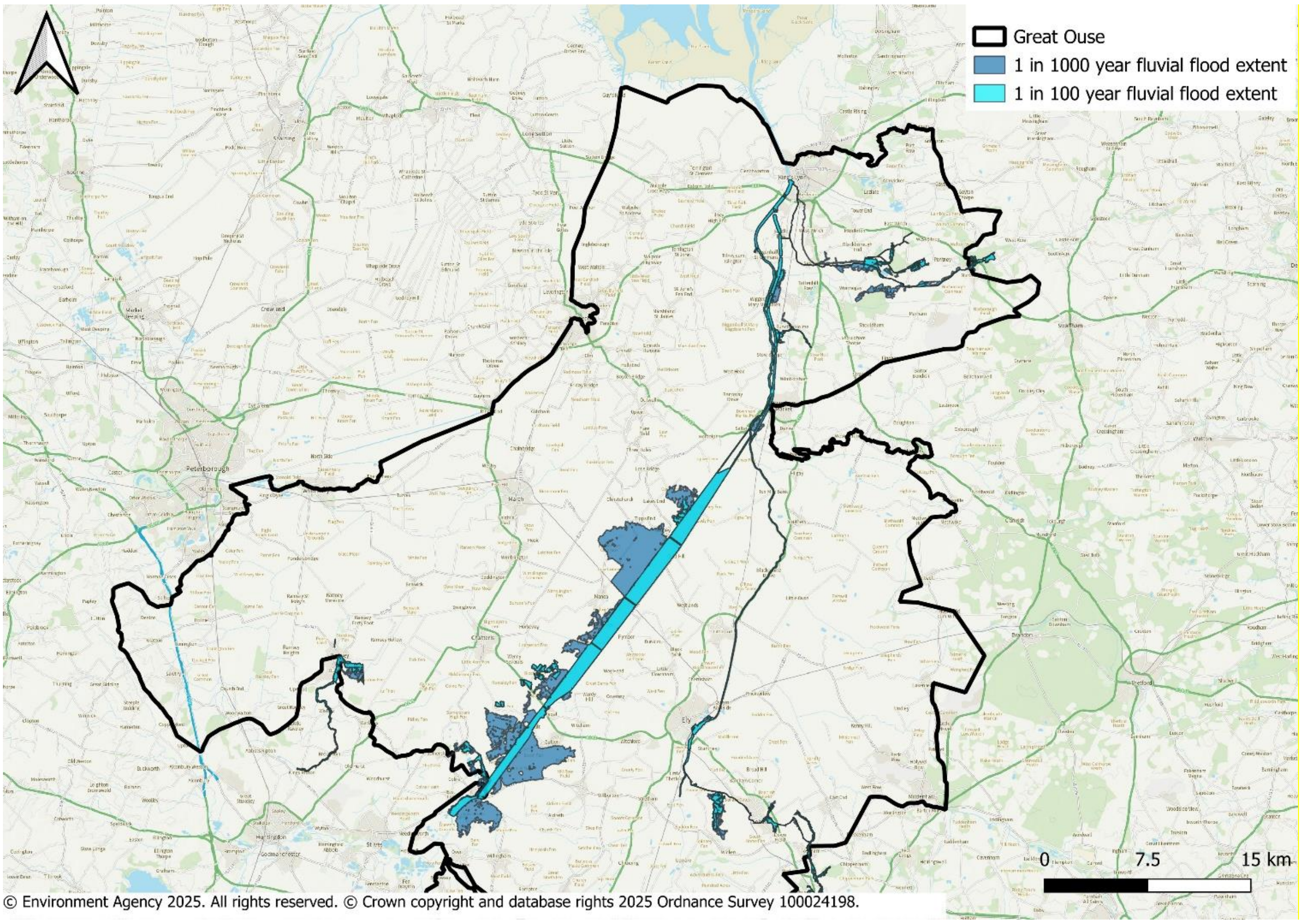

Figure 54: Great Ouse catchment 1% AEP event with and without climate change[67]

6.3 Key metrics

6.3.1 Total area

The total area at risk of fluvial flood risk within the Great Ouse catchment is as follows:

- Current 1% AEP (1 in 100-year) event – 41.06km^2 (4,106ha) – 1.87% of total catchment area.
- Future 1% AEP (1 in 100-year) event with allowance for climate change – 45.29km^2 (4,529ha) – 2.06% of total catchment area.
- Current 0.1% AEP (1 in 1000-year) event – 90.35km^2 (9,035ha) – 4.11% of total catchment area.

