# Kent Spatial Risk Assessment for Water: 2021 Update

Volume 1

Kent County Council

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## Quality information

| Prepared by | Checked by | Verified by | Approved by |
| --- | --- | --- | --- |
| Rhiannon Humm<br>Graduate Water Engineer<br><br>Benjamin Andrews<br>Senior Sustainability Consultant<br><br>Jessica Tinkler<br>Graduate Consultant | Richard Moore<br>Senior Consultant | Carl Pelling<br>Technical Head – Water Resources | Richard Moore<br>Senior Consultant |

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## Prepared for:

Kent County Council

## Prepared by:

AECOM Limited
3rd Floor, Portwall Place
Portwall Lane
Bristol BS1 6NA
United Kingdom

T: +44 117 315 0700
aecom.com

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## Glossary of Terms

| Term | Definition |
|---|---|
| Adaption planning | An assessment of where adaptation and mitigation should be focused and how this can be planned for each receptor group. |
| Aquifer | A source of groundwater comprising water bearing rock, sand or gravel capable of yielding significant quantities of water. |
| CAMS | Catchment Abstraction Management Strategy. An Environment Agency strategy developed for the management of water resources at a local level. They provide information on water resources and licensing practice to allow the needs of abstractors, other water users and the aquatic environment to be considered in consultation with the local community and interested parties. |
| Change Source | The source of change which are likely to carry in the long-term and which lead to some form of response in a water system i.e. climate change, land use change or population change. |
| Change Response | The response of a water system to a source change e.g. higher river flows as a result of higher rainfall volumes and intensity predicted with climate change. |
| Eutrophication | The enrichment of waters by inorganic plant nutrients that results in increased production of algae and/or other aquatic plants, which can affect the quality of the water and disturb the balance of organisms present within it. |
| Fluvial Flooding | Flooding resulting from water levels exceeding the bank level of a watercourse (river or stream). |
| Groundwater | All water which is below the surface of the ground in the saturated zone and in direct contact with the ground or subsoil. |
| LiDAR | Light Detection and Ranging. A technique to measure ground and building levels remotely from the air. LiDAR data is used to develop Digital Terrain Maps. |
| Mitigation measures | The controls put in place to moderate or lessen the impact from a proposed action. |
| RBMP | River Basin Management Plan. For each River Basin District, the Water Framework Directive requires a River Basin Management Plan to be published. These are plans that set out the environmental objectives for all the waterbodies within the River Basin District and how they will be achieved. The plans are be based upon a detailed analysis of the pressures on the waterbodies and an assessment of their impacts. The plans must be reviewed and updated every six years. |
| Risk | In this study, risk has been defined as the susceptibility of water systems to adverse impacts as a result of predicted future changes in climate, population or land uses. |
| RoFSW | Risk of Flooding from Surface Water. A national dataset held by the Environment Agency showing areas where surface water would be expected to flow or pond, as a result of two different rainfall events. |
| SMP | Shoreline Management Plan. An Environment Agency large-scale assessment of the risks associated with coastal processes. |
| Soil Erodibility | The measure of a soil’s susceptibility to raindrop impact, runoff and other erosional processes. |
| Spatial Indicators | Features used to determine how water system change responses would vary in magnitude across Kent (e.g. geology, hydrology, population change). |

| Term | Definition |
|---|---|
| SRA | Spatial Risk Assessment. A strategic spatial analysis of how risks and opportunities to Kent's water systems (and the users or and receptors of those systems) may vary across the County's administrative area. |
| SuDS | Sustainable Drainage System. Methods of management practices and control structures that are designed to drain surface water in a more sustainable manner than some conventional techniques. Includes swales, wetlands, bioretention devices and ponds. |
| SWMP | Surface Water Management Plan. Plans developed for an area where surface water flood risk is a concern to determine the level of flood risk posed from surface water flooding and actions required to alleviate flood risk. |
| Water demand | The amount of water required for a particular purpose, e.g. agriculture, businesses. |
| WFD | Water Framework Directive. European Union legislation (2000/60/EC) that requires all waterbodies to be at Good Ecological Status by 2015 or 2027. |
| Water System Impact Susceptibility | The graphical representation of risk as defined for this study. A series of maps showing the susceptibility of water systems in Kent to impacts derived from a series of change sources and change responses. |
| WFD waterbody catchments | A manageable unit of surface water, being the whole (or part) of a stream, river or canal, lake or reservoir, transitional water (estuary) or stretch of coastal water. |
| WRMP | Water Resource Management Plan. A Water Company plan produced every five years that determines how they propose to meet projected demand over a 25 year planning period. |
| WRZ | Water Resource Zone. The largest zone within which the water sources can be shared. |
| Q50 | Median flow or flow that is available at least 50% of the time. |

# Glossary of Acronyms

| Term | Definition |
|---|---|
| BGS | British Geological Society |
| BOD | Biochemical Oxygen Demand |
| CAMS | Catchment Abstraction Management Strategy |
| CCRA | Climate Change Risk Assessment |
| Defra | Government Department for Environment, Food and Rural Affairs |
| DO | Dissolved Oxygen |
| EBA | Ecosystem based adaption |
| ECR | Economics of Climate Resilience |
| GIS | Geographical Information System |
| KCC | Kent County Council |
| NAP | National Adaption Programme |
| NbS | Nature based Solution |
| NEA | UK National Ecosystem Assessment |
| NFM | Natural Flood Management |
| P | Phosphorous |
| PES | Payment for Ecosystem Services Scheme |
| RBMP | River Basin Management Plan |
| SMP | Shoreline Management Plan |
| SRA | Spatial Risk Assessment |
| SuDS | Sustainable Drainage System |
| SWMP | Surface Water Management Plan |
| WFD | Water Framework Directive |
| WRMP | Water Resource Management Plan |
| WRZ | Water Resource Zone |
| WSIS | Water System Impact Susceptibility |
| WwTW | Wastewater Treatment Works |

# 1. Introduction

AECOM were commissioned by Kent County Council (KCC) to undertake a Spatial Risk Assessment (SRA) of the impacts of changing climate, land use and population on water systems in Kent. This is an update on the previous Kent SRA for Water[1] produced in 2014 by AECOM (formerly URS Infrastructure and Environment Ltd) and Climate Change Risk Management (CCRM).

## 1.1 Project Background

The 2014 SRA provided a sound evidence base to understand risk to water systems in Kent. The study output was used to understand the risks to water systems and subsequent consequences to a range of receptors as a result of future climate, land use and population induced change, and to support decision making around mitigation and adaptation to the water environment and water infrastructure systems in the County.

Some of the risks and consequences identified in 2014 have begun to materialise, and importantly, information sources on climate and population change have also advanced since the 2014 analysis was completed. Therefore, KCC and study partners require an update to the study to refresh risks with new information and to better understand some of the key risks, consequences and mitigation. In particular, there is a need to reconsider how risk is defined to allow a better understanding of the future physical impacts to water systems and facilitate a focus on how nature-based solutions (NbS) and working with natural processes can contribute to managing and mitigating the risk. Additionally, there is a need to understand the risks and mitigations in the Stour catchment specifically as part of the H2O:Source2Sea project to facilitate stronger partnership working in delivering those solutions.

## 1.2 Project Funding

This project has been funded by Interreg V A France (Channel) England 2014 – 2020, H2O:Source2Sea project which is co-financed by the European Regional Development Fund. The H2O:Source2Sea project aims to implement Natural Flood and Drought Management Measures on the Stour in the UK and the Authie in France to demonstrate how these solutions reduce water management costs, improve freshwater quality, reduce pollution and benefit the local wildlife and communities.

## 1.3 Aims and Objectives

There are four main objectives of the updated 2021 Kent SRA for water ("the Kent SRA update") as follows;

1. Re-define risk from the 2014 study, focusing on mapping impacts to the physical water systems[2] and then qualitatively assessing how those impacts could affect environmental condition and human receptors.
2. Using updated climate and population change projection data, provide an updated set of risk mapping showing how medium to long-term water system risks and opportunities arising from climate change, land use change and population change vary spatially across the County.
3. Provide an updated evidence base for KCC and other stakeholders to support the production of adaption planning and guidance in relation to these risks, specifically focused on NbS delivery.
4. Prioritise areas within the County that are most at risk in the medium to long-term to guide where adaptation planning and mitigation is needed the most.

It is important to stress the strategic nature of the mapping and assessment process that has been undertaken for this Study. The purpose of the Kent SRA update is to broadly estimate areas that have the highest risk, using analysis of a large range of water system change such that mitigation can be targeted to areas of most relevance. It is not intended to be a detailed study which precisely determines the extent and effect of each risk or identifies mitigation location at a fine resolution.

[1] URS & CCRM (2014) Kent Spatial Risk Assessment for Water
[2] Primarily watercourses, aquifers and coastal waterbodies

## 1.4 Study Reporting

The study has produced a large number of mapped outputs and hence has been reported in two volumes for ease of reference:

- Volume 1: Kent SRA Update Report – Methodology, mapping discussions (this volume); and
- Volume 2: Mapbook – presentation of maps produced for the Kent SRA update.

# 2. Approach to Kent SRA Update

## 2.1 Introduction

In order to understand risks to water systems arising from changing climate, land use and population within Kent, it is important to understand how these sources of change influence the hydrological functioning of the natural water systems in the County. How natural water systems function is a product of several key factors. The physical geography of an area is a key factor which defines a significant element of hydrological processes and many of these physical geographic elements are unchanging within the timeframes considered for this project e.g. topography and geology. However, several key factors which influence hydrological processes vary across many temporal scales and include factors such as varying rainfall patterns and temperature, as well as human geographical factors such as land use change, and population pressures in the form of abstraction and drainage management.

The variable factors described are subject to change sources that are likely to occur in the longer-term and include factors such as climate change, planned population increase and technology driven land use changes. How these ‘change sources’ impact on natural water systems (and the man-made water systems that rely on them) in a given area is, in part, a function of the physical geography of that area. In order to define risks related to these changes, it is important to consider how pressures such as climate change may vary spatially, and also the spatial variability in physical geography of that area. In so doing, it is important to take into consideration the inherent uncertainties in climate change projections and that these projections will be refined over time.

In determining risk, it is also important to consider all change sources in combination because functioning of water systems is complex and affected by a number of different factors acting concurrently. It was important at an early stage in the study to define all the change sources, how water systems respond to these change sources, and then consider how responses combine to result in a range of impacts on water systems affecting the users or receptors of those water systems.

## 2.2 Defining Risk – Update From 2014

It is important to clearly define the use of the term ‘risk’ for the Kent SRA update. The definition of risk needs to consider that the Kent SRA update aims to focus on adaptation and mitigation on NbS delivery as a means to manage any impact on the water systems, the related environment and human receptors or users of the water systems.

The 2014 Kent SRA mapped risk as a series of consequences according to four broad receptors types; however, aside from flood risk, a causal link between a potential future change in a water system and spatially specific impacts on different receptors was not always strong enough to support a detailed mapping approach and to identify spatially specific adaptation and mitigation measures; identifying NbS delivery using this method would have been more challenging.

Risk has therefore been reconsidered for the Kent SRA update as an assessment of the susceptibility of water systems to future impacts, with the assessment of effects (or consequences) on receptors undertaken largely as a qualitative exercise using the redefined risk mapping. Risk is defined as:

> The **susceptibility** of water systems to adverse impacts as a result of predicted future changes in climate, population of land uses.

This definition of risk, and how it is derived is further illustrated in Figure 2-1.

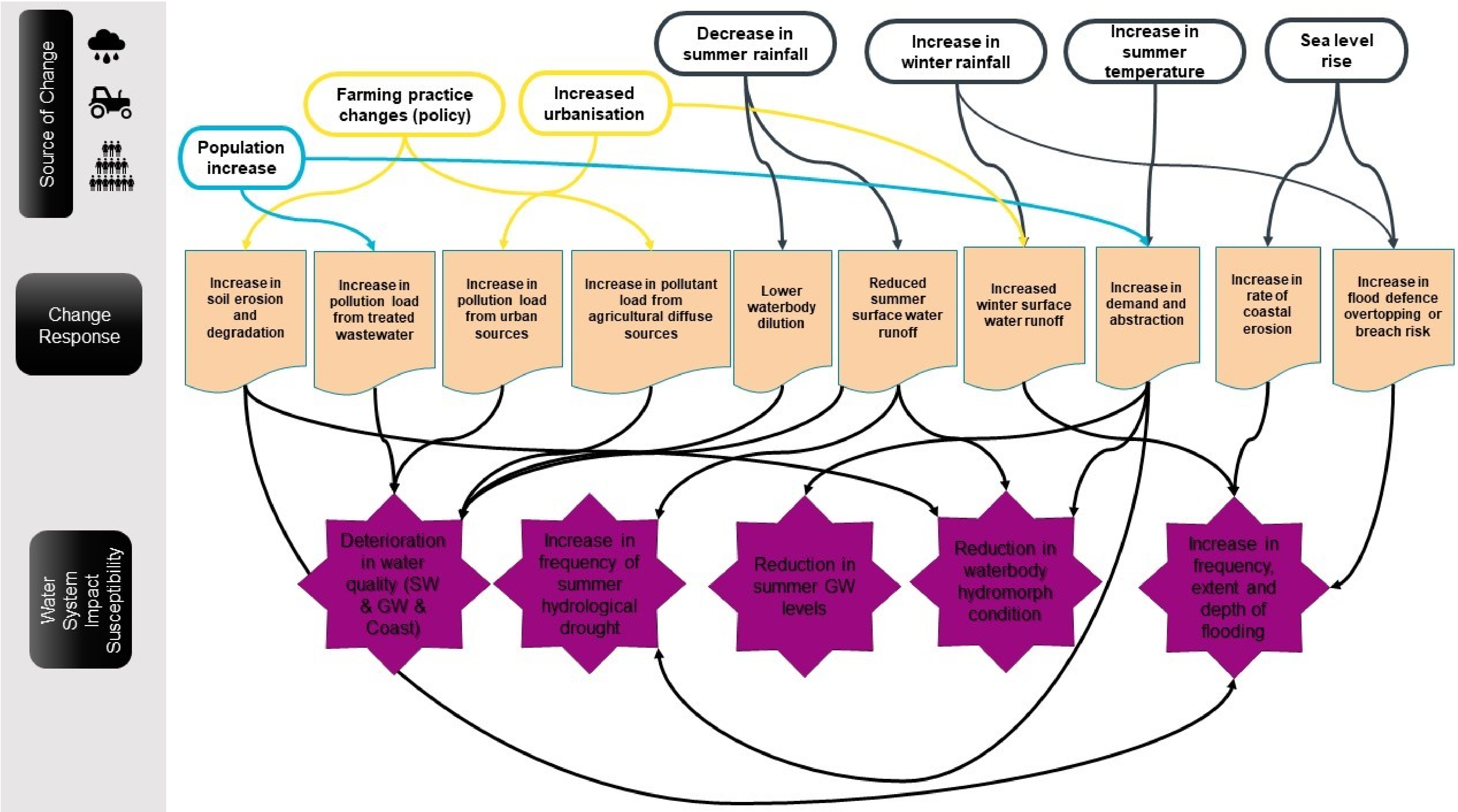


**Figure 2-1: Determining risk through change sources, change responses and Water System Impact Susceptibility**

An alternative format of this figure that is digitally accessible is available in Appendix B.

