2 Catchment Overview

This section describes the characteristics of the Great Ouse CFMP area. We have used information on topography, geology, soils, geomorphology, hydrology, land use and the environment to highlight the catchment features that may contribute to flood risk, that could be affected by flooding, or that provide opportunities or constraints for future flood risk management.

2.1 Definition and extent of the Great Ouse CFMP area

The River Great Ouse is located in the east of England. It is a large catchment that covers an area of 8,596km^2. The catchment extends from its headwaters near Brackley in Northamptonshire, through Milton Keynes, Bedford and King's Lynn to its outfall into The Wash, as shown in Figure 2-1.

The Wash Shoreline Management Plan (SMP) covers the coastal boundary of the CFMP. Along the River Great Ouse, the downstream limit of the CFMP catchment is located at the Vinegar Middle drain which is The Wash SMP boundary. The Wash SMP and North Norfolk SMP deal with coastal flood risk management, whilst the CFMP considers tidal flood risk along the River Great Ouse upstream of the Vinegar Middle drain to the tidal limit at Brownshill Staunch near Earith.

The catchment includes the main tributaries of: the Tove (Towcester), Ouzel (east of Milton Keynes), Cam (Cambridge), Ivel (Biggleswade), Lark (Bury St Edmunds/Mildenhall), Little Ouse (Thetford) and Wissey (south of Downham Market).

The main features of the catchment are shown in Figure 2-1. The catchment is predominantly rural and the major land use is agricultural. Significant urban areas include Milton Keynes, Cambridge, Bedford and King's Lynn, with many smaller market towns such as Buckingham, St Neots, St Ives, Huntingdon, Thetford and the small city of Ely. The M11, M1, and A1(M) motorways, numerous A-roads, including the A14, rail links to the capital, and King's Lynn Docks are all important parts of the transport infrastructure in the catchment.

The catchment covers all or parts of the counties of Oxfordshire, Buckinghamshire, Northamptonshire, Bedfordshire, Cambridgeshire, Hertfordshire, Essex, Suffolk and Norfolk and the unitary authorities of Bedford Borough Council, Central Bedfordshire Council, Milton Keynes Council and Peterborough City Council. There are also 22 district/borough councils. These administrative areas are shown on Figure 2-2.

The Great Ouse and its tributaries form seven separate sub-catchments based on their different hydrological characteristics. These are:

- The River Great Ouse and its tributaries upstream of Bedford (called the Upper Bedford Ouse);
- The navigable River Great Ouse and its tributaries upstream of the tidal boundary to and including Bedford (called the Lower Bedford Ouse);
- The River Cam catchment and its tributaries upstream of the low lying Fenland areas (called the River Cam Catchment);
- The low lying pumped Fenland area of the Middle Level (called the Fens - Middle Level);
- The Ely Ouse and downstream defended reaches of the Cam, Lark, Little Ouse and Wissey within the South Level (called the Fens - South Level);
- The upstream undefended sections of the Lark, Little Ouse and Wissey plus their tributaries (called the Eastern Rivers);

- The North West Norfolk Rivers including coastal streams flowing into The Wash (called North West Norfolk).

A map of the sub-catchments is included in Figure 2-3 and an overview is given in Table 2-1 below.

The majority of the watercourses within the Great Ouse CFMP area are heavily modified, either for flood defence, navigation, or land drainage purposes. Modifications include completely artificial man-made channels. Channel realignment and re-sectioning, bank reinforcement, weirs/locks ad loss of floodplain channel diversity.

We have permissive powers to manage flood risk on the Main Rivers in the catchment. IDBs and District Councils look after non main rivers, which are called ordinary watercourses. IDBs look after ordinary watercourses within their drainage district and local authorities look after ordinary watercourses that are not within an Internal Drainage District. Internal Drainage Boards (IDBs) undertake flood management activities across a large part of the catchment. There are five principal IDB groups: Ely Group, Bedford Group, Downham Market Group, Water Management Alliance and Middle Level Commissioners. The Whittlesey Consortium of IDBs falls within the Middle Level area. The drainage areas covered by the IDBs and their features are shown in Figure 2-4.

Anglian Water and the local authorities manage urban surface water drainage, see Appendix A.

Table 2-1 Sub-catchment overview

Sub-catchment	Area (km^2)	Length of main river (km)	Major watercourses
Upper Bedford Ouse	1,444	232	River Great Ouse, River Ouzel, River Tove
Lower Bedford Ouse	1,569	245	River Great Ouse, River Ivel, River Kym, Alconbury Brook
River Cam Catchment	804	130	River Cam, River Rhee, River Granta, Bin Brook, Bourne Brook
Fens – Middle Level	1,098	210	Tidal River Great Ouse/100ft, River Delph, Counter Drain, Middle Level Main Drain (non-Main River)
Fens – South Level	1,259	300	Ely Ouse, Soham Lode, Cottenham Lode lower reaches of the River Cam, River Lark, River Little Ouse and River Wissey
Eastern Rivers	1,661	299	River Lark, River Little Ouse, River Wissey, River Kennet and River Thet
North West Norfolk	760	105	Heacham River, Gaywood River, River Ingol, Babingley River and River Nar
Tidal limits	Brownshill Staunch, near Earith		
Average annual rainfall	Average annual rainfall varies across the CFMP area from less than 550mm in the Fenland areas to over 750mm in North West Norfolk.		
Geology	Chalk (south east) Mudstone (north west) Limestone (west)		
Major urban areas	Bedford, Bury St Edmunds, Cambridge, King's Lynn and Milton Keynes		

Assets	Total for catchment	At risk of flooding based on Flood Zone 3 (1% undefended AEP)
Population	1,700,000	86,000
Area (km^2)	8,596	1,743
Number of properties	752,000 (709,000 residential)	38,000 (36,000 residential)
Motorways (km)	111	6
A-class roads (km)	641	95
Railways (km)	549	143

Sites of Special Scientific Interest	241	89
Special Areas of Conservation	11	8
Special Protection Areas	3	2
Ramsar Sites	7	4
Scheduled Monuments	1040	121

Historic flooding in many parts of the Great Ouse CFMP area has occurred. The March 1947 flood saw extensive flooding on the Bedford Ouse system and many of its tributaries. Flooding in Buckingham, Newport Pagnell, Bedford, St Neots, St Ives and Huntingdon amongst other towns and villages flooded back then and are at-risk today, although many flood alleviation schemes have now reduced the risk. Further flooding on the Bedford Ouse occurred in 1998 and 2003. In 1968, many parts of the Eastern Rivers suffered fluvial and groundwater flooding including Bury St. Edmunds and Thetford. Other parts of the CFMP area affected in 1968 include Towcester, Little Wymondley, Newmarket, Trumpington and Alconbury. The River Cam catchment is predominantly rural with Cambridge being the largest urban area. In 2001, Cambridge was affected by fluvial flooding as were many rural communities in the surrounding area including the village of Bourn. The Fens are well drained by the activities of Internal Drainage Boards who maintain the drains to a good standard, through maintenance and pumping. Flooding on the Fens is usually restricted to low lying agricultural land or from the threat of potential failure of defences/pumps etc. The tidal River Great Ouse poses a risk to people and property along its course, more so in King’s Lynn which was severely affected in 1953 and 1978. Since then defences have been raised in King’s Lynn which reduces the risk and has protected King’s Lynn on many occasions.

Figure 2-1 Main Features

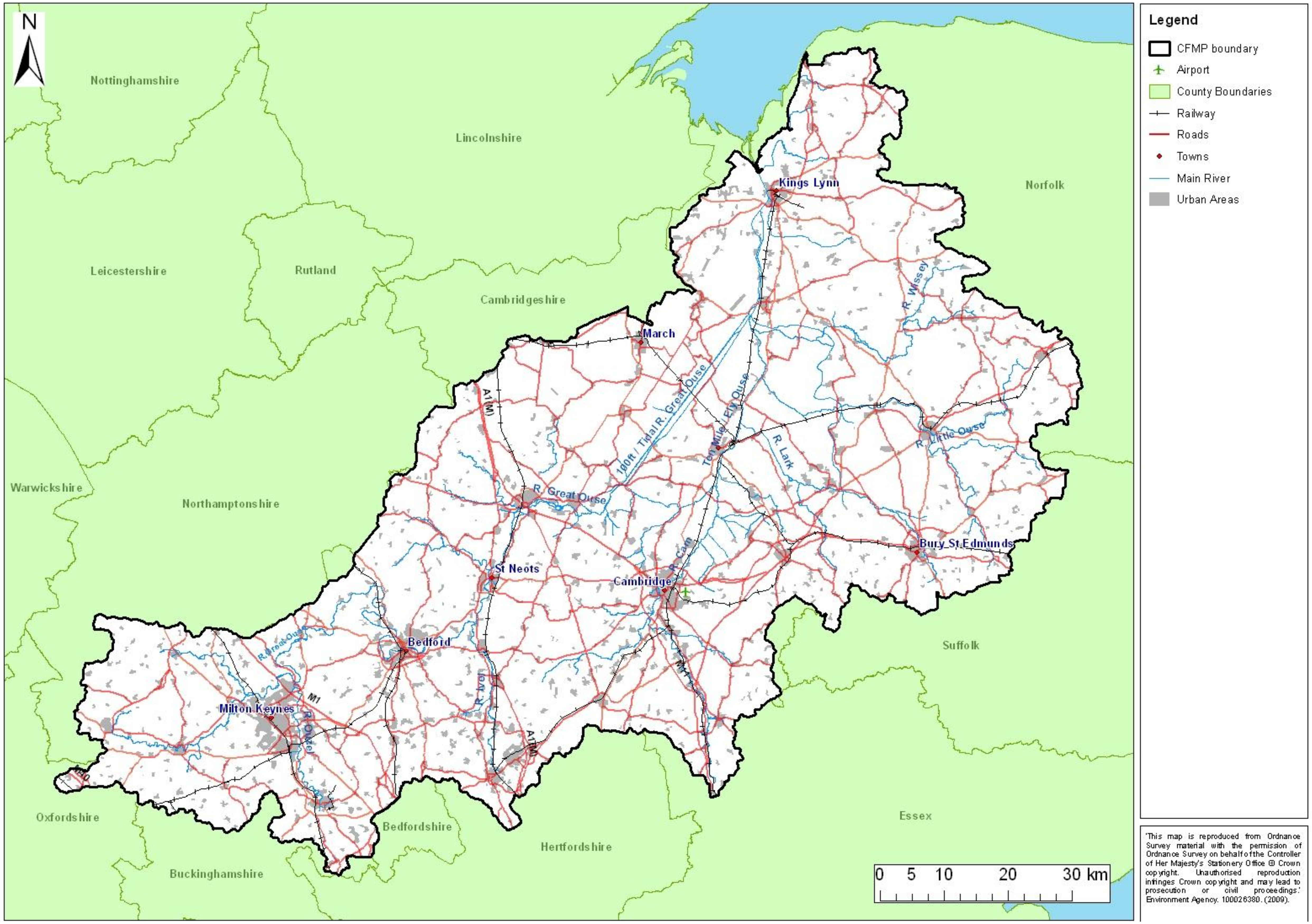


Figure 2-2 Administrative councils and districts

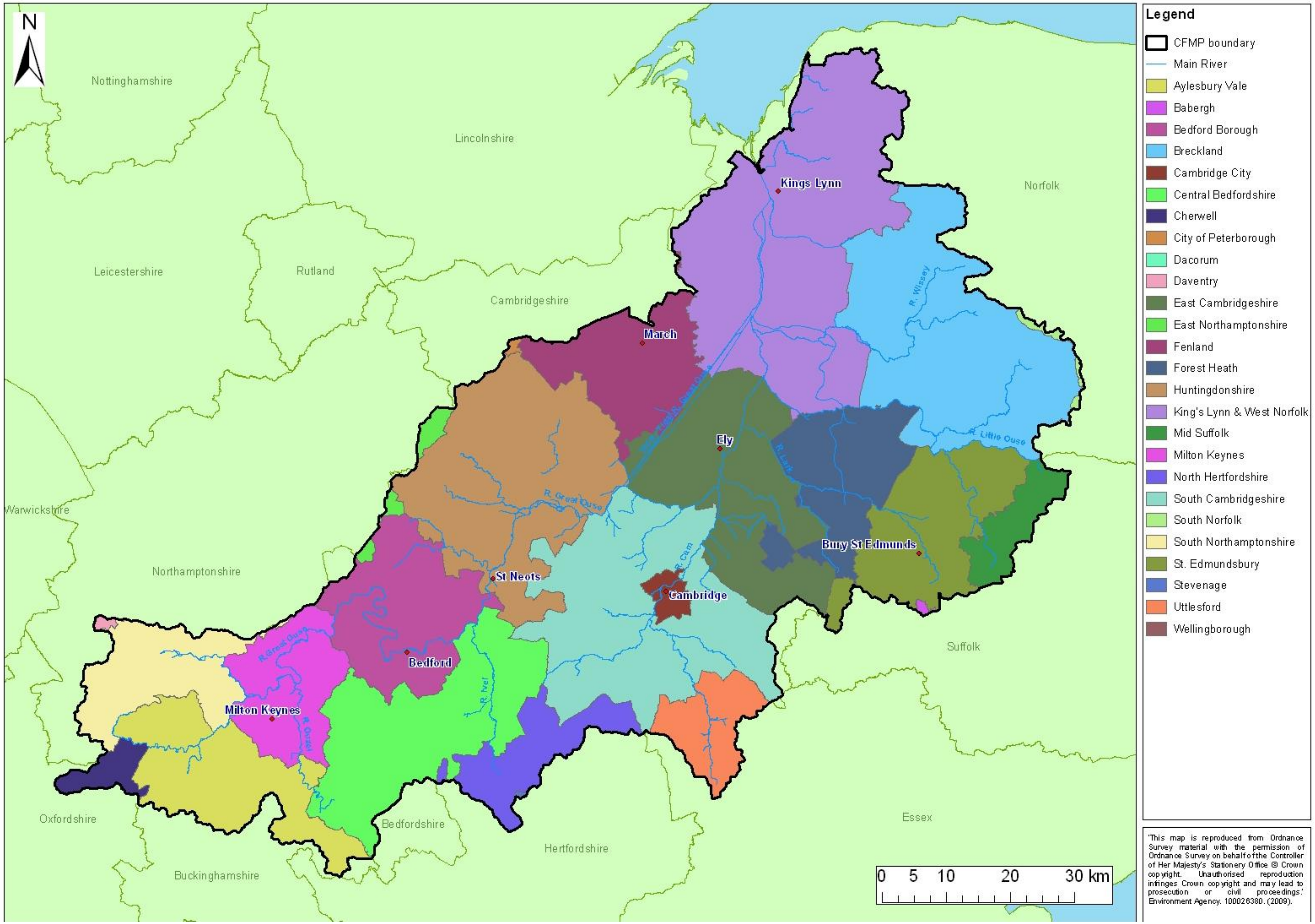


Figure 2-3 Sub-catchments

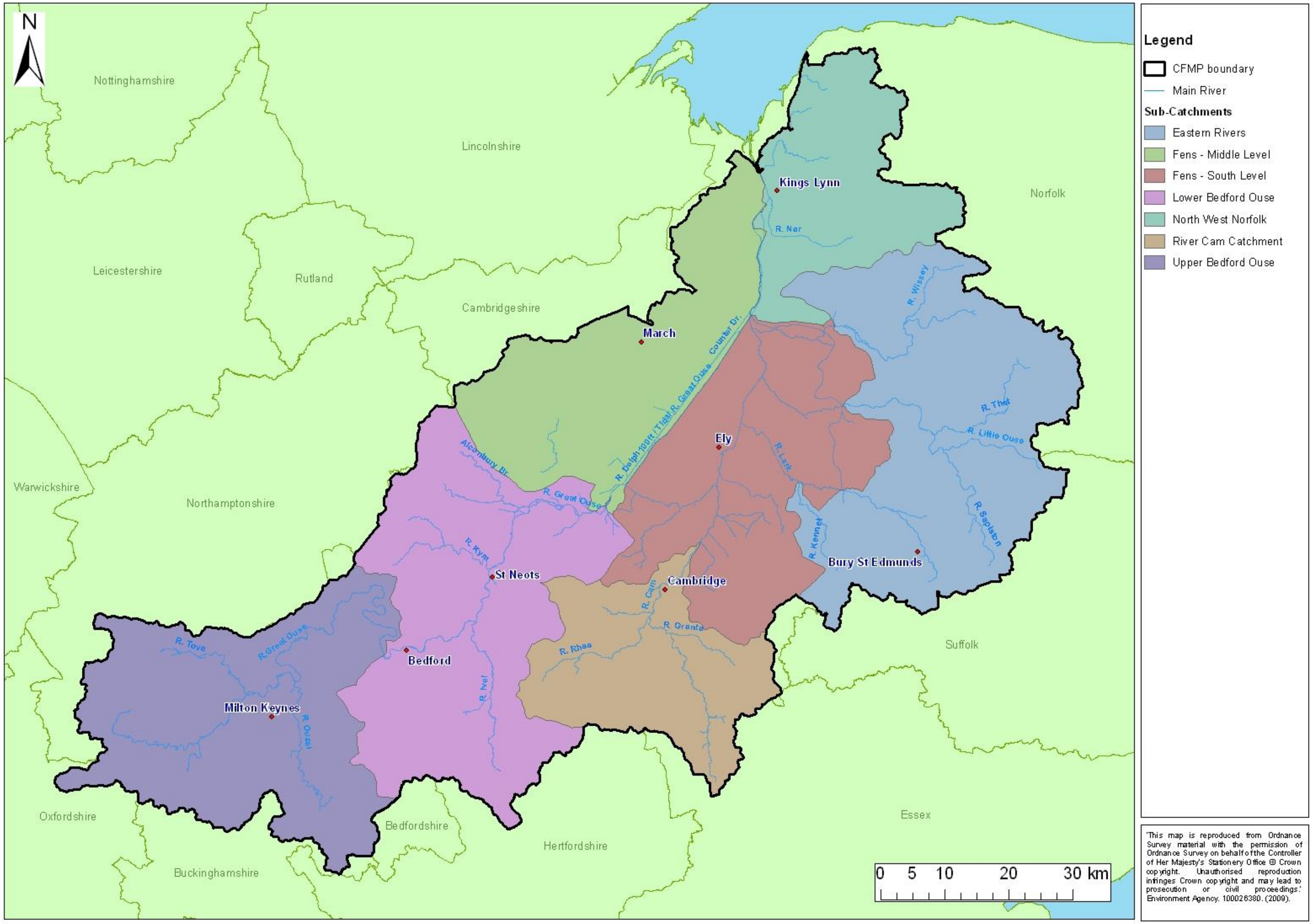
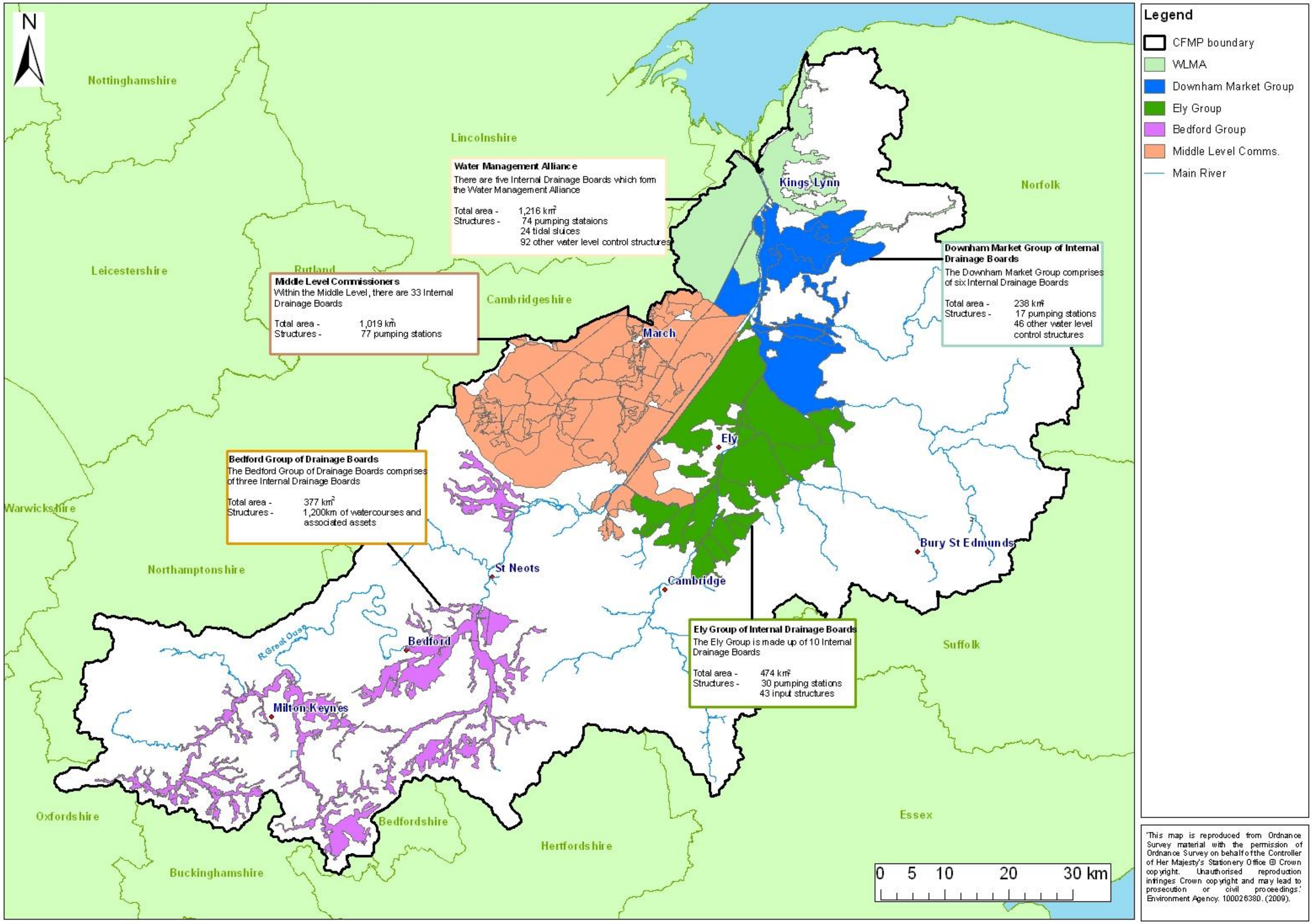


Figure 2-4 Internal Drainage Board features



2.2 Topography

The topography of the Great Ouse CFMP area is shown in Figure 2-6. Land is highest to the west of Milton Keynes and in the southern parts of the catchment at a height of approximately 250mAOD (Above Ordnance Datum). The Fens include the lowest lying land surrounding the City of Ely and comprise approximately one fifth of the total catchment area. This low lying land is at an elevation close to and often below mean sea level.

Topography dictates the gradient of the river which influences the velocity of flow and speed of flooding. Where channel gradients are steeper, the river will respond quicker to rainfall and flow velocities can be high. In contrast where river gradients are flatter the river responds slower to rainfall and flow velocities tend to be slower. However, there are many other factors beside topography that determine the speed of runoff including, geology, land use/vegetation, urbanisation and field drainage systems.

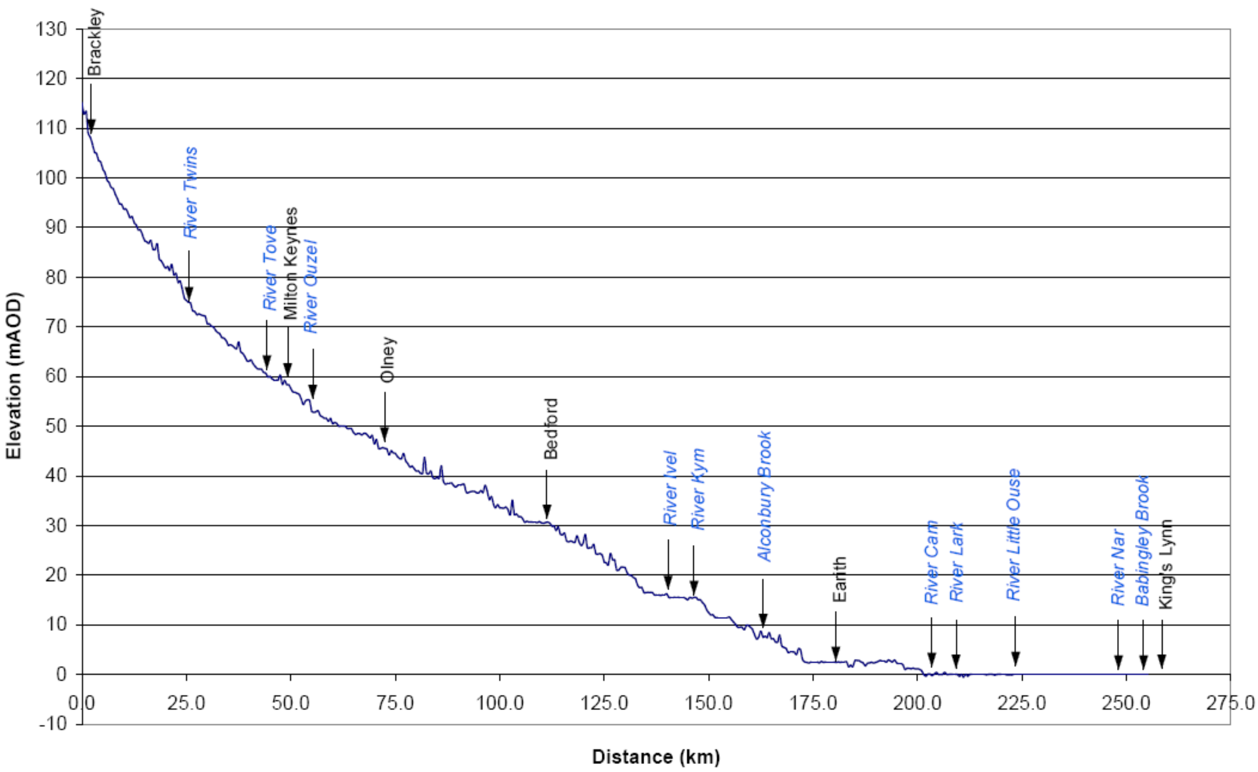
The source of the River Great Ouse is located in the highest part of the catchment, just east of Brackley at a level of approximately 120mAOD. The river flows east through relatively steep terrain towards Buckingham before changing direction to flow north east towards Bedford. From Bedford it continues to flow at a relatively moderate gradient in a north easterly direction towards Earith and The Fens before the topography flattens downstream of Earith Bridge and through the Fens. River flows downstream of this point are much slower as the bed slope becomes much flatter and the floodplain widens through the Fens before reaching the sea.

Due to the steeper slope the upstream section of the River Great Ouse would be expected to respond more quickly to rainfall and is also more likely to experience flow velocities higher than those in the downstream section. Due to the flat low lying topography, the rainfall response is much slower in these areas in comparison to the steeper gradients found in the Upper Great Ouse CFMP area.

The steepness of the catchment also determines the duration of flooding. In the upstream parts of the River Great Ouse, and its tributaries, the steeper slopes mean that flood duration is not as long as in the flatter parts of the catchment downstream.

The bed level of the Great Ouse from its source in the south west to The Wash in the north is shown on Figure 2-5. This also shows the location of the main areas along its length, and the location of the tributary confluences.

Figure 2-5 Great Ouse bed levels



2.3 Geology and hydrogeology

The underlying solid geology of the Great Ouse CFMP area crosses the catchment in bands running approximately north east to south west. This is shown in Figure 2-7. Chalk dominates the south east of the CFMP area (e.g. around Bury St Edmunds, Thetford, and Saffron Walden), whilst mudstone becomes dominant in the northwest (e.g. around St Neots, Huntingdon, and March), and limestone dominates the very western end of the catchment (e.g. around Buckingham, Brackley, and Towcester). Additionally ironstone can be found in the most western parts of the catchment around the upper reaches of the River Tove.

These rocks are overlain by more recent drift deposits shown in Figure 2-8. At the upstream end of the catchment gravelly clays lie over the mudstone and limestone whilst in the lower part of the catchment, particularly in the Fens, thick deposits of peat or mud cover the mudstone.

Geology has a significant influence on the response of the catchment to rainfall, as it contributes to how quickly and how much water will run-off and give rise to river flow. Drift deposits may form a hydrological connection with the underlying solid geology, or they may be impermeable and limit the connection, for example till. Some drift deposits form minor aquifers which will store water and reduce runoff, unless they are already saturated.

The chalk geology in the catchment is permeable containing many cracks and fissures, and in many places it lacks any drift geology and is covered by surface soils only. If the surface soils are permeable, rain can easily percolate down into the rock reducing the amount of water that flows across the ground surface into rivers. As a result, rivers underlain by chalk deposits tend to have a slower and less significant response to rainfall events. In contrast, the mudstone, found in the north west of the catchment, is relatively impermeable so rain cannot easily percolate which leads to more run-off and faster responses to rainfall events.