6.3.2 Grades of agricultural land

The agricultural land within the Great Ouse catchment area is assessed for fluvial flood risk based on different grades, this has been summarised in Table 8. The greatest proportion of agricultural land at risk of fluvial flooding is Grade 1 agricultural land. It is worth noting that the Ouse Washes, which are intended to flood, constitute the majority of

[67] Combined results of three fluvial models: 2015 River Nar model, 2015 River Snail model & 2016 Fenland Flood Risk model

the Grade 4 land flooded. Hence there is only a minimal increase in the flooded area of Grade 4 land as the AEP increases in severity.

Table 8: Agricultural land grading at risk of fluvial flooding

Agricultural Grade	1% AEP (km^2)	1% AEP with an allowance for climate change (km^2)	0.1% AEP (km^2)
Grade 1	5.24km^2 (524ha)	7.82km^2 (782ha)	30.86km^2 (3,086ha)
Grade 2	5.78km^2 (578ha)	6.42km^2 (642ha)	18.50km^2 (1,850ha)
Grade 3	4.76km^2 (476ha)	5.53km^2 (553ha)	14.52km^2 (1,452ha)
Grade 4	23.73km^2 (2,373ha)	23.88km^2 (2,388ha)	24.51km^2 (2,451ha)
Grade 5	0	0	0
Total	**39.51km^2 (3,951ha)**	**43.66km^2 (4,366ha)**	**88.40km^2 (8,840ha)**

6.3.3 Percentage area over 30cm flood depth

The area that floods over 30cm for each event is as follows:

- Current 1% AEP event – 35.28km^2 (3,528ha) – 1.61% of total catchment area.
- Future 1% AEP event with allowance for climate change – 37.27km^2 (3,727ha) – 1.7% of total catchment area.
- Current 0.1% AEP event – 70.51km^2 (7,051ha) – 3.21% of total catchment area.

6.4 Discussion

The existing fluvial flood defences which consist of embankments, sluices, pumping stations and the Ouse Washes Reservoir, mean that current fluvial flooding in the 1% AEP event is very minor and is predominantly to low grade agricultural land situated in the Ouse Washes Reservoir. There is also limited flood risk to properties.

However, the 0.1% AEP event would lead to significant areas of Grades 1, 2 & 3 land being flooded, primarily due to flood water breaching the embankments that form the Ouse Washes basin and flooding surrounding agricultural land. In this scenario there is still limited flood risk to properties.

The increase in flood risk within the Great Ouse as a result of climate change, is limited, with only a small increase in flooding to agricultural land predicted, assuming that existing flood defences continue to be maintained.

7. Other sources of flooding

Aside from fluvial and tidal, other sources of flooding include surface water, groundwater, and reservoirs. These sources can be the sole cause of flood events or compound the effects of flooding from fluvial or tidal sources. This section sets out these other sources of flood risk, and potential impacts from these sources. It will also consider historical events in the catchment which highlight these issues. This information is intended to provide a high-level summary of the risk of flooding from these wider sources.

7.1 Surface water

Surface water flooding, also known as rainwater flooding, occurs when intense rainfall results in an excess of overland flow before it can reach a watercourse or drainage network. This type of flooding can also happen when rainwater is unable to drain away through the usual drainage systems or soak into the ground. Contributing factors may include insufficient system capacity, saturated ground, or failures in the drainage system due to blockages or culvert collapses. Presence of sandy or gravel soils can mean increased susceptibility to movement of groundwater and flooding from this source.

While surface water flooding is typically caused by high-intensity rainfall, it can also occur during lower-intensity rainfall if the land has low permeability. Permeability can be reduced by factors such as development, frozen ground, or already saturated soil. Additionally, flooding can occur if the drainage network is already at capacity, preventing efficient water drainage to the intended watercourse or sewer.

The Environment Agency's long term flood risk service[68] provides mapping of surface water flood risk. It shows that flood risk from surface water is generally highly localised, with dense but small and isolated patches where surface water flooding is likely. However, there are larger areas of surface water flood risk concentrated on the agricultural land around March and Ely. The towns themselves also have numerous small areas (usually one or two streets) with a high chance (more than 3.3%) of flooding each year.

As can be seen in the proceeding sections, surface water flooding or "flash flooding" is common in the Great Ouse catchment – particularly in March and Ely but also affecting Wisbech and King's Lynn.

7.1.1 July 2006

In July 2026 an inch and a half of rain fell in just 30 minutes, causing flash flooding in Ely entering a number of properties[69].

7.1.2 August 2006

Ely was again struck by two freak storms within 5 days causing flash flooding, affecting homes and businesses[70].