Figure 2-1 illustrates that risk has been determined through a process of a '**change source**' (such as future changes in climate, or population), resulting in one or more '**change responses**' within a water system (e.g. reduced groundwater levels, or increases in pollution). These change responses then combine to lead to a water system impact with different levels of impact susceptibility, referred to in this study as '**water system impact susceptibility'** (WSIS). It is important to note that WSIS can occur from a number of different change responses in water systems which in turn can result from one or more change responses as illustrated in Figure 2-1.

An example of how a specific WSIS is derived is illustrated in Figure 2-2, using the WSIS of 'susceptibility to an increase in frequency and extent of flooding' as an example.

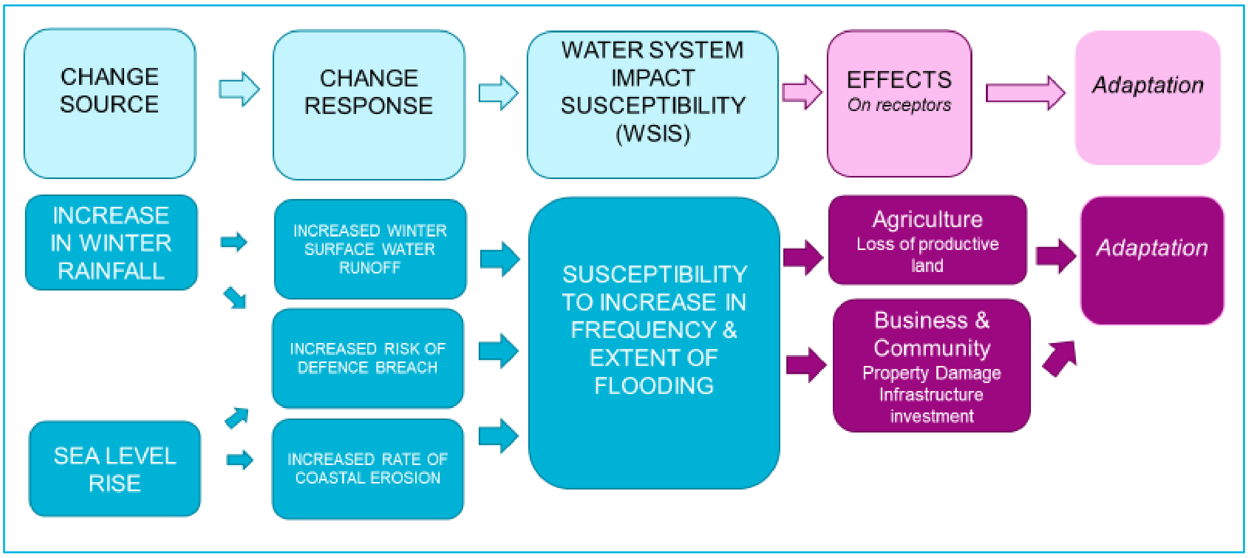


**Figure 2-2: Example of a Water System Impact Susceptibility determination process (using flood risk)**

An alternative format of this figure that is digitally accessible is available in Appendix C.

## 2.3 Risk Mapping Process - Summary

In order to map the risks, the steps required to identify change sources, change responses and WSIS used a combination of some quantitative, but mostly qualitative assessment and a Geographical Information System (GIS). The detailed steps are explained within Section 3 (Discussion of Change Sources), Section 4 (Presentation of Change Responses) and Section 5 (Presentation of Water System Impact Susceptibilities) of this report. The general overview of the approach is described below.

To determine all of the risks that would be mapped, it was important to consider and determine all of the change sources and change responses that would contribute to the risks (the WSIS). It was also key to determine which elements varied spatially across Kent and whether there was a means to determine this variability based on existing data. Potential data sources related to change sources, the geographical context of Kent and water management were analysed, firstly to determine whether they could act as an indicator for magnitude of change responses in the water systems; and secondly, whether the data was sufficiently detailed to enable determination of spatial variance in magnitude of change response across Kent's water systems. Such data sources and specific attributes of these data sources were defined as 'spatial indicators'.

This study identified spatial indicators that would be used to determine how change responses would vary in magnitude across Kent. The 2014 Kent SRA identified that population and land use change sources would vary across Kent, but the resolution of available climate change projections (using UKCP09) meant that identifying spatial variability in climate change sources was limited. This meant the spatial variability for these climate change induced change responses had to be driven by how the changes lead to differences in response according to the geography and hydrological functioning of the catchments in Kent. However, updated UKCP18 data was available for the Kent SRA update showing a spatial variation in change source factors, such as changes in winter and summer rainfall as well as temperature changes, which have allowed these change sources to be used directly as spatial indicators within the County for the update.

The change sources have been used directly alongside interpretation of how the geography, hydrology and management of water systems by human intervention in Kent would influence change responses as spatial indicators. For simplicity and ease of mapping, a high, medium or low magnitude was assigned to each change response. How this was assigned for each change response is explained in further detail in Section 4. The high, medium or low magnitude scoring allowed assimilation of change response scores in GIS to inform the risk (WSIS) mapping.

### 2.3.1 Change Timescales

Due to the variance in data sources used for developing spatial indicators, the time period over which changes in land use, climate change and population change have been assessed, also varies. To assist with interpretation of change and risk mapping outputs which represent a degree of future change, indicative time horizons have been recommended for each map type.

## 2.4 Risk Mapping Outputs

Maps have been produced for the study context, change sources, change responses and the WSIS outcomes. Context and change source maps have been produced in a range of output formats and colours; however, colour coding has been used in the change response and WSIS mapping as follows:

- Water System Change Response – gold scale colouring; and
- Water System Impact Susceptibility Map – purple scale colouring.

### 2.4.1 Context and Change Source Mapping

In order to determine the extent of change responses that water systems might experience, it was necessary to review and map some of the geographic context in the GIS as well as mapping the change sources which would be used as spatial indicators. Several context and change source maps have been produced and are presented in Volume 2 of the Kent SRA Update Report. Table 2-1 sets out the list of maps produced along with their mapping reference and time horizon.

**Table 2-1: Context and Change Source Maps**

| Map Category | Map Reference | Map Name | Time Horizon |
|---|---|---|---|
| **Context Maps** | CON1 | River Systems in Kent | **N/A** |
| **Context Maps** | CON2 | Bedrock Geology | **N/A** |
| **Context Maps** | CON3 | Superficial Geology | **N/A** |
| **Context Maps** | CON4 | Water Framework Directive (WFD) Groundwater Resource Rating | **2019** |
| **Context Maps** | CON5 | WFD Groundwater Quality Rating | **2019** |
| **Context Maps** | CON6 | Bedrock Permeability | **N/A** |
| **Context Maps** | CON7 | Superficial Permeability | **N/A** |
| **Context Maps** | CON8 | Agricultural Land Classification | **2021** |
| **Context Maps** | CON9 | Wastewater Treatment Works (WwTW) Locations | **2021** |
| **Context Maps** | CON10 | Water Company Resource Zones (WRZ) | **2021** |
| **Context Maps** | CON11 | Agricultural Pressures – Groundwater | **2019** |
| **Context Maps** | CON12 | Agricultural Pressures – Rivers | **2019** |
| **Context Maps** | CON13 | Slope Gradient | **N/A** |
| **Change Source** | CSO1 | Water Company Supply and Demand Deficits to 2045 | **2045** |
| **Change Source** | CSO2 | Future Population Change Per District to 2038 | **2038** |
| **Change Source** | CSO3 | Potential Scale of Land Use Changes by 2080 | **2080** |

| | | | |
|---|---|---|---|
| **Change Source** | CSO4 | Decrease in Summer Rainfall by 2080 (UKCP18 Projections) | **2080** |
| **Change Source** | CSO5 | Increase in Winter Rainfall by 2080 (UKCP18 Projections) | **2080** |
| **Change Source** | CSO6 | Increase in Maximum Summer Temperatures by 2080 (UKCP18 Projections) | **2080** |
| **Change Source** | CSO7 | Increase in Urbanisation | **2038** |

A brief discussion of the key change sources is provided in Section 3.

### 2.4.2 Change Response Mapping

The change response maps are provided in Volume 2. Table 2-2 details the maps produced for each change response, alongside their reference number and time horizon.

There is no standard spatial unit for mapping change responses, with the spatial resolution of each change response map depending on the spatial indicators used in each case and the spatial scale of available data. A range of magnitude scores have been calculated according to the number of spatial indicators used to determine the change response, but all response maps have been classified using a high (3), medium (2) or low (1) magnitude response as described further in Section 4.

**Table 2-2: Change Response Maps**

| Map Ref | Map Name | Indicative Time Horizon: Decade and Explanation | |
|---|---|---|---|
| **CRE1** | Increase in Risk of Lower Summer River Flows | Up to 2080s | **Climate change data has been used as the primary indicator – pressures from population change are likely to extend to this time horizon** |
| **CRE2** | Increase in Tidal and Fluvial Flood Risk | Up to 2080s | **Hydraulic modelling outputs have used climate change projections to the 2080s** |
| **CRE3** | Increase in Surface Water Flood Risk | Up to 2080s | **Hydraulic modelling outputs have used climate change projections to the 2080s** |
| **CRE4** | Increase in Groundwater Flood Risk | Up to 2080s | **Climate change projections to the 2080s have been used** |
| **CRE5** | Risk of Increase in Summer Demand and Abstraction - Surface Water | Up to 2050s | **Climate change data used to 2080, but combined with existing abstraction pressures which may change in the longer term** |
| **CRE6** | Risk of Increase in Summer Demand and Abstraction - Groundwater | Up to 2050s | **Climate change data used to 2080, but combined with existing abstraction pressures which may change in the longer term** |
| **CRE7** | Increase in Risk of Soil Erosion and Degradation | N/A | **This change has used physical characteristics to indicate where future climate change may exacerbate the change; this could occur across a range of future timescales** |
| **CRE8** | Risk of Increase in Pollution Load from Wastewater Treatment to Surface Waterbodies | 2040s | **Population change to 2038 is the key indicator for change** |
| **CRE9** | Risk of Increase in Pollutant Load from Urban Sources | 2040s | **Population change to 2038 is the key indicator for change** |

| | | | |
|---|---|---|---|
| **CRE10** | Risk of Increase in Rate of Coastal Erosion (No Active Intervention) | Up to 2050s | **Erosion risk to the middle epoch 2050s has been used** |

### 2.4.3 Water System Impact Susceptibility

WSIS were mapped by combining the magnitude scores assigned for each change response contributing to that risk. As described, each change response contributing to a WSIS was scored according to whether it was a high (3), medium (2) or low (1) magnitude response. GIS was used to assign this response magnitude scoring, and these impact scores were combined for each relevant grid resolution in the GIS to give a consequence overall WSIS 'risk score'; this score was categorised across a range of either high, medium or low. Further detail on this process is provided for each WSIS in Section 5.

It is acknowledged that each WSIS has different levels of risk when compared to each other; however, a key aim of the study was to determine where there are a greater number of high risks for water systems spatially within Kent, and hence a weighting system was not used for the strategic purposes of the assessment.

The initial output for each WSIS was a map demonstrating risk level (high, medium or low) across Kent. The WSIS maps are provided in Volume 2 of the Kent SRA Update Report. Table 2-3 details the maps produced for each of the WSIS risks. This table also indicates the recommended indicative time horizon to which the WSIS should apply based on the time horizons of the change response maps used.

**Table 2-3: Water System Impact Susceptibility Maps**

| Map Reference | Map Name | Indicative Time Horizon |
|---|---|---|
| **WSIS1** | Increase in Frequency, Extent and Depth of Flooding | **Up to 2080s** |
| **WSIS2** | Increase in Frequency of Summer Hydrological Drought | **Up to 2050s** |
| **WSIS3** | Deterioration in Water Quality – Surface Water | **Up to 2050s** |
| **WSIS4** | Deterioration in Water Quality – Groundwater | **Up to 2050s** |
| **WSIS5** | Deterioration in Hydromorphological Condition - Fluvial | **Up to 2050s** |
| **WSIS6** | Reduction in Summer Groundwater Levels | **Up to 2050s** |


| Map Reference | Map Name | Indicative Time Horizon |
|---|---|---|
| **WSIS1** | Increase in Frequency, Extent and Depth of Flooding | **Up to 2080s** |
| **WSIS2** | Increase in Frequency of Summer Hydrological Drought | **Up to 2050s** |
| **WSIS3** | Deterioration in Water Quality – Surface Water | **Up to 2050s** |
| **WSIS4** | Deterioration in Water Quality – Groundwater | **Up to 2050s** |
| **WSIS5** | Deterioration in Hydromorphological Condition - Fluvial | **Up to 2050s** |
| **WSIS6** | Reduction in Summer Groundwater Levels | **Up to 2050s** |


## 2.5 Risk Assessment and Receptor Effects

Following completion of the risk mapping in the GIS, analysis was undertaken to identify the water systems in Kent at highest risk from each of the identified water system impacts and how those risks related to receptors.

In order to support a more detailed assessment of the WSIS related to surface water quality in the Stour catchment, a water quality modelling exercise was also undertaken to consider how nutrient pollution risk may increase as a result of climate change (lower flows) and increases in population (increases in wastewater discharges).