The peat deposits, like the chalk, are highly permeable. However, the ability of these deposits to absorb water is constrained by the small difference between the ground surface level (close to mean sea level) and high water table. Once the water table reaches the ground surface no more water can be absorbed and flooding will occur.

The gravelly clays at the upstream end of the catchment are relatively impermeable; rain is therefore unable to penetrate into the ground and runs across the surface to the nearest river. As a result rivers in this part of the catchment, such as the River Tove or River Ouzel, tend to react very quickly to rainfall events creating a much greater likelihood of flooding.

The main areas of groundwater flow in the catchment are the chalk and sandstone rocks in the centre and east of the catchment (Figure 2-7), running from north east to south west underlying parts of the River Wissey, River Little Ouse, River Lark, River Cam and River Ivel catchments. These regions are classed as primary aquifers, although the capacity of the aquifer to absorb and store rainfall is highly dependent on the moisture conditions at the time. Less productive aquifers (secondary), but equally important for water supply, are the limestone rocks in the very western part of the catchment, around Brackley and Towcester (Figure 2-7). If groundwater levels are high the rainfall may run overland to the nearest watercourse and flooding is more likely. When there is storage available within the aquifer, the runoff following rainfall is lower as it is stored in the aquifer and may later reappear as flow in rivers or emerge as springs. Groundwater flows are important to some of the upper reaches of the rivers in the catchment in order to maintain adequate flows, for example, the River Nar relies heavily on base flow from the chalk aquifer.

This complex aquifer system is difficult to manage in terms of flood risk as groundwater flooding is dependent on a number of factors, especially the local geological structure and topography. This means that although the conditions that cause a flood (high groundwater levels and/or rainfall) can be monitored, it is difficult to predict where and when flooding may occur. This is a challenge for flood risk management in the Great Ouse CFMP area.

Figure 2-6 Topography

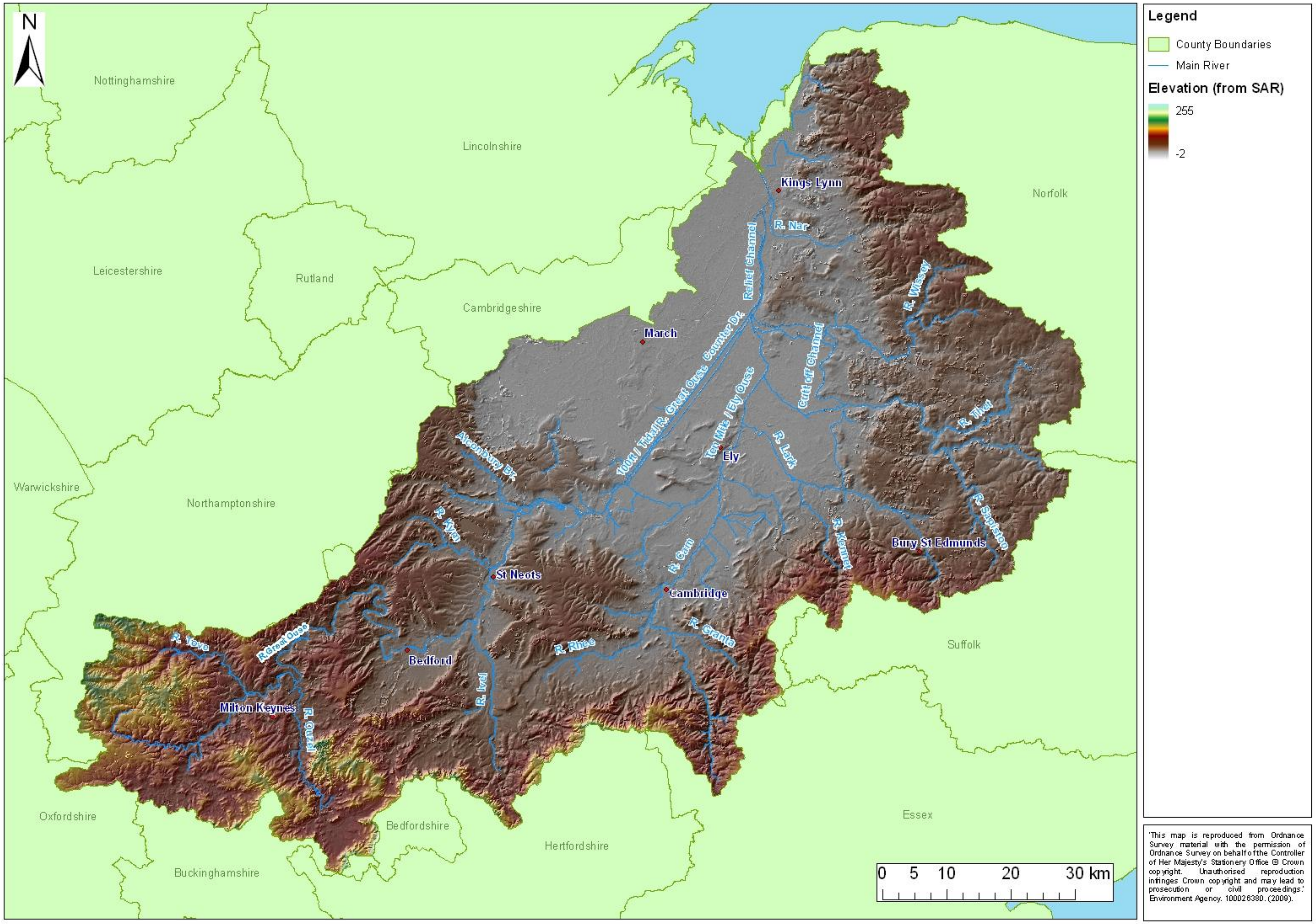


Figure 2-7 Solid geology

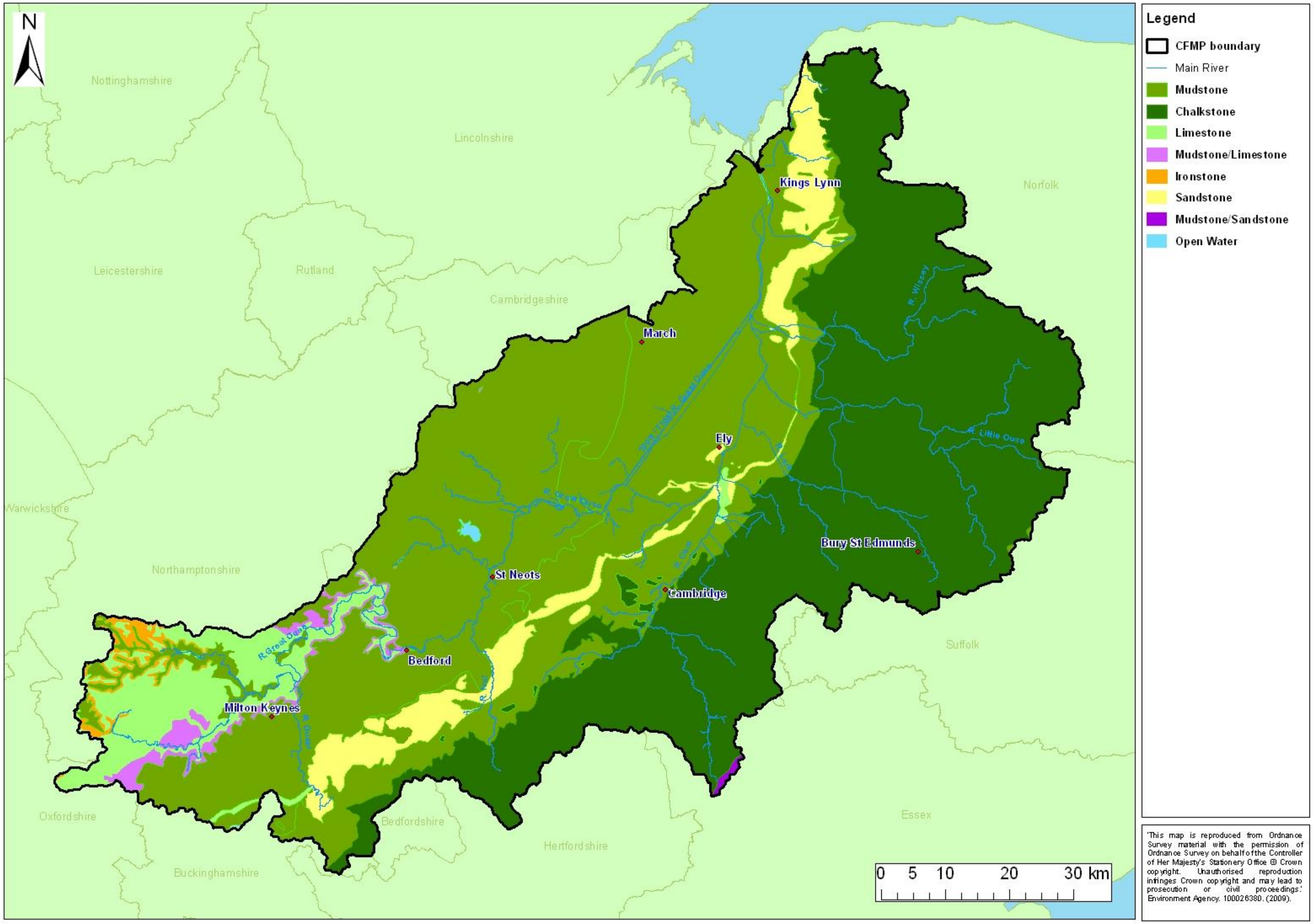
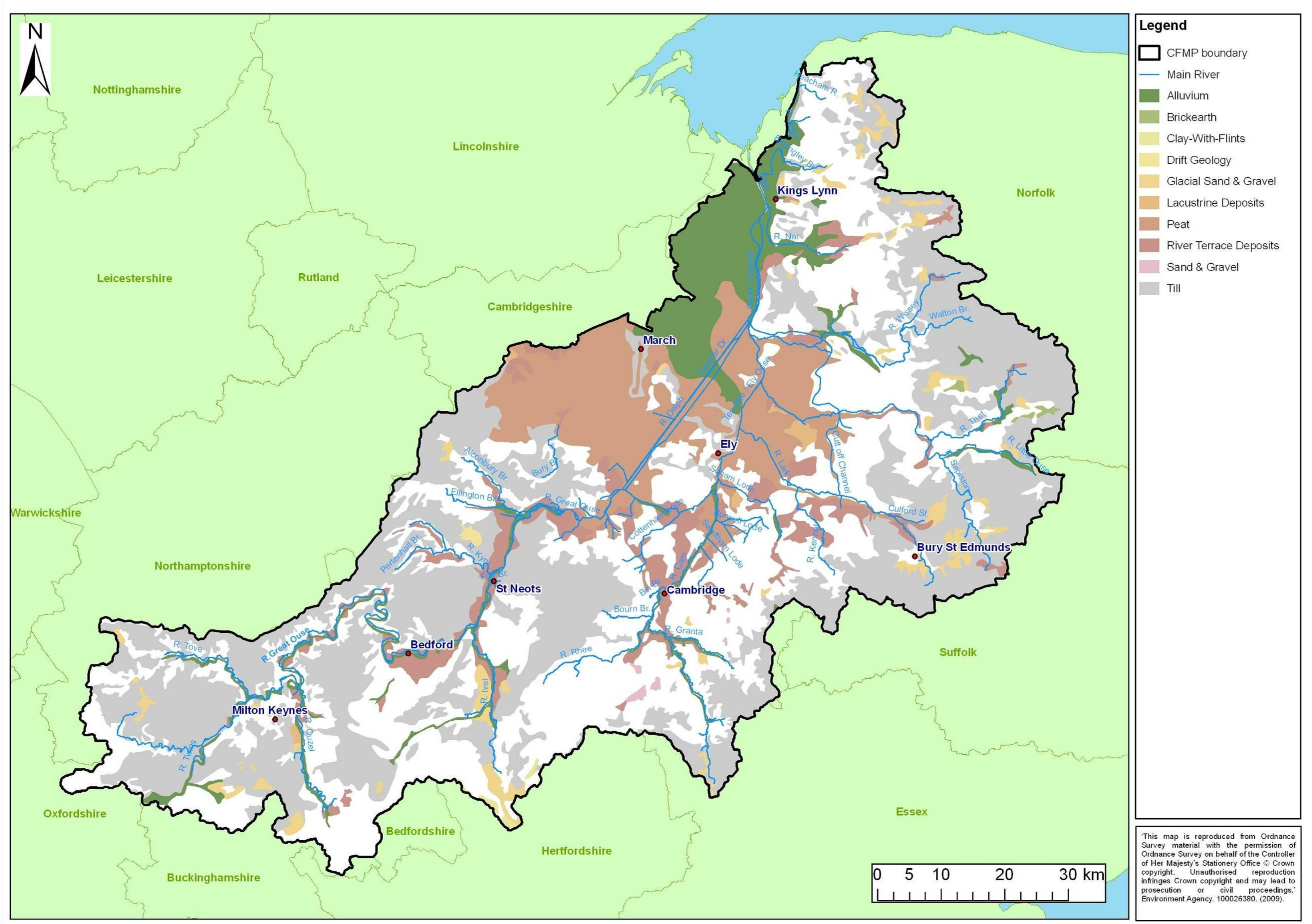


Figure 2-8 Drift geology



2.4 Geomorphology

Geomorphology is the study and understanding of the processes that change the land surface over time. River geomorphology is controlled by erosion, transport and deposition of sediment. These processes cause changes in the shape of river channels. Human activities, such as land use, channel structures, channel engineering works and the construction of flood defences can influence the geomorphological processes of natural river systems. We have considered geomorphology in the CFMP because;

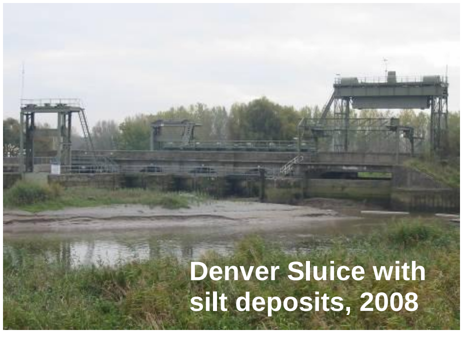
- the build-up of sediment can reduce the capacity of river channels and slow down the passage of water. This may increase the frequency of flooding;
- erosion and the build-up of sediment around flood control structures can affect their ability to work properly;
- changes in river shape affect how fast water moves and where flooding is likely to occur;
- erosion of river banks can damage flood control structures and other infrastructure;
- we can use geomorphology to assess the potential effects that flood risk management may have on environmentally important features and natural processes;
- geomorphological processes can affect the condition of habitats and biodiversity.

The primary sediment sources are generally located in the headwaters of a catchment, where there are steep gradients and therefore greater potential for sediment delivery to the watercourses. Conversely, sediment deposits are often found in the lower reaches of the catchment where there are shallower gradients and less energy in the river system,

The Great Ouse is a significantly modified lowland river that has been heavily engineered for flood defence and land drainage purposes. Modifications include river regulation for navigation on many tributaries, artificial cut-off channels, channel re-alignment and re-sectioning, bank reinforcement, construction of weirs and locks and the creation of flood embankments. All these modifications, together with land use and climate change, have altered the sediment load that reaches the watercourses, and the river has adjusted its channel shape accordingly. The series of weirs and locks within the catchment result in a decrease in sediment transfer through the system as velocities are reduced. Sedimentation may be exacerbated as a result of increased flows, due to climate change, supplying additional sediment from upstream via dense drainage networks and tributary sources.

Geomorphological issues within the Great Ouse system are significantly influenced by tidal processes. The tidal Great Ouse, particularly from the Wash to Earith, shows significant marine-derived sediment accumulation, most notably when flows from the Bedford Ouse are low. For example, the reach between Welmore and Salters Lode, which includes the Denver Sluice complex, is prone to sedimentation. De-silting is carried out within this part of the Great Ouse system to ensure navigation, and maintain the operational use of structures.

Such maintenance activities can have both beneficial and detrimental effects on biodiversity. As such, they need to be carried out in ways which are sensitive to the environment. It is important to note that the natural river flow acts as an effective scouring mechanism, transporting sediment back towards The Wash. Releases from the Ely Ouse river system to the tidal River via Denver Sluice are also effective in scouring sediment back to The Wash.

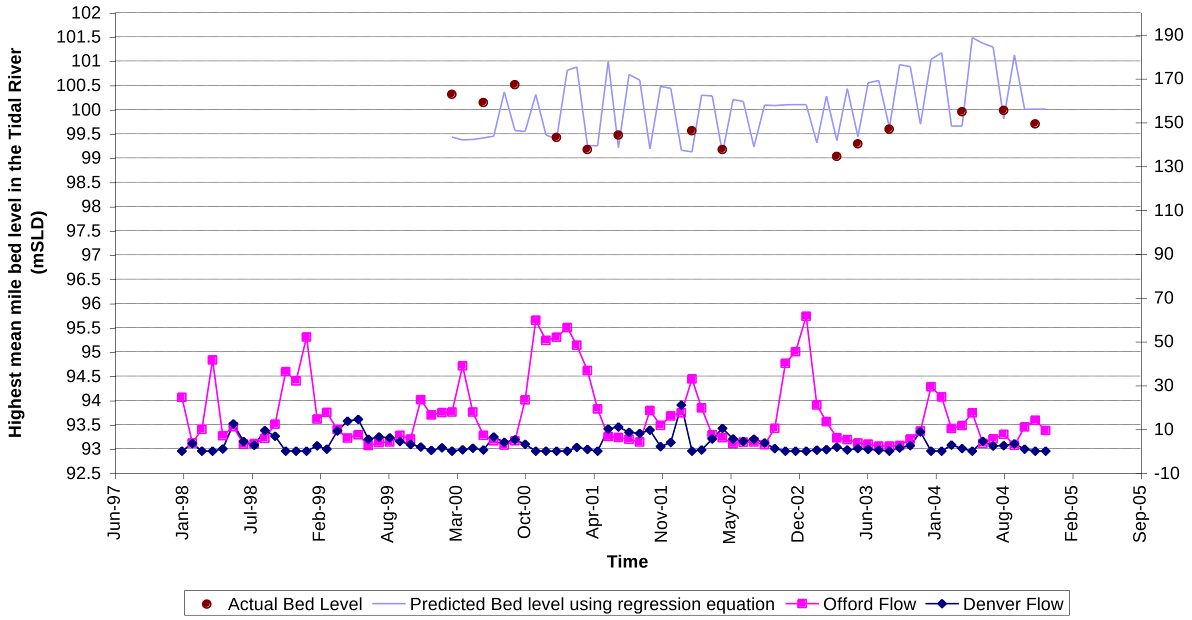


Denver Sluice with silt deposits, 2008

Records show that if sediment accumulates due to repeated tidal flows, whilst the river flows are low, then the bed level at Stowbridge can reduce drainage from the Ouse Washes. Figure 2-9 shows a clear relationship between the bed level in the tidal River and the river flows following a period of dry weather, based on empirical studies in the 1990s. If drainage from the Ouse Washes is reduced, then fluvial flood water levels are raised, thereby reducing the defence standard provided by the barrier banks which bound the River and the Ouse Washes. This potential for increased flood risk has resulted in the Environment Agency undertaking works to raise the Cradge Bank at low spots, dredge the Hundred Foot River to control bed levels, and replace the Welmore Lake Sluice with the John Martin Sluice.

Figure 2-9 also shows that the increase in normal river flows from the Bedford Ouse reverses this process and removes sediment from this area. Current high bed levels in the tidal Great Ouse are causing concern and a Tidal River Strategy has been commissioned.

Figure 2-9 Comparison of river flows and bed levels in the Tidal River since 1998



We see geomorphology as an important component of biological diversity in the Great Ouse. The range of river habitats that is available for animals and plants is directly related to the ability of geomorphological processes to operate. Although existing information relating to geomorphology for the Great Ouse is limited, the flood risk management policies that we have selected for the catchment will need to encourage the protection of areas with high geomorphological status. We will also promote the restoration of potentially important river corridors and habitats wherever possible. It is also important that we link our actions to the Water Framework Directive, by working towards achieving the ecological objectives it sets out. Also, the Tidal River Strategy that we are undertaking explores the best ways for managing siltation of the New Bedford River and the tidal River Great Ouse.

2.5 Soils

The soils of the catchment are shown in Figure 2-10. Soil characteristics derived from the underlying geology and soil types have a significant impact on how the catchment responds to rainfall. Loosely packed, deep soils retain more rainfall and have a slower surface runoff response to rainfall than shallow or densely packed soils such as clays. The type of soil and its drainage properties dictate the rate of infiltration to the sub-surface and hence the relationship between runoff, flow along soil horizons and infiltration to groundwater.

Soils in the catchment can be broadly divided into five areas.

1. The area around the upper and lower Bedford Ouse is generally covered in low permeability clay soils. The slow draining soils can force more water to move over the surface of the land in the upper catchment as run-off and could lead to the rapid onset of flooding, particularly if the ground is saturated in the winter.

2. In the River Cam catchment the soils is mainly clay in the upper reaches and in the area to the west of Cambridge and chalk in the rest of the lower reaches. There are also some small pockets of loam and peat. The well-drained chalk soils will allow water to soak into the ground, meaning that less water flows into the watercourses and flood risk is reduced. However, if groundwater levels in the underlying aquifers are already high, then flooding may occur.

3. The eastern area of the catchment is dominated by well drained sand and chalk soils over underlying chalk geology, with some pockets of mixed clay. Like the River Cam catchment, these well-drained sand and chalk soils will allow water to soak into the ground leading to less surface runoff.
4. The Fens area in the middle of the catchment is comprised of clay, loam and peaty soils, with large pockets of silt, particularly north-west of King's Lynn. The clay and peaty soils are prone to waterlogging, although the Fenland drainage system has been used to lower the water table in these areas.

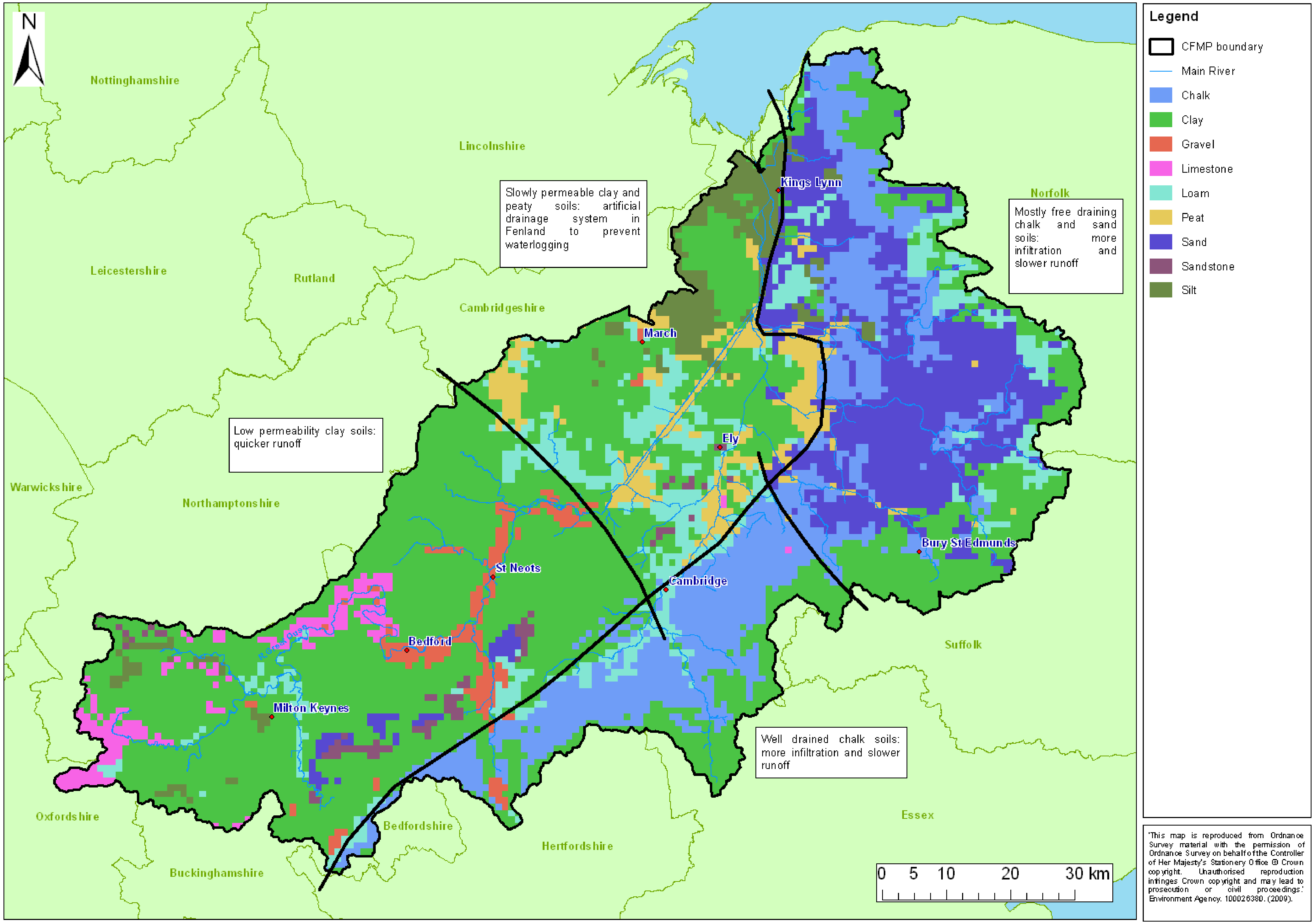
Soil type also influences the hydrology of the catchment indirectly as it is one of the factors determining land use, particularly the type of agriculture, land management and environmental habitats. Agricultural land across the catchment, particularly in the Fens, is drained to help improve production and land quality for farming. The influence of land drains on agricultural areas in the catchment plays an important part in how water reaches the watercourses. Land drains disperse water from agricultural land more quickly. The draining of agricultural soil helps farming production and can minimize agricultural losses. Whilst this can benefit agricultural activities it also means the rivers can rise much faster.

Areas categorised as class 3 or 4 are poorly drained soils such as gravelly clays. These areas tend to be found in the upper reaches of the catchment.

Those areas categorised as class 1 or 2 are well drained soils such as sand and gravels (found along the river valleys of the Bedford Ouse catchment) and peat and mud (found down in the lower catchment areas).

We discuss the influence of land management on how runoff is generated and soil erosion in section 2.6.2.

Figure 2-10 Soil type



2.6 Land use and Land management

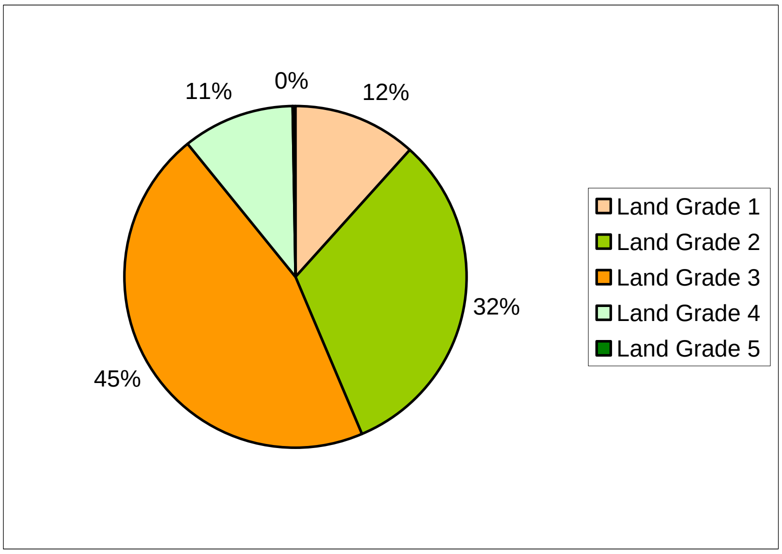
Different types of land cover and land management practices influence how floods are generated, where and when they may occur and how much damage they can cause. In this section we describe the extent of different land types in the Great Ouse CFMP area, how the land is managed and how this relates to flooding.

2.6.1 Land types

The Agricultural Land Classification (ALC) provides a method for assessing the quality of farmland to enable informed choices to be made about its future use within the planning system. Grades are related to climate, topography, drainage, soil characteristics and other site factors, and the interactions between them. Grades 1 and 2 are the best and most versatile land for agriculture, Grade 3 is considered moderate for agricultural production and Grades 4 and 5 are poor.

Figure 2-11 displays the agricultural land in the Great Ouse CFMP area in terms of which agricultural grade it falls in. Almost half (44%) of the agricultural land can be classified as Grade 1 and 2 and most of the remaining (53%) is classified as Grade 3. Only 11% of the agricultural land in the catchment is classed as Grade 4 and there is no Grade 5 agricultural land.