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[68] Environment Agency (2024) Check the long term flood risk for an area in England. Available at: Information for planning - Check your long term flood risk - GOV.UK. Accessed 04/04/2025.

[69] Ely Standard: Flash flood chaos (2006) Available at: https://www.elystandard.co.uk/news/22751263.flash-flood-chaos/ Accessed: April 2025

[70] Ely Standard: Floods Special: It's water torture (2006) Available at: https://www.elystandard.co.uk/news/22751327.floods-special-water-torture/ Accessed: April 2025

7.1.3 August 2014

In August 2014, heavy rainfall brought by the remnants of ex-hurricane Bertha led to flooding in Ely and March. Various roads were flooded, as well as properties on 30 streets and Ely station was closed[71]. Several homes were also flooded in the village of Upwell[72].

Figure 55: Flooding in March on 8th August 2014[73]

[71] EA: Future Fens Flood Risk Management – Baseline Report (2020) Available at: https://www.ada.org.uk/wp-content/uploads/2021/05/Future-Fens-Flood-Risk-Management-Baseline-Report-Final_web.pdf Accessed: April 2025

[72] Cambs Times: "You can't describe how distressing it is" - Sara Rodgers, Upwell flood victim (2014) Available at: https://www.cambstimes.co.uk/news/22869158.cant-describe-distressing---sara-rodgers-upwell-flood-victim/ Accessed: April 2025

[73] Cambs Times: Nine months on from March floods, Cambridgeshire County Council issues update on what has been done to tackle issue (2015) Available at: https://www.cambstimes.co.uk/news/22866268.nine-months-march-floods-cambridgeshire-county-council-issues-update-done-tackle-issue/ Accessed: April 2025

Figure 56: 2014 Flooding in March[74]

7.1.4 October 2019

Flash flooding was reported in Wisbech following a 20-minute downpour with residents blaming the drainage system[75].

Figure 57: 2019 Flooding in Wisbech[76]

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[74] BBC: Flash flooding in Cambridgeshire traps drivers, cuts off power (2014) Available at: https://www.bbc.co.uk/news/uk-england-beds-bucks-herts-28713677 Accessed: May 2025

[75] Wisbech Standard: Fen floods! Dramatic pictures and videos show flash floods in Wisbech after just 20 minutes of heavy rain (2019) Available at: https://www.wisbechstandard.co.uk/news/22651897.fen-floods-dramatic-pictures-videos-show-flash-floods-wisbech-just-20-minutes-heavy-rain/ Accessed: May 2025

[76] Wisbech Standard: Fen floods! Dramatic pictures and videos show flash floods in Wisbech after just 20 minutes of heavy rain (2019) Available at: https://www.wisbechstandard.co.uk/news/22651897.fen-floods-dramatic-pictures-videos-show-flash-floods-wisbech-just-20-minutes-heavy-rain/ Accessed: May 2025

7.1.5 June 2020

Flash flooding entered a restaurant in Downham Market.[77]

7.1.6 December 2020

On 23rd December 2020, the already saturated catchment received heavy rainfall. At its peak, the St Germans pumping station was pumping 70 tonnes of water each second, equivalent to emptying two Olympic swimming pools a minute[78]. Several homes in March and Wisbech were flooded. Flooding was in part blamed on the fact that "March is a low-lying island of clay and till surrounded by reclaimed marsh/fen. This makes managing excessive rainfall and the resulting surface water a major challenge"[79].

7.1.7 May 2023

Flash flooding caused by an intense 20-minute rainfall event overwhelmed drainage systems in King's Lynn flooding a number of homes[80]. Flash flooding was also reported in Wisbech affecting roads and several homes[81].

7.1.8 October 2023

Heavy rain from Storm Babet led to surface water flooding in March and Ely[82] affecting residential streets and supermarket carparks.

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[77] Ely Standard: Arbuckles 'heartbroken' after 'devastating' flash flooding (2020) Available at: https://www.elystandard.co.uk/news/22758445.arbuckles-heartbroken-devastating-flash-flooding/ Accessed: April 2025

[78] Ely Standard: 'The largest and most challenging event we have faced since 1998' (2020) Available at: https://www.elystandard.co.uk/news/22753996.the-largest-challenging-event-faced-since-1998/ Accessed: April 2025

[79] Cambs Times: March could be the key focus of major flood prevention project (2021) Available at: https://www.cambstimes.co.uk/news/22843669.march-key-focus-major-flood-prevention-project/ Accessed: April 2025

[80] BBC: Flash flooding hits Norfolk after torrential rain (2023) Available at: https://www.bbc.co.uk/news/uk-england-norfolk-65544578 Accessed: April 2025