## 2.6 Adaptation Response

The adaptation response to the identified risks to water systems in Kent has focused on opportunities for the implementation of NbS to mitigate adverse environmental impact, including where measures such as Natural Flood

Management (NFM) can potentially work to manage flood risk to people, places and businesses. Where implementation of measures would lead to wider benefit to people, places and businesses, this has also been identified.

This work included:

- assessment of generic adaptation and mitigation measures for each of the WSIS risks identified; and
- identification of potential catchment specific NbS mitigation measures according to where the highest risk areas for each consequence coincide with receptor extent.

The process for this adaptation assessment and the outputs are detailed in Section 6.

### 2.6.1 Limitations and Assumptions on Approach

Due to the strategic nature of the study, the approach to the analysis of risk, mapping and solution identification is subject to some key assumptions and limitations which need to be considered when using the study outputs for informing decision making.

A key limitation is the strategic scale at which the analysis of risk and vulnerability has been undertaken. A key requirement of the study was that it covered risk at the Kent County level (including Medway) for a large range of change sources and change responses; this scale of assessment necessitated the adoption of metrics and spatial indicators which drew on readily available information and data sources and which could be applied rapidly at a large geographic scale. This prevented a detailed analysis of how different water systems (such as individual rivers or water dependent sites) would be impacted by change responses and hence the assessment of risk does not seek to predict with any degree of certainty what will happen to each water system (or feature) at a local level. Instead, the study considers potential impacts as a degree of vulnerability of different water systems (and their receptors) to different sources of change based on macro scale indicators such as geology type, catchment size, aquifer properties or land use/topography. This means the study allows focus on solutions to be considered at a broad geographical scale, but does not negate the need for further assessment of the likely local scale changes and hence identification of local scale solutions which may be most appropriate in each case.

Further specific assumptions and limitations to the approach or information used are listed below. It should be noted that this list is not exhaustive and further limitations and assumptions are listed within relevant sections in relation to the specific change sources, change responses, WSIS and NbS adaptation analysis.

- The level of risk assigned to the change response and WSIS is dependent on the quality of the data that was made available for the study at the time of completing the assessment work. It was not possible within the remit of the study to collect new data via surveys or additional monitoring;
- Impacts could only be mapped where spatial indicators were available across Kent for that specific impact;
- Through the use of WFD waterbody catchments to map some impacts and consequences, local variances within the catchment will not be captured; and,
- UKCP18 data has been used as a key indicator of change for this study. The dataset represents a comprehensive assessment of potential future climate conditions providing data at a greater spatial resolution than has been possible in the past; however, the outputs are projections and should not be viewed as a definitive prediction of exactly how climate change will manifest at a local scale.

# 3. Discussion of Change Sources

As discussed in Section 2.3, to determine all of the risks that would be mapped, it was important to consider all of the change sources and change responses that would contribute to the risks. It was also key to assess which elements varied spatially across Kent and whether there was a means to determine this variability based on existing data. The key change sources that were assessed as part of this study related to climate change, population change, urbanisation, water supply-demand and land use change. The mapping process and a summary of what is shown from each figure are detailed below.

## 3.1 Climate Change

As part of a separate study, KCC undertook a comprehensive and detailed analysis of the new UKCP18 outputs. As part of this analysis, probabilistic and local land projections were used to create GIS outputs for a range of variables across Kent for different emission scenarios. It was agreed for consistency that this data should be taken forward and applied as part of the Kent SRA update.

As part of the new UKCP18 outputs, a new climate model at a resolution on par with operational weather forecast models has been produced for national climate scenarios. This model allows users to examine the risk of extreme weather events in local areas for the coming decades. Previously, global and regional climate models have typically used resolutions of 60-300km$^2$ and 10-50km$^2$ respectively. The new local climate model applies a 2.2km$^2$ resolution and represents a step forward in the ability to simulate small scale behaviour seen in the real atmosphere and the influence of features such as mountains, coastlines and urban areas. It was agreed that data produced from this local climate model should be used as part of the Kent SRA update as it described climate changes according to geographical variables across the County.

It should be highlighted that outputs from this local model were only available from the RCP8.5 (Representative Concentration Pathway 8.5) scenario. This high-emissions scenario is frequently referred to as “business as usual” suggesting a likely outcome if society does not make concerted efforts to cut greenhouse gas emissions.

From the information provided by KCC, figures were created showing the following:

- Decrease in summer rainfall to 2080 (**High**: >-0.80mm/d **Medium**: -0.60mm/d to -0.80mm/d and **Low**: <-0.60mm/d).
- Increase in winter rainfall to 2080 (**High**: >0.80mm/d **Medium**: 0.60mm/d to 0.80mm/d and **Low**: <0.60mm/d); and
- Increase in summer temperature to 2080 (**High**: >5.5$^o$C, **Medium**: 4.5$^o$C to 5.5$^o$C and **Low**: <4.5$^o$C).

Generally the areas which are projected to experience the greatest decrease in summer rainfall are located to the west of Kent in areas such as Sevenoaks, Gravesham, Medway, Tonbridge & Malling and Maidstone (west). When considering increase in winter rainfall, the central districts are shown to have the greatest increase including Swale, Maidstone (east) and Tunbridge Wells. Finally, when considering increases in summer temperature, coastal areas experience less increase than inland areas with temperatures increasing from east to west. Sevenoaks and parts of Tonbridge & Malling and Tunbridge Wells show temperature increases greater than 6$^o$C if nothing is done to cut global emissions.

## 3.2 Sea Level Rise

To be consistent with the climate change mapping approach, UKCP18 data was used to assess sea level rise based on the RCP8.5 emission scenario. This involved using 1981-2000 baseline data and considering the rise in sea level to 2080. According to this data, there is likely to be an increase in sea level of 0.80m around the coastline of Kent if nothing is done to cut global emissions.

## 3.3 Population Change

To understand changes to population, KCC provided district level population forecasts for the whole of the County to 2038. Initially ward level population forecasts were requested as was used for the 2014 Kent SRA; however, at the time of the study this information was unavailable. The 2019 small area population estimates produced from the Office for National Statistics were not due to be released until the end of 2020 / start of 2021 and the previous 2015/2016 ward level forecasts were not considered reliable and suitable for the Kent SRA update. It was therefore recommended by KCC that the district level population forecasts should be applied. It is likely that small area forecasts will be available in the future and it is recommended that these are considered as part of any future work.

The figure created for this study was based on the following bandings: Projected level of population change by district by 2038 - **High**: >25,000, **Medium**: 15,000 to 24,999 and **Low**: <15,000.

The figure showing population change demonstrates that Ashford, Medway and Dartford have the greatest projected increase in population while Sevenoaks, Dover, Folkestone & Hythe and Gravesham have the lowest projected increase.

## 3.4 Urbanisation

To represent changes in urban areas, KCC provided 2017 mapping data used for the Growth and Infrastructure framework[3] housing sites. Two separate GIS outputs were provided as part of this dataset which included Allocation Sites and Strategic Sites. When mapped, the majority of these sites are located around key towns and cities. As no quantitative data is associated with these datasets, no high, medium or low banding has been assigned.

## 3.5 Supply-Demand

Water supply and demand deficits were extracted from Water Resources Management Plans (WRMPs). This included Affinity Water WRMP (2020), SES Water WRMP (2019), Southeast Water WRMP (2020), Southern Water WRMP (2020) and Thames Water WRMP (2020). From these plans, the Dry Year Annual Average baseline supply and demand balance were extracted to 2045-2050 and were then mapped by WRZ.

The figure created for this study was based on the following bandings: Forecast supply and demand deficits (2045 – 2050) - **High**: >50ml/d, **Medium**: 10ml/d to 50ml/d and **Low**: <10ml/d.

Results from this figure show that to the west of Kent, areas within Dartford and Sevenoaks generally have a high supply-demand deficit while to the east of Kent in areas of Dover and Folkestone & Hythe, they generally have a low supply-demand deficit. All other areas are considered to have a medium supply-demand deficit.

## 3.6 Land Use Change

To map land use change, the 2012 Kent Habitat Survey data has been used to link categories of land cover to the following uses: forest, cropland, grassland, wetland and settlement. This was based on the 2003 IPCC Good Practice Guidance for Land Use, Land Use Change and Forestry. The next part of the mapping process was to apply 2100 percentage changes to these categories which were produced from a study by Cambridge Econometrics[4]. The results from this process were then sense checked against other sources of information about past change in land cover, including the assessment of changes in habitat within Kent since 1961[5]. It should be noted that it was difficult to conceptualise all the potential impacts of land use change on the water environment across the entire County, so this wasn't used in future phases of mapping and has been provided for context to the Kent SRA update.

[3] https://www.kent.gov.uk/about-the-council/strategies-and-policies/environment-waste-and-planning-policies/growth-and-infrastructure-framework-gif
[4] https://www.theccc.org.uk/wp-content/uploads/2019/07/Consistent-Set-of-Socioeconomic-Dimensions-Final-Report-Cambridge-Econometrics.pdf
[5] https://www.kent.gov.uk/__data/assets/pdf_file/0007/95317/Kent-land-cover-change-analysis-1961-2008.pdf

# 4. Presentation of Change Responses

## 4.1 Increase in Risk of Lower Summer River Flows

### 4.1.1 Figure Reference

Volume 2: Mapbook Figure Reference

**Figure CRE1 – Increase in Risk of Lower Summer River Flows**

**Figure CON1 – River Systems in Kent**

**Figure CON6 – Bedrock Permeability**

**Figure CON7 – Superficial Permeability**

**Figure CSO2 – Future Population Changes per District to 2038**

**Figure CSO4 – Decrease in Summer Rainfall by 2080 (UKCP18 Projections)**

### 4.1.2 Introduction to Change Response

The mapping undertaken for this change response represents the possible impact of lower summer river flows, which is driven by two key change sources, namely:

- Changes in summer rainfall patterns as a result of climate change; and,
- Increases in population.

UKCP18 climate change modelling indicates that by the 2080s, summer rainfall volumes across Kent could decrease by up to 60% (Figure CSO4). More generally, it is predicted that there will be much longer periods of dry hot summer weather where there is no rainfall which exacerbates the onset of low flows in rivers. Additionally, increasing population will lead to a higher demand for water, which has the potential to result in lower flows where water supply is sourced from surface water systems or groundwater abstraction removes river baseflow.

### 4.1.3 Determining Spatial Indicators

Change in summer rainfall volumes was considered to be sufficiently spatially variable across the County for it to be used directly as a spatial indicator (Figure CSO4). However, it was also important to consider the risk in relation to the varying geographical catchment characteristics which would influence responses to lower rainfall. Population change data demonstrates that there is a spatial variability in predicted population growth across the County (Figure CSO2); however, how this influences river flows as a result of abstraction is not directly related to where this growth occurs. The various water companies supplying Kent with treated water have flexible supply systems that allow raw and treated water to be moved around their supply area, and transferred into the County such that it is not possible to draw direct relationships between where population growth might occur in the future and which river catchment will therefore be at greater risk of lower flows.

For these reasons, spatial indicators in addition to UKCP18 summer rainfall prediction were drawn from the following sources:

- The Environment Agency Catchment Abstraction Management Strategies (CAMS) - based on where there are restrictions on available water for further abstraction in river systems. The CAMS assessment takes into account the natural flow variability of a river system and the existing abstractions licenced from each catchment.
- The British Geological Society (BGS) aquifer permeability information (Figure CON6 and Figure CON7) was utilised to determine river catchments that are more at risk from low summer flows. Rivers that drain relatively impermeable soils and geology (such as clay catchments) are more likely to experience lower summer river flows in response to lower summer rainfall as they are reliant on surface water runoff to generate river flow. Permeable catchments (such as chalk) are less likely to experience lower summer flows as they would maintain an element of baseflow from groundwater which is predicted to be less adversely impacted by climate change induced rainfall changes.

The analysis was completed at the WFD surface waterbody catchment level and data was compared to this spatial scale.

### 4.1.4 Magnitude of Change Assessment

UKCP18 outputs were used to determine the change in summer rainfall from summer 2021 to 2080. Change in summer rainfall is shown in Figure CSO4 using the scaling as indicated below;

- High: > -0.80mm/day
- Medium: -0.60mm/day to -0.80mm/day
- Low: <-0.60mm/day.

Table 4-1 shows the change magnitude score assigned based on the decrease in summer rainfall across catchments. The magnitude score is taken from the data category covering the largest percentage area of a waterbody catchment with the analysis completed in the GIS.

**Table 4-1: Change in Summer Rainfall magnitude**

| Decrease in Summer Rainfall | <0.60mm/day | 0.80mm/day – 0.60mm/day | >0.80mm/day |
|---|---|---|---|
| Score | 1<br>Low | 2<br>Medium | 3<br>High |

The aquifer permeability of a WFD river waterbody catchment was determined using BGS Bedrock Permeability. The proportion of underlying aquifer type within the WFD catchment was calculated in the GIS and the most abundant aquifer type determined. Catchments were assigned a magnitude score according to Table 4-2.

**Table 4-2: Aquifer Permeability**

| Aquifer Permeability | High/Very High | Medium | Low/Very Low |
|---|---|---|---|
| Score | 1<br>Low | 2<br>Medium | 3<br>High |

WFD river waterbody catchments were matched as closely as possible to the corresponding CAMS waterbodies. The availability of water at Q95 was used to indicate where catchments are already under pressure in relation to existing abstraction and hydrological function of the catchments. If catchments have little available water for abstraction, they are more likely to be at risk of climate and population pressure change effects at lower flows. The CAMS catchments were assigned a magnitude score as shown in Table 4-3.

**Table 4-3: Water available for licencing at Q95**

| Water availability | Available | Restricted | Not Available |
|---|---|---|---|
| Score | 1<br>Low | 2<br>Medium | 3<br>High |

The three spatial indicators were then combined in the GIS for each waterbody catchment to determine the overall magnitude of change response associated with lower summer river flows. Table 4-4 shows the categorisation of the combined scores to get a high, medium and low overall magnitude score and Table 4-5 the overall magnitude score for the combined parameters. The mapping result is shown in Figure CRE1.