Figure 2-11 Proportions of agricultural land grade



The distribution of the agricultural land grades within the Great Ouse CFMP area is shown in Figure 2-12. Most of the highest quality land is located in the Fens within Cambridgeshire and Norfolk. Figure 2-12 also shows the relationship between soils and land type. The highest grade agricultural land is predominantly located on the fertile peat soils within the CFMP area. Artificial drainage of these flat, Fenland areas has enabled the land to be used for arable production, however these artificial drains have implications for runoff as water can be dispersed more quickly.

The lower grade land is found in the most east and western ends of the catchment on gravelly or clay soils, with the majority of the land classed as Grade 3 with some pockets of Grade 4 and non-agricultural land. The poorly drained clay soils, combined with steeper slopes, make arable production less viable in these areas.

The largest area of non-agricultural land is found to the north of Bury St Edmunds at Thetford Forest.

The Great Fen project aims to restore 3,000 hectares of natural Fenland habitat between Huntingdon and Peterborough and is an example of how the future land use may change. Changes of this type would have implications for future flood risk management by providing opportunities for the storage of floodwater.

2.6.2 Land use and land management

Several categories of land cover in the Great Ouse CFMP area are shown in Figure 2-13 and the proportion of the land cover categories within the catchment are shown in Table 2-2. Land use tends to be linked to the agricultural land classification class, and thereby to soils, topography and geology.

The catchment contains a mixture of land uses with agriculture and urban development comprising 65% and 7% of the total catchment area respectively. The Fens area, with its deep clay and peat soils, intensively managed drainage and Grade 1 and 2 land classes, is dominated by arable land, in comparison to the more varied land use in the surrounding areas.

The area to the north of Bury St Edmunds has a higher density of woodland due to Thetford Forest, as well as large pockets of set-aside and natural grassland. To the west of Milton Keynes, where soils are mainly clay with some pockets of limestone, gravel and sand, and where there are pockets of Grade 2 and Grade 3 land, the land use is more complex and mixed. Here there are larger areas of improved grassland and broadleaf/mixed woodland as well as arable land. The main areas of arable land correlate with those areas of grade 2 or grade 3.

Table 2-2 Land use

Land Use	Area (km^2)	%
Arable	5,562	64.7
Grassland	1,605	18.7
Woodland	744	8.6
Urban	586	6.8
Other	99	1.2
Total	8,596	100

Land management practices continue to change as agriculture tends to become more intensive. Drainage and cultivation on the Fens has resulted in peat shrinkage and wind erosion of the fragile soils. Good practice aims to control the erosion of agricultural soil through contour ploughing and leaving uncultivated strips around field boundaries. Whilst there is some conversion to grazing, the extent of intensive agriculture, the drainage infrastructure (managed drains, pumping stations and raised watercourses) and recent rises in food prices means that it is unlikely that the use of this land will change significantly in the near future.

The way land is managed can influence flood risk by affecting how water run-off is generated and sediment transported. Factors that influence these processes on agricultural land include:

- the type of crops grown (for example, crops that cover less of the soil surface are likely to generate more run-off and sediment during rainfall events, which could exacerbate flooding);
- the way the land is prepared for sowing or planting (for example, coarser and less compacted seedbeds produce less surface wash and sediment transport, which reduces run-off);
- the time of year fields are cultivated or left fallow (for example, uncultivated over-winter set aside is more likely to generate run-off and sediment, thereby increasing the likelihood of flooding);
- intensity of animal grazing (for example, soil compaction by trampling encourages run-off and cattle access to ditches can break up banks and increase erosion).

Seasonal variability in land use cover, due to farming and land use practices, is also likely to have an effect on flooding. For example, run-off is likely to be promoted more during the winter months when there is less coverage by crops. Land management practices which could potentially mitigate flood risk are encouraged as part of the Environmental Stewardship Scheme. The Higher Level Stewardship, which targets high priority situations and areas, aims to:

- make land ‘available’ for flooding; and

- implement resource protection measures that will reduce the likelihood of localised flooding incidents.

These aims will be achieved by encouraging land management options that reduce surface water run-off and/or promote storage of floodwater. The opportunity to convert arable land to grassland and change farming practices to those requiring less drainage, has potential flood management benefits through a reduction in surface water run-off. As well as government policy influencing how agricultural land is used and protected, other key factors will drive the future of agricultural land use. These include; consumer demand, climate change, availability of water resources, and the productivity of soils.

2.6.3 Urban development

The Great Ouse CFMP area is predominantly rural, but has several large urban centres and many more scattered communities. The main urban centres are shown in Figure 2-13 and the rural nature of the catchment is apparent from the relatively slight urban fraction listed in Table 2-3. The main urban centres of Milton Keynes, Bedford, St Neots, Ely and King's Lynn are located along the River Great Ouse. Other main urban centres lie on its tributaries; Towcester on the River Tove, Cambridge on the River Cam, Bury St Edmunds on the River Lark and Thetford on the River Little Ouse.

While the urban areas represent a small proportion of the catchment, these are important areas that can have a notable affect on flood risk, not just locally but also to neighbouring areas. The extent and location of urban areas define the distribution of impermeable surfaces such as roads and buildings, and are generally served by piped drainage systems. This results in a more rapid response to rainfall, due to the increased runoff, and quicker discharge into rivers. Urban areas may also be at risk from surface water, groundwater and sewer flooding.

Development in flood plains can significantly increase flood risks, even if defences are put in place, as although defences can reduce risk they cannot eliminate risk completely. Development in the flood plain not only increases runoff but also reduces flood storage capacity and flow conveyance across the flood plain. Current planning practice is to provide storage areas, such as the Towcester Flood Alleviation Scheme and the Milton Keynes Balancing Lakes. The Milton Keynes Balancing Lakes are specifically designed to store surface water, although Anglian Water who manages them can use them for also storing flood flows if the conditions allow it. Urban areas are normally drained by urban drainage systems comprising piped drainage and open watercourses. It is possible that during severe flooding these systems can become overwhelmed.

There are many urban areas within the CFMP area which are rapidly growing, such as Milton Keynes, Bedford, and Cambridge. The East of England Plan sets out a plan for the provision of 508,000 additionally dwellings in the East of England area between 2001 and 2021, with 19,000 of these new dwellings in Cambridge, 20,800 in Milton Keynes and Bedford and 11,000 in Fenland. Much of the development and growth is linked with improvements in road and rail connections, in particular connections to London. Growth is less rapid away from these major connections, for example towards the eastern side of the catchment around Swaffham and Brandon. Some of the key urban areas and their populations are detailed in Section 2.9. In Chapter 4 we look at how urban growth in the CFMP area is likely to influence river flows in the future, and we examine growth expected in each sub-catchment.

Table 2-3 Comparison of urban development in the UK

Catchment	Area (km^2)	Percentage Urban Catchment (%)
Thames (downstream to Teddington Weir)	10,000	8.8
Trent (downstream to Cromwell Weir)	8,225	14.6
Severn to Sandhurst	9,986	5.5
Great Ouse	8,596	7

Source: FEH Handbook, 1999

Figure 2-12 Agricultural land classification

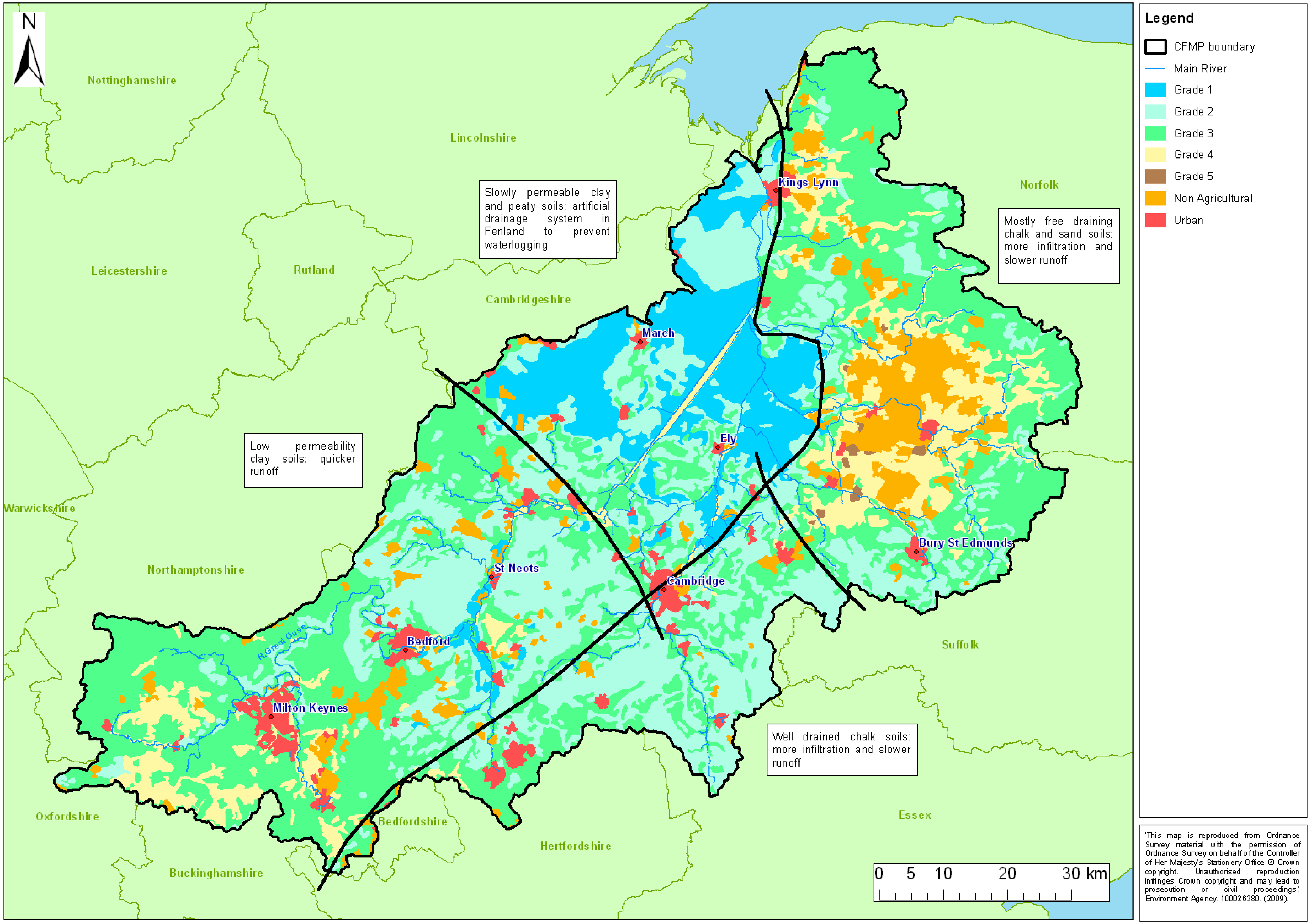
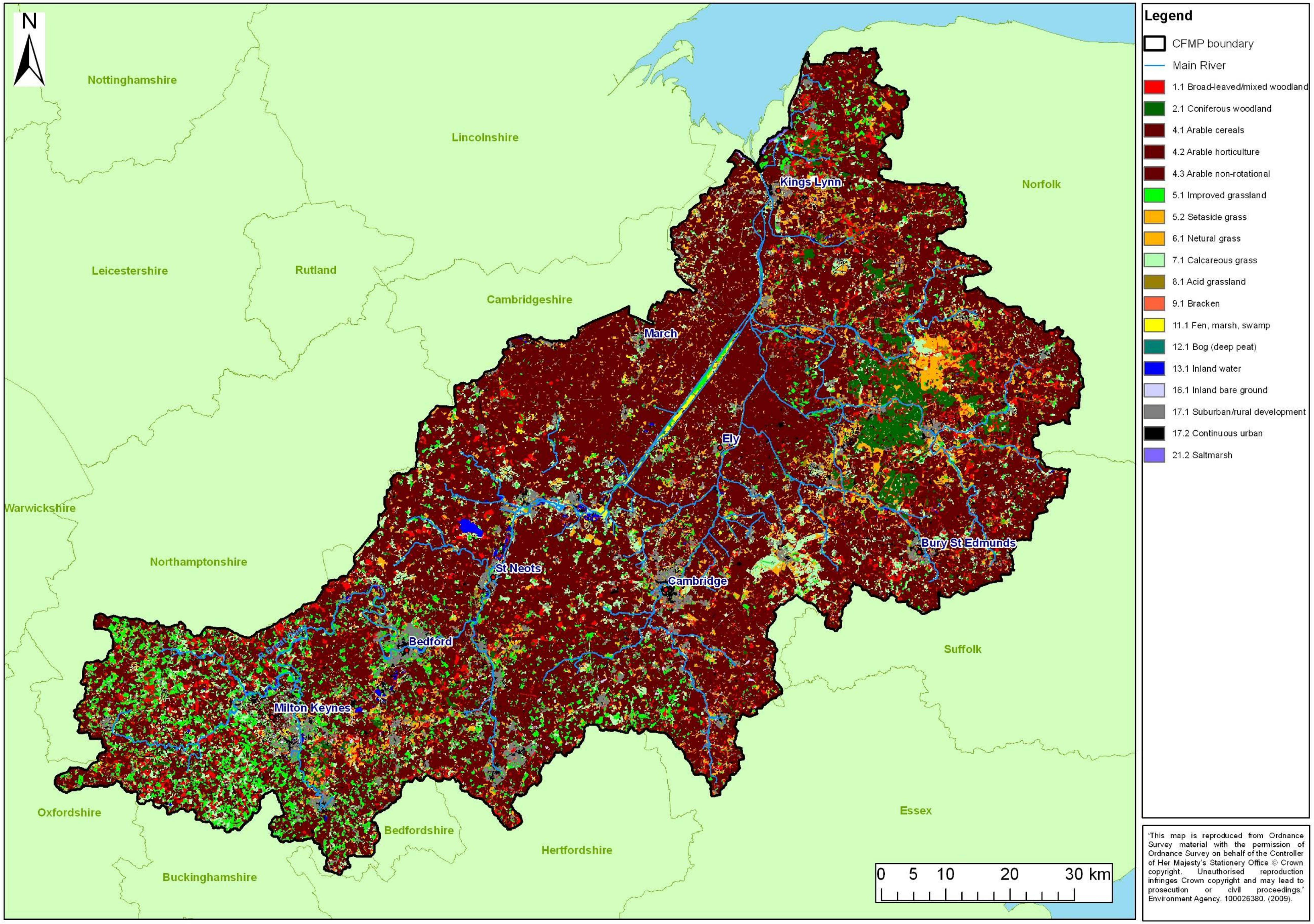


Figure 2-13 Land use



2.7 Hydrology

2.7.1 Introduction

To effectively develop flood risk management polices it is important that we fully understand the processes that lead to flooding. An important aspect of this is how the catchment responds to rainfall. In this chapter, we discuss how the catchment characteristics influence flows in the rivers. We present theoretical design flood hydrographs for the Great Ouse and the major tributaries so that we can compare the design peak flow and the time-to-peak of each of the tributaries. The design hydrographs are calculated using the Revitalised Rainfall Run-off (ReFH) method from FEH-CD ROM version 2. Where information is available, we also show flood flows measured at river flow gauging stations.

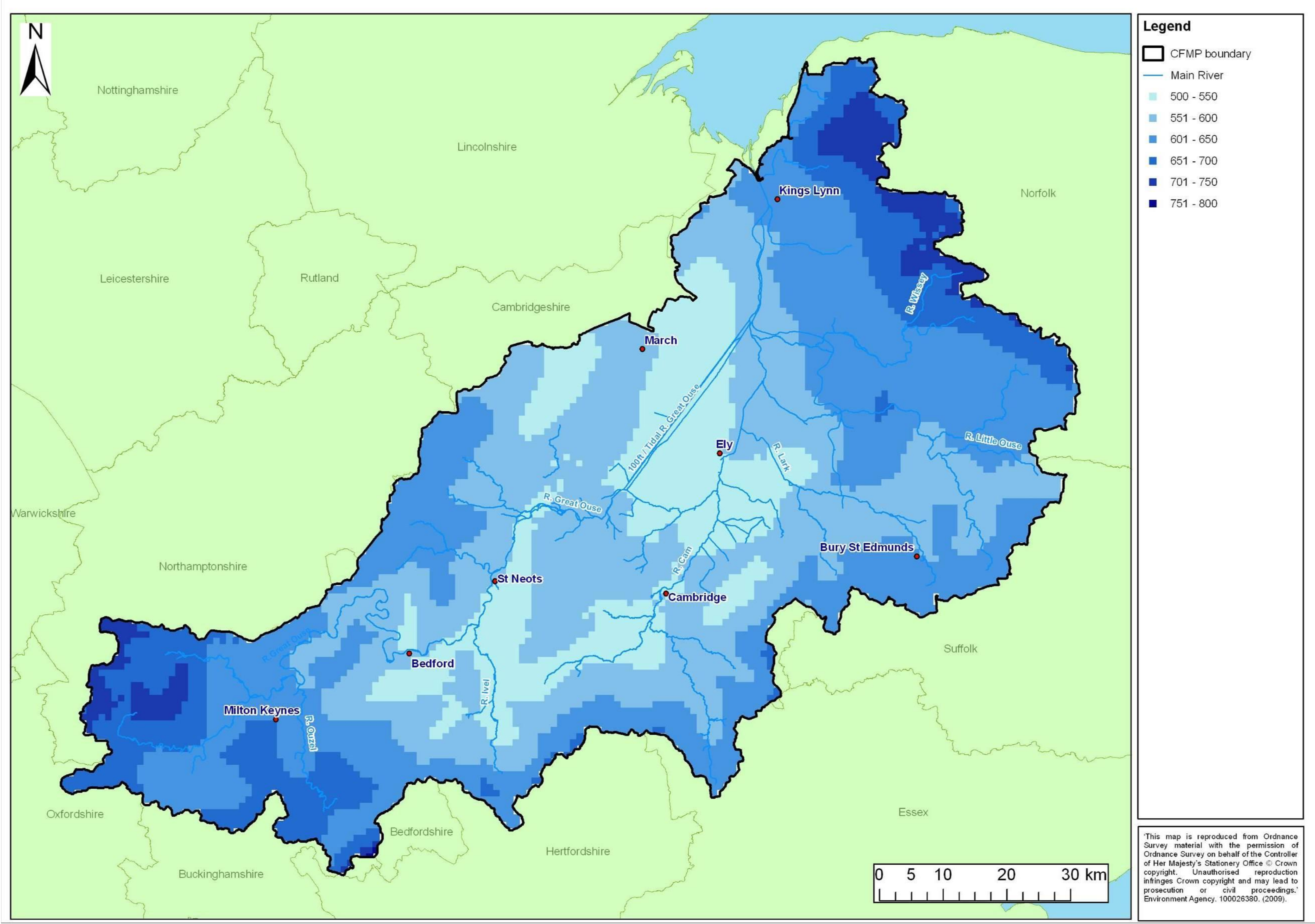
The main rivers of the Great Ouse CFMP area are shown on Figure 2-1. The River Great Ouse is the primary river system, and the main tributaries include the River Tove, River Ouzel, River Ivel and the River Cam. The drains and small watercourses of the Fens are also an important feature. The catchment consists of seven main hydrological units defined by their topography and hydrological similarities. Figure 2-4 shows these hydrological units as sub-catchments. We will use these sub-catchments to help describe the hydrology of the CFMP area and also in Chapters 3 and 4 to help describe current and future flood risk.

The seven sub-catchments are:

- **Upper Bedford Ouse:** River Great Ouse from its source near Brackley to Kempston Weir near Bedford including tributaries such as River Tove and River Ouzel;
- **Lower Bedford Ouse:** The navigable River Great Ouse from Kempston Weir to the tidal boundary at Brownshill Staunch, near Earith including tributaries such as River Ivel, River Kym and Alconbury Brook;
- **River Cam Catchment:** River Cam from its source to Bottisham Lock downstream of Cambridge including the Rivers Rhee, Granta and Bourn Brook;
- **Fens - Middle Level:** includes the major drains of the Hundred Foot Drain (Old Bedford River) and the River Delph (New Bedford River) which flow from the Bedford hydrological unit at Earith to Denver Sluice. The Middle Level area covers numerous drains which are pumped into the main Great Ouse system, including the Counter Drain which is pumped into the River Delph via Welches Dam Pumping Station south of Manea and the Middle Level Main Drain which discharges to the tidal River Great Ouse via St Germans Pumping Station at Wiggenhall St Germans;
- **Fens - South Level:** includes the Ely Ouse / Ten Mile River and drains water from both the River Cam Catchment and the Eastern Rivers sub-catchment and includes the Lodes such as Soham, Cottenham and Bottisham. Water levels in the Fens - South Level are maintained by Denver Sluice;
- **Eastern Rivers:** including the upstream undefended reaches of the Rivers Lark, Little Ouse, Wissey and their tributaries;
- **North West Norfolk:** includes the Rivers Heacham, Ingol and Babingley, which drain directly into the Wash and the Rivers Nar and Gaywood which drain into the tidal River Great Ouse at King’s Lynn.

Much of the CFMP area lies within one of the driest parts of the UK. The annual rainfall distribution over the catchment is shown on Figure 2-14. The areas of greatest precipitation occur in the western (to the south and west of Towcester) extremes of the catchment and to the north east and east of King’s Lynn with over 700mm/year of rainfall. Much of the central part of the catchment has less than 600mm/year of rainfall. In comparison, the average rainfall for England is 838mm/year (1971-2000, source: Met Office). The measurement of river flow, water levels and rainfall takes place at gauges throughout the catchment. The locations of these gauges are shown in Chapter 3. We use these to help us monitor river flows and also to calibrate our river models.

Figure 2-14 Annual rainfall distribution



The response of a catchment to rainfall or snowmelt is controlled by a variety of catchment characteristics, including vegetation, soils, geology and the surrounding topography. Often the first point of impact for rainfall is vegetation. Temporary storage of rainwater can be created, depending upon the type and extent of vegetation cover. Water leaving the plant surface of falling directly on the ground as rainfall will either seep into the soil or run-off the surface into a stream or river channel. In some circumstance water seeping into the soil can percolate to groundwater. Once within the soil, water can move laterally to rivers or other watercourses.

The flow path is controlled by the characteristics of the vegetation, soil, geology and topography. For example, in some of the higher elevations of the smaller tributary catchments, the steep slopes promote higher run-off. The network of small watercourses on the Slade system in Saffron Walden has steep slopes and this promotes quick response times and run-off.

The response of the River Great Ouse to rainfall varies along its length. In the Upper Bedford Ouse the response can be quick, especially in the upstream reaches, due to surrounding topography. By contrast the Lower Bedford Ouse responds more slowly to rainfall as it receives flow from the Upper Bedford Ouse and tributaries. This increases the lag time between rainfall and flooding.

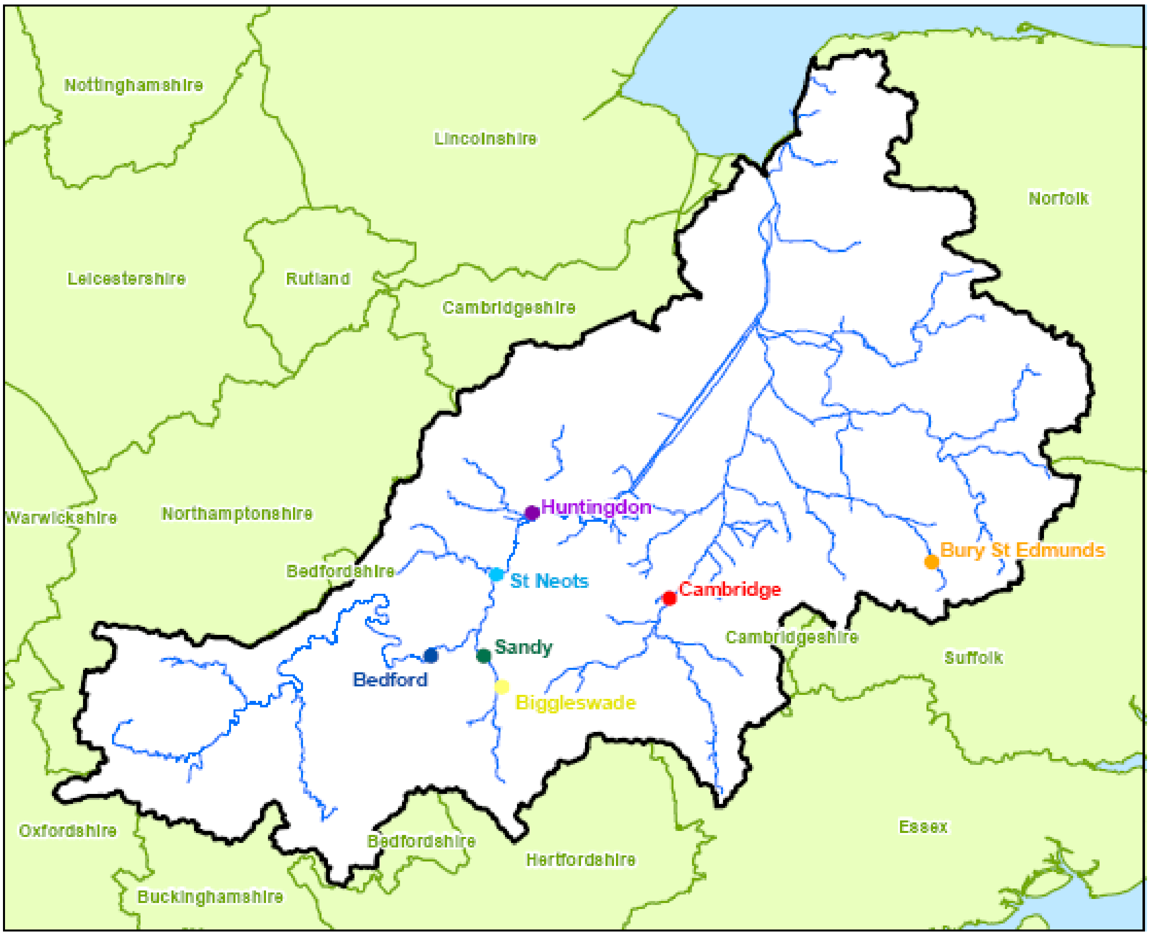
Figure 2-15 shows how the flow varies with time at key locations throughout the catchment for the 1% AEP river flood. Along the River Great Ouse, the catchment response changes with distance downstream due to the influence of tributaries and floodplain storage. On the River Cam, at Cambridge, and River Lark, at Bury St Edmunds, the storm hydrographs show that the catchment responds quickly to runoff, principally due to the steeper slopes.

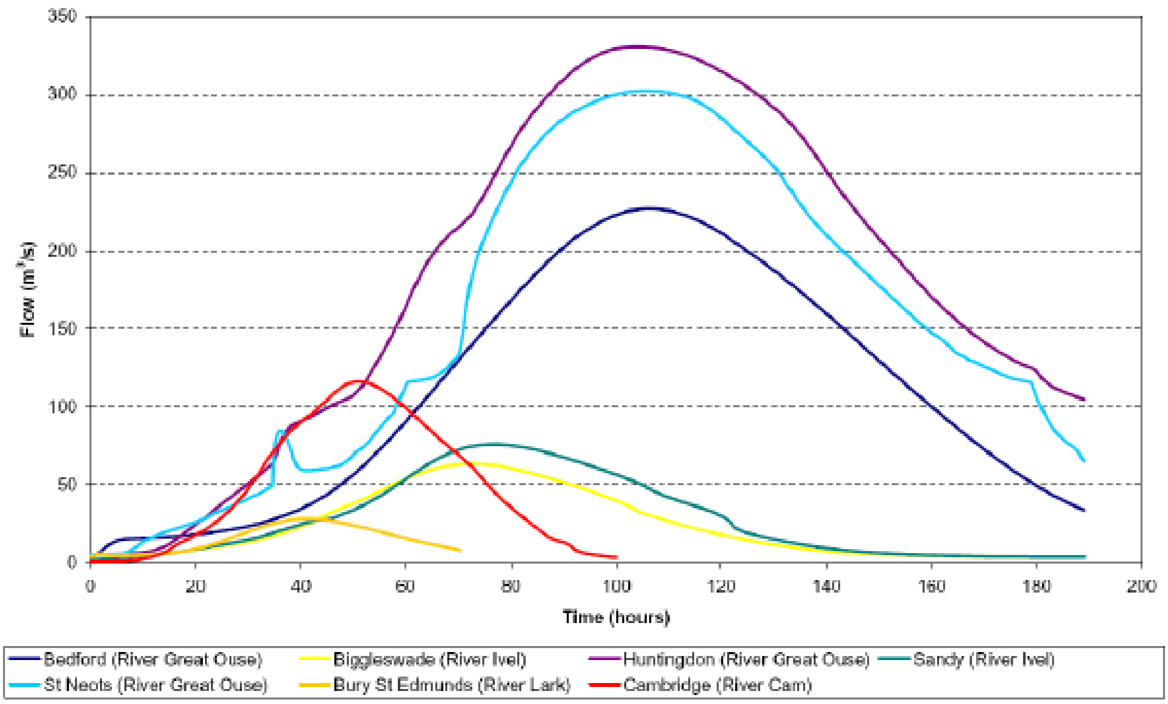

Great Ouse

In contrast, along the main River Great Ouse, between Bedford and St Neots, the flood peak increases significantly, showing the impact of tributary contribution with distance downstream, and also due to limited floodplain storage in the upper catchment. The Great Ouse at Huntingdon shows a slightly higher peak hydrograph compared to the Great Ouse at St Neots, demonstrating the impact of diminishing tributary contribution moving downstream. Figure 2-15 shows that by the time the hydrograph peaks at Huntingdon, all flows from major tributaries have already peaked and started to decline. This illustrates the importance of the flow volume from the upper catchment, principally the Bedford Ouse part of the Great Ouse system.