[81] Fenland Citizen: Flashfloods hit Wisbech as what was reportedly inches of rain fell in less than an hour (2023) Available at: https://www.fenlandcitizen.co.uk/news/flashfloods-hit-wisbech-aswhat-was-reportedly-inches-of-rain-9311905/ Accessed: May 2025

[82] Ely Standard: Storm Babet: Heavy rain causes flooding in Cambridgeshire (2023) Available at: https://www.elystandard.co.uk/news/23868307.storm-babet-heavy-rain-arrives-cambridgeshire/ Accessed: April 2025

Figure 58: Flooding in the Ellingham Avenue area of March[83]

7.1.9 July 2024

Heavy rain led to flooding on the A47 near King's Lynn.

[83] Ely Standard: Storm Babet: Heavy rain causes flooding in Cambridgeshire (2023) Available at: https://www.elystandard.co.uk/news/23868307.storm-babet-heavy-rain-arrives-cambridgeshire/ Accessed: April 2025

7.2 Groundwater

Groundwater flooding occurs when the water table, the level of the water within the land, rises above the ground surface. This type of flooding typically follows extended periods of sustained rainfall. Groundwater flooding can persist for a prolonged duration, often lasting longer than other types of flooding. Throughout the year, the water table naturally fluctuates in response to seasonal rainfall. Groundwater flooding is most common in spring, following prolonged rainfall during the preceding autumn. Presence of sandy or gravel soils can mean increased susceptibility to movement of groundwater and flooding from this source.

Across the Great Ouse catchment, the land is low-lying, which can contribute to a higher risk of groundwater flooding through the water table being at a shallow depth. There is also a risk that flooding will not recede for long periods of time due to the flat nature of the catchment and the reliance on pumping for drainage. The SFRA for Borough Council of King's Lynn & West Norfolk[84] identifies no recorded incidents of groundwater flooding in the Great Ouse catchment, although it is possible that high groundwater levels contributed to flooding in a number of historic flood events caused by other sources.

7.3 Reservoir

Reservoir flooding is very rare but occurs when there is a failure of reservoir impounding structures such as raised embankments. In the Great Ouse catchment, the Ouse Washes are classified as a reservoir. It is approximately 19 miles long and half a mile wide providing 90 million m^3 of flood water storage.

[84] Borough Council of King's Lynn & West Norfolk Level 2 Strategic Flood Risk Assessment (2019) Available at: https://www.west-norfolk.gov.uk/downloads/download/825/strategic_flood_risk_assessment_level_2 Accessed: May 2025