**Table 4-4: Combined Score**

| | Low | Medium | High |
|---|---|---|---|
| Combined Score | <4 | 5-6 | >7 |

**Table 4-5: Overall Magnitude for Lower Summer River Flows**

| Change in Summer Rainfall | | High | | | Medium | | | Low | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Aquifer Permeability | | H | M | L | H | M | L | H | M | L |
| Water available for licencing at Q95 | Not available | H | H | H | H | H | M | H | M | M |
| Water available for licencing at Q95 | Restricted | H | H | M | H | M | M | M | M | L |
| Water available for licencing at Q95 | Available | H | M | M | M | M | L | M | L | L |

## 4.1.5 Change Response Summary

This method has determined that most of the catchments in Kent are at high risk of lower summer river flows. The main areas at risk are:

- the upper river catchments of Medway, including Upper Medway, Middle Medway, Teise, Eden and Beult;
- the upper reaches of the Darent;
- the upper reaches of the Rother; and
- the Stour river catchments, including the Upper and Lower Stour.

## 4.2 Increase in Tidal and Fluvial Flood Risk

### 4.2.1 Figure Reference

Volume 2: Mapbook Figure Reference

**Figure CRE2 – Increase in Tidal and Fluvial Flood Risk**

**Figure CON1 – River Systems in Kent**

**Figure CSO5 – Increase in Winer Rainfall by 2080 (UKCP18 Projections)**

### 4.2.2 Introduction of Change Response

The mapping undertaken for this change response is driven by the change sources of rising sea levels and changes in winter rainfall patterns both as a result of climate change. In relation to fluvial flood risk, UKCP18 climate change projections show that by the 2080s, average daily rainfall in the winter months could increase by up to 0.70mm/day (Figure CSO5) resulting in a 30% increase in winter rainfall volume. In addition, it is predicted that there will be an increase in rainfall intensity. Both of these effects will increase the likelihood of higher fluvial flows and hence water levels in rivers which (if not mitigated) would increase the extent of land at risk of flooding and also the depth in areas that are already at risk of flooding.

With respect to tidal flooding, sea level rise (if not mitigated) may result in extreme tidal levels, increasing the extent of land at risk of tidal flooding (both in coastal areas, and from tidal river systems) and also the depth in areas that are already at risk of flooding.

### 4.2.3 Determining Spatial Indicators

The risk of increases in fluvial flooding extent and depth as a result of increased rainfall volumes and intensity is driven by catchment characteristics (geology, catchment size) and topographical levels of the floodplain as well as the physical change in rainfall. Analysis of sea level change predictions from UKCP18 show little spatial variation across the Kent coastline (average of 0.8m); the magnitude of change in resultant tidal flood risk is therefore driven largely by land levels.

Flood modelling and resultant flood mapping (Flood Zones) provided by the Environment Agency[6] has therefore been used as the spatial indicator, as the hydraulic models used to generate Flood Zones simulate rainfall and sea level and also take into account the geographical factors that influence how increasing fluvial and tidal levels will affect flooding extent on land.

To supplement the Flood Zone information, specific climate change simulation outputs were supplied by the Environment Agency where they were available for specific catchments. Through previous projects, climate change modelling has been undertaken for some catchments and coastal areas in Kent, adding additional climate change allowance on to sea level rise and fluvial flows; these outputs add the effect of climate change to the extent of Flood Zone 3 and have been used in addition to the Environment Agency Flood Zones to determine risk where available. It should be noted that these modelled climate change outputs use UKCP09 projections which inform the currently published guidance on climate change allowance for Flood Risk Assessments[7]. At the time of completing analysis for the Kent SRA update, the Environment Agency were in the process of updating climate change allowance guidance based on research of hydrological responses to predicted rainfall changes from the UKCP18 projections, however this was not available for use in the Kent SRA update.

The key watercourses with modelled climate change outlines are listed below with many including smaller tributaries as part of the modelling:

- Lower Stour watercourses (2010);
- River Beult (2013);
- River Ebbsfleet (2015);

[6] Flood Zone Maps were provided from the Environment Agency's data share as of September 2020
[7] https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances - accessed June 2021

- Great Stour / River Stour, Whitewater Dyke, Ruckinge Dyke, Aylesford Stream, East Stour (2016);
- Hythe Streams including Saltwood & Mill Lease, Brockhill Stream and Seabrook Stream (2016);
- Little Stour and River Wingham (2016);
- Oyster Coast Brooks including Kite Farm Ditch, Swalecliffe Brook and West Brook (2016);
- Pent Stream (2016);
- Plenty Brook (2016);
- River Dour (2016);
- Springbrook Sewer (2016);
- Gorrel Stream (2017);
- Nailbourne (2018); and,
- River Darent, Honeypot Stream, Watercress Stream (2019).

Tidal climate change flood extents were also provided from the East Kent Coast Model[8], Lower Stour Model (2010 and 2012), Romney Marsh Model (2017) and Thames Tidal Downriver Breach Model (2018).

Where no modelled climate change outlines were available, Flood Zones were used. Environment Agency Flood Zone mapping represents the extent of flood risk based on probability (or return periods) of flood events:

- Flood Zone 1 represents low risk land with less than a 1 in 1000 year probability of flooding from fluvial or tidal sources;
- Flood Zone 2 represents medium risk land, with between a 1 in 100 and a 1 in 1000 year probability of flooding from fluvial sources and between a 1 in 200 and a 1 in 1000 year probability of flooding from tidal flooding; and,
- Flood Zone 3 represents high risk land with a greater than 1 in 100 year probability of flooding from fluvial sources and a greater than 1 in 200 year probability of flooding from tidal sources.

### 4.2.4 Magnitude of Change Assessment

The Environment Agency Flood Zone mapping combined with modelled climate change events (where available) has been used in the following way to determine magnitude of change response in relation to fluvial and tidal flooding extent. The change response is mapped in Figure CRE2.

- Where climate change modelling was not available, undefended areas of Flood Zone 2 were considered high risk. Climate change modelling throughout the UK often shows that the extent of Flood Zone 2 (1 in 1000 year event) is similar to the Flood Zone 3 (1 in 100 year event) extent with an allowance for climate change, hence this assumption provides a reasonable estimate of the change in extent of high risk areas.
- Modelled 1 in 100 year outlines with an allowance for climate change were considered high risk.
- Undefended Flood Zone 3 remains as high risk.
- Defended areas of Flood Zone 2 and 3 were considered as medium risk.
- Flood Zone 1 will remain as low risk.

### 4.2.5 Change Response Summary

The areas of Kent most susceptible to a high magnitude change response from increase extent of tidal and fluvial flooding are;

- the upper catchments of the middle and upper Medway;
- the lower reaches of the Great Stour;
- the coastal area around Deal;
- the southern shoreline around Sheppey (the Swale); and
- the middle reaches and tributaries of the Rother.

[8] (date unknown)

## 4.3 Increase in Surface Water Flood Risk

### 4.3.1 Figure Reference

Volume 2: Mapbook Figure Reference

**Figure CRE3 – Increase in Surface Water Flood Risk**

**Figure CON6 – Bedrock Permeability**

**Figure CON7 – Superficial Permeability**

**Figure CON13 – Slope Gradient**

**Figure CSO5 – Increase in Winter Rainfall by 2080 (UKCP18 Projections)**

### 4.3.2 Introduction of Change Response

The mapping undertaken for this change response is driven by the change sources of increase in winter rainfall volumes and rainfall intensity, both as a result of climate change.

UKCP18 climate change projections show that by the 2080s, average daily rainfall in the winter months could increase by up to 0.70mm/day (Figure CSO5) resulting in a 30% increase in winter rainfall volume. It is also predicted that there will be an increase in rainfall intensity. Both of these change sources, but most importantly rainfall intensity changes, will increase the likelihood of surface water flooding as existing drainage systems will be overwhelmed more frequently and to a greater extent. If not mitigated, this would increase the extent of land, property and infrastructure at risk of surface water flooding and also the depth in areas that are already at risk of flooding.

### 4.3.3 Determining Spatial Indicators

Updates in the UKCP18 datasets indicate that the spatial distribution of rainfall does vary across Kent; however, spatial variation in the intensity of rainfall is unlikely to be a location specific issue and hence such changes in intensity can be considered to be a Kent wide potential impact. Therefore, the spatial variability of the change response of increases in surface water flood risk (as a result of both volume and intensity increases) is driven by both topography (Figure CON13) and soil permeability (Figures CON6 and CON7), with ponding of excess surface water in low lying areas where infiltration capacity of the ground is low.

Surface water flood modelling has been undertaken across England at a strategic level by the Environment Agency and has been combined with more detailed local surface water flood modelling (where available) undertaken by Lead Local Flood Authorities (LLFA). The resultant dataset is referred to as the Risk of Flooding from Surface Water (RoFSW) and this has been used in combination with Aquifer Permeability as the spatial indicators for this change response. This dataset best represents the potential impact of increased rainfall intensity as a result of climate change.

### 4.3.4 Magnitude of Change Assessment

Aquifer permeability using BGS Superficial Permeability Index data (v7, 2015 – Figure CON7) has been used to represent infiltration capacity across the County and a magnitude score assigned as shown in Table 4-6. For locations where Superficial Permeability Index data was not available (due to no superficial geology identified), Bedrock Permeability Index data (v7, 2015 – Figure CON6) has been used.

**Table 4-6: Aquifer Permeability**

| | Low | Medium | High |
|---|---|---|---|
| **Aquifer Permeability** | Low/Very Low Permeability | Moderate Permeability | High/Very High Permeability |

The RoFSW dataset has been used to determine a surface water depth magnitude, based on the depth of flooding modelled and the return period associated with the depth of flooding as follows;

- no flood depth predicted – low magnitude;
- 0.30m deep flooding during 1 in 200 year event – medium magnitude; and,
- 0.30m deep flooding during 1 in 30 year event – high magnitude.

The surface water flood depth magnitude and the aquifer permeability rating have been used to determine a magnitude score associated with deeper surface water flooding as set out in Table 4-7. This has been mapped and shown in Figure CRE3.

**Table 4-7: Magnitude for Increase in Surface Water Flooding**

| | | Aquifer Permeability | | |
|---|---|---|---|---|
| | | **Low** | **Medium** | **High** |
| **Flood Map for Surface Water** | **High magnitude** | High | Medium | Low |
| **Flood Map for Surface Water** | **Medium Magnitude** | Medium | Low | No Risk |
| **Flood Map for Surface Water** | **Low Magnitude** | No Risk | No Risk | No Risk |

### 4.3.5 Change Response Summary

The areas of Kent most susceptible to a high magnitude impact from increase in surface water flooding occur in the valleys of catchments; however, there are more occurrences of high risk where valleys are located over the weald clay formation and the London Clay (Figure CRE3) along the northern coast.

## 4.4 Increase in Groundwater Flood Risk

### 4.4.1 Figure Reference

Volume 2: Mapbook Figure Reference

**Figure CRE4 – Increase in Groundwater Flood Risk**

**Figure CON2 – Bedrock Geology**

**Figure CON3 - Superficial Geology**

**Figure CON13 – Slope Gradient**

**Figure CSO5 – Increase in Winter Rainfall by 2080 (UKCP18 Projections)**

### 4.4.2 Introduction of Change

The mapping undertaken for this change response is driven by the changes in winter rainfall patterns as a result of climate change.

Rising temperatures and variation in rainfall patterns will change the recharge to groundwater in UK aquifers[9]. UKCP18 climate change projections show that by the 2080s, average daily rainfall in the winter months could increase by up to 0.70mm/day (Figure CSO5) resulting in a 30% increase in winter rainfall volume. In addition, it is predicted that there will be an increase in rainfall intensity.

As a result, the groundwater recharge season, typically September to April, could become shorter but more intensive. This could lead to a flashier response in groundwater levels, with higher peaks, and (if not mitigated) could increase the extent of land at risk of groundwater flooding and depth in areas that are already at risk of flooding resulting in the potential for more groundwater flooding.

### 4.4.3 Determining Spatial Indicators

The potential for higher peaks in groundwater level and more flooding increases under many of the climate change scenarios, but the results are not uniform across the UK. The potential for areas to be considered at risk of increases in groundwater flooding extent and depth is driven by where groundwater flooding has occurred in the past and where groundwater flooding is possible, i.e. where there is a “susceptibility” to groundwater flooding. This susceptibility is as a result of catchment geology and topography, as well as the spatial variation of the physical change in rainfall. It should also be noted that where aquifers are in hydraulic continuity with adjacent river systems, via gravel deposits, any climate change-induced rises in river levels could also cause a response and increase in adjacent groundwater levels.

In determining spatial indicators for this change response, the BGS Susceptibility to Groundwater Flooding dataset was considered first. This dataset shows where groundwater flooding could occur, or where there is a susceptibility, rather than the risk or likelihood of it occurring. It relies upon a GIS rule-based methodology based on the presence or absence of permeable or impermeable bedrock or superficial deposits, using the BGS Permeability Index Dataset. As the BGS Susceptibility to Groundwater Flooding dataset was not available to this study, the BGS Permeability Index was used to identify the following geological occurrences in Kent, in line with the GIS rule-based methodology:

- where superficial deposits are of very high or high permeability and are underlain by bedrock of low or very low permeability; and,
- where bedrock is of very high or high permeability, except where overlain by superficial deposits of low or very low permeability.

These areas identified on the basis of geology and permeability, were sense-checked against anecdotal information on groundwater flooding from KCC[10] to create a new spatial indicator for the study which identified whether an area

[9] https://geosmartinfo.co.uk/2019/10/groundwater-flooding-and-climate-change/
[10] Phone call between Max Tant of Kent County Council and Jenny Rush of AECOM on 19th November 2020.

has potential, or limited potential, for groundwater flooding. This indicator was then used in combination with UKCP18 winter rainfall changes to identify areas within Kent with the potential to experience this change response.

### 4.4.4 Magnitude of Change Assessment

UKCP18 outputs were used to determine the change in winter rainfall from 2021 to 2080. Change in winter rainfall is shown in Figure CSO5 using the scaling as indicated below;

- High: > 0.80mm/day
- Medium: 0.60mm/day to 0.80mm/day
- Low: <0.60mm/day.