In the lower Fenland area, the lower gradients mean that water moves more slowly to the network of watercourses. In these areas there is a reliance on pumped drainage. Flood risk is therefore significantly reduced by the management of the drainage systems by the various IDBs which operate.

Figure 2-15 Flow hydrographs for the 1% AEP river flood at key locations

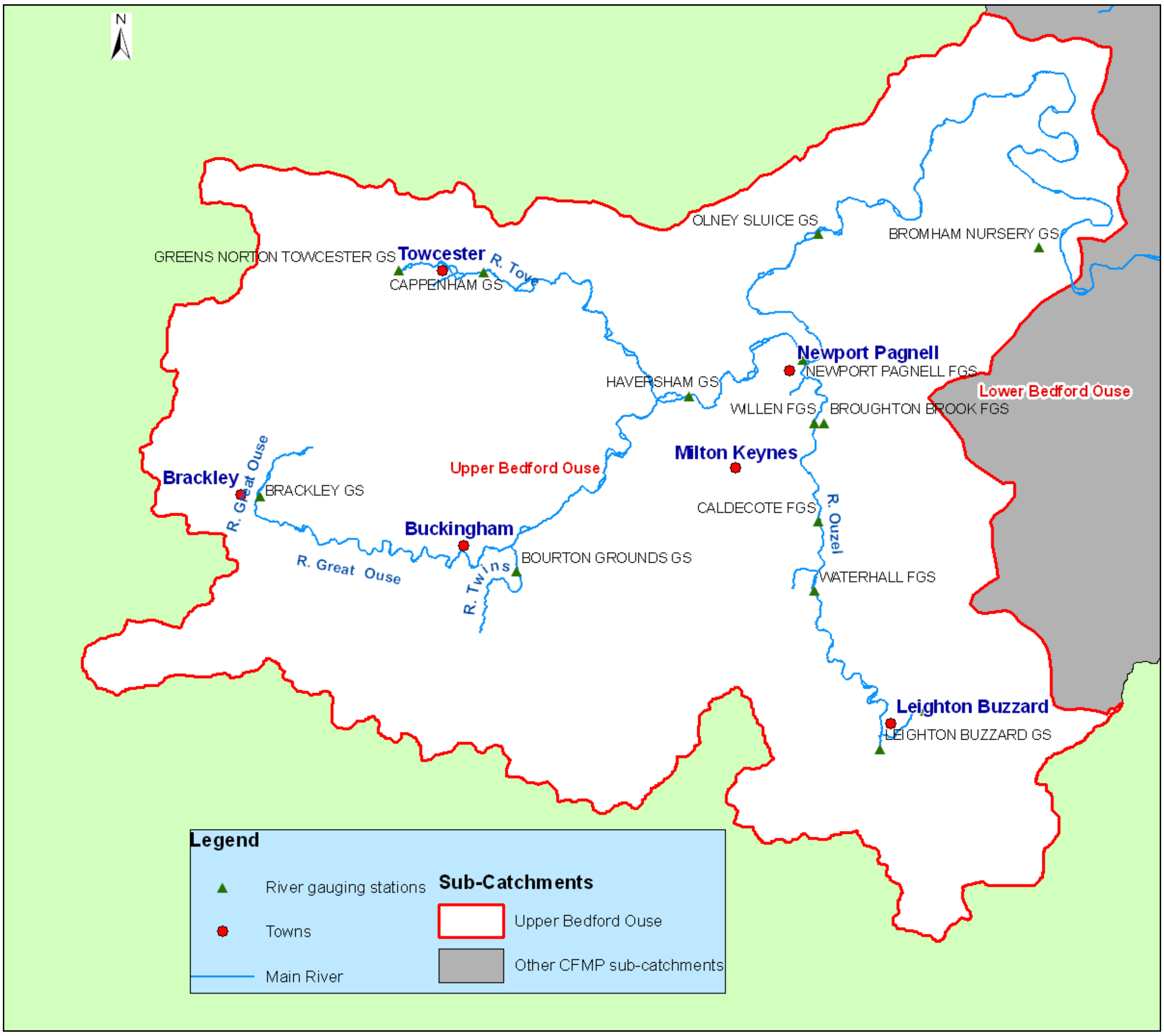




2.7.2 Upper Bedford Ouse

The Upper Bedford Ouse sub-catchment is the furthest upstream in the CFMP area. The River Great Ouse rises in this sub-catchment near Brackley and flows through Buckingham, past Milton Keynes, Newport Pagnell, Olney and Harrold on its way to Bedford. The downstream limit of this sub-catchment is Kempston Weir just upstream of Bedford. Tributaries of the Great Ouse include River Twins, River Tove and River Ouzel. Figure 2-16 shows the main rivers, towns and river gauging network.

Figure 2-16 Upper Bedford Ouse sub-catchment



The Upper Bedford Ouse sub-catchment is susceptible to rainfall from typical winter frontal systems moving across the catchment from the south west. Widespread winter rainfall is common. Much of the sub-catchment has soils of moderate or low winter rain acceptance potential. As a result, rainfall can cause rapid and relatively large run-off which can result in flooding. The most important man-made flood storage areas in the Upper Bedford Ouse sub-catchment are the Towcester Flood Alleviation Scheme (FAS) and the Milton Keynes Balancing Lakes. These flood storage areas allow upstream and/or urban areas to be drained quickly while preventing high flows affecting downstream areas.

The main tributaries of the Upper Bedford Ouse are the River Tove and the River Ouzel. Table 2-4 indicates their importance in relation to the main River Great Ouse, based on design peak flows calculated using the ReFH method. This shows that contribution from the River Ouzel is greater than that from the River Tove.

Table 2-4 Relative importance of tributaries to Upper Bedford Ouse

Tributary	Location of confluence	Catchment area (km^2)	1% AEP peak flow of tributary (m^3/s)	1% AEP peak flow of Great Ouse d/s of confluence (m^3/s)
River Tove	Stony Stratford	217	71	184
River Ouzel	Newport Pagnell	366	100	280

Peak flows calculated using ReFH - winter profile was assumed to produce the runoff hydrographs.

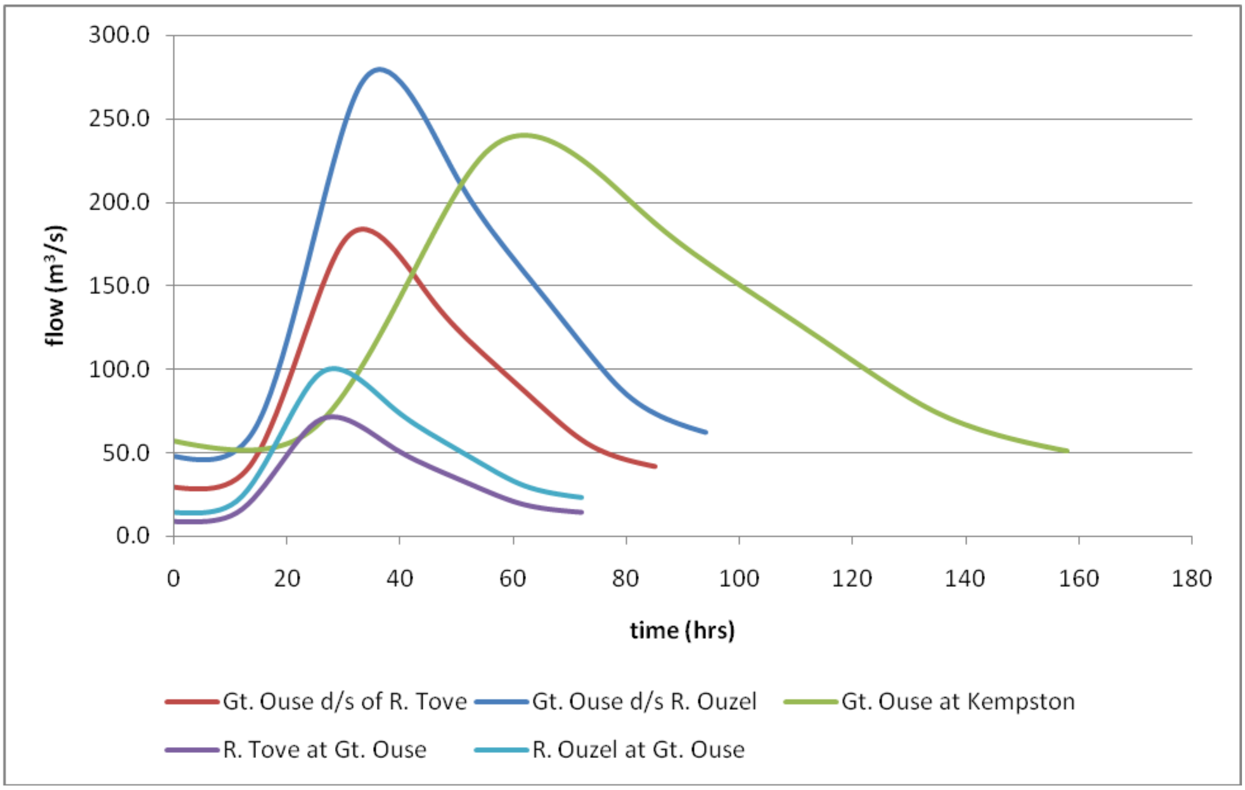
The speed with which a flood occurs following heavy rainfall event is a major contributory factor to flood risk and its associated impacts. The size of the catchment, slope of the watercourse and the land use have major impact on the time that the flow travels downstream and the peak flow that it produces.

Generally, in large river catchments, time-to-peak is relatively slow. In small, steep catchments, or upper parts of large catchments for example at the upstream extents of the River Great Ouse, the response time is short and in some cases there is often very little available warning time. For example, the flood peak travels relatively quickly along the Great Ouse in the upper reaches, taking on average nine hours to reach Buckingham from Brackley. By contrast, as the topography starts to flatten and flood flows slow down, the peak of the flood takes an average 41 hours to travel between Newport Pagnell and Bedford.

In Figure 2-17, we have plotted the 1% AEP design flood hydrographs created from the ReFH analysis. From the design hydrographs we can see the smaller and shorter duration floods of the tributaries against the flow hydrographs of the Great Ouse just downstream of the confluences. The Rivers Tove and Ouzel respond quickly to the rainfall due to the steeper topography, water then travels towards the River Great Ouse where discharge increases due to the combined incoming flows from the Great Ouse upstream.

We also show the design hydrograph of the Great Ouse at Kempston (downstream limit of the sub-catchment). As the river approaches Kempston, the catchment is characterised by a flatter and lower topography. In this part of the catchment between the confluence of the River Ouzel and Kempston, there are no major tributaries flowing into the Great Ouse. This is illustrated by flatter hydrograph and large volume of the runoff. Whilst the peak flow reduces by approximately $40m^3/s$, the longer duration flood generates a much greater area under the hydrograph which effectively means a much larger volume of water is flowing through Kempston.

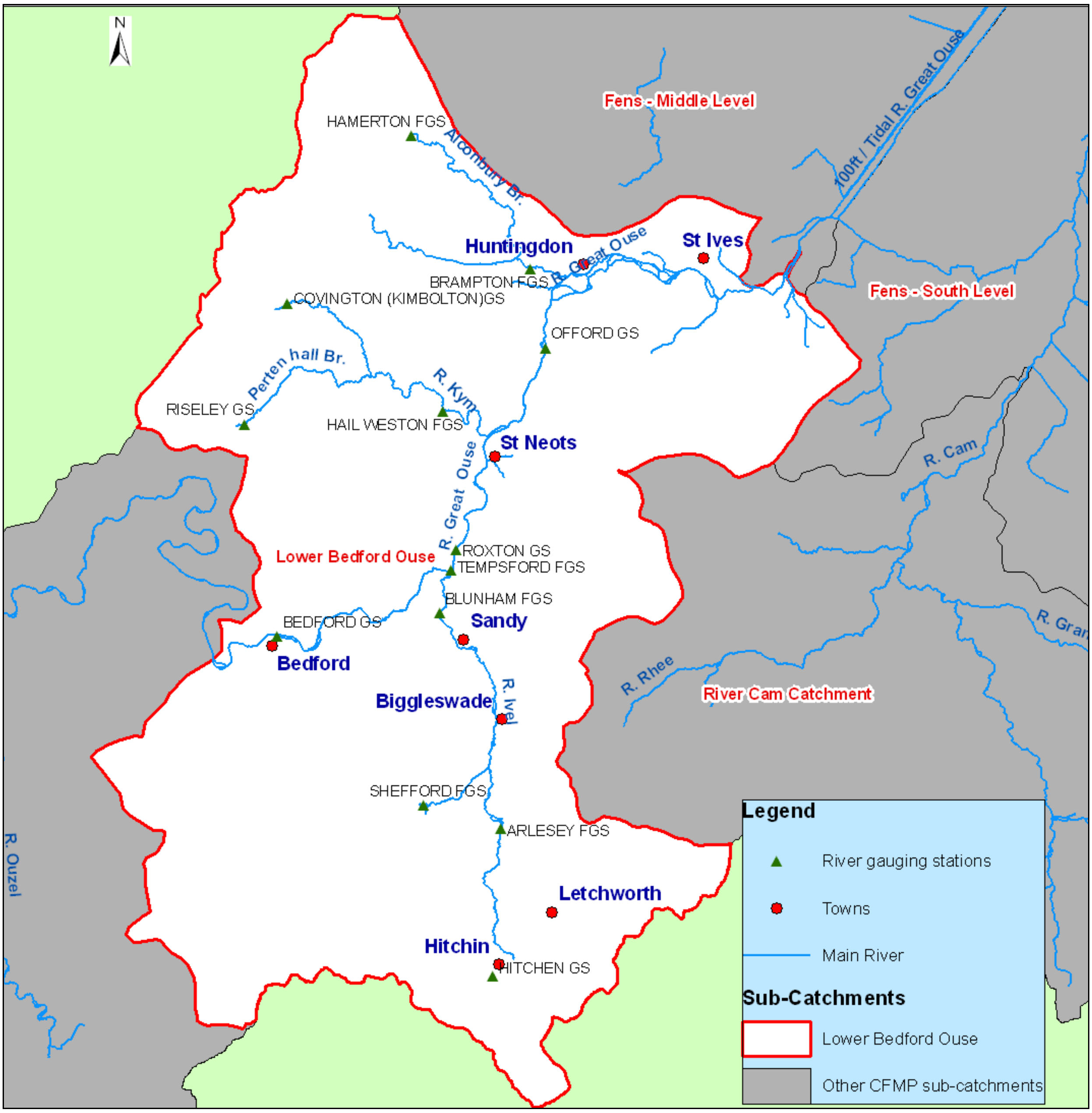
Figure 2-17 1% AEP design flood hydrographs for Upper Bedford Ouse



2.7.3 Lower Bedford Ouse

The Lower Bedford Ouse receives water from the Upper Bedford Ouse at Kempston Weir and flows north easterly to the tidal limit towards Earith, discharging to the tidal/100ft River. Here the Great Ouse is navigable and artificially maintained at levels suitable for navigation by a network of locks and river control structures such as sluices and weirs. Tributaries of the Great Ouse include River Ivel, River Kym, Brampton Brook and Alconbury Brook. Figure 2-18 shows the main rivers, towns and river gauging network.

Figure 2-18 Lower Bedford Ouse sub-catchment



As with the Upper Bedford Ouse, the Lower Bedford Ouse is susceptible to rainfall from typical south westerly winter frontal systems and widespread winter rainfall is common. Much of the sub-catchment has soils of moderate or low winter rain acceptance potential. As a result, rainfall can cause rapid and relatively large run-off which can turn into floods.

The main tributaries of the Lower Bedford Ouse are the River Ivel, River Kym and Alconbury Brook. Table 2-5 indicates their importance in relation to the main River Great Ouse, based on approximate peak flows from ReFH. This shows that the contribution of the River Ivel and Alconbury Brook is similar, with a lesser contribution from the River Kym.

Table 2-5 Relative importance of tributaries to Lower Bedford Ouse

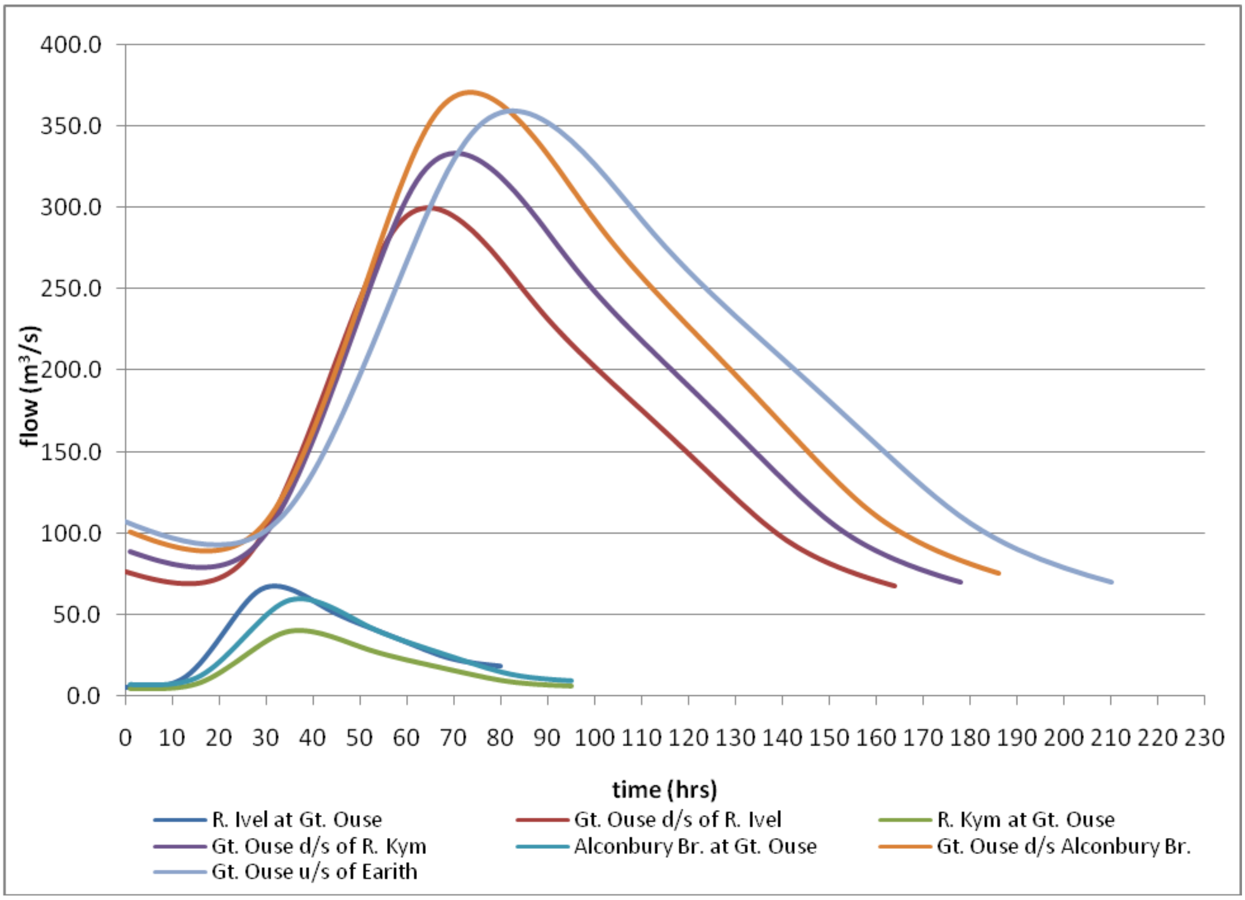
Tributary	Location of confluence	Catchment area (km^2)	1% AEP peak flow of tributary (m^3/s)	1% AEP peak flow of Great Ouse d/s of confluence (m^3/s)
River Ivel	Roxton	541	68	300
River Kym	St Neots	142	40	333
Alconbury Brook	Huntingdon	215	60	370

Peak flows calculated using ReFH - winter profile was assumed to produce the runoff hydrographs.

In Figure 2-19 we have plotted the 1% AEP design flood hydrographs created from the ReFH analysis. From the design hydrographs we can see the smaller and shorter duration floods of the tributaries against the flow hydrographs of the Great Ouse just downstream of the confluences. The Rivers Ivel and Alconbury Brook respond quickly to the rainfall due to the steeper topography.

The design hydrographs of the Great Ouse show an increase in peak flow and volume as we move down the catchment and the influence of each tributary is taken into consideration. As the river approaches Earith, the catchment becomes very flat with little gradient. In this part of the catchment between the confluence of the Alconbury Brook and Earith, there are no major tributaries flowing into the Great Ouse. This is illustrated by flatter hydrograph and large volume of the runoff. Whilst the peak flow reduces slightly, the longer duration flood generates a much greater area under the hydrograph which effectively means a much larger volume of water is flowing through Earith. The floodplain of the Great Ouse between Alconbury Brook and Earith is very wide characterised by a slow meandering channel with many side channels and backwaters.

Figure 2-19 1% AEP design flood hydrographs for Lower Bedford Ouse



The peak flow from the River Ivel reaches the confluence more than a day in advance of the peak flow from the Great Ouse CFMP area. As a result, the peak flow downstream of the confluence is dominated by the Great Ouse flow rather than the contribution from the Ivel.

Between the Ivel confluence and Huntingdon, principal tributaries are the River Kym, Brampton Brook and Alconbury Brook, all from the west. These tributaries respond relatively quickly to rainfall. However, between Huntingdon and Earith there is a very wide floodplain, allowing significant flood storage and flow attenuation before the river reaches Earith and the Ouse Washes. It is common for high flood levels to be sustained for a week or more in this area as flood waters enter and leave the floodplain storage. The average travel time for flood peaks between Huntingdon and Earith is 16 hours.

2.7.4 River Cam catchment

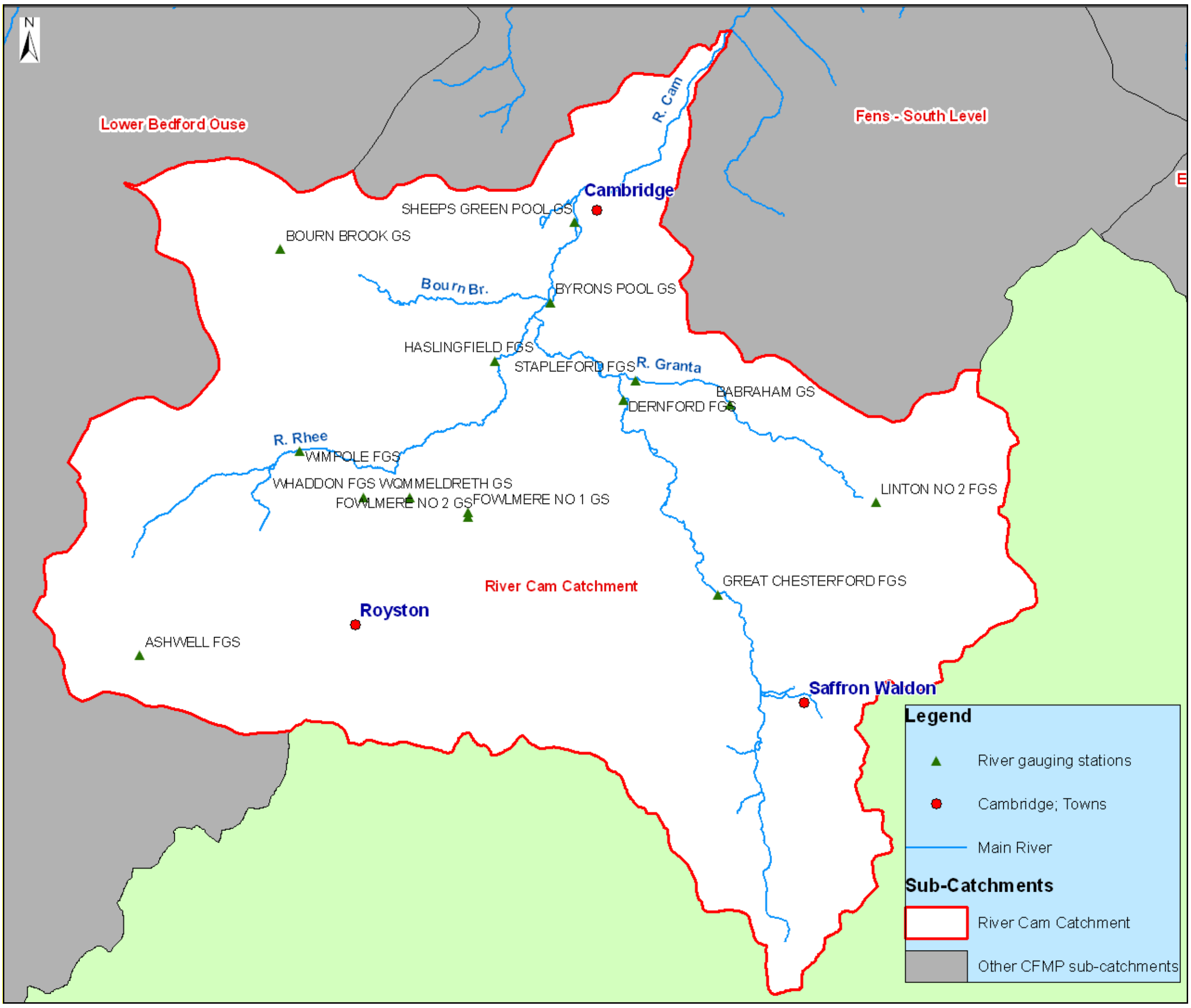
The River Cam rises north east of Henham village to the south of Saffron Walden at an elevation of approximately 123mAOD and flows in northerly direction towards Cambridge. Water levels in the River Cam through Cambridge and downstream are controlled for navigation by a series of locks and weirs. It is navigable for motorised boats as far upstream as Jesus Lock. Upstream of Jesus Lock the River is used mainly for leisure and tourism by punts.

Downstream of Cambridge the River Cam flows mostly within raised earth embankments and passes through low lying Fenland to the downstream limit of the sub-catchment at Bottisham Lock. Downstream of Bottisham Lock, the Cam flows within the Fens-South Level sub-catchment.

Tributaries include the River Granta to the east which joins the River Cam south of Great Shelford, the River Rhee to the west which discharges into the River Cam at Hauxton Junction and the Bourn Brook, also to the west, which joins the River Cam at Byron's Pool. Within Cambridge, the River Cam is joined by the Bin Brook downstream of Magdalene Street.

Figure 2-20 shows the main rivers, towns and river gauging network.

Figure 2-20 River Cam sub-catchment



The main watercourse within the River Cam sub-catchment is the River Cam. Principal tributaries are the River Rhee, Bourn Brook and the River Granta. None of the rivers have an extensive floodplain, so there is only limited flow attenuation through natural flood storage. Although the southern part of this catchment rises on chalk, groundwater flow from the chalk is not seen as a factor in flood flows.

Table 2-6 indicates the importance of the tributaries in relation to the River Cam, based on approximate peak flows from ReFH. The scale of the contribution of flow made by the Rivers Rhee and Granta and the Bourn Brook is similar.