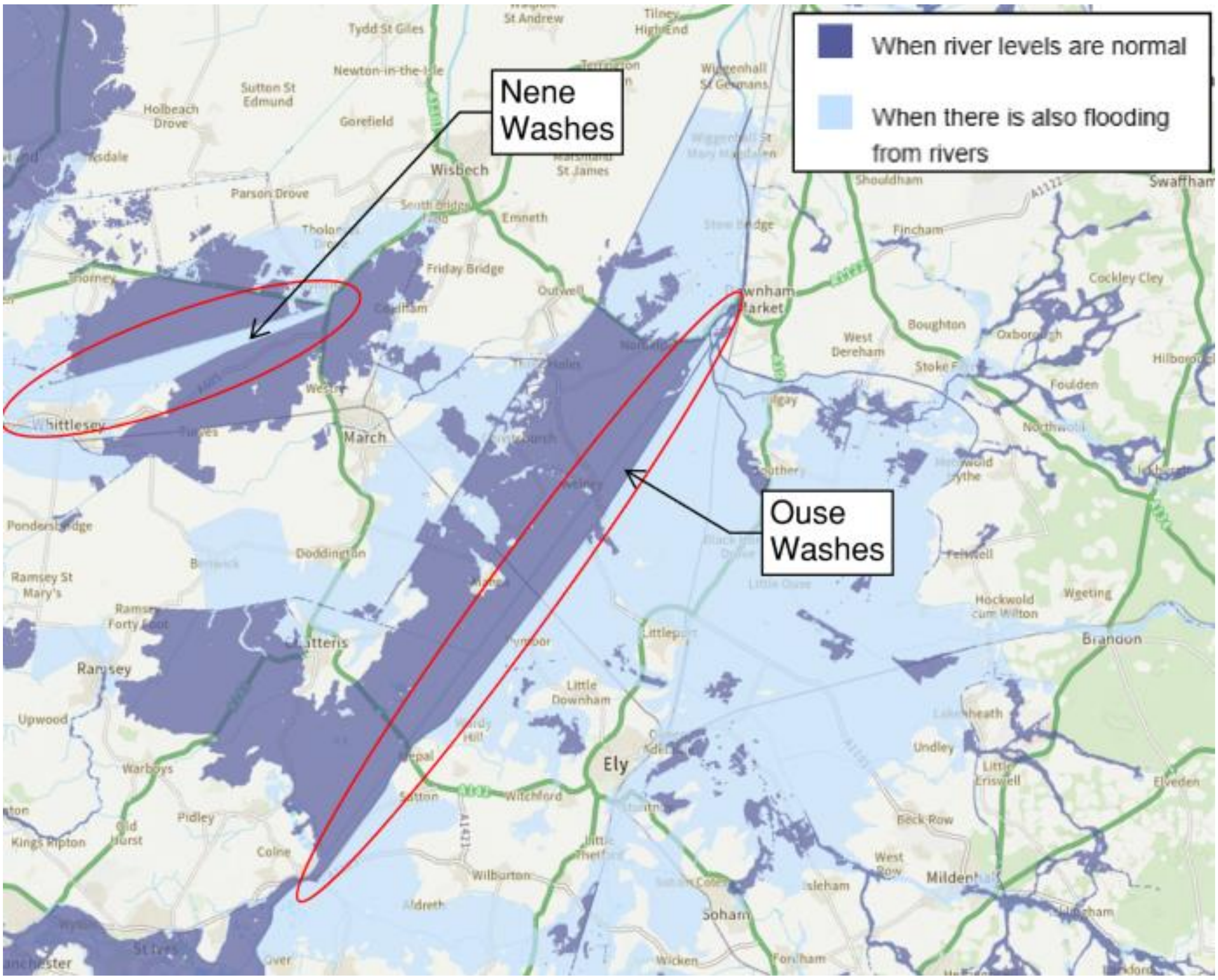

Figure 59: Reservoir Flood Extent © Environment Agency

Mapping of reservoir flood risk across the UK[85] (see Figure 59) shows that reservoir flooding is mainly concentrated to the land around the Ouse Washes. There is also some risk from the Nene Washes which sit in just outside the catchment border. In both locations, significant areas of farmland are at risk of flooding, even if river levels are normal. The provisions of the Reservoirs Act (1975) mean that the likelihood of a severe breach occurring is low, minimising overall risk.

A new reservoir has been proposed by a partnership of Anglican Water and Cambridge Water to help provide a secure water supply. It would be built just north of Chatteris and be operational by 2036, supplying water to approximately 250,000 households[86].

[85] Environment Agency (2024) Check your long-term flood risk. Available at: Technical map - Check your long-term flood risk - GOV.UK. [Accessed 07/04/2025].

[86] Cambridge Water: Proposed location for new reservoir confirmed (2022) Available at: https://www.cambridge-water.co.uk/news/proposed-location-for-new-reservoir-confirmed Accessed: May 2025

8. Summary

8.1 Tidal flood risk

There is limited present day tidal flood risk in the catchment. This is due to the Great Ouse catchment being protected by significant tidal defences, such as the King's Lynn tidal defences. The majority of flooding is to Grade 4 land in the Ouse Washes.

Unsurprisingly, the tidal flood risk increases in the future. Overtopping of embankments results in large portions of King's Lynn being flooded. However, there is still limited flooding to agricultural land, with majority of flooding still occurring in the Ouse Washes.

8.2 Fluvial flood risk

The flood history suggests fluvial flood risk in the Great Ouse catchment is relatively low since the construction of the Relief Channel and Cut-off Channel in the 1950's and 1960's. These channels in combination with the Ouse Washes and the large network of embankments, sluices and pumping stations allow flood water to be safely stored until it can be discharged into the sea. Any fluvial flooding tends to be localised and affect only small numbers of properties.

The present-day modelling backs this up with fluvial flooding in the 1% AEP event predominantly to low grade agricultural land situated in the Ouse Washes, with limited flood risk to properties. However, the 0.1% AEP event would lead to significant areas of Grades 1, 2 & 3 land also being flooded, primarily due to flood waters escaping the Ouse Washes and flooding surrounding agricultural land.

When climate change is applied, there is a limited increase in fluvial flood risk assuming continuing maintenance and upkeep of the extensive existing flood defences.

8.3 Summary

Modelled present day tidal flood risk is low, however when climate change is applied, large areas of King's Lynn are at risk of flooding.

Current fluvial flood risk withing the catchment is low – modelled results show flooding predominantly contained to low-grade land within the Ouse Washes. The future fluvial flood risk increase is relatively small.