Table 4-8 shows the change magnitude score assigned based on the change in winter rainfall across catchments. The magnitude score is taken from the data category covering the largest percentage area of a waterbody catchment with the analysis completed in the GIS.

**Table 4-8: Change in Winter Rainfall magnitude**

| Increase in Winter Rainfall | <0.60mm/day | 0.80mm/day – 0.60mm/day | >0.80mm/day |
|---|---|---|---|
| Score | 1<br>Low | 2<br>Medium | 3<br>High |

The newly created spatial indicator for groundwater flood risk potential was then assigned a magnitude score as set out in Table 4-9.

**Table 4-9: Groundwater Flood Risk Potential Score**

| Groundwater Flood Risk | No change | Limited potential/ not considered prone to flooding | Potential for flooding |
|---|---|---|---|
| Score | 0<br>No change | 1<br>Low | 3<br>High |

These winter rainfall magnitude scores were then combined with the groundwater flood risk potential score to give the combined magnitude shown in Table 4-10. Figure CRE4 displays the Increase in Risk of Groundwater Flooding across Kent.

**Table 4-10: Magnitude for Increase in Risk of Groundwater Flooding**

| | | Change in Winter Rainfall | | | |
|---|---|---|---|---|---|
| | | High | Medium | Low | No Change |
| Groundwater Flood Risk | Potential for Flooding | High | High | High | Low |
| Groundwater Flood Risk | Limited potential | Low | Low | Low | Low |

### 4.4.5 Change Response Summary

The areas of susceptibility to this change response span all of the CAMS areas in Kent and 13 out of the 14 WFD groundwater bodies mapped within Kent (all bar Epsom North Downs Chalk groundwater body).

In addition, these areas lie predominantly outside of the geographical areas where, according to the Environment Agency's Flood Warning Areas and Flood Alert Areas datasets[11] [12], it is possible for flooding to occur, and where flooding is expected and where there is a Flood Warning Service.

[11] Flood Alert Areas - data.gov.uk
[12] Flood Warning Areas - data.gov.uk

## 4.5 Risk of Increase in Summer Demand and Abstraction

### 4.5.1 Figure Reference

Volume 2: Mapbook Figure Reference

**Figure CRE5 – Risk of Increase in Summer Demand and Abstraction – Surface Water**

**Figure CRE6 – Risk of Increase in Summer Demand and Abstraction – Groundwater**

**Figure CON4 – WFD Groundwater Resource Rating**

**Figure CON5 – WFD Groundwater Quality Rating**

**Figure CON8 – Agricultural Land Classification**

**Figure CON11 – Agricultural Pressures – Groundwater**

**Figure CON12 – Agricultural Pressures – Rivers**

**Figure CSO6 – Increase in Maximum Summer Temperatures by 2080 (UKCP18 Projections)**

### 4.5.2 Introduction of Change Response

The mapping undertaken for this change response is driven by potential land use changes and warmer summers as a result of climate change.

Future changes in agricultural practices (farming types and crops farmed) have the potential to lead to greater summer demand for water to support different practices. Additionally, summer temperature increases are likely to lead to an increase in irrigation frequency and volumes over summer months. UKCP18 climate change projections show that by the 2080s, average daily temperatures in Kent could increase by up to 6ºC (Figure CSO6).

### 4.5.3 Determining Spatial Indicators

The UKCP18 outputs for projected summer temperature change show spatial variability across the County, with the west (upper reaches of the Medway catchment and the Darent catchment) showing the greatest increases (up to 6ºC) and the eastern coastal areas showing up to 4ºC increase. This data was therefore used as a spatial indicator for the change response.

Detailed information on existing agricultural abstraction volumes for existing licences was not available for the study; therefore, as an indicator of where agricultural abstraction is currently an issue and likely to be exacerbated in the future, WFD information on pressures confirmed as Reasons for Not Achieving Good (RNAG) status was analysed in the GIS. This identified where agricultural abstractions are currently a RNAG for both surface water and groundwater bodies. Uncertainties on how land use and agricultural practices may change in the future meant that land use was not used directly as a spatial indicator.

The assessment was undertaken separately for groundwater bodies and surface waterbody catchments.

### 4.5.4 Magnitude of Change Assessment

UKCP18 outputs were used to determine the change in summer temperature from summer 2021 to 2080. Change in summer temperature is shown in Figure CSO6 using the scaling as indicated below:

- High: >5.5ºC
- Medium: 4.5ºC to 5.5ºC
- Low: <4.5ºC

The change in summer temperature has been assigned a change magnitude scoring based on the scaling as follows: greater than 5.5ºC is assigned high risk (scoring of 3), 4.5ºC to 5.5ºC is assigned medium risk (scoring of 2), and less than 4.5ºC is assigned low risk (scoring of 1).

To assess the magnitude of change for agricultural abstraction, the WFD RNAG data was analysed for surface water and groundwater bodies in Kent to determine if agriculture was a confirmed RNAG for the waterbody and a score assigned as shown in Table 4-11.

**Table 4-11: Agricultural Abstraction Magnitude Scoring for Change Response**

| Agricultural Abstraction a Reason for Not Achieving Good Status | No | Yes |
|---|---|---|
| Score | 1<br>Low | 3<br>High |

The summer temperatures indicator and the agricultural abstraction indicator were combined into two maps (one for surface water catchments and one for groundwater bodies) to determine the change response for increases in summer demand and abstraction for agriculture by combining the associated impact score for each catchment or groundwater body. Table 4-12 shows the categorisation of the combined scores to get a high, medium and low overall magnitude score and Table 4-13 the overall magnitude score for the combined parameters. The mapping result is shown in Figure CRE5 and Figure CRE6.

**Table 4-12: Combined Score**

| | Low | Medium | High |
|---|---|---|---|
| Combined Score | 1-2 | 3-4 | >5 |

**Table 4-13: Overall Magnitude for Increase in Summer Demand and Abstraction for Abstraction**

| | | Change in Summer Temperature | | |
|---|---|---|---|---|
| | | High | Medium | Low |
| Agricultural Abstraction a Reason for Not Achieving Good Status | Yes | High | High | Medium |
| Agricultural Abstraction a Reason for Not Achieving Good Status | No | Medium | Low | Low |

## 4.5.5 Change Response Summary

The areas of Kent most susceptible to a high magnitude impact from increase summer demand and abstraction (surface water) are:

- the middle river catchments of Mid Medway, including Middle Medway, Eden, Teise and Beult;
- the upper reaches of the Darent;
- the upper reaches of the Rother; and,
- the Upper Stour catchment.

The groundwater bodies most susceptible to a high magnitude impact from increase summer demand and abstraction are:

- East Kent Chalk – Stour;
- West Kent Darent and Cray Chalk; and,
- North Kent Tertiaries.

## 4.6 Increase in Soil Erosion and Degradation

### 4.6.1 Figure Reference

Volume 2: Mapbook Figure Reference

**Figure CRE7 – Increase in Risk of Soil Erosion and Degradation**

**Figure CON13 – Slope Gradient**

**Figure CSO5 – Increase in Winter Rainfall by 2080 (UKCP18 Projections)**

### 4.6.2 Introduction of Change Response

There has been no change in the Slope Gradient or Soil Erodibility Risk data used in the previous 2014 Kent SRA and therefore this figure has not been updated.

The mapping undertaken considers the impact of both more intense rainfall events and higher winter rainfall volumes, both of which have the potential to increase the rate of water erosion of soils. UKCP18 climate change modelling predicts climate change will lead to an increase in the intensity of some rainfall events which would increase potential for water induced erosion of soils and lead to longer term degradation.

### 4.6.3 Determining Spatial Indicators

Updates in the UKCP18 datasets indicate that the spatial distribution of rainfall does vary across Kent; however, spatial variation in the intensity of rainfall is unlikely to be a key factor (as it is not a location specific issue at the Kent scale) and increases in soil erosion can be considered to be a Kent wide potential change response. Whether soil erosion risk increases depends on two key factors which do vary across the County and which have been used as spatial indicators for this impact:

- Land slope – water erosion (via rills and gullies) is greater in areas of steeper sloping topography.
- Soil Type – some soil types are more vulnerable to erosion by water, based on their grain size and other key factors.

Where vulnerable soils and steep slopes occur together spatially, the magnitude of impact from soil erosion will be higher.

### 4.6.4 Magnitude of Change Assessment

A slope dataset was created in the GIS using topographic information across the County. The resultant slope was mapped and the grade of slope in relation to erosion risk was classified as set out in Table 4-14.

**Table 4-14: Slope Grade in relation to erosion risk**

| | No Risk | Low | Medium | High |
|---|---|---|---|---|
| Fall per 150m grid square | <2m | 2-5m | 5-10m | >10m |

Soil type data were collated from the LANDIS Soilscapes dataset (June 2013) for England as provided by Cranfield University as part of the 2014 Kent SRA. Soil series from this dataset were used to assign the defined soil type within 1km grid squares to a soil erosion category as defined by the Soil Survey of England and Wales as set out in Table 4-15.

**Table 4-15: Soil Erosion categories as defined by the Soil Survey of England and Wales**

| | No Risk | Low | Medium |
|---|---|---|---|
| Soil Survey risk classification | 'No Risk' from water erosion | 'Slight Risk of water erosion' | 'at Risk of water erosion' |

The slope grade and soil erosion categories were then combined to assign a change response magnitude as summarised in Table 4-16; these criteria have been used to create the change response map as shown in Figure CRE7.

**Table 4-16: Overall Magnitude for Soil Erosion and Degradation**

| | | Slope Grade | | | |
|---|---|---|---|---|---|
| | | **High** | **Medium** | **Low** | **No Risk** |
| **Soil Erosion Category** | **Medium** | High | High | Medium | Low |
| **Soil Erosion Category** | **Low** | High | Medium | Low | Low |
| **Soil Erosion Category** | **No Risk** | Low | Low | Low | No Risk |

## 4.6.5 Change Response Summary

Soil erosion risk is greatest along the Greensand Ridge as a result of the combination of high soil erodibility and steep slope aspect. High risk erosion areas are also located in the north east of the County along the coastal areas of Margate, Broadstairs and Ramsgate, as well as along the North Downs dip slope.

## 4.7 Risk of Increase in Pollution Load from Wastewater Treatment to Surface Waterbodies

### 4.7.1 Figure Reference

Volume 2: Mapbook Figure Reference

**Figure CRE8 – Risk of Increase in Pollution Load from Wastewater Treatment to Surface Waterbodies**

**Figure CON1 – River Systems in Kent**

**Figure CON9 – Wastewater Treatment Works Locations**

**Figure CSO1 – Water Company Supply and Demand Deficits to 2045**

**Figure CSO2 – Future Population Change per District to 2038**

### 4.7.2 Introduction of Change Response

The mapping undertaken for this change response is driven by forecast increases in population. Population increases will lead to an increase in wastewater generation and increases in the need to discharge treated wastewater volumes and associated pollutant load to waterbodies.

Whilst treatment processes will be applied to future wastewater volumes to remove some of the pollutant load, overall increases in discharge of nutrients and parameters which affect the physico-chemical quality of waterbodies (and hence health of aquatic ecology) will still occur in some catchments due to limitations in treatment technologies and spatial indicators needed to be developed to identify where this may occur in the County.

### 4.7.3 Determining Spatial Indicators

Since completion of the 2014 Kent SRA, a further study was undertaken in Kent assessing the impact of future growth on water systems in the County - the 'Kent Water for Sustainable Growth study'[13] (KWfSG). The KWfSG Study considered the impact of growth in the County on the water quality of waterbodies as a result of increases in population.

The KWfSG Study included an exercise in identifying which Wastewater Treatment Works (WwTW) in the County would be likely to receive growth as a result of housing forecasts within each of the County's planning authority Local Plans (including Medway Unitary authority). It then undertook a modelling exercise to determine which of the WwTWs would likely require a change in permitted discharge volumes and potentially changes in the quality restrictions applied to those discharges in order to comply with the requirements of the WFD. This identified high risk WwTWs where changes to the quality conditions of the future discharges were likely to be difficult to achieve within the limits of treatment technologies currently utilised within the water industry. These WwTWs were identified as high risk because further improvements in treatment required to maintain water quality in receiving waterbodies would be either technically infeasible or cost prohibitive to implement. The water quality parameters modelled were:

- Biochemical oxygen demand (BOD);
- Ammonia; and
- Phosphate (P).

It was considered that the KWfSG modelling exercise provided a reasonable spatial indicator to identify where surface waterbodies are likely to be at risk of increased pollutant load from wastewater discharges.

### 4.7.4 Magnitude of Change Assessment

Modelling results from the KWfSG Study were used to determine the increase in pollutant load from surface water wastewater treatment change magnitude.

[13] AECOM (2017) Kent Water for Sustainable Growth Study, available at https://www.medway.gov.uk/download/downloads/id/2374/kent_water_for_sustainable_growth_2017.pdf

Figures 5-5 to 5-7 of the KWfSG Study spatially display the locations where investment at WwTWs is more likely to be required to meet the discharge permit conditions for the three water quality parameters modelled. The assessment produced summary outputs for WwTW catchments based on ensuring no deterioration tests for BOD, Ammonia and Phosphate as follows;

- no permit tightening required – pollutant load unlikely to increase;
- permit tightening required – may result in increases in pollutant load; and
- already below conventional treatment limits – pollutant load likely to increase.

These summary outputs for each WwTW catchment were then compared to the WFD surface waterbody catchments within which they fall. Table 4-17 displays the criteria used to determine magnitude of change associated with pollutant load from surface water wastewater treatment in each catchment as displayed on Figure CRE8.

**Table 4-17: Pollutant Load Risk Magnitude**

| | Low | Medium | High |
|---|---|---|---|
| Pollutant Load from Surface Water Wastewater Treatment | No assessed WwTW in catchment<br>Or<br>No permit tightening required for any parameter | Permit tightening required for one or two parameters for a WwTW catchment | One or more parameter being below conventional treatment limits<br>Or<br>All three parameters need tightening |

### 4.7.5 Change Response Summary

The high risk areas are located in the following areas in Kent;

Medway Catchment;

- Alder Stream and Hammer Dyke;
- Barden Mill Stream;
- Grom;
- Hammer Stream;
- Len;
- Loose Stream;
- Lower Eden;
- Lower Teise;
- Mid Medway from Eden Confluence to Yalding;
- Somerhill Stream;
- Tributary of Eden at Four Elms;
- Tudeley Brook;
- Upper Beult - High Halden and Bethersden Stream; and
- Upper Teise.