Table 2-6 Relative importance of tributaries to River Cam

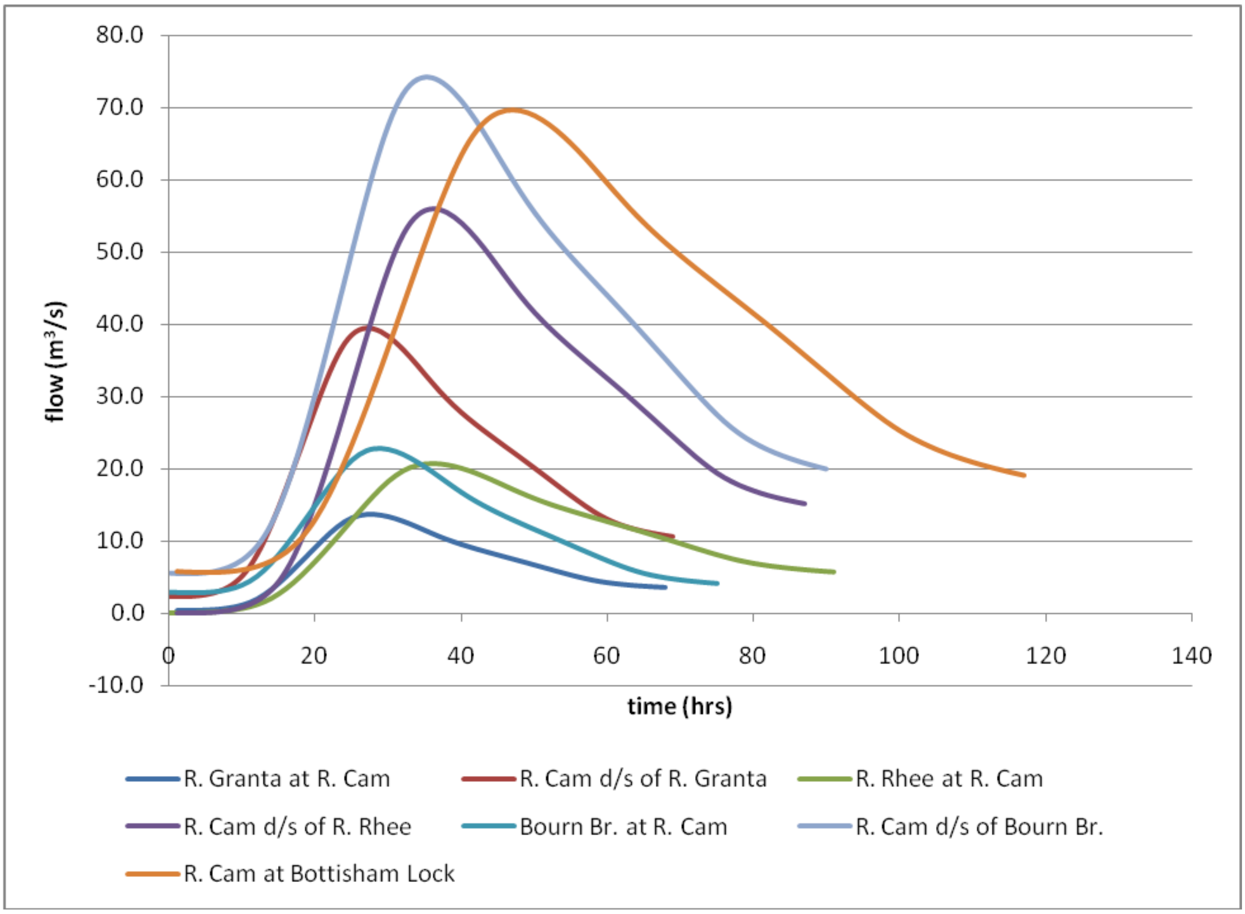
Tributary	Location of confluence	Catchment area (km^2)	1% AEP peak flow of tributary (m^3/s)	1% AEP peak flow of Cam d/s of confluence (m^3/s)
River Granta	Great Shelford	116	14	40
River Rhee	Hauxton Junction	310	21	56
Bourn Brook	Byron's Pool	87	23	74

Peak flows calculated using ReFH - winter profile was assumed to produce the runoff hydrographs.

In Figure 2-21, we have plotted the 1% AEP design flood hydrographs created from the ReFH analysis. From the design hydrographs we can see that although the Bourn Brook has a much smaller catchment area than the Rhee or Granta, the 1% AEP peak flow is actually greater. This reflects the fact that the Rhee and Granta flow mainly on highly permeable chalk catchments whilst the Bourn Brook flows on relatively impermeable mudstone.

It is evident from the graphs that as we move downstream on the River Cam, the peak flow increase as the influence of the tributaries is felt. This is certainly the case upstream of Cambridge, however, as the catchment flattens and the gradient of the River Cam reduces significantly downstream of Cambridge we notice that at Bottisham Lock the peak flow is less than the peak flow upstream at the Bourn confluence although the overall volume of water is greater.

Figure 2-21 1% AEP design flood hydrographs for the River Cam catchment



Historical flood records have shown us that the Rivers Cam and Rhee dominate overall flood flows. The Rhee and Granta are often characterised by an initial rapid rise in flows, however the travel time between Wimpole and Burnt Mill (Haslingfield) on the River Rhee can be as much as 24 hours. Downstream of Cambridge, the River Cam soon becomes an embanked river crossing the South Level.

2.7.5 Fens – Middle Level

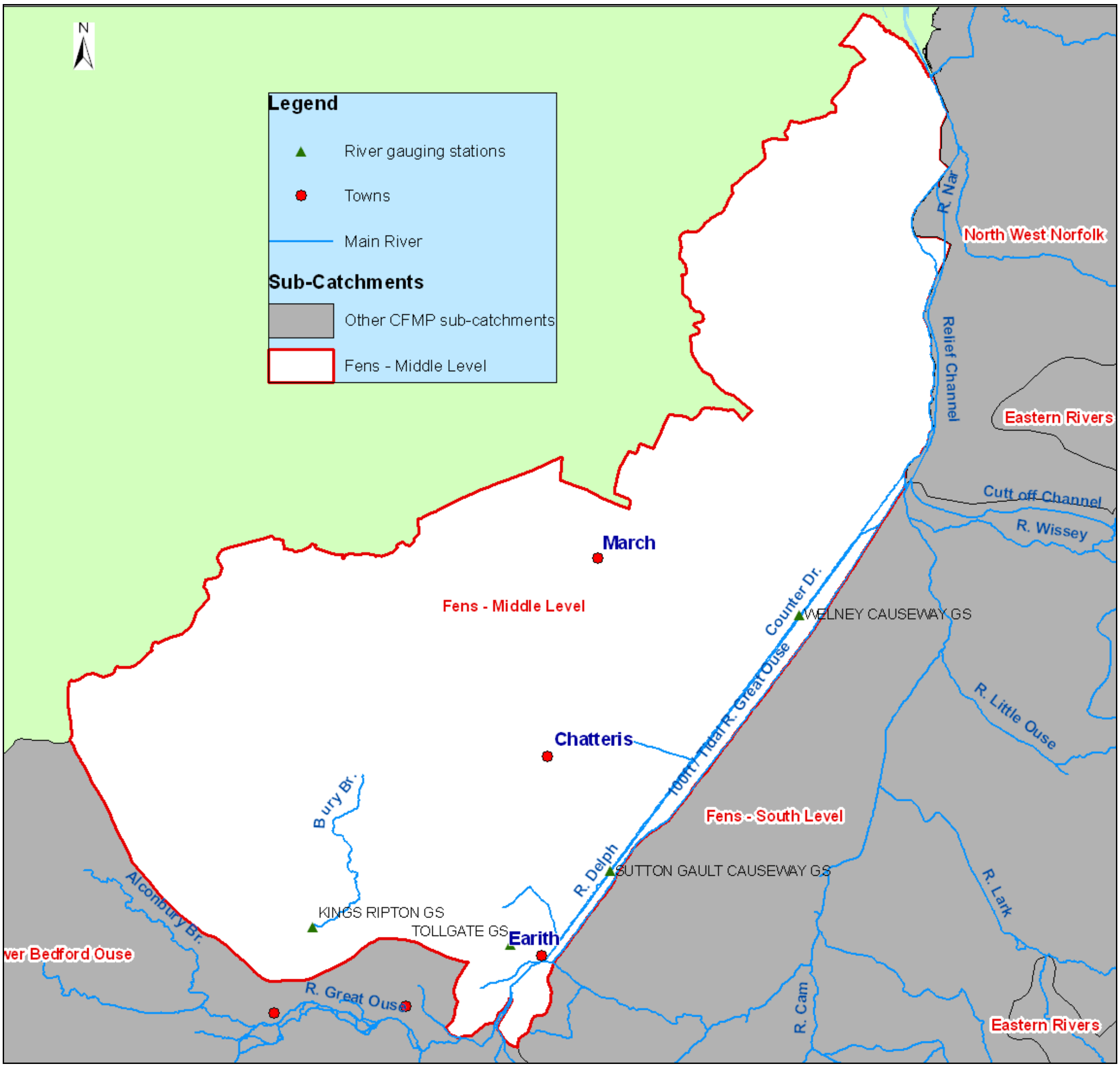
This part of the catchment runs from the Bedford Ouse tidal limit at Brownshill Staunch to Kings Lynn and the mouth of the tidal River Great Ouse. It is dominated by the low lying Fenland area of the Middle Level, much of which sits at or below sea level. It is a mostly pumped catchment discharging to the tidal River. The sub-catchment includes the main rivers of the tidal River Great Ouse/100ft drain (Old Bedford River), the River Delph (New Bedford River) which flow from the Bedford hydrological unit at Earith to Denver Sluice and the Counter Drain which is pumped into the River Delph via Welches Dam Pumping Station south of Manea.

The Middle Level area covers numerous IDB drains and watercourses which drain high grade agricultural land. The Middle Level Commissioners manage the drainage of this area. The low level drains are pumped into a high level system of main drains then into the Great Ouse via the Middle Level Main Drain which discharges to the tidal River Great Ouse via St Germans Pumping Station at Wiggenhall St Germans.

To the west of King's Lynn, the King's Lynn IDB (part of Water Management Alliance) manages the low level drainage network. Much of this part of the sub-catchment is pumped into the tidal Great Ouse, including Smeeth Lode which is pumped via Islington Pump.

During normal flow conditions the Bedford Ouse discharges down the tidal River/100ft drain, a man-made cut. This channel has a limited capacity and in times of flood, water is diverted via the sluice at Earith into the Ouse Washes. The Ouse Washes act as a flood storage reservoir discharging into the tidal River Great Ouse via the Welmore Lake Sluice (also known as John Martin Sluice) when tidal conditions permit. In very large floods the entire Washes acts as a channel for the passage of flood water. The Cradge Bank between the Washes and the Hundred Foot River is deliberately set at a low level so that in larger floods, or in the case of sluice or failure at Earith, water will overtop the bank and enter the Washes. In addition, this part of The Fens also collects water from the Ely Ouse (Fens – South Level), which drains the east part of the Great Ouse CFMP area, collecting water from three directions. Water, by way of the Ely Ouse, drains via the Denver Sluice where if low water conditions permit it is discharged to the Tidal River.

Figure 2-22 Fens - Middle Level sub-catchment



2.7.6 Fens – South Level

This sub-catchment comprises the Ely Ouse catchment, which includes the South Level Fenland area where drainage is managed by IDB's. The Ely Ouse drains water from both the River Cam catchment and Eastern Rivers and includes the Lodes such as Soham, Cottenham and Bottisham. Most of the catchment is flat and has soils with a very high or high winter rain acceptance potential. As a result, the response of river flows to rainfall is slow compared to the Bedford Ouse catchment. The catchment is almost wholly rural. There are a number of man-made flood storage areas, including the Cut-off Channel and Adventurer's Fen.

The Ely Ouse to Denver collects flood flow from three directions:

- the Old West River from Earith and its tributaries (to the south west);
- the Cam and its tributaries (to the south);
- the Lark, Little Ouse and Wissey (the Eastern Rivers).

Figure 2-23 Fens - South Level sub-catchment

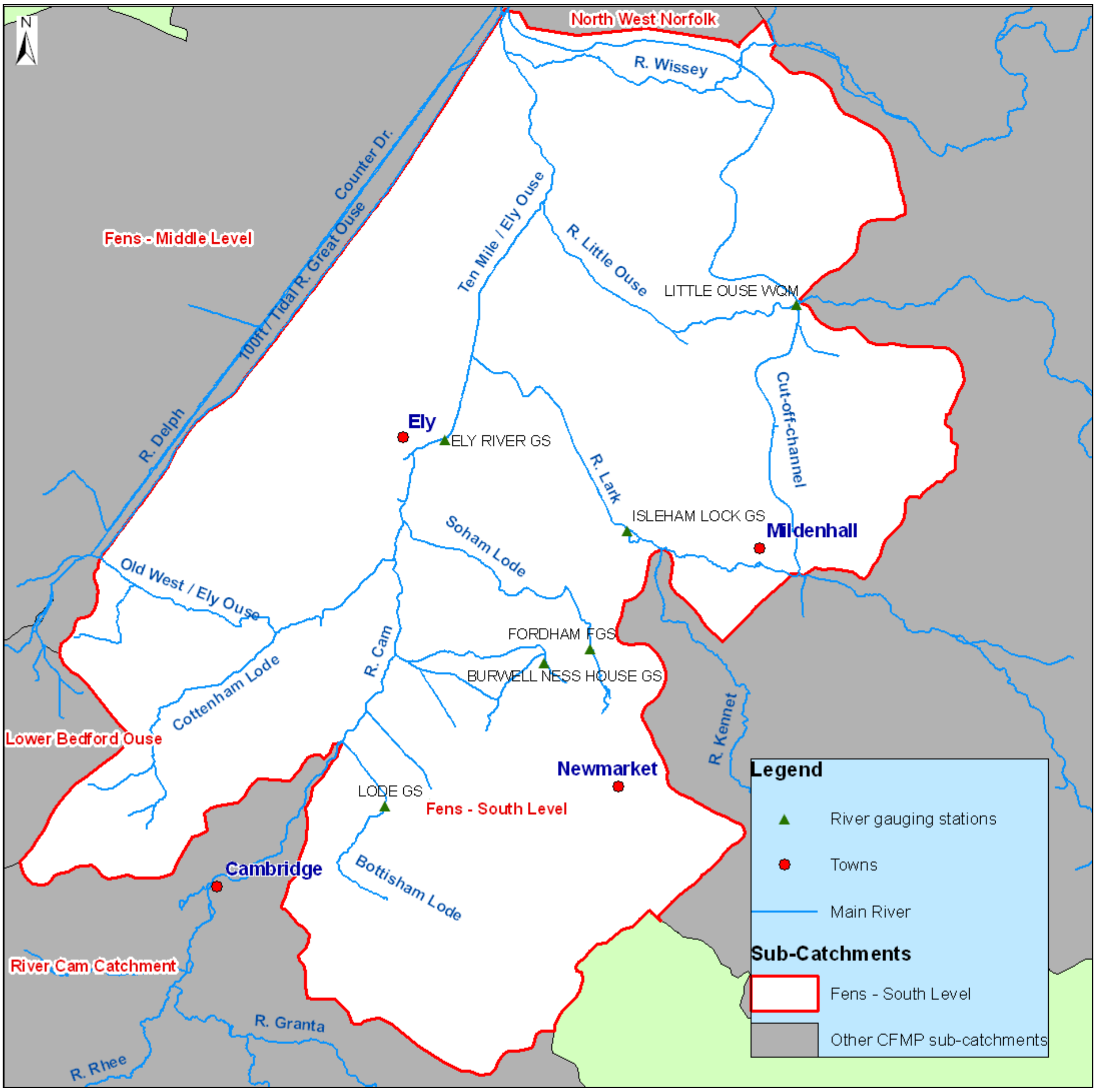


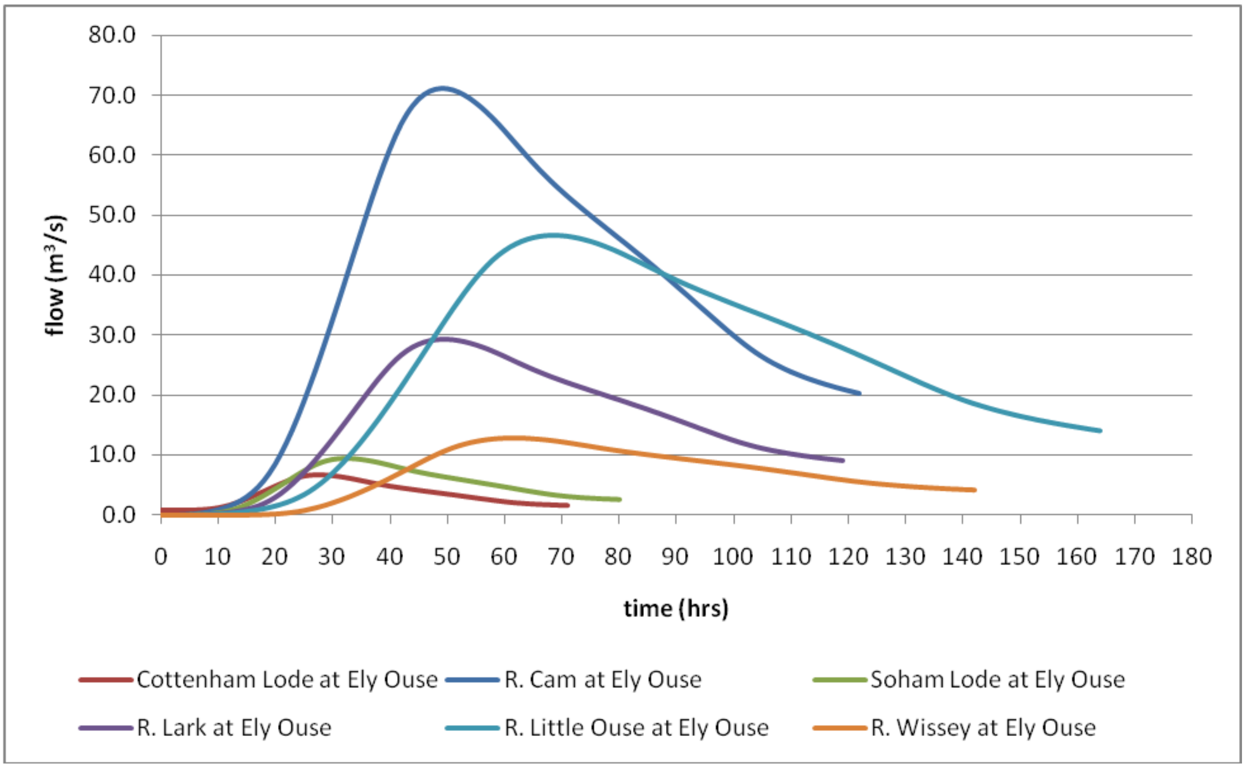
Table 2-7 indicates the importance of the tributaries in relation to the main River Great Ouse, based on approximate discharge values from FEH and broad scale modelling at locations just upstream from the relevant confluences. We can see that the largest watercourse by flow in the Fens South Level is the River Great Ouse, with the greatest contribution coming from the River Cam. The contributions from the River Little Ouse, River Lark, River Wissey and the Lodes are less.

In Figure 2-24, we have plotted the 1% AEP design flood hydrographs created from the ReFH analysis. The graph clearly shows the much slower response to rainfall than the Bedford Ouse tributaries. The River Wissey in particular, shows a very long time-to-peak and extended duration of flooding. The rivers in this sub-catchment sit mainly on chalk, which allows rainwater to percolate through and storing much of it in underground aquifers.

Table 2-7 Relative importance of sub-catchments in the Fens - South Level

Tributary	Catchment area (km^2)	1% AEP peak flow (m^3/s)
River Great Ouse (Earith)	3034	360
River Cam	1075	71
River Little Ouse	927	47
River Lark	630	29
River Wissey	546	13
Soham Lode	92	9
Cottenham Lode	32	7

Figure 2-24 1% AEP design flood hydrographs for the Fens – South Level



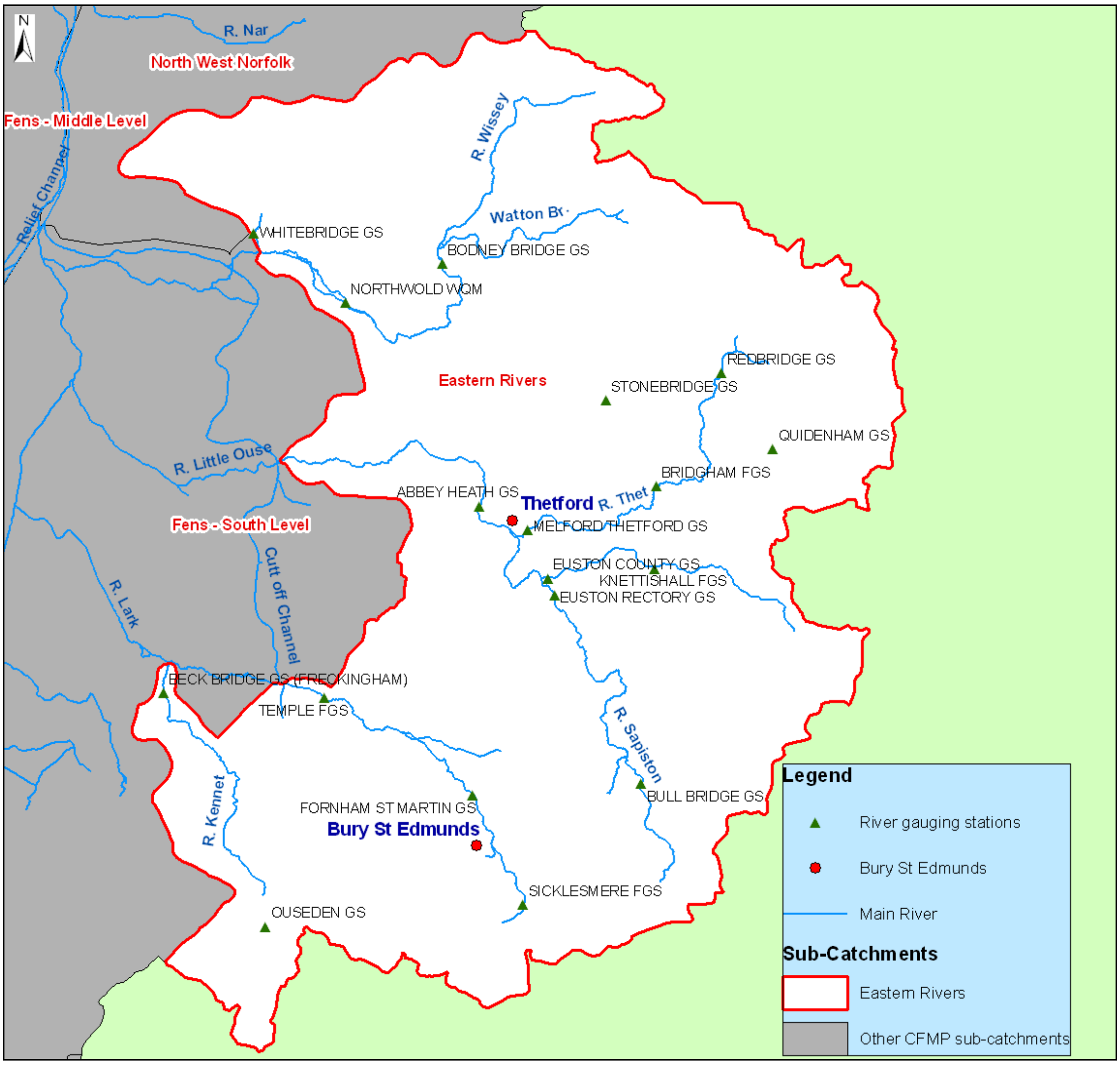
2.7.7 Eastern Rivers

The Eastern Rivers sub-catchment contains the upper reaches of the Rivers Lark, Little Ouse and Wissey and their tributaries. The downstream boundary of the sub-catchment is located at the point where each of the three tributaries becomes embanked before flowing through the Fens – South Level sub-catchment. For the Lark and Little Ouse, this is where the Cut-off Channel crosses. For the Wissey, this is a point just upstream of the Cut-off Channel at Whittington.

Tributaries include:

- River Lark – River Kennet and Culford Stream;
- River Little Ouse – River Thet and River Sapiston;
- River Wissey – Watton Brook.

Figure 2-25 Eastern Rivers sub-catchment



The geology of the sub-catchment is predominantly chalk. As a result, the rivers here react slower to rainfall than elsewhere in the Great Ouse CFMP area. They flow from east to west, towards the Ely Ouse and the Fens - South Level.

Table 2-8 Relative importance of tributaries to Eastern Rivers

Tributary	Location of confluence	Catchment area (km^2)	1% AEP peak flow of tributary (m^3/s)
River Lark			
Culford Stream	West Stow	48	1.7
River Kennet	Isleham	134	12
River Lark d/s of Culford Stream		207	14
River Little Ouse			
Sapiston	Euston	198	30
River Thet	Thetford	312	32
River Little Ouse d/s Sapiston		207	46
River Little Ouse d/s Thet		691	69

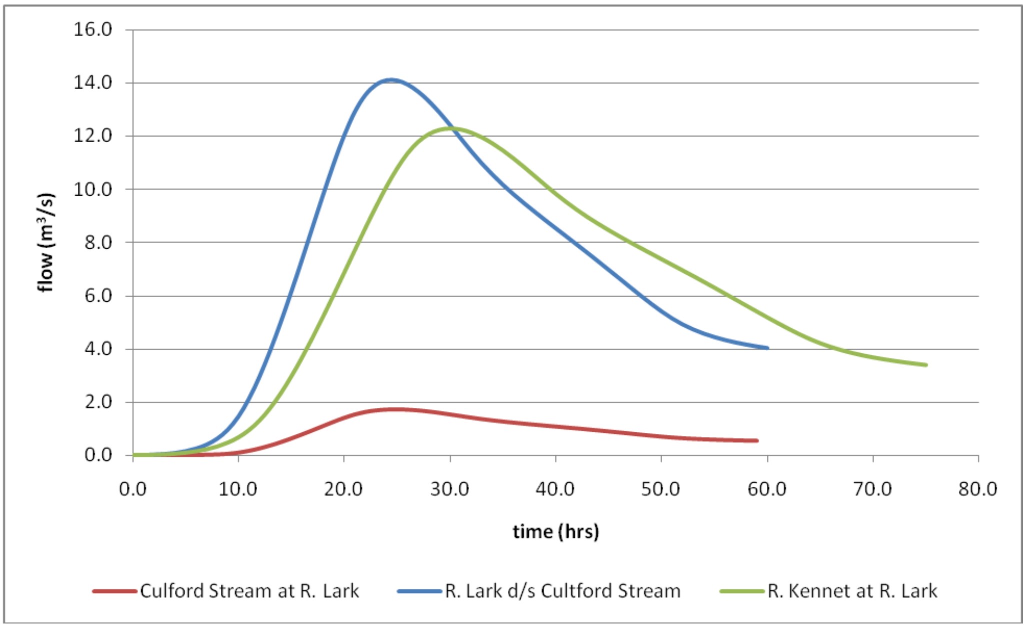
Tributary	Location of confluence	Catchment area (km^2)	1% AEP peak flow of tributary (m^3/s)
River Wissey			
Watton Brook	Hilborough	61	11
River Wissey d/s of Watton Brook		160	26
River Wissey u/s of South Level		445	16

Peak flows calculated using ReFH - winter profile was assumed to produce the runoff hydrographs.

In Figure 2-26 we have plotted the 1% AEP design flood hydrographs created from the ReFH analysis for the River Lark and its tributaries. The Culford Stream which enters the Lark at West Stow shows a very slow response to rainfall with time-to-peak equalling that of the much larger River Lark.

Flow in the River Kennet is broadly in proportion to that in the River Lark given their respective catchment areas. Although shown below that the River Lark peaks earlier than the River Kennet, our river flow records of part floods have shown us that the peak in the Kennet can occur up to 18 hours earlier than that in the Lark. The peak flow at Temple, a little to the east of Mildenhall, occurs about 36 hours after the rainfall peak.

Figure 2-26 1% AEP design hydrographs for River Lark and tributaries

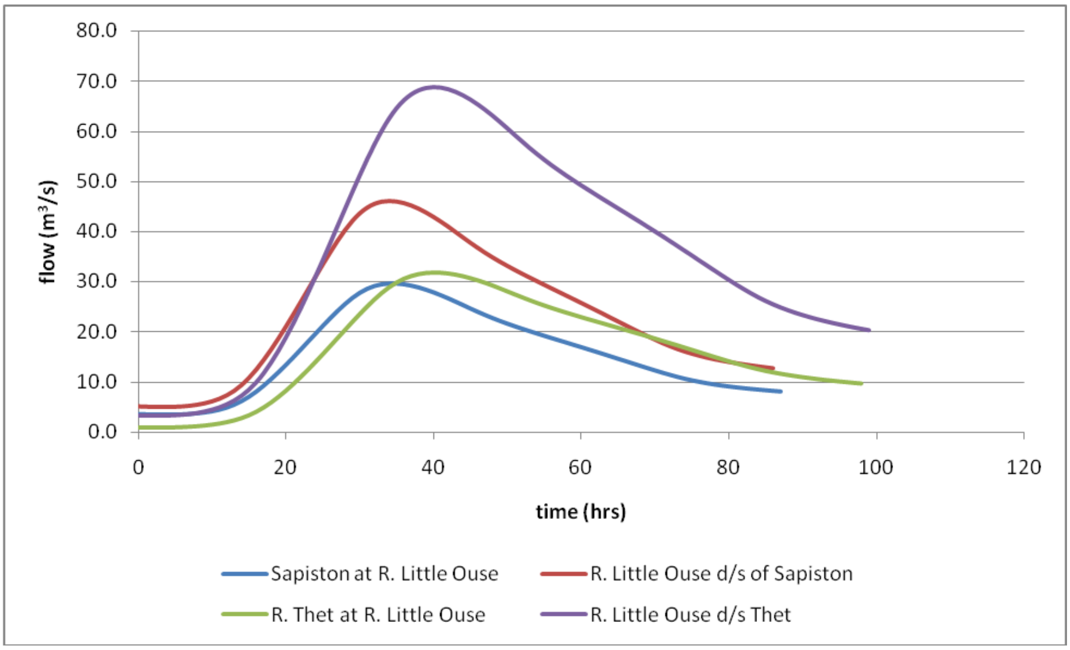


In Figure 2-27 we have plotted the 1% AEP design flood hydrographs created from the ReFH analysis for the River Little Ouse and its tributaries. The River Sapiston and the River Thet have very similar time-to-peak and 1% AEP peak flows, therefore contributing equally to the River Little Ouse flood flows. The River Little Ouse grows in peak flow and volume as it collects flow from each of the two tributaries.