Rother Catchment;

- Tenterden Sewer; and
- Upper Newmill Channel.

## 4.8 Risk of Increase in Pollutant Load from Urban Sources

### 4.8.1 Figure Reference

Volume 2: Mapbook Figure Reference

**Figure CRE9 – Risk of Increase in Pollutant Load from Urban Sources**

**Figure CSO2 – Future Population Change Per District to 2038**

**Figure CSO7 – Increase in Urbanisation**

### 4.8.2 Introduction of Change Response

The mapping undertaken for this change response considers the change sources of urban land use changes and population increases combined, which could lead to an increase in the volume and pollutant load of urban diffuse sources.

### 4.8.3 Determining Spatial Indicators

As shown in Figure CSO2, data is available on forecast population growth across Kent; however the latest forecasts were only available at the District (or local planning authority) level, which limited a detailed spatial analysis of which sections of watercourses could be linked to increased urban extent. Data was available in the form of point source information on where urban extension or new major urban development was included in Local Plans as site allocations, however, the spatial extent of these was not available at a Kent-wide level. Additionally, the extent of pollution source from population and new urban areas will depend on how surface water and drainage is managed on those sites in terms of discharge to the environment and interaction with existing drainage infrastructure.

As a result, spatial indicators were based on the extent of forecast population growth at a District level (and compared to WFD surface waterbody catchment spatial area) as well as where urban pollution is already identified as confirmed RNAG status for waterbodies. This indicates where existing drainage limitations could result in further polluting load as a result of growth.

### 4.8.4 Magnitude of Change Assessment

The Environment Agency has identified where WFD surface waterbody catchments have urban pollution as a confirmed RNAG in Kent as part of the development of the South East and Thames RBMP under the WFD. This takes into account the extent of urbanisation, the flow regime of the watercourse, and trends shown by historical monitoring. How this data has been used in assessing the magnitude of change is included in Table 4-18.

KCC provided the population increase projections for each of the Planning Authority areas in Kent[14] and these were classified as a high, medium and low magnitude within the GIS as follows:

- High: >25,000;
- Medium: 15,000 – 24,999; and
- Low: 1 – 14,999

The magnitude scoring for population growth were combined with the RNAG data for urban pollution pressures to produce a combined risk magnitude shown in Table 4-18. Figure CRE9 displays the Increase in Pollutant Load from Urban Sources.

[14] Including Medway

**Table 4-18: Increase in pollution load from urban sources change magnitude matrix**

| | | Local Planning Authority Growth rating in catchment | | |
|---|---|---|---|---|
| | | **High** | **Medium** | **Low** |
| **Urban pollution a confirmed pressure affecting WFD status** | **Yes** | High | Medium | Low |
| **Urban pollution a confirmed pressure affecting WFD status** | **No** | Medium | Low | Low |

### 4.8.5 Change Response Summary

The waterbodies determined to be at high risk from increase in pollutant load from urban sources are:

- New Sewer at New Romney;
- Hammer Stream;
- Newmill Channel downstream of A28;
- Aylesford Stream;
- Sections of the Upper Great Stour, particularly linked with development around Ashford; and,
- Tributary of Newmill Channel upstream of Rolvenden.

## 4.9 Risk of Increase in Rate of Coastal Erosion (No Active Intervention)

### 4.9.1 Figure Reference

Volume 2: Mapbook Figure Reference

**Figure CRE10 – Risk of Increase in Rate of Coastal Erosion (No Active Intervention)**

### 4.9.2 Introduction of Change Response

The mapping undertaken for this change response considers the impact of an increase in coastal erosion as a result of sea level rise linked to climate change. This mapping remains unchanged from the 2014 Kent SRA.

Sea levels are rising due to a combination of land falling in the south east since the melting of ice over Britain in the last ice age, increasing temperatures causing ice melt in major glaciers and the polar regions causing sea levels to rise, and storm patterns becoming stronger and less predictable.

These combined processes are likely to lead to an increase in coastal erosion in some areas over the next hundred years and more. The natural man-made barriers that absorb wave energy will become increasingly submerged or prone to damage over time as sea levels rise. This means greater exposure of the coast to the direct impact of the sea.

### 4.9.3 Determining Spatial Indicators

The rates of coastal erosion around Kent's coastline have been modelled as part of a series of Shoreline Management Plans (SMP) in the County. These have been used to indicate the magnitude of impact from an increase in coastal erosion in Kent.

### 4.9.4 Magnitude of Change Assessment

Coastal erosion risk has been modelled for the Kent coast for three time periods and under three climate change scenarios as part of the development of SMPs. The level of erosion risk (as provided by the Environment Agency) has been categorised for mapping as for the medium scenario by the middle epoch (2050s) as shown in Table **4-19**.

**Table 4-19: Coastal Erosion Risk score**

| | Low | Medium | High |
|---|---|---|---|
| Erosion Risk | 0-10cm | 11-39cm | 40-100cm |
| Score | 1 | 2 | 3 |

For ease of viewing on a Kent-wide scale a 'buffer' of 300m was created around the coastline to map the erosions risk category for each management unit. This is presented in Figure CRE10 Increase in Rate of Coastal Erosion (No Active Intervention).

### 4.9.5 Change Response Summary

There are only a small number of high risk areas which are located in the following locations in Kent:

- The southern coastline of the Romney Marsh peninsular; and
- A small area of the south-eastern coastline of Sheppey.

# 5. Water System Impact Susceptibilities and Risk Assessment

As described in Section 2.4.3, the WSIS maps have been derived by combining the magnitude scores for each of the change responses which could contribute to a water system being susceptible to an impact occurring. They represent the overall risk related to water systems as a result of how different responses (resulting from a range of change sources) combine and aggregate. The rationale and method for each of the WSIS assessed and mapped is presented in this section.

Following completion of the WSIS risk mapping in the GIS, analysis was undertaken to identify the water systems in Kent at highest risk from each of the identified water system impacts. Given the focus on identification of NbS for mitigation, the analysis focused on identifying:

- where WFD groundwater bodies (aquifers) were most at risk of deterioration as a result of changes in water quality or quantity;
- where WFD surface waterbodies were most at risk of deterioration as a result of changes in water quality, flow or hydromorphological pressures;
- areas of coastal habitat most at risk of coastal erosion; and
- water dependent habitats, including WFD defined Groundwater Dependent Terrestrial Ecosystems (GWDTE) located within areas of highest risk of groundwater or surface water change.

Flood risk was considered with respect to vulnerability of people and places by identifying locations where the highest risk of increased frequency of flooding coincides with areas of highest social deprivation. Identification of NbS, such as NFM, could then be prioritised for these areas of greatest vulnerability.

In order to identify habitats which are water dependent, a review of nationally and internationally protected sites[15] was undertaken to determine whether the habitats or species for which they are (at least in part) designated have a material water dependency e.g. such as a narrow range of tolerable water levels, or water quality conditions. This process involved a comprehensive review of site citations and other information available for protected sites to establish the presence of a water dependency.

[15] Sites of Special Scientific Interest (SSSI), Special Conservation Areas (SAC), Special Protection Areas (SPA) and Ramsar sites

## 5.1 Increase in Frequency, Extent and Depth of Flooding

### 5.1.1 Figure Reference

Volume 2: Mapbook Figure Reference

**Figure WSIS1 – Increase in Frequency, Extent and Depth of Flooding**

**Figure CRE2 – Increase in Fluvial and Tidal Flood Risk**

**Figure CRE3 – Increase in Surface Water Flood Risk**

**Figure CRE4 – Increase in Groundwater Flood Risk**

### 5.1.2 Rationale

Whilst flooding is not a risk to a water system, it is a risk to different receptors derived as a result of change responses in water systems and hence is a risk that can be managed through adaptation processes such as the delivery of NbS. It is therefore a key consideration in this study.

The future risk of areas susceptible to an increase in the frequency, extent and depth of flooding is influenced by change responses of tidal, fluvial, surface water and groundwater risk. Therefore, the following change response maps have been used in deriving this WSIS:

- Increase in Tidal and Fluvial Flood Risk.
- Increase in Surface Water Flood Risk.
- Increase in Groundwater Flood Risk.

### 5.1.3 Mapping Method

Each magnitude change score from the three change response maps was given a rating score for high, medium and low as shown in Table **5-1**.

**Table 5-1: Risk Score assigned to each change response**

| | No Risk | Low | Medium | High |
|---|---|---|---|---|
| Score | 0 | 1 | 2 | 3 |

These scores were then combined spatially in the GIS to determine an overall high, medium or low risk for Increase in Frequency, Extent and Depth of Flooding (WSIS1), using the magnitude ratings displayed in Table 5-2.

**Table 5-2: Increase in Frequency, Extent and Depth of Flooding Impact Score**

| Low | Medium | High |
|---|---|---|
| 1-3 | 4-6 | 7-9 |

### 5.1.4 Risk Assessment

#### 5.1.4.1 Flood Risk

Figure WSIS1 identifies significant areas of medium to high risk, particularly for Romney Marsh, the mid-Medway catchment (where the Beult, the Teise, the upper Medway and the Bourne combine), the lower Medway as it reaches the Thames Estuary, the Lower Stour (Sandwich and Deal) and north of the County along the Swale, the Isle of Sheppey and the Isle of Grain.

The locations in Kent with the highest risk of increases in frequency, extent and depth of flooding were compared to areas of highest deprivation in the County as a means to establish where people and places are most sensitive to this risk as shown in Figure 5-1.

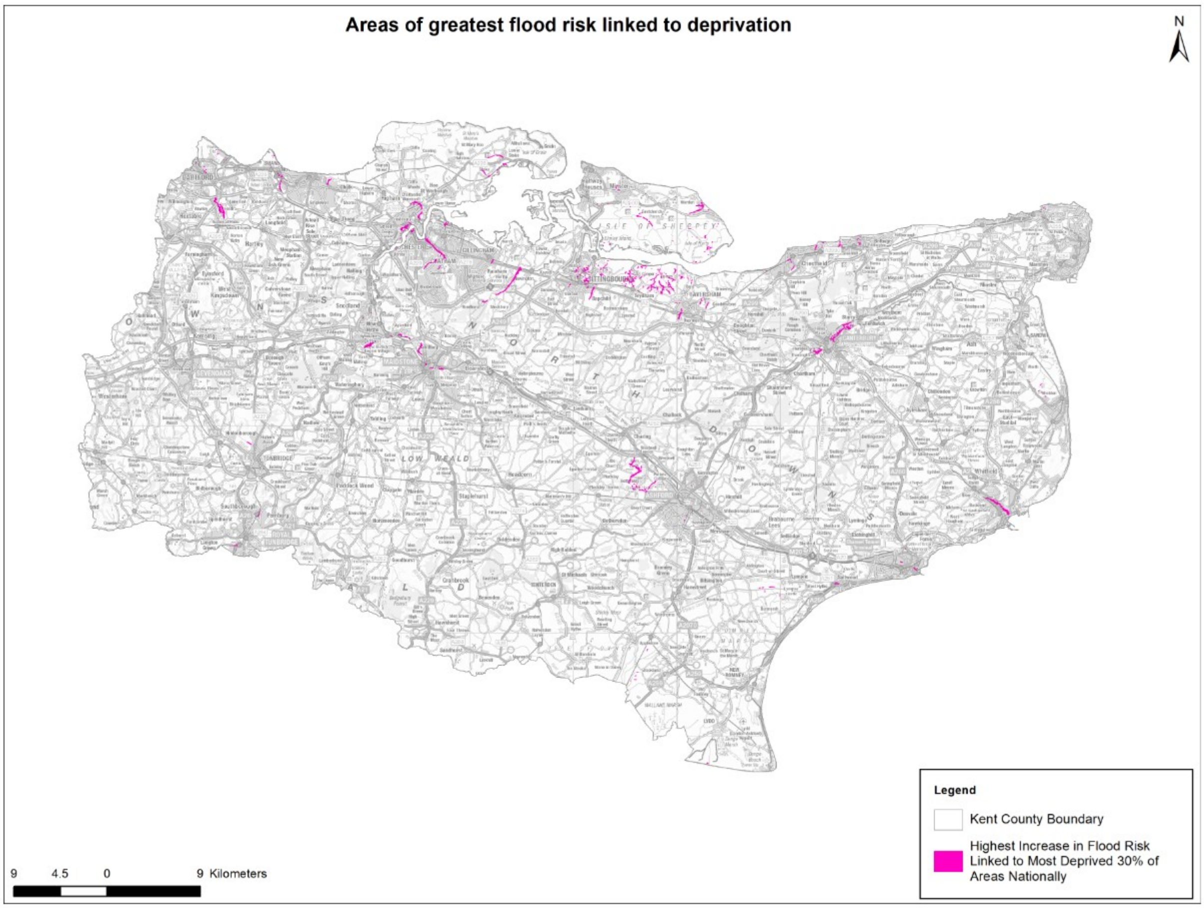


**Figure 5-1: Areas of Greatest Flood Risk Linked to Deprivation**

This analysis highlights areas of high susceptibility to flood risk in several locations, including:

- Canterbury – as a result of high fluvial flood risk from the Stour as well as groundwater flood risk.
- Dover – as a result of surface water flood risk, groundwater flood risk and fluvial risk from the River Dour.
- North Kent between Sittingbourne and Faversham - due to surface water risk, groundwater risk and tidal flooding; and
- Parts of Chatham, Rochester and Strood - due to a combination of fluvial flood risk from smaller watercourses, groundwater flooding, tidal/fluvial flooding combined from the Medway and surface water flood risk.

Potential adaptation responses linked to NbS are discussed in Section 6.

#### 5.1.4.2 Coastal Erosion and Coastal Habitats

In addition to considering increases in frequency, extent and depth of flooding, the risk assessment also considered the effect of increases in the rate of coastal erosion change response directly on coastal habitats in the County. Designated sites with identified coastal habitat were compared spatially to areas where high risk of future coastal erosion is likely to occur and where there is likely to be topographical connectivity of the habitat to areas of erosion. The outcome is shown in Figure 5-2 and identifies several sites with connected risk, including the Swale SSSI & SPA, Dungeness SAC, and Dungeness, Romney Marsh and Rye Bay Ramsar, SPA and SPA. Potential adaptation responses linked to NbS are discussed in Section 6.

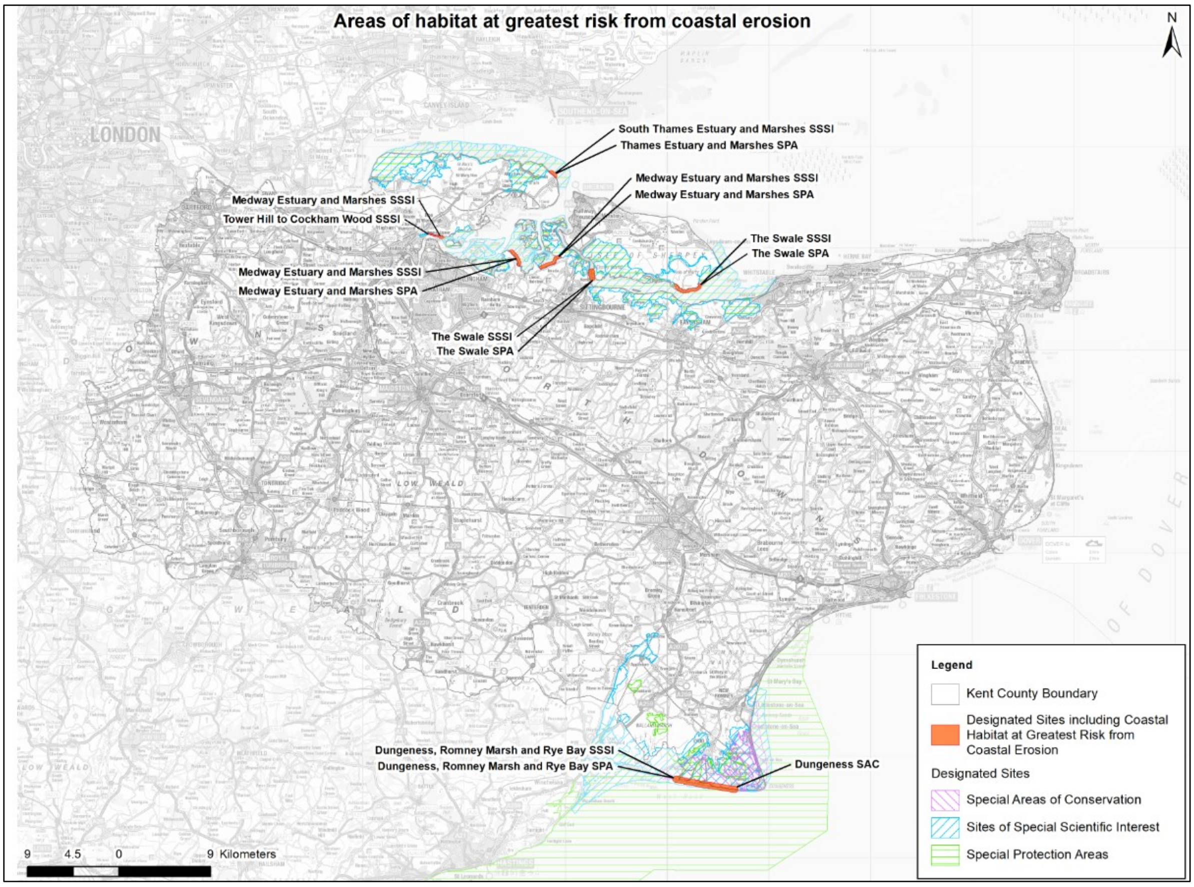


**Figure 5-2: Areas of Coastal Habitat at Greatest Risk from Coastal Erosion[16]**

[16] Sites which are also Ramsar sites are shown In Volume 2, Map REC1.

## 5.2 Increase in Frequency of Summer Hydrological Drought

### 5.2.1 Figure Reference

Volume 2: Mapbook Figure Reference

**Figure WSIS2 – Increase in Frequency of Summer Hydrological Drought**

**Figure CRE1 – Increase in Risk of Lower Summer River Flows**

**Figure CRE5 – Risk of Increase in Summer Demand and Abstraction – Surface Water**

### 5.2.2 Rationale

Drought in this context refers to hydrological drought, as opposed to meteorological or water supply drought. Hydrological drought occurs as a result of periods of precipitation shortfall which affects river flow and reservoir storage and is typically analysed at a river basin scale; in the context of this study, it is also considered to occur as a result of abstraction demand from catchments.

It is an important water system impact to consider as it has a range of potential effects and consequences on receptors, including:

- Water environment receptors - lower river flows can affect aquatic species reliant on specific flow conditions (including water level and velocity) within river systems as well as terrestrial ecosystems with hydrological connectivity such as wetlands. Flow regime is also an important quality element in determining WFD river waterbody status both directly, and through resultant impacts on the biological quality elements that may be less than 'Good' status as a result of perturbed hydrological regimes.
- Agricultural receptors who rely on non-mains water supply (such as rivers) as a source for irrigation.
- People and places through the need for water supply charges to pay for investment in additional resilience measures such as new water supply sources, transfers or demand management measures undertaken by the water supply company.

The future susceptibility of river systems to this impact has been derived using the following change responses:

- Lower Summer River Flows.
- Increase in Summer Demand and Abstraction – Surface Water.

### 5.2.3 Mapping Method

Each magnitude change score from the two change response maps were given a rating score for high, medium and low as shown in Table 5-3.

**Table 5-3: Risk Score assigned to each change response for Hydrological Drought risk**

| | Low | Medium | High |
|---|---|---|---|
| Score | 1 | 2 | 3 |

The two scores were then combined spatially in the GIS to determine an overall high, medium or low risk for the WSIS of Increase in Frequency of Summer Hydrological Drought (WSIS2), using the magnitude ratings displayed in Table 5-4.

**Table 5-4: Increase in Frequency of Summer Hydrological Drought Impact Score**

| Low | Medium | High |
|---|---|---|
| 3 | 4-5 | 6 |

### 5.2.4 Risk Assessment

Figure WSIS2 identifies that the Medway catchment and parts of the Rother catchment are at the highest risk of experiencing future hydrological drought. The specific WFD waterbodies considered to have the highest risk are shown in Figure 5-3.

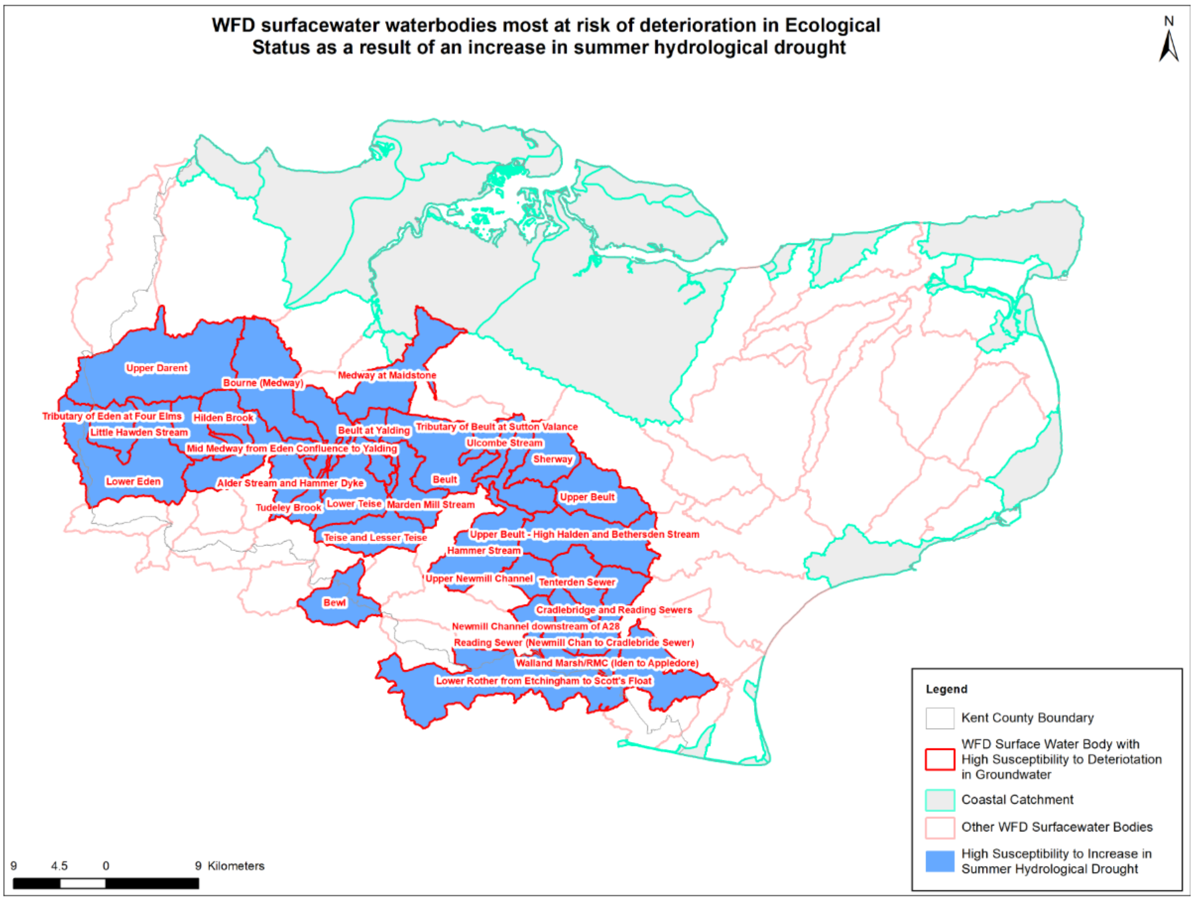


**Figure 5-3: WFD Surface Waterbodies Most at Risk from Increase in Summer Hydrological Drought**

The surface waterbodies highlighted in Figure 5-3 are more likely to be at risk of failing the hydrological regime element of WFD Ecological Status due to perturbations in summer flow patterns. Using the most recently available 2019 WFD classification data[17], 86% of these surface waterbodies currently support 'Good' status and this could be affected by this future risk (Table 5-5) leading to effects on biological quality elements and overall WFD status.

**Table 5-5: WFD Surface Waterbodies at High Risk of Summer Hydrological Drought and Current Hydrological Regime Status**

| WFD SW Body Name | WFD SW Body ID | Current Hydrological Regime Status (2019) |
|---|---|---|
| Mid Medway from Eden Confluence to Yalding | GB106040018182 | Supports Good |
| Bourne (Medway) | GB106040018210 | Supports Good |
| Upper Darent | GB106040024221 | Does Not Support Good |
| Marden Mill Stream | GB106040018310 | Supports Good |
| Bewl | GB106040018500 | n/a |
| Tributary of Beult at Sutton Valence | GB106040018040 | Supports Good |

[17] Environment Agency, Catchment Data Explorer - https://environment.data.gov.uk/catchment-planning/ – Accessed April 2021

| WFD SW Body Name | WFD SW Body ID | Current Hydrological Regime Status (2019) |
|---|---|---|
| Tributary of Eden at Four Elms | GB106040018060 | Supports Good |
| Alder Stream and Hammer Dyke | GB106040018110 | Does Not Support Good |
| Tudeley Brook | GB106040018120 | Supports Good |
| Lower Teise | GB106040018130 | Supports Good |
| Beult at Yalding | GB106040018140 | Supports Good |
| Little Hawden Stream | GB106040018150 | Supports Good |
| Lower Eden | GB106040018160 | Supports Good |
| Hilden Brook | GB106040018170 | Supports Good |
| Reading Sewer (Newmill Channel to Cradlebride Sewer) | GB107040013520 | High |
| Teise and Lesser Teise | GB106040018260 | n/a |
| Beult | GB106040018270 | Supports Good |
| Upper Beult - High Halden and Bethersden Streams | GB106040018280 | Supports Good |
| Hammer Stream | GB106040018290 | Supports Good |
| Upper Beult | GB106040018300 | High |
| Sherway | GB106040018320 | Supports Good |
| Ulcombe Stream | GB106040018330 | Supports Good |
| Medway at Maidstone | GB106040018440 | Supports Good |
| Newmill Channel downstream of A28 | GB107040013630 | Supports Good |
| Lower Rother from Etchingham to Scott's Float | GB107040013640 | Supports Good |
| Walland Marsh/RMC (Iden to Appledore) | GB107040013670 | Supports Good |
| Cradlebridge and Reading Sewers | GB107040019530 | Supports Good |
| Tenterden Sewer | GB107040019540 | High |
| Upper Newmill Channel | GB107040019690 | High |

Potential adaptation responses to hydrological drought in some of these catchments linked to NbS are discussed in Section 6.

## 5.3 Deterioration in Water Quality – Surface Water

### 5.3.1 Figure Reference

Volume 2: Mapbook Figure Reference

**Figure WSIS3 – Deterioration in Water Quality – Surface Water**

**Figure CRE1 – Increase in Risk of Lower Summer River Flows**

**Figure CRE7 – Increase in Risk of Soil Erosion and Degradation**

**Figure CRE8 – Risk of Increase in Pollutant Load from Wastewater Treatment to Surface Waterbodies**

**Figure CRE9 – Risk of Increase in Pollutant Load from Urban Sources**

**Figure CON12 – Agricultural Pressures - Rivers**

### 5.3.2 Rationale

The water quality condition of surface waterbodies has the potential to be affected by a range of change source pressures including land use change, population change and climate change. Runoff from both rural and urban land uses is a key factor in influencing the quality of water systems across a range of determinants and in many catchments, discharges of wastewater from increasing population sizes will lead to an increase in pressure on the quality of river systems. Climate change also influences this future risk through changes to flow (and hence dilution capacity) of watercourses and temperature changes which alter water quality processes in aquatic systems.

A further change source which has not been assessed in this study is the risk of lower dissolved oxygen (DO) levels as a result of increasing summer watercourse and waterbody temperatures. Warmer water holds less DO and as a result, this can have a limiting impact on some aquatic species, particularly salmonid fish species. It is recommended that this be considered in any future iterations of the Study (Section 7).