The River Little Ouse and its tributaries upstream of Thetford have areas of floodplain which are utilised in river floods. Downstream of Thetford the river valley is more defined so floodplain storage is not a notable feature.

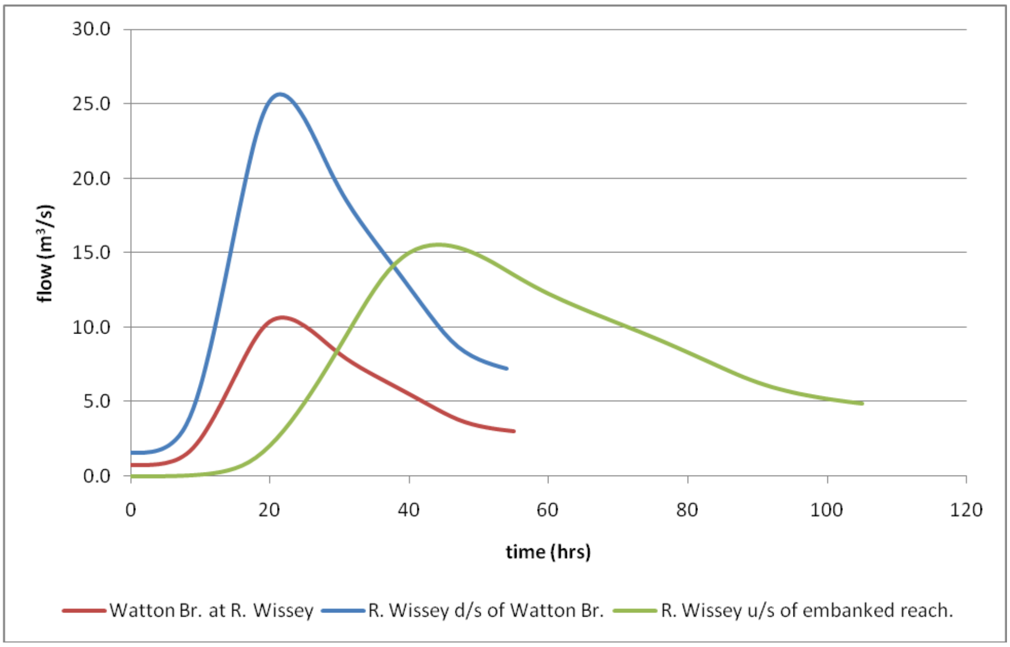
There is a slow reaction to rainfall on all the tributaries, including Sapiston Brook and the Little Ouse to County Bridge and the River Thet to Melford. Peak flows occur two days after the rainfall and the response is not rapid. The response times of the tributaries are similar to the response time at Abbey Heath, just downstream of Thetford.

Figure 2-27 1% AEP design hydrographs for River Little Ouse and tributaries



In Figure 2-28 we have plotted the 1% AEP design flood hydrographs created from the ReFH analysis for the River Wissey and its tributaries. The River Wissey dominates it's much smaller tributary, Watton Brook which joins the Wissey at Hilborough. There is a noticeable drop in peak flow as the River Wissey travels downstream towards the much flatter Fenland area. This can be attributed to the fact that there are no major tributaries entering the Wissey below Watton Brook and that the gradient of the river becomes much flatter as it moves downstream. The peak is essentially flattening out, taking longer move the volume of flood water downstream.

Figure 2-28 1% AEP design hydrographs for River Wissey and tributaries



The time from the rainfall to peak flow reaching the Ely Ouse/Cut-off Channel system at the South Level area is generally a little over 36 hours (Cam, Lark, Wissey) but is longer, at about 3 days, for flow from the Little Ouse.

Analysis of land drainage pumping from Burnt Fen, in the South Level, between the Little Ouse and Ely Ouse rivers, shows that rain on one day will initiate pumping on the next day. Taking this response as typical of the South Level, and combining it with the rivers' response as described above, it seems that the separate peak discharges to the Ely Ouse/Cut-off Channel system are likely to be broadly coincident in their timing. An exception is flow from the Little Ouse, which would peak later than from other sources.

2.7.8 North West Norfolk Rivers

The Norfolk Rivers include the Rivers Heacham, Ingol and Babingley, which drain directly into The Wash and the Rivers Nar and Gaywood (non-main river) which drain into the tidal River Great Ouse at King's Lynn. Each system is independent. The Nar downstream of Marham is embanked across the lowland to King's Lynn. In the past these banks have breached when river levels have been high, flooding adjacent farmland and some properties.

Figure 2-29 North West Norfolk sub-catchment

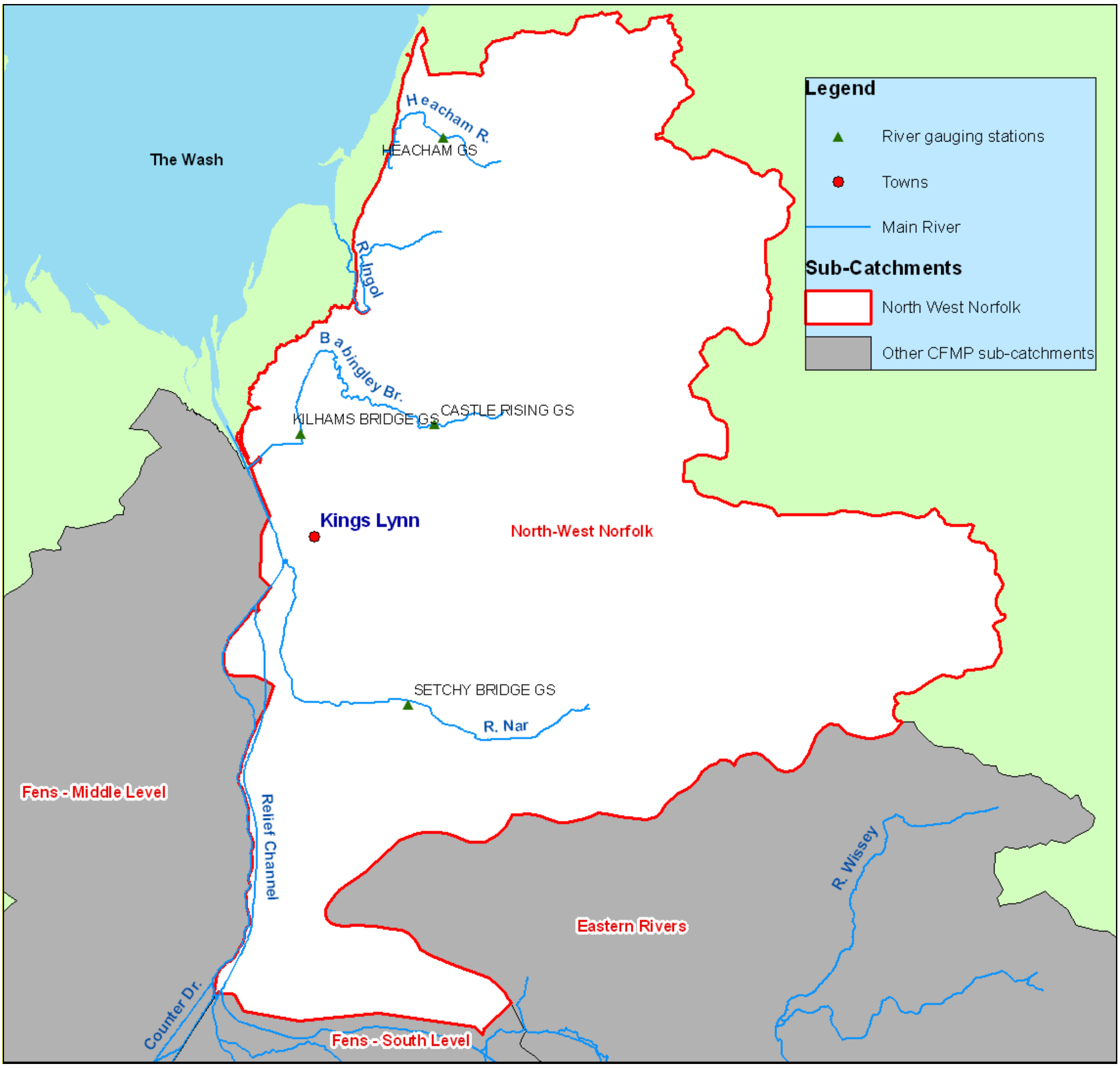


Table 2-9 shows the catchment area and 1% AEP design peak flows calculated using ReFH.

Table 2-9 Relative flows of tributaries in North West Norfolk

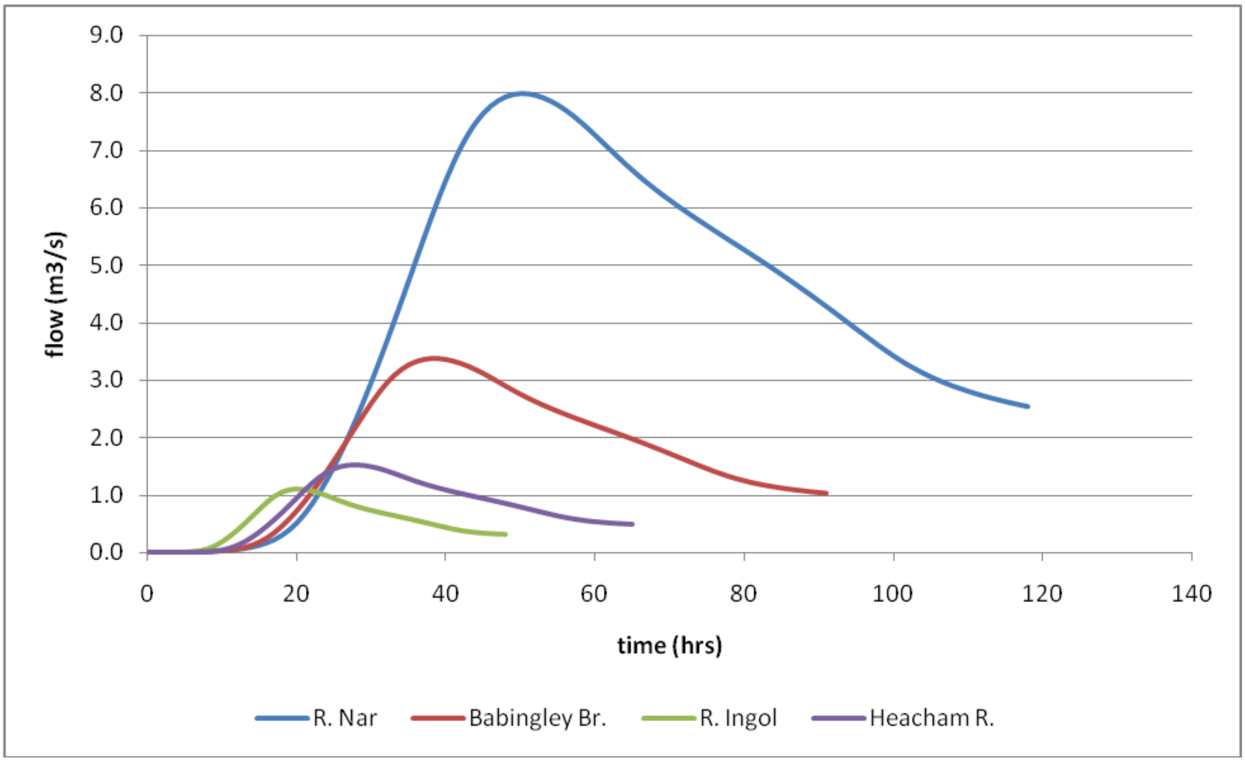
Tributary	Catchment area (km^2)	1% AEP peak flow (m^3/s)
River Ingol	25	1.1
Heacham River	41	1.5
Babingley Brook	312	3.4
River Nar	250	8

Peak flows calculated using ReFH - winter profile was assumed to produce the runoff hydrographs.

In Figure 2-30, we have plotted the 1% AEP design flood hydrographs created from the ReFH analysis. The flows in the North West Norfolk Rivers are relatively small when compared to the rest of the CFMP area and do not contribute to flooding in the tidal River Great Ouse, although there may be localised flooding problems in their respective catchments.

The response after rainfall of the River Nar is much slower than the other watercourses in the North West Norfolk sub-catchment. This is mainly because the contributing area of the catchment is larger so the flood water has further to travel before flowing into the Ouse.

Figure 2-30 1% AEP design flood hydrographs for North West Norfolk Rivers



2.7.9 Summary of Hydrology

The analysis we have undertaken of the hydrology of the Great Ouse CFMP area has shown us that there is a variety in the nature and characteristics of the watercourses. There are quicker responding tributaries which often have a smaller catchment area and steeper slopes. These include the Alconbury Brook, River Kym and also the River Ouzel. There are also slower responding tributaries which contribute more flow into the River Great Ouse, such as the River Cam.

The River Great Ouse itself changes in nature from the steeper, quicker responding slopes of the upstream areas to the flatter and slower responding areas towards the Fens.

2.8 Natural and historic environment

2.8.1 Introduction

The environmental and cultural make up of the Great Ouse CFMP area present both opportunities and constraints for flood risk management. Understanding the nature and location of these sites is essential for developing our flood risk management policies so they fit in with the wider objectives of biodiversity and environmental conservation. We will consider the environment fully when we make our decisions, making sure that we manage flood risk in a sustainable and integrated way. We do not consider flooding from coastal processes in the CFMP, so we have not considered environmental features at risk from flooding in coastal areas.

International sites are protected under the Conservation (Natural Habitats &c.) Regulations 1994 (the Habitats Regulations). In accordance with Environment Agency policy, plans (including CFMPs) which are not required for the conservation of a site, and are likely to have a significant effect on an international site, must be subject to assessment under the Habitats Regulations. This approach applies to all Special Protection Areas (SPAs) and Special Areas of Conservation (SACs) and as a matter of policy we are also applying it to Ramsar Sites.

We have therefore undertaken an assessment under the Habitats Regulations for all international sites that have the potential to be significantly affected by the CFMP. This involves an assessment of likely significant effects on the interest features of the sites and, where significant effects cannot be ruled out, a further stage of 'appropriate assessment'. The output from the appropriate assessment can be found in Appendix B.

A Strategic Environmental Assessment (SEA) is a process for anticipating and evaluating the environmental consequences of plans and programmes prior to decisions being made. There is no legal requirement for us to undertake an SEA for CFMPs. However, because CFMPs set the framework for future planning decisions, and have the potential to result in significant environmental effects we have produced an SEA as part of the Great Ouse CFMP. A summary of the SEA that we have undertaken is described in Appendix B.

2.8.2 Biodiversity

Designated sites

Statutory Designated sites

There are numerous sites designated for international, national and local nature conservation or geological importance in the CFMP area. We summarise the number and type of designated areas in Table 2-10.

Designated nature conservation sites of international importance include Ramsar Sites, Special Protection Areas (SPA) and Special Areas of Conservation (SAC). Within the Great Ouse CFMP area there are seven Ramsar Sites, three SPAs and 11 SACs. However, several sites have multiple designations.

The Ouse Washes Ramsar Site, SPA and SAC is a key site within the CFMP area. It is an extensive area of seasonally flooded wet grassland ('washland') lying between the Old and New Bedford Rivers. Its principal role is as a floodwater storage system during winter months and occasionally during the spring and summer. It is one of the few remaining areas of extensive washland habitat in the UK. The cycle of winter floodwater storage along with traditional summer grazing by cattle and hay production has given rise to a mosaic of rough grassland and wet pasture with a rich biodiversity, particularly important for wetland birds.

Table 2-10 Nature conservation designations in the CFMP area

Designation	Legislation	Number	Sites
Sites of International Importance			
Ramsar sites	Convention on Wetlands of International Importance (1971)	7	• Chippenham Fen • Dersingham Bog • Ouse Washes • Roydon Common • The Wash • Wicken Fen • Woodwalton Fen
SPAs Special Protection Areas	EC Directive on the Conservation of Wild Birds (1979)	3	• Breckland • Ouse Washes • The Wash
SACs Special Areas of Conservation	EC Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (Habitats Directive) (1992)	11	• Breckland • Devils Dyke • Eversden and Wimpole Woods • Fenland • Norfolk Valley Fens • Ouse Washes • Portholme • Rex Graham Reserve • Roydon Common and Dersingham Bog • The Wash and North Norfolk Coast • Waveney and Little Ouse Valley Fens
Sites of National Importance			
SSSIs Sites of Special Scientific Interest	Section 28 of the Wildlife and Countryside Act (1981)	241	
NNRs National Nature Reserves	Section 19 of the National Parks and Access to the Countryside Act (1947) or Section 35 of the Wildlife and Countryside Act (1981)	18	
Sites of Local Importance			
LNRs Local Nature Reserves	Section 21 of the National Parks and Access to the Countryside Act 1949	48	
CWS County Wildlife Sites	Sites designated by local Wildlife Trusts and Local Planning Authorities. Recognition in Local Authority Plans gives them some protection from development	2,144	

Nationally important nature conservation sites include Sites of Special Scientific Interest (SSSI) and National Nature Reserves (NNR). The CFMP area contains 241 SSSIs, including the internationally important sites which are also designated as SSSIs. These sites are designated by Natural England for their biological and/or geological interest. The sites range in size from 0.12ha to over 18,000ha. There are also 18 NNRs within the CFMP area.

The CFMP area also contains 48 Local Nature Reserves (LNRs). However, this CFMP is mainly concerned with internationally and nationally designated sites, as these have the most potential to contribute to and/or be affected by catchment-scale flood risk management. We will take sites of local importance into account when we need to make decisions on more specific flood risk management issues. The risks to international and national statutory designated nature conservation sites are discussed in sections 3.5 and 4.3.

Flooding can have a positive or negative effect on designated sites. Effects can be large or small depending on where protected areas are and their environmental character. Direct flooding causes the greatest damage to non-aquatic habitats, but aquatic habitats can also be affected if they are flooded by low quality water. However, periodic flooding of the flood plain is a natural process that some species and habitats require, and flooding can benefit low-lying wetland habitats of high ecological status by providing nutrients and improving physical habitat conditions.

Freshwater flooding of saline and brackish environments can cause significant damage and may have long-term negative effects. This is a risk in the coastal and estuarine environments of the CFMP area where species and plants are adapted to salt-water conditions.

Natural England has assessed the conservation status of each SSSI, with a view to achieving the Government's Public Service Agreement (PSA) target of 95% of SSSI land to be in 'favourable' or 'recovering' condition by 2010. Indirect impacts of water level management and flood risk management can contribute to a site's unfavourable status, for example scrub encroachment in part resulting from low water levels. Flood risk management activities should where possible contribute to the achievement of 'favourable' or 'recovering' condition of SSSIs.

The appropriate management of water levels therefore has an important role in maintaining and restoring the condition of wetland SSSIs where drainage, flooding and inappropriate ditch management may cause site condition to deteriorate. As a result, we and/or our professional partners have developed Water Level Management Plans (WLMPs) for sites that are significantly affected by changes in water level. WLMPs help to balance and integrate water level requirements for a range of different uses in a particular area, including agriculture, flood risk management and nature conservation. WLMPs have been produced for 50 SSSIs in the CFMP area and are subject to an ongoing review process. WLMPs will be taken into account within this CFMP.

We aim to make sure that flood risk management policies do not adversely affect the environment in line with national and international statutory requirements. It is our intention to promote CFMP policies that support the protection of important environmental features and allow other beneficial measures to be put in place.

Non-statutory designated sites

Across the Great Ouse CFMP area there are 2,144 non-statutory sites that are designated by the relevant local authority because of their local importance as sites of nature conservation. These sites are known as County Wildlife Sites (CWS), and although they are not protected by law, they do appear on the relevant local plans and have some level of protection through the planning process.


River Cam

Although generally small, CWS do form an important network of sites which can provide links between some of the larger designated sites (e.g. SSSIs). However, given the high level of the CFMP we do not think it appropriate to consider CWS in our policy appraisal process. When our policies are implemented, however, these sites will be considered in more detail.

There are several sites in the CFMP area which have been identified for current and future wetland creation, including Wicken Fen, sand and gravel extraction pits at Needingworth and Woodwalton Fen and Holme Fen, which form part of the Great Fen Project. Further details of these large-scale projects are provided in Appendix E, however, wetland creation can also occur on a smaller scale outside of these major areas.

Figure 2-31 Designated nature conservation sites of national, European and international interest

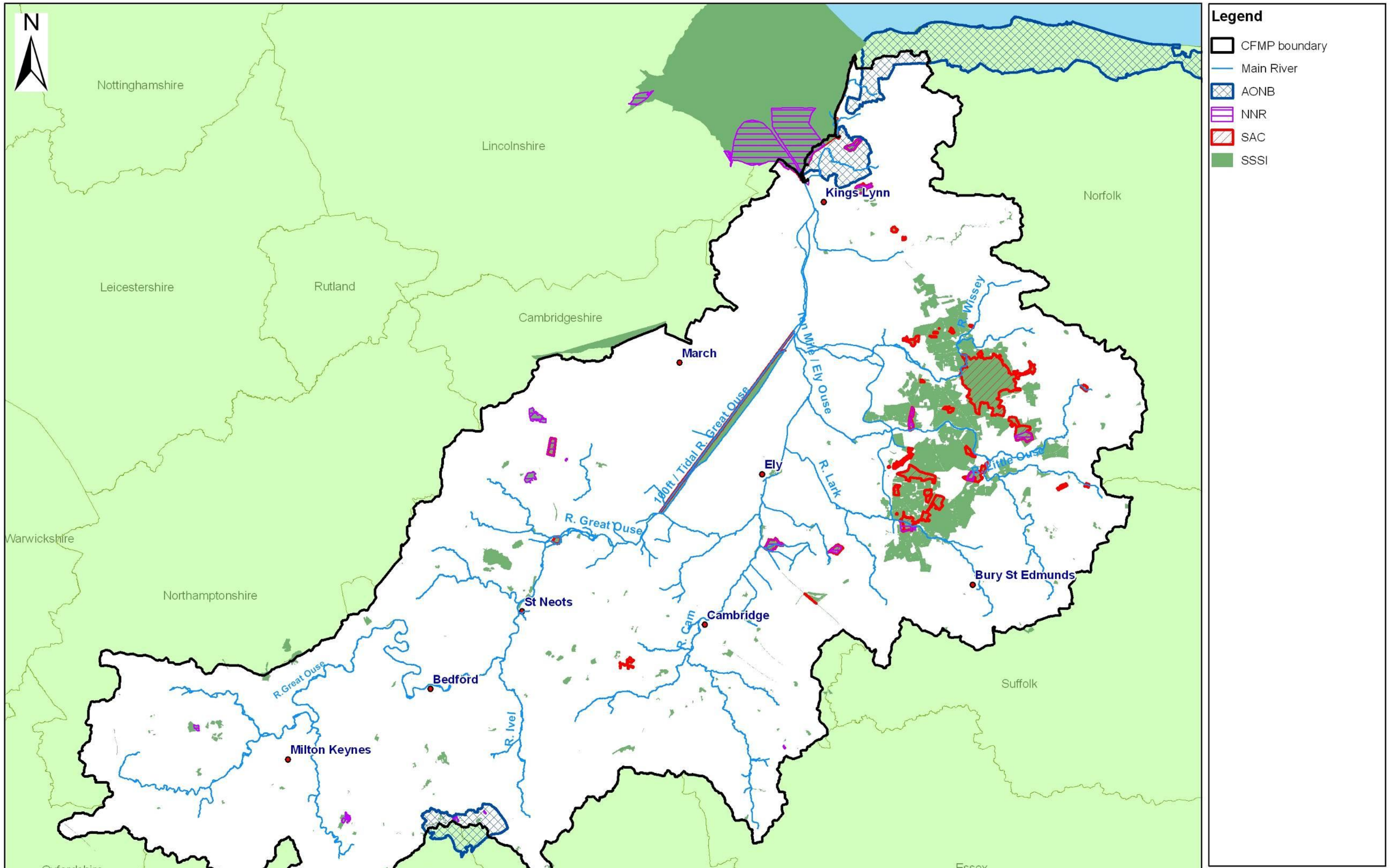


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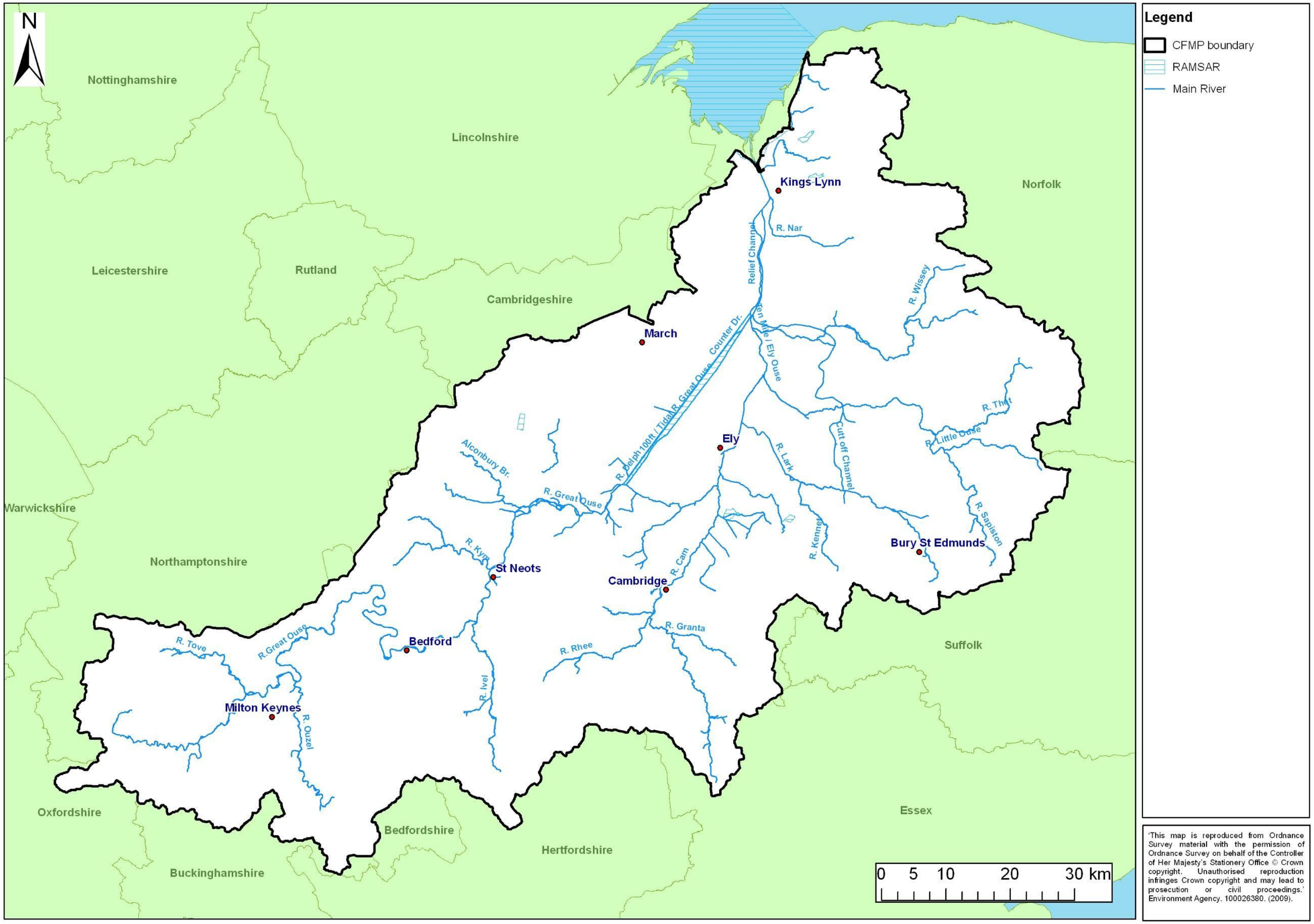
Figure 2-32 Designated nature conservation sites of international importance



Biodiversity Action Plans

Biodiversity Action Plans (BAPs) have been produced to conserve, protect and improve the variety of animals, plants and habitats in the UK. The UK BAP includes 1,149 priority species and 65 priority habitats of national conservation concern. Priority species are those that require conservation action because of their rarity, decline and/or the international importance of their UK populations. Priority habitats have been identified based on a range of criteria including international importance, rarity and rate of decline, or their role in supporting key species. We aim to make sure there is no net loss of BAP habitats as a result of flood risk management. Habitats and species identified in the UK BAP, which are of relevance to this CFMP, are listed in Table 2-11.

In addition, Local Biodiversity Action Plans (LBAPs) have been developed which set out local targets, based on UK BAP targets, for relevant UK BAP species and habitats. They also set out objectives, targets and actions for the conservation of any additional species and habitats which may be locally important. The CFMP area is included within the Cambridgeshire LBAP, and parts of the Norfolk, Suffolk, Bedfordshire and Luton, and Buckinghamshire and Milton Keynes LBAPs.

Table 2-11 UK BAP habitats and species in the CFMP area (data compiled from the Biodiversity Action Reporting System)

Habitat/Species	Flooding-related threats							Status in England
	Drainage	River/Channel Modification	Water Pollution	Water Abstraction	Habitat Loss and Degradation	Nutrient Enrichment	Invasive Species	
Habitats								
Aquifer fed naturally fluctuating water bodies				✓	✓	✓		Fluctuating – probably stable
Coastal and flood plain grazing marsh	✓		✓	✓		✓		Increasing
Coastal saltmarsh			✓		✓	✓		Declining (continuing/ accelerating)
Eutrophic standing waters			✓	✓	✓	✓	✓	Declining (slowing)
Intertidal mudflats			✓		✓		✓	Unknown
Lowland fens	✓			✓		✓		Declining (slowing)
Lowland heathland					✓	✓		Increasing
Lowland meadows	✓			✓				Declining (slowing)
Maritime cliff and slope						✓	✓	Unknown
Mesotrophic lakes			✓			✓		Declining (slowing)
Ponds	✓		✓		✓	✓	✓	Unknown
Purple moor grass and rush pasture	✓					✓		Declining (slowing)
Reedbeds	✓		✓	✓		✓		Increasing
Rivers		✓	✓	✓		✓	✓	Unknown
Saline Lagoons			✓			✓		Stable
Wet Woodland	✓	✓	✓	✓		✓	✓	Increasing
Species								
Otter		✓	✓		✓			Increasing
Water Vole		✓	✓		✓		✓	Declining (slowing)
Bittern	✓	✓		✓	✓			Increasing

Habitat/Species	Flooding-related threats							Status in England
	Drainage	River/Channel Modification	Water Pollution	Water Abstraction	Habitat Loss and Degradation	Nutrient Enrichment	Invasive Species	
Habitats								
Reed Bunting	✓	✓			✓			Fluctuating – probably stable
Great Crested Newt	✓	✓	✓		✓		✓	Declining (slowing)
Depressed River Mussel		✓	✓					Stable
Little Whirlpool Ram's-horn Snail	✓					✓		Declining (continuing/ accelerating)
Narrow-mouthed Whorl Snail	✓							Stable
Shining Ram's-horn Snail	✓					✓		Declining (slowing)
Freshwater White-clawed Crayfish			✓		✓		✓	Declining (continuing/ accelerating)
Fen Orchid	✓			✓				Stable
Greater Water Parsnip	✓				✓			Declining (continuing/ accelerating)
Pillwort	✓		✓				✓	Fluctuating – probably declining
Ribbon-leaved Water-plantain						✓		No clear trend
Spined Loach		✓	✓		✓	✓		Unknown
Pashford Pot Beetle	✓							Unknown

Several of the habitats listed in Table 2-11 are in decline or have suffered considerable degradation because of land drainage, excessive water abstraction, conversion to intensive agriculture, inappropriate management, water pollution, nutrient enrichment and the introduction of non-native species. In particular, agricultural pressures and modifications/maintenance of river channels has lead to considerable loss and fragmentation of habitats, particularly wetlands. Several of the UK BAP priority species listed have also suffered as a result of these factors. The degradation and loss of habitats can increase run-off to watercourses which exacerbates flooding. Identifying opportunities for the protection and enhancement of existing habitat diversity will therefore be a priority for the Great Ouse CFMP.

2.8.3 Landscape


Norfolk Coast

The landscape of Britain varies considerably, mostly because of differences in geology and climate that influence soil development, vegetation and farming practices. The CFMP area contains two Areas of Outstanding Natural Beauty (AONBs), but no National Parks.

The value of the Norfolk Coast landscape, which forms the northern boundary to the CFMP area, was recognised in 1968 with its designation as an AONB. It has a total area of approximately 450km^2, however, only 87km^2 of this falls within the CFMP area. The AONB comprises a diverse landscape from high boulder clay cliffs east of Weybourne, through the remote marsh coastlands, to the silt expanses of The Wash.

A small part of the Chilterns AONB (40km^2 which equates to 9% of the AONBs total area) also lies within the south west portion of the CFMP area. The landscape of the AONB is dominated by gently rolling hills with woodland and chalk downland. Figure 2-33 shows the landscape designations in the CFMP area.

National Character Areas (previously known as Joint Character Areas) are sub-divisions of England based on landscape, wildlife and cultural features. They provide a picture of the differences in landscape character at the national scale. There are 16 National Character Areas (described by Natural England) that fall within the CFMP area. The main landscape characteristics of these areas are summarised in Table 2-12 and shown on Figure 2-33.

Across the Great Ouse CFMP area it is not possible to summarise the area into one typical landscape type. Similarly, the majority of the National Character Areas are not defined by any riverine processes and although flooding would occur in many of these landscapes, the impact would be temporary and would be expected to happen infrequently.

However, one National Character Area that would be significantly affected by flooding would be The Fens. The landscape is defined by flat, open land with extensive vistas with rich and varied intensive agricultural use. Major high-level drains run though this landscape, amongst fragments of relic wet fen areas. Changes in water levels, flooding and the implementation or removal of flood risk management activities would have a significant impact on this unique landscape.

Table 2-12 Main characteristics of National Character Areas in the CFMP area

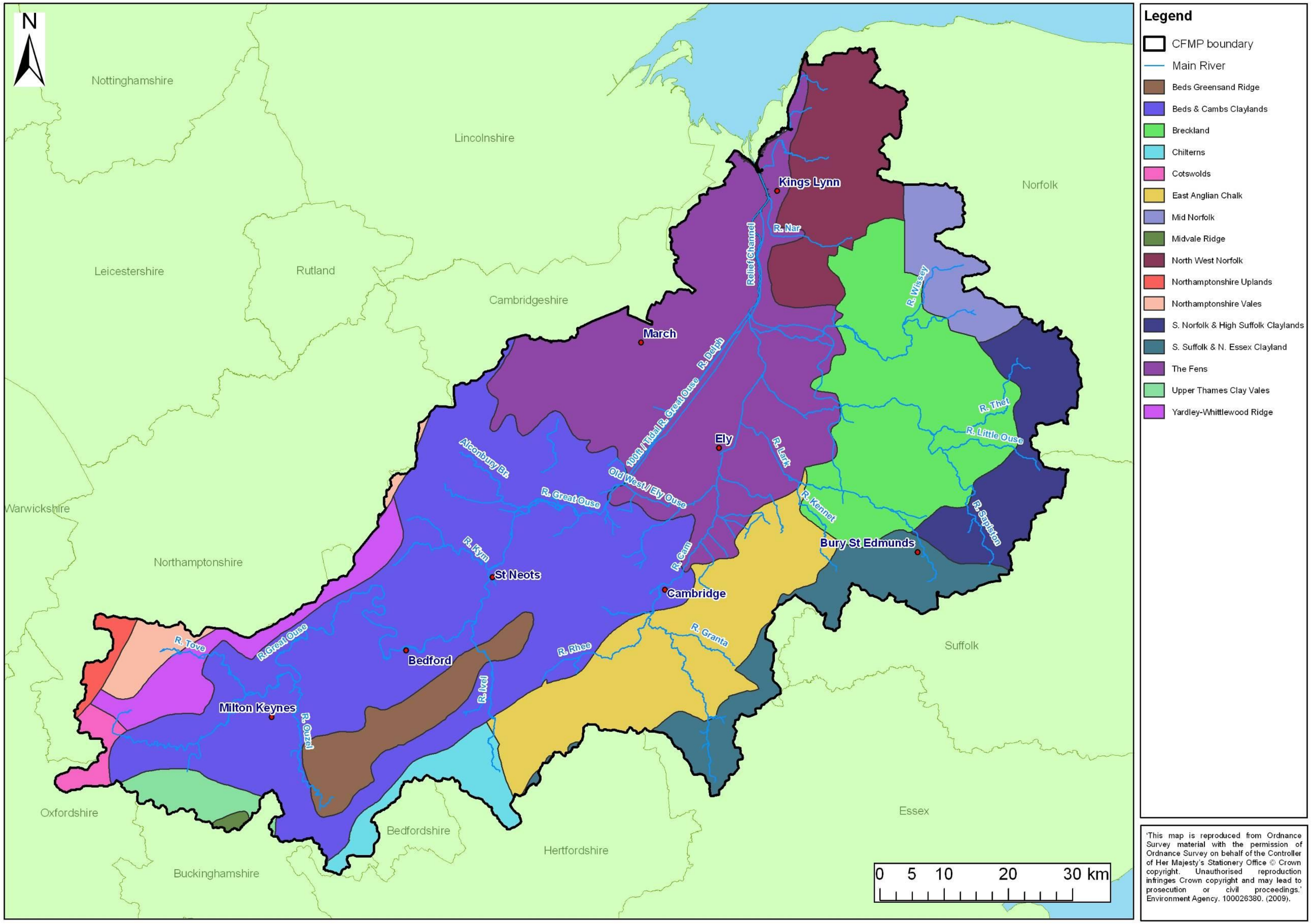
National Character Area	Key Landscape Features
Bedfordshire and Cambridgeshire Claylands	• Predominantly an open and intensive arable landscape. • Settlements clustered around major road and rail corridors (A1 and M1). • Man-made reservoir at Grafham Water. • Gently undulating topography and plateaus, divided by broad shallow valleys. • River corridors of the Great Ouse and Ivel.
Bedfordshire Greensand Ridge	• Narrow escarpment of Lower Greensand, with a scarp slope to north west. • Number of historic parklands and estates. • Existing and redundant sand quarries especially around Leighton Buzzard. • Mixed land use.
Breckland	• Slightly undulating, dry terrain with shallow, wooded river valleys. • Vast commercial conifer plantations. • Distinctive large-scale landscape. • Unique geology.
Chilterns	• Extensive areas of beech woodland. • Chalk hills and plateau, with remnant chalk downland. • Small fields and dense network of ancient hedges.
Cotswolds	• Landscape defined by underlying geology. • Rolling, open, high wold plateau. • Incised landscape with deep wide valleys.
East Anglian Chalk	• Distinctive, open, variable topography of the Chalk. • Long straight roads. • Large-scale rolling downland, mainly arable. • Ash-dominated woodland and Beech belts. • Significant linear earthworks, including Devil's Dyke and Fleam Dyke.
Mid Norfolk	• Variable geology and topography, with extensive sand and gravel. • Predominantly arable, with variable field sizes. • Relatively well-wooded.
Midvale Range	• Low irregular wooded limestone ridge. • Large geometrically spaced fields, with both arable and pastoral farming. • Spring-line settlements associated with blocks of ancient woodland.

National Character Area	Key Landscape Features
North West Norfolk	• Large-scale arable and grassland landscape. • Large estates giving a unified and well-managed quality to the landscape. • Wide road verges with uniform hawthorn hedges set well back and well-maintained. • Large and widely spaced villages.
Northamptonshire Uplands	• Rounded, undulating hills with many long, low ridgelines. • Sparse settlement of nucleated villages on hilltops and valley heads. • Straight, wide enclosure roads. • Little woodland.
Northamptonshire Vales	• Gentle clay ridges and valleys. • Little woodland. • Strong patterns of enclosure.
South Norfolk and High Suffolk Claylands	• Large plateau with little relief, except where incised by small rivers. • Numerous Saxo-Norman and medieval churches. • Almost entirely arable. • Few major transport routes.
South Suffolk and North Essex Claylands	• Broadly flat, chalky, boulder clay plateau dissected by undulating river valley topography. • Predominantly arable with a wooded appearance. • Remnant ancient countryside. • Irregular field patterns.
The Fens	• Large-scale, flat, open landscape. • A hierarchy of rivers, drains and ditches provide a strong influence throughout. • Isolated 'islands' of higher ground where most settlement, roads and railways are located. • Fragments of relict wet fen areas at Wicken, Woodwalton and Holme. • Rich and varied intensive agricultural land use.
Upper Thames Clay Vales	• Gently undulating lowland farmland. • In Buckinghamshire, the Vale is a predominantly pastoral landscape. • Brick-built buildings reflect the widespread use of the local clay as a building material.
Yardley-Whittlewood Ridge	• Broad plateau with shallow soils. • Strong historic landscape character with extensive areas of ancient woodland. • Mixed land uses of pasture, arable and woodland. • Low density of settlement.

Flooding in itself is not likely to have a major impact on the rural landscape of the CFMP area since periodic inundation of flood plains has actually helped to develop the landscape as we know it today. It is more likely to have an impact in historic settlements where rivers and flood plains have been modified for thousands of years. We discuss this in more detail in the historic environment section below and in chapters 3 and 4.

Flood risk management policies have the potential to significantly change the landscape. They can have a positive effect, for example by re-creating lost habitats such as wetland or a negative effect by poor integration of defences into the landscape. We need to retain, where possible, the rural appearance of the landscape and consider the importance of townscape characteristics throughout the CFMP area, including the places of historic, archaeological and cultural significance, to make sure that flood risk management measures do no adversely affect landscape character.

Figure 2-33 Landscape designations



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2.8.4 Fisheries

We have a statutory duty to maintain, improve and develop salmon, trout, freshwater and eel fisheries. We have various powers to protect fish stocks and reduce exploitation under the Salmon and Freshwater Fisheries Act 1975 (as amended).

The EC Freshwater Fish Directive was adopted in 1978 to protect and improve fresh waters that support fish life. The Directives requires the classification of appropriate rivers into two categories based on water quality parameters;

- Those suitable for cyprinids (including carp, tench, bream, roach, chub and minnows);
- those suitable for salmonids (mainly salmon and trout but also grayling).

The CFMP area contains a diverse range of fisheries habitats covering both salmonids and cyprinids. The habitats range from the drains and slow moving rivers in the lower catchment, to the faster flowing upper reaches of the Great Ouse. The majority of these rivers and drains also support recreational fishing.

Many of the water bodies in the CFMP are heavily modified. The consequences of these modifications are detrimental to biodiversity and fisheries, and therefore the river system does not provide the optimum environment to sustain healthy fish populations. These activities have eliminated important breeding, nursery, refuge and feeding habitats. They also constrain natural ecological processes which results in poorly structured plant and animal communities.

Policies for flood risk management will need to consider the impact upon fish habitat. Flood-related threats could include siltation due to changes in flow affecting erosional and depositional patterns, pollution from flooding episodes (for example, from STWs, industry), and displacement of fish (juvenile and adult). Opportunities for habitat enhancement could be possible through the opening up of areas for fish passage (weirs, sluice gates) and through the further development of spawning grounds (pools and riffles, aquatic vegetation cover).

2.8.5 Tourism and recreation

The Great Ouse and some of its tributaries, some of the Fenland watercourses, and the Grand Union Canal provide approximately 240km of navigable waterway within the CFMP area. This includes the recently opened Relief Channel navigation, which runs between Denver and King's Lynn. Several authorities are responsible for Navigation including British Waterways, Middle Level Commissioners, and the Environment Agency. Additional proposed waterways (subject to approval) include the Nar Canal, the Bedford to Milton Keynes Link and the Fens Waterways Link between the River Witham, the Middle Level and the Great Ouse. Figure 2-34 shows the navigable watercourses in the CFMP area.

Changes to flood risk management could impact upon a number of tourism and recreational sites and cause temporary disruption to the use of these sites and their activities. For example, changes to the flooding regime in the Ouse Washes, such as increased summer flooding would impact upon recreational activities in the area. It would affect bird watching opportunities at the RSPB Ouse Washes reserve and the Wildfowl and Wetlands Trust (WWT) reserve at Welney, along with angling, walking and also leisure activities at the Mepal Outdoor Centre. Bridleways, trails, cycleways and footpaths linking these tourism and recreational sites could all be at risk of flooding.

2.8.6 Surface water quality

Maintaining water quality is vital for many activities in the CFMP area including spray irrigation, fisheries, amenity and conservation. Water quality can be affected by different sources of pollution and can affect, or be affected by, the ecology of a river. Water quality is affected by point source pollution (from farms, STWs, roads and urban areas) and diffuse pollution (from agricultural run-off). Surface water run-off in rural areas can cause pollution from organic material, agrochemicals and nutrients. In urban areas it can cause pollution in the form of run-off from roads, urban and industrial areas and overflows from the sewer system. The CFMP will seek to ensure that water quality is not adversely affected by any flood risk management operations.

General Quality Assessment

We use a grading system to classify and monitor the quality of rivers and canals. The General Quality Assessment (GQA) grading system is based on chemical, biological, nutrient and aesthetic character of watercourses. This system allows us to identify trends in water quality over time, so we can identify degrading rivers and take action where necessary.

Chemical GQA grades ('A' to 'F') represent pollution from the most common sources (including agriculture and waste treatment works) by measuring the presence of dissolved oxygen, biochemical oxygen demand, and ammonia. The grading system for Biological GQA ('a' to 'f') is based on the character of macro-invertebrate communities (such as insect larvae). As different macro-invertebrates have varying tolerances to pollutants, they can be used to give an indication of pollution, by their presence or absence, and abundance, compared to what would be expected if the water was in good environmental condition. At present only macro-invertebrate data is robust enough to be used for classifying water quality. The WFD will potentially require us to use other fauna and flora (e.g. phytoplankton, macrophytes and fish) to assess and monitor the condition of the water environment.

Figure 2-35 and Figure 2-36 show chemical and biological GQA grades (2006 data) respectively for monitored river stretches in the Great Ouse CFMP area. Table 2-13 shows the lengths and percentages of rivers that we have given each GQA grade. The majority of classified rivers in the CFMP area are of 'good' or 'fairly good' chemical quality (26.3% and 24.6% respectively) and 'good' or 'very good' biological quality (33.0% and 32.6% respectively).

Table 2-13 Chemical and biological water quality in 2006

Chemical GQA	Length of river (km)	Percentage of river (per cent)	Biological GQA	Length of river (km)	Percentage of river (per cent)
A (Very Good)	202.1	10.5	a (Very Good)	629.0	32.6
B (Good)	507.8	26.3	b (Good)	636.7	33.0
C (Fairly Good)	473.9	24.6	c (Fairly Good)	317.1	16.4
D (Fair)	275.3	14.3	d (Fair)	54.3	2.8
E (Poor)	220.5	11.4	e (Poor)	9.6	0.5
F (Bad)	0	0	f (bad)	0	0
U (Ungraded)	249.3	12.9	u (Ungraded)	282.2	14.6

We also assess Main Rivers for nitrate and phosphate content to determine nutrient conditions. The results of 2006 show that nitrate content for over 64% of watercourses in the Great Ouse CFMP catchment is very high or excessively high. Phosphate content is also a problem in the CFMP area with 61% of watercourses having very high or excessively high phosphate levels.

High nitrate and phosphate levels in watercourses are a problem because they lead to eutrophic conditions which encourage the excessive growth of algae and aquatic plants. Plants that thrive in high nutrient conditions grow rapidly and become dominant, causing changes in river and lake margin plant communities. This can negatively affect invertebrates, fish and other species. Eutrophication also impacts amenity uses such as fisheries, navigation, water sports and angling and can also affect public drinking water supplies.

Water Framework Directive

The WFD came in to force in 2000 and sets a target of aiming to achieve at least 'good' status in all inland and coastal waters by 2015. For surface waters, good status has an ecological and a chemical component. Good ecological status is measured on the scale 'high', 'good', 'moderate', 'poor' and 'bad'; and good chemical status as 'pass' or 'fail'.

River Great Ouse at Welney

Flood risk management is unlikely to have a significant impact on chemical water quality except where maintenance works disturb sediment (such as de-silting) or where pollutants are mobilised from contaminated land by flood waters. The main impact of the WFD on flood risk management, both now and in the future, relates to the ecological quality of water bodies. River morphology can be changed by channel works, such as straightening and deepening, or following management schemes that modify geomorphological processes. For example, flow control structures or artificially strengthened banks change the way sediment is produced and deposited. This can cause changes in river shape, habitat diversity and the range of animals and plants that these habitats can support.

Good ecological status is defined as a slight variation from undisturbed natural conditions. However, certain bodies of surface water are deemed unable to achieve 'good ecological status' as a result of physical modifications. Such water bodies will be designated either as 'Artificial (AWB)' or 'Heavily Modified (HMWB)' as appropriate. AWB describe water bodies that are entirely man-made, for example canals. A HMWB has had its original appearance significantly altered to suit a specific purpose, for example extensive re-alignment of a river channel for navigation would result in a HMWB. These watercourses are therefore required to achieve an alternate objective of at least 'good ecological potential'. This is also measured on the scale high, good, moderate, poor and bad. The chemical status of these water bodies is measured in the same way as natural water bodies.

Preliminary assessment of river water bodies in the Great Ouse CFMP area has identified that the vast majority (68.8%) are HMWB and 19.6% are AWB (11.6% are not yet designated). The majority of artificial water bodies are drains within the Old Bedford and Middle Level catchment and the Grand Union Canal. Within the CFMP area 61.5% of river water bodies have been assessed has having moderate ecological potential, with only 2.5% achieving good ecological status or potential. Figure 2-37 shows the distribution of watercourses of good, moderate and poor ecological status/potential in the CFMP area. Only a 35% of river water bodies in the CFMP have been assessed for chemical status; the majority passed.

However, the WFD does not only concentrate of river water bodies; lakes, coastal waters and transitional waters are also assessed. The assessment for lakes, coastal and transitional waters is similar to that for river water bodies. Of the 10 monitored lakes in the CFMP area, two are HMWB and three are AWB. The ecological status of only two of these lakes has been assessed; Thompson Water has moderate ecological status and Grafham Water has poor ecological potential. There are three transitional water bodies in the Great Ouse CFMP area; two of these are HMWB with moderate ecological potential and the third is not yet assessed. The CFMP area discharges into one coastal water, as monitored under the WFD (The Wash). This coastal water is assessed as a HMWB, but has not yet been assessed for ecological status. Chemical status has been assessed as a pass.

Within the Anglian River Basin District, which includes the Great Ouse CFMP area, a number of specific pressures have been identified as significant water management issues. These include:

- abstraction and other artificial flow pressures;
- invasive, non-native species;
- nitrate in surface and ground water;
- phosphorous in rivers and standing water;
- physical modification (of estuaries, coasts, rivers and streams);
- sediment (high levels of sediment and contaminated sediment).

The draft Anglian RBMP sets targets for water bodies to reach good status or potential by 2015, and if not by 2021 of 2027. Table 2-14 below summarises the status objectives for each type of water body in the CFMP area.

Table 2-14 Proposed ecological status objective for water bodies in CFMP area

Water body category		Good in 2015	Good in 2021	Good in 2027	Less than good	Not yet assessed	Total number of water bodies
River	HMWB	4	0	103	0	39	146
	AWB	0	0	20	0	12	32
	Not Designated	10	0	22	0	4	36
Lake		0	0	2	0	8	10
Transitional Water		0	0	2	0	1	3
Coastal Water		0	0	0	0	1	1
Groundwater		7	0	15	0	0	22

2.8.7 Ground water quality and abstraction

The major aquifers (productive strata) within the CFMP area include: the Great Oolite, Chalk and Woburn Sands and alluvial sand and gravel aquifers, which are located in the Upper and Lower Bedford Ouse and tributaries, and the southern and eastern areas of the CFMP area. Figure 2-38 shows the location of the productive aquifer strata in the CFMP area, both primary and secondary strata. This shows there are also significant aquifers located in the north-west Norfolk area, including the Sandringham sands and chalk aquifer. There are no substantial aquifers in the Old Bedford and Middle Level areas.

The quality of groundwater determines how best it can be used. Groundwater is important for public, industry and agricultural water supply. They also feed into rivers and support wetlands. The WFD requires us to identify and assess groundwater and groundwater-fed terrestrial systems, similarly to surface water bodies. For groundwater, good status has a quantitative and a chemical component, which together provide a single final classification: ‘good’ or ‘poor’ status. Of the 22 monitored groundwater bodies in the CFMP area 12 have good status and 10 poor.

All flood risk management measures will need to consider what environmental measures, in relation to groundwater resources and quality, will be required to comply with the Directive. This will in turn affect the selection of flood risk management policies within this CFMP.

For management of water abstraction, four strategies cover the Great Ouse CFMP area; the Upper Ouse and Bedford Ouse CAMS, Cam and Ely CAMS, Old Bedford and Middle Level CAMs and the North West Norfolk CAMs. The ways in which abstracted water is used in the CFMP area, both groundwater and surface water, are listed in Table 2-15.

Table 2-15 Use of abstracted water in CFMP area

Purpose	% of total abstractions in the area			
	Upper and Lower Bedford Ouse	Cam and Ely	Old Bedford and Middle Level	North West Norfolk
Surface Water Abstractions for Public Water Supply	75.5	35.5	0	42.0
Groundwater Abstraction for Public Water Supply	10.6	0	0	
Abstractions for Industrial and Commercial Use	7.3	7.0	17.3	16.0
Abstractions for Spray Irrigation, General Agriculture, and Domestic Uses	6.6	17.5	80.0	28.0
Fish Farms	0	0	0	14.0
Environmental Support	0	5.0	0.7	1.0

Purpose	% of total abstractions in the area			
	Upper and Lower Bedford Ouse	Cam and Ely	Old Bedford and Middle Level	North West Norfolk
Water Transfers	0	35.0	0	0
Other	0	0	2.0	1.0

Data compiled from the Upper and Lower Bedford Ouse CAMS, Old Bedford including Middle Level CAMS, Cam and Ely Ouse CAMS, and North West Norfolk CAMS.

Much of the CFMP area, including parts of Cambridgeshire, Bedfordshire, Buckinghamshire, Norfolk and Suffolk, have been designated as either groundwater and/or surface water Nitrate Vulnerable Zones (NVZs) in accordance with the EC Nitrates Directive. This Directive is an environmental measure designed to reduce water pollution by nitrate from agricultural sources and to prevent such pollution occurring in the future.

We discuss the potential consequences of flooding on groundwater quality in sections 3.5 and 4.3.

2.8.8 Historic environment

The Great Ouse CFMP area is rich in historic sites, as shown in Figure 2-39. There are 941 Scheduled Ancient Monuments (SAMs) within the CFMP area, which have been designated based on their rarity, current condition, fragility and potential contribution to our understanding and appreciation of the historic environment. In sections 3.5 and 4.3 we will discuss the current and future flood risks to these sites.

There are no World Heritage Sites or registered battlefields within the CFMP area.

English Heritage has a Register of Parks and Gardens of Special Historic Interest and 81 sites within the CFMP area are included on this register. Grade I sites are of international importance; Grade II* sites are of exceptional historic interest and Grade II sites are of sufficient interest to have a national designation. Six of the Parks and Gardens in the CFMP area are listed as Grade I (Audley End, Houghton Hall, Stowe House, Wimpole Hall, Woburn Abbey and Wrest Park).

Conservation Areas are present throughout the CFMP area, including at Barton-Le-Cley, Toddington, and Leighton Buzzard town centres. These are ‘areas of special architectural or historic interest, the character or appearance of which it is desirable to preserve or enhance’, designated under the Planning (Listed Building and Conservation Areas) Act 1990. Designation gives control to the local planning authority over the demolition of buildings, and policies are put in place to preserve or enhance the aspects of character or appearance that define an area's special interest.

Listed buildings are structures of special architectural or historic interest. There are three grades of listed buildings, although all are designated for their national importance:

- Grade I = buildings of exceptional interest;
- Grade II* = particularly important buildings of more than special interest;
- Grade II = buildings of special interest warranting every effort to protect them.

Data from the National Monuments Record (NMR) shows that the CFMP area contains 20,219 listed buildings. Of these, there are 718 Grade I, 1,133 Grade II* and 18,301 Grade II (67 are ungraded). Many of the historic structures in the CFMP area are key relics of the previous land use in the area, for example early windmills and steam engine pumping houses. Most historic environmental assets will be vulnerable to damage from flooding. If flooding occurs more often in the future and is more severe it may lead to the loss or damage of these assets. Historic environmental assets and their settings may also be vulnerable to damage resulting from flood risk management schemes, in particular those requiring construction of defences. The alteration of water levels may also impact upon historic resources, for example altering the preservation environment of buried archaeology or causing structural damage to historic buildings. It is an offence under the 1979 Ancient Monuments and Archaeological Areas Act to deliberately flood land in, on or under which there is a SAM.

Figure 2-34 Navigation

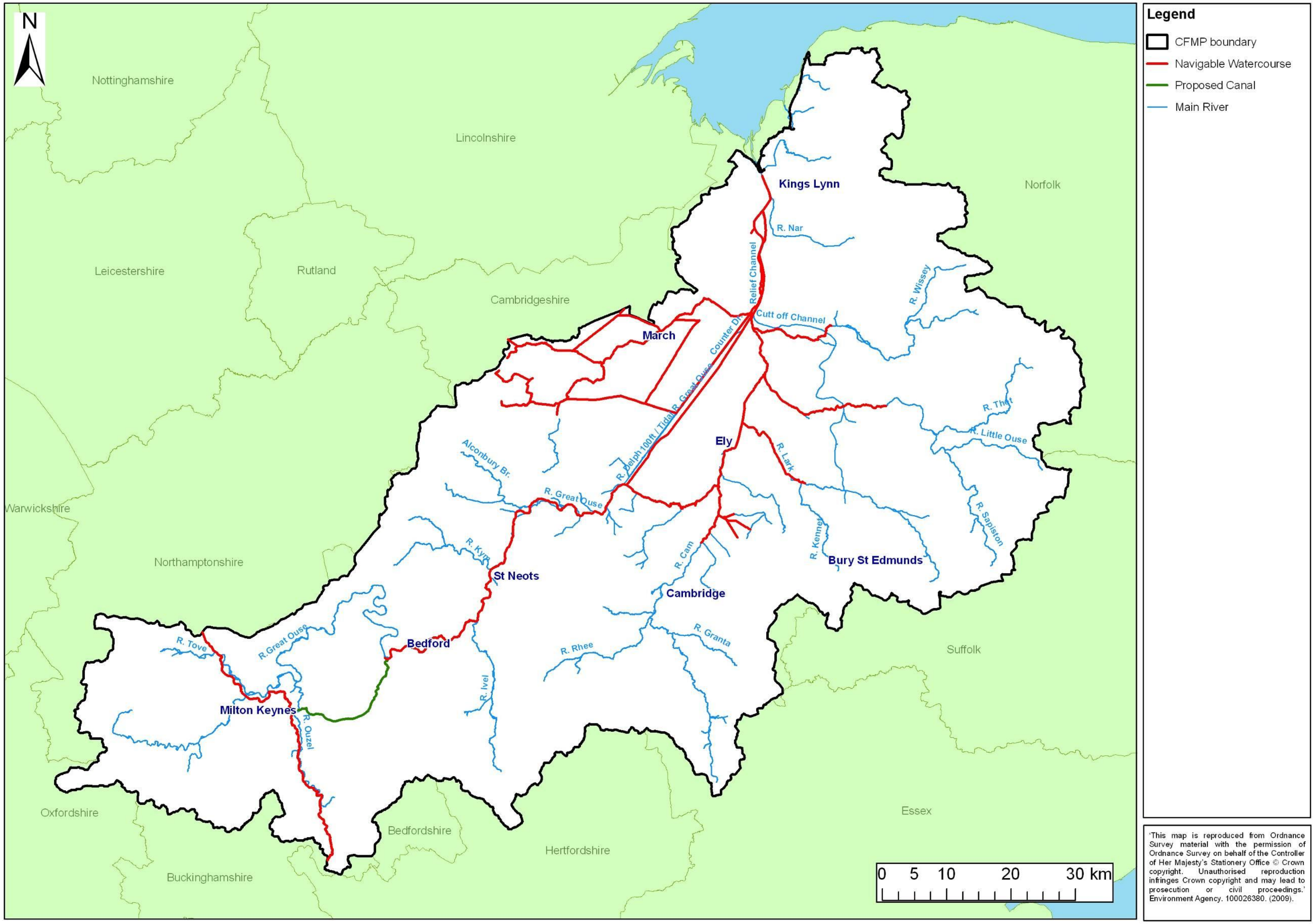


Figure 2-35 Chemical Water Quality (GQA, 2006)

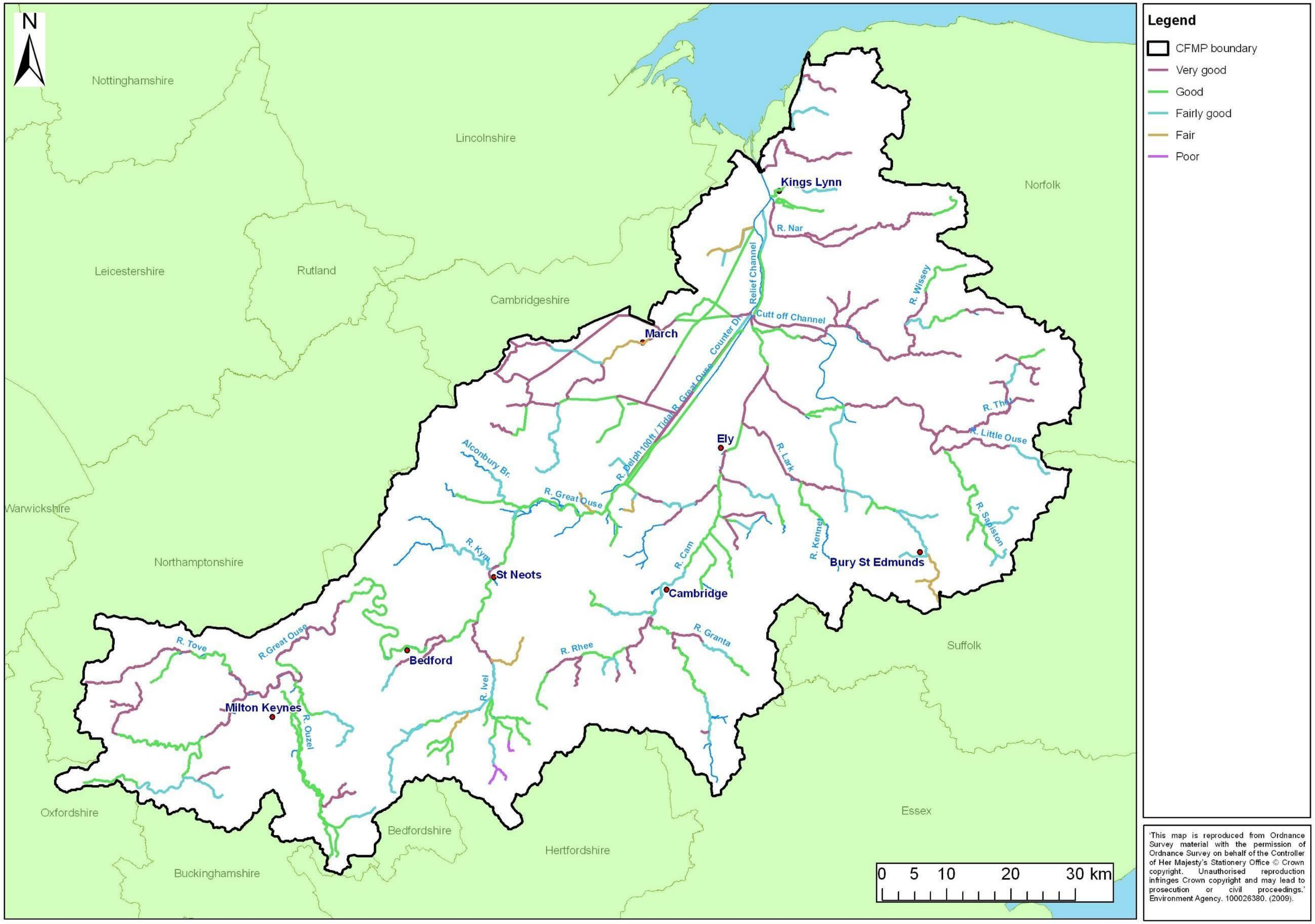


Figure 2-36 Biological Water Quality (GQA, 2006)

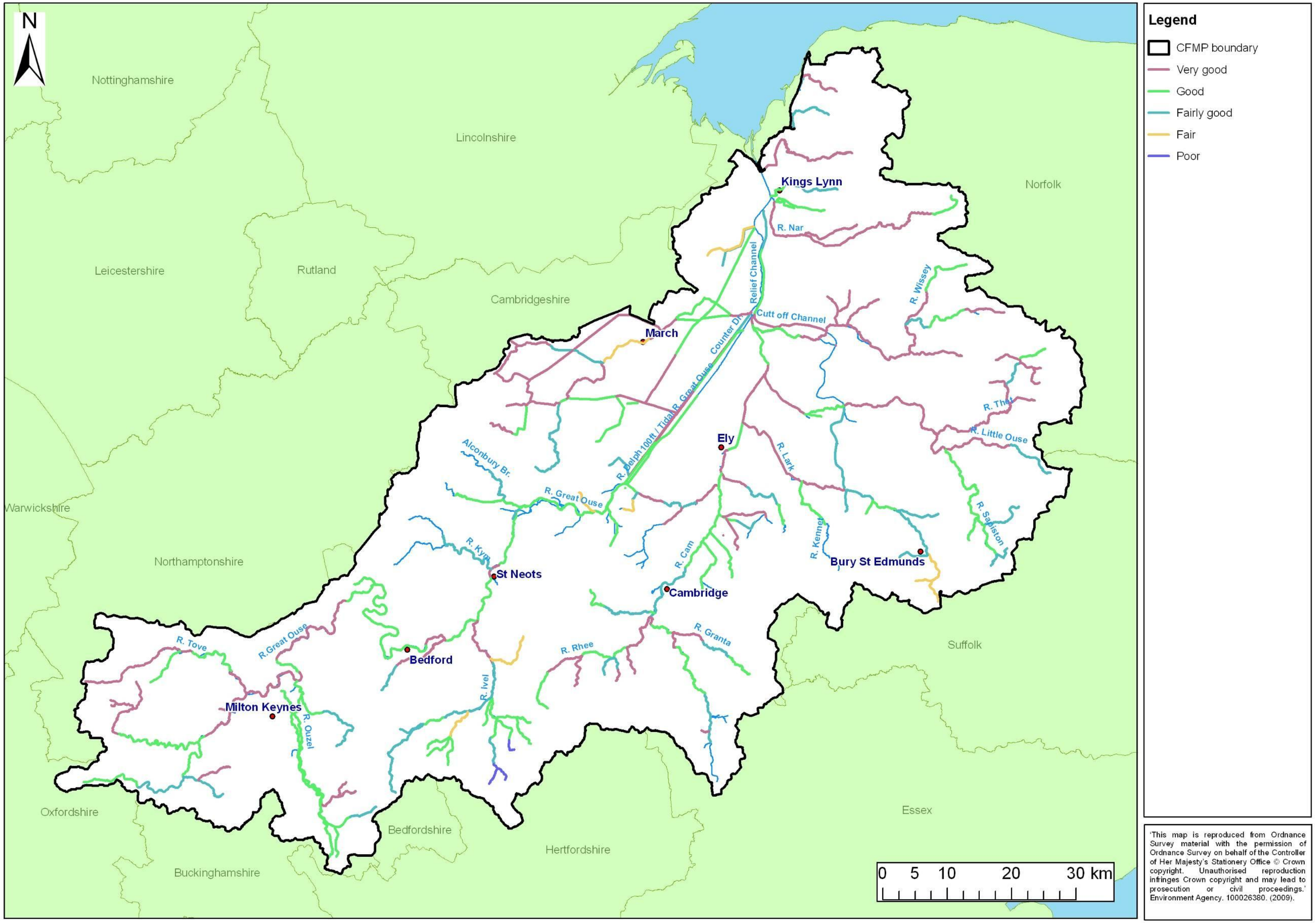


Figure 2-37 Current ecological status of river water bodies under the WFD

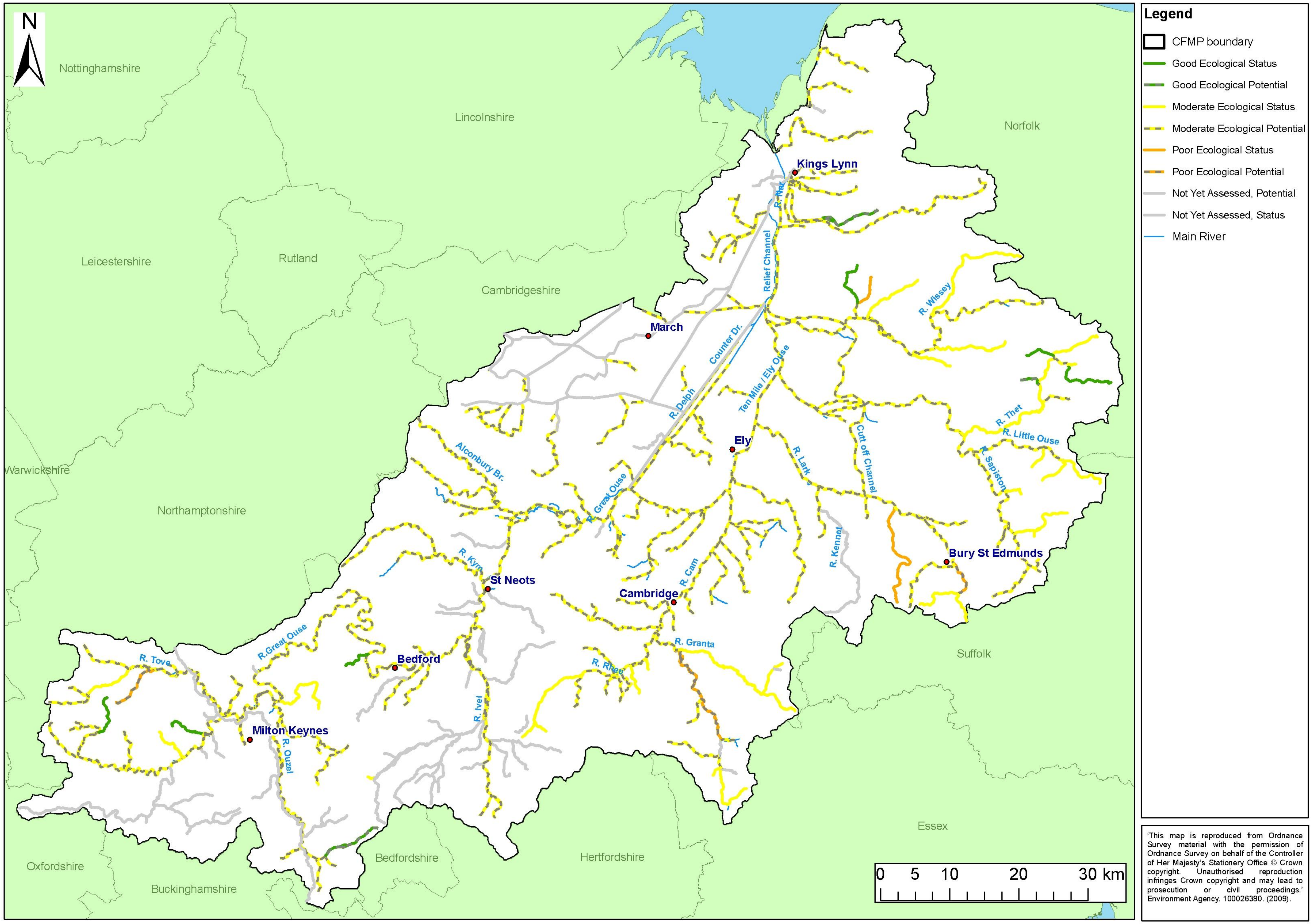


Figure 2-38 Groundwater bodies

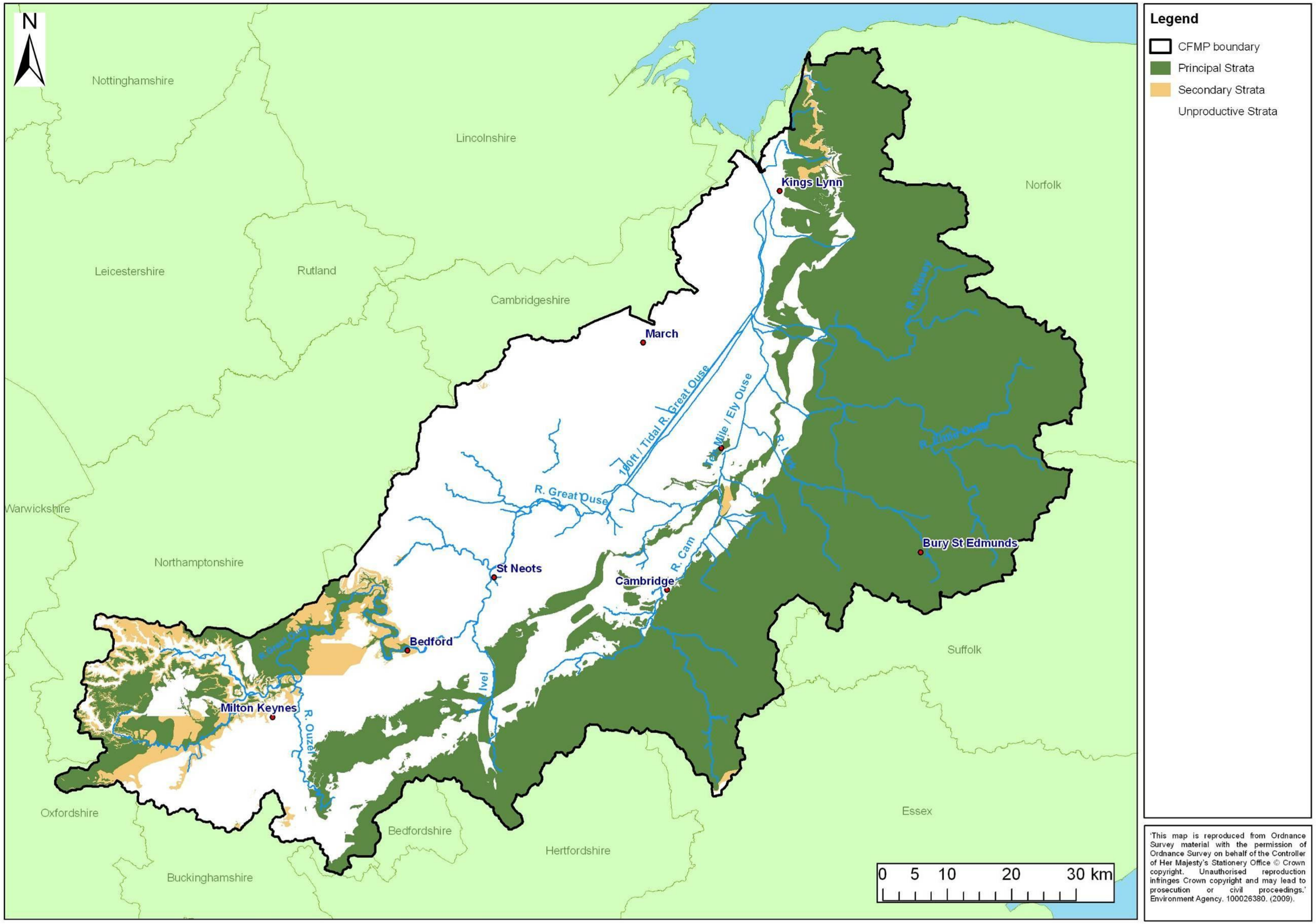
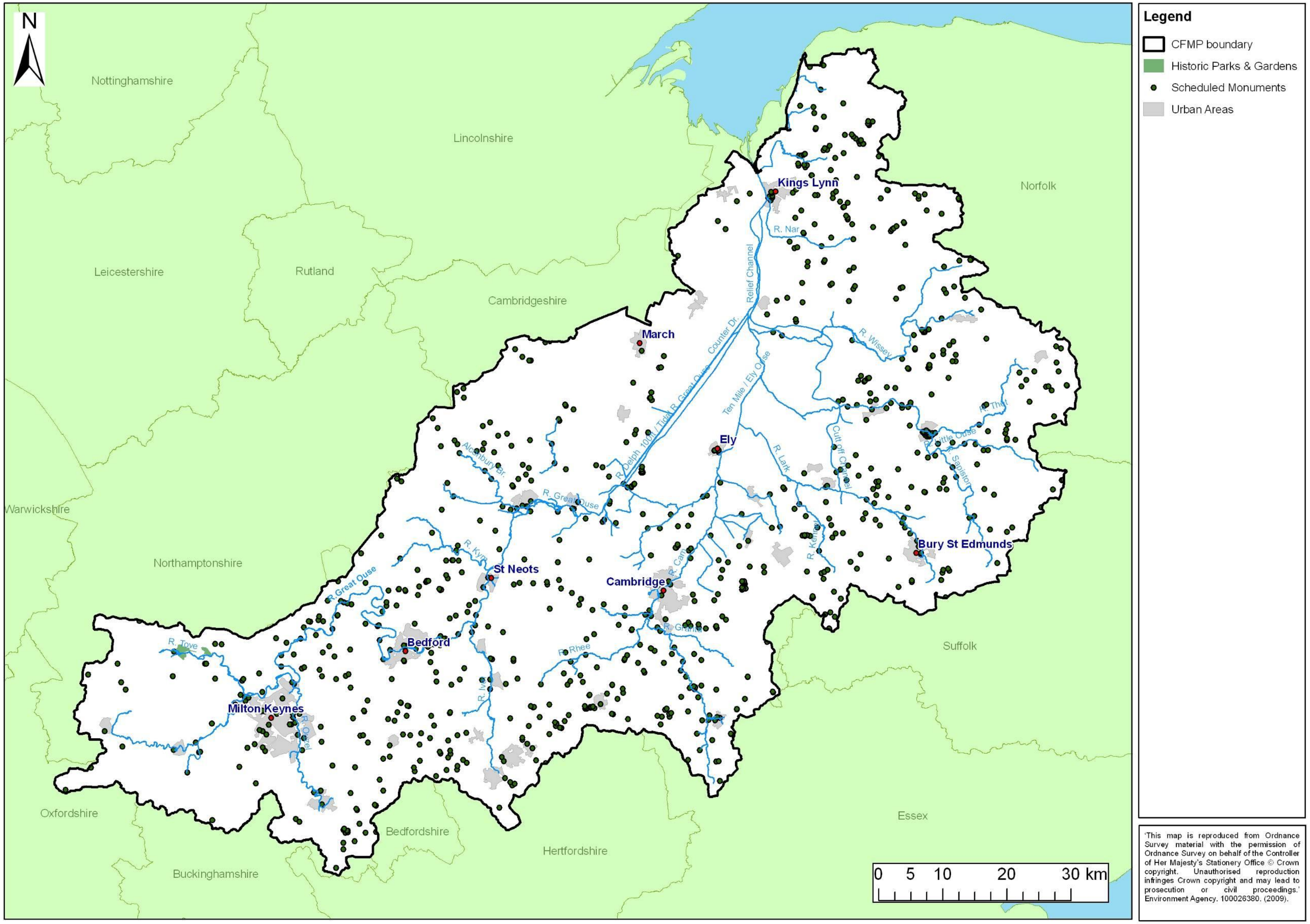


Figure 2-39 Scheduled Ancient Monuments and historic parks and gardens



2.9 Communities and the local economy

2.9.1 Population

The River Great Ouse CFMP area has a population of about 1,750,000, mainly living in the smaller towns, villages and hamlets scattered across the catchment with the rest of the population living in the cities and larger towns such as Cambridge, Bury St Edmunds, Milton Keynes, Bedford, King's Lynn and Huntingdon. Milton Keynes is the largest town in the catchment and has the highest population.

Outside the main towns and cities, the population densities drop significantly, particularly in the more remote rural areas. Levels of community deprivation are likely to vary across the CFMP area, given the variety of nature of the urban and rural areas.

Being a largely rural catchment, agriculture has always been important to the region. Although employment in the industry has fallen significantly, it remains important to the economy and for its impact on the countryside, especially within the intensively farmed Fens region. Table 2-16 shows the population distribution within the catchment.

Table 2-16 Population distribution within the catchment

Location	Population 2006 (local authorities)	Proportion of catchment population (%)
Milton Keynes (Local Authority)	224,800	12
Bedford (Local Authority)	154,700	9
Kings Lynn and West Norfolk (Local Authority)	142,300	8
Huntingdon (Local Authority)- including St Neots, St Ives, Huntingdon and Ramsey	166,600	9
Cambridge (Local Authority)	117,900	6
Bury St. Edmunds (Parish)	101,900	6
Leighton Buzzard (Parish)	32,000	2
Hitchin (Parish)	30,000	2
Thetford Parish)	22,000	1
Newport Pagnell (Parish)	15,000	1
Fenland District	90,100	5
South Cambridgeshire District	135,400	8
Other towns and villages	563,000	31
Total	**1,795,700**	**100**

The size and location of towns can have a major effect on flood risk. Increasing urbanisation within the catchment will create more impermeable areas and this means the area will respond more quickly to flooding. The risk of surface water and sewer flooding will also be increased as a result of urbanisation unless appropriate measures are put in place to control runoff. The impact of new development may occur both locally and further downstream. Any further development in those areas prone to flooding will cause an increase in the risk of future flooding if protective measures are not taken in new and existing urban areas.

The increase in flood risk, resulting from development in flood plains, may remain high even if flood defences are in place as flood defences rarely defend against all flood magnitudes. The main areas of population growth in the catchment are associated with the main towns. Information from the Regional Spatial Strategies shows that the major development areas are associated with Milton Keynes and Bedford, and Cambridge.

2.9.2 Economy

Economic growth rates have been high in the catchment but uneven. The decline in employment in agriculture and traditional manufacturing industries, structural changes to employment patterns and limited inward investment have all had a major impact on the economy of the more isolated north and east of the catchment (exacerbated by poor transport links from east to west). Growing, and more stable, industries across the rest of the catchment include; research and technology (focused around Cambridge), manufacturing, ports (Wisbech and King's Lynn), business, finance, services and tourism.

Alongside economic growth rates, population growth has also been high, largely fuelled by inward migration to the area as a result of planned urban expansions. This increasing population has led to increased housing demand, which in turn, has put pressure on water supply, especially as the catchment contains some of the driest parts of the country.

Employment in the main urban areas such as Cambridge and Milton Keynes is higher than the more rural parts of the catchment, with financial, wholesale and retail trade, transport and communication, real estate, renting and business activities and construction sectors now dominating employment in these regions. Agricultural and tourism sectors dominate the more rural parts of Norfolk, Suffolk, and North Cambridgeshire.

Such urban growth can however increase flood risk in two ways: development within the floodplain will increase the impact of flooding, and the presence of more hard surfaces such as concrete or paving can increase the amount of surface water run-off. The enforcement of good practices in Sustainable Drainage Systems (SUDS) can however reduce these effects on the latter.

2.9.3 Transport

The CFMP area contains a large number of transport routes that are of both local and regional importance and which, by necessity, cross most of the main rivers of the CFMP. There are two motorways within the CFMP area, the M1 (providing links to London and the north) and M11 (linking north east London to Cambridge). Other notable roads include the A1, A14 and A43, which provide regional links with the north, south and west, and other A-roads linking the main urban areas within the catchment.

There are approximately 549km of standard gauge railway in the Great Ouse CFMP area which cross many of the main rivers of the CFMP area. The main railway link in the CFMP area is the East Coast mainline which links London King's Cross, through the eastern counties, to the north of England and to Scotland. The area also has other local routes to the main urban areas such as King's Lynn, Cambridge and Milton Keynes.

The River Great Ouse, some of its tributaries and Fenland watercourses and the Grand Union Canal provide around 240km of navigable waterway in the CFMP area. This included the Relief Channel navigation running between Denver and King's Lynn which was recently opened in 2001. The length of navigable waterway may be increased in the future due to proposed waterways including the Bedford to Milton Keynes Link and the Fens Waterways Link.

There is also one airport within the CFMP area at Cambridge.

Current and future growth is concentrated around the larger urban areas in the catchment including Cambridge, Milton Keynes, Kings Lynn, Bedford, Ely, Leighton Buzzard, and along the A14 and M11 Corridor. The growth proposed by the Regional Spatial Strategies is likely to lead to traffic growth and will have implications for the transport infrastructure.

2.10 Catchment Overview Summary

The previous discussions have provided an overview to the Great Ouse CFMP area. This forms the background to the analysis we will undertake for assessing flood risk, as many of the themes we have identified will be important for flood risk (such as gradient, slopes, geology etc).

We have also identified many of the catchment characteristics, which will form some of the receptors to flooding. These include environmentally designated sites and major transport routes.

The Great Ouse CFMP area is highly varied in many ways. It includes the main urban areas of Milton Keynes, Bedford and Cambridge, as well as highly important agricultural areas which are more sparsely populated such as the Fens. The catchment characteristics vary, for example from steep slopes in some of the smaller tributary catchments towards the flatter areas of the Fens and lower catchment areas. These changes, as well as those to geology, soils and land use influence the way in which water moves across the land, and are therefore important controls on how floods can be generated.

We will now examine current (Chapter 3) and future (Chapter 4) flood risk and use the information we have gathered on the characteristics of the Great Ouse CFMP area to explore flood risk.