As with changes in river flow, changes in surface water quality are an important water system impact to consider as they have a range of potential effects and consequences on receptors, including:

- Water environment receptors - water quality changes can affect aquatic species directly through changes in available oxygen (DO) as a result of eutrophication resulting in reduced aquatic biodiversity, and as a result of toxicity of some chemicals/pollutants which run off (or a discharged directly) to waterbodies e.g. pesticides or un-ionised ammonia. Additionally, terrestrial ecosystems with hydrological connectivity and dependence can be impacted by poor water quality which feeds the habitat.
- People and places - through deterioration in aesthetic and recreational value of watercourses, as well as the need for charges to pay for investment in treatment processes for water supply and wastewater treatment undertaken by the water and sewerage supply company.

The future susceptibility of river systems to this impact has been derived using the following change responses:

- Increase in Soil Erosion and Degradation.
- Increase in Pollutant Load from Treated Surface Water Wastewater.
- Increase in Pollutant Load from Urban Sources.
- Lower Summer River Flows.

The Agricultural Pressures context map which shows waterbodies not achieving ‘Good’ status due to agricultural practices has also been used to derive the overall risk score as it plays a key role in defining the susceptibility of surface waters to deterioration.

### 5.3.3 Mapping Method

Each magnitude change score from the four change response maps was given a rating score for high, medium and low shown in Table 5-6.

**Table 5-6: Risk Score assigned to each change response for surface water quality risk**

| | Low | Medium | High |
|---|---|---|---|
| Score | 1 | 2 | 3 |

For the Agricultural Pressures context map, a score was assigned based on whether it fell into a catchment with agricultural pressures as shown in Table 5-7.

**Table 5-7: Risk Score assigned to Agricultural Pressures**

| | Yes | No |
|---|---|---|
| Score | 1 | 0 |

The scores were then combined to determine an overall risk for Deterioration of Water Quality – Surface Water (WSIS3), displayed using the magnitude ratings in Table 5-8.

**Table 5-8: Deterioration of Water Quality – Surface Water Magnitude**

| Low | Medium | High |
|---|---|---|
| 4-6 | 7-9 | 10-13 |

### 5.3.4 Risk Assessment

Figure WSIS3 identifies several locations which are most susceptible to the future risk of water quality deterioration, including the Upper Stour and Stour near Canterbury, the Hammer Stream and River Beult, the Lower Eden, the Bourne, the Mid Medway, the Lower Teise, and the Len. The highest risk WFD surface waterbodies are illustrated in Figure 5-4.

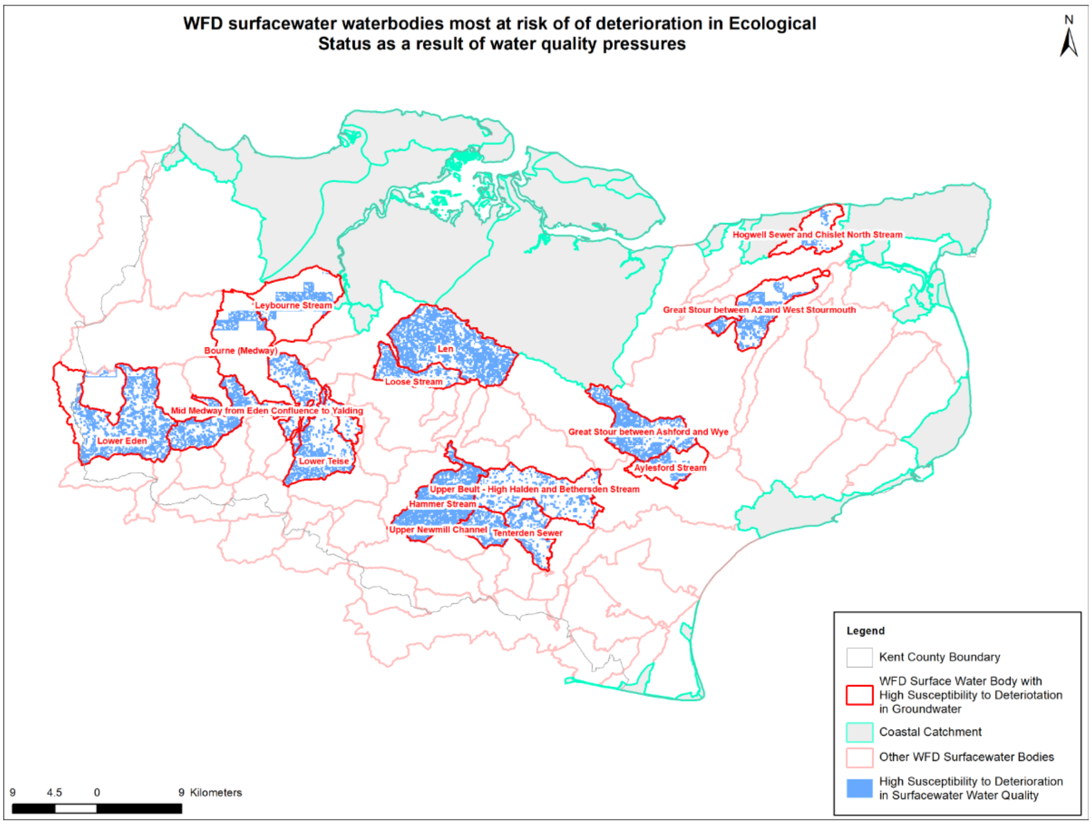


**Figure 5-4: WFD surface waterbodies most at risk of deterioration in Ecological Status as a result of water quality pressures**

The majority of the waterbodies identified are at ‘Moderate’ status for physico-chemical quality as of 2019, however the Upper Newmill Channel and Leybourne Stream are at ‘Good’ and ‘High’ status respectively, and this future risk could contribute to these waterbodies not achieving ‘Good’ status in the future. In addition, the surface waterbodies with a ‘Moderate’ status could be prevented from reaching future ‘Good’ status by the water quality deterioration risk.

#### 5.3.4.1 River Stour – Water Quality Modelling

To further support the assessment of water quality impacts in the Stour, nutrient modelling was undertaken to better understand the vulnerability of river systems to changes in nutrient status as a result of population increases (additional wastewater discharge) and climate change affecting river flows. Full details are provided in Appendix A.

Information from the Environment Agency SAGIS (Source Apportionment using GIS) dataset and the SIMCAT (SIMulation of CATchments) water quality model were combined to provide an insight into phosphate and total nitrate sources and potential future trends within the Stour WFD Management Catchment.

The SIMCAT model uses quantitative information on river flows, effluent flows and quality, and observed water quality monitoring data to simulate the movement of contaminants through a catchment system. SIMCAT can be used to test different future scenarios in terms of impact on water quality, e.g. reductions in river flow due to climate change and changes in effluent flows and loads. Population growth was represented in the model by increasing flows and overall discharge loads from Southern Water’s WwTW, whilst climate change was represented by altering the input flow statistics to represent lower summer river flows.

The combined impact on nutrient concentrations as a result of climate change and population increase is shown in Figure 5-5 and Figure 5-6. These figures show potential vulnerability to change by estimating the simulated maximum range of change that could occur in both phosphate and nitrate concentrations due to increases in wastewater discharges and reductions in summer flow.

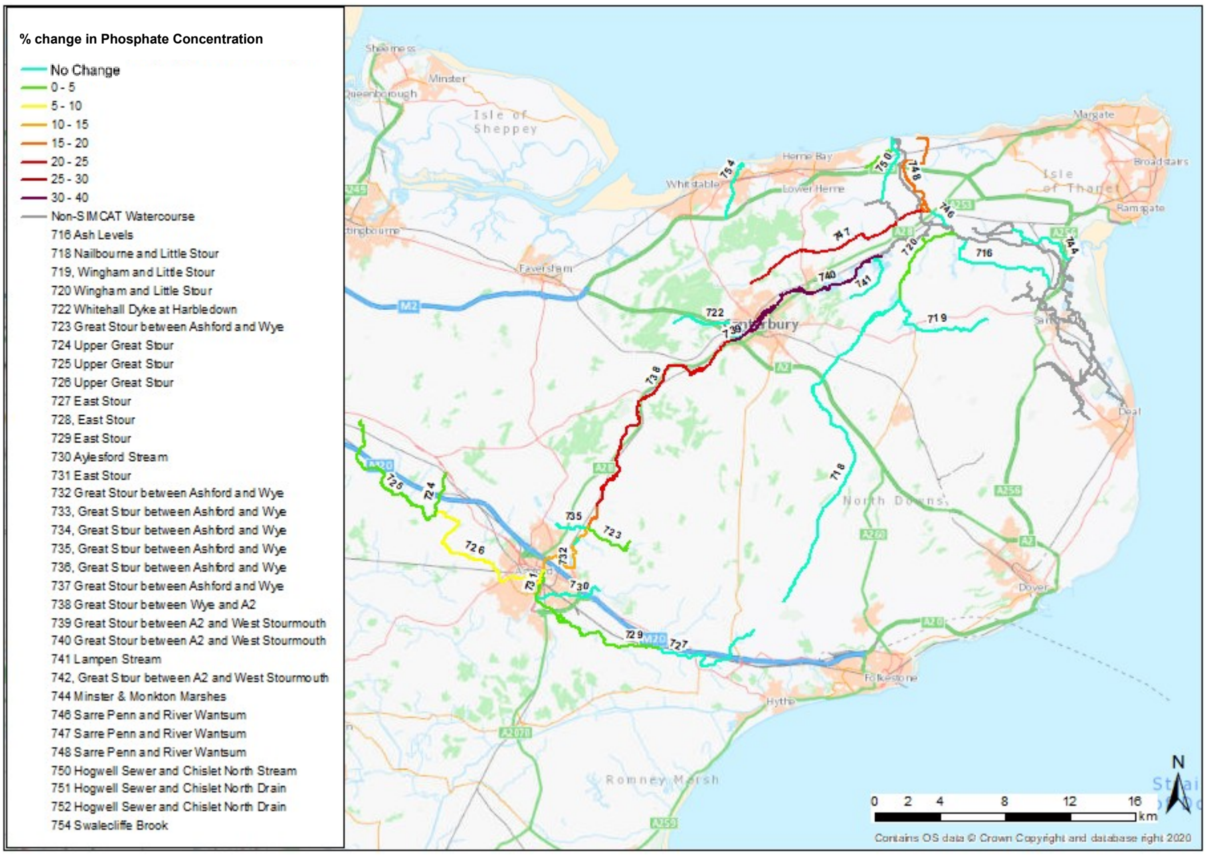


**Figure 5-5: SIMCAT Future Scenario Modelling Results: Vulnerability of Phosphate Concentrations to Combined Impacts of Population and Climate Change**

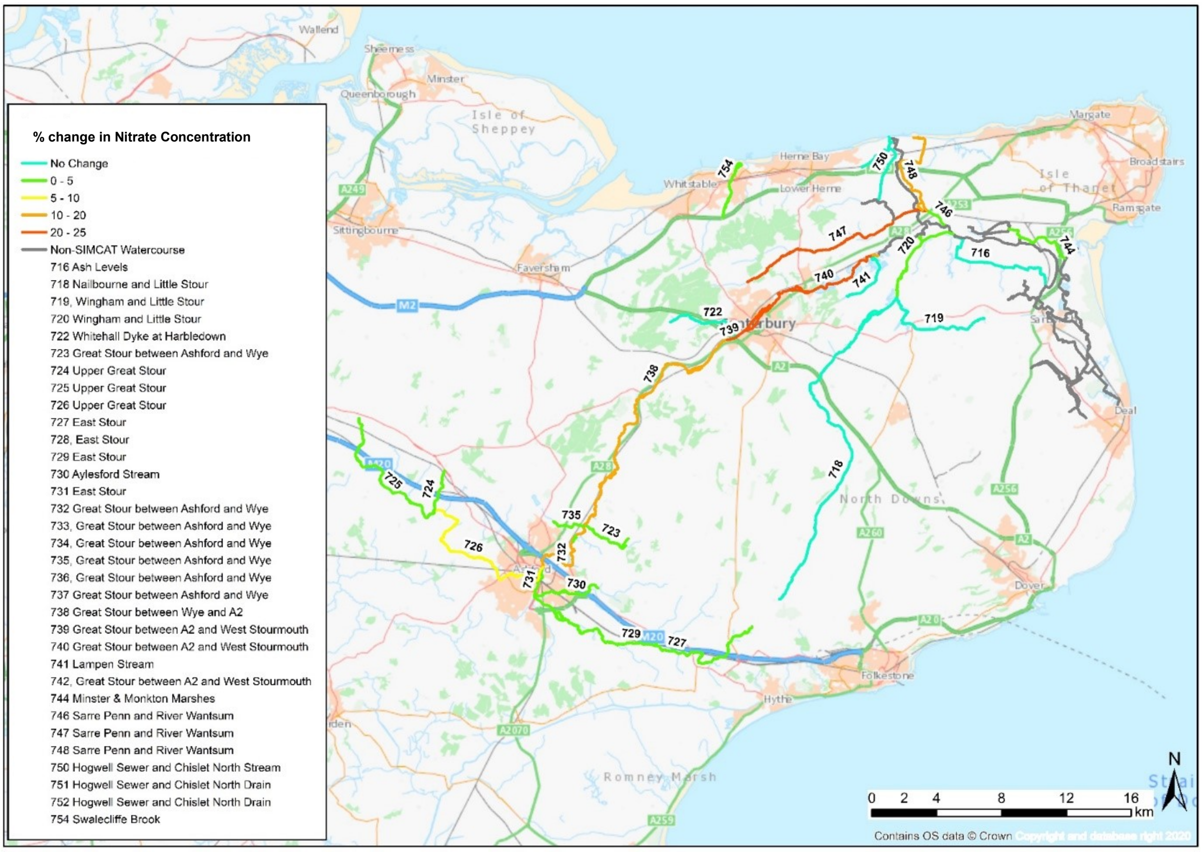


**Figure 5-6: SIMCAT Future Scenario Modelling Results: Vulnerability of Nitrate Concentrations to Combined Impacts of Population and Climate Change**

Figure 5-5 shows that the vulnerability of the River Stour to increased phosphate concentrations significantly increases when lower river flows and increases in population are combined, with the whole of the main Great Stour waterbodies vulnerable from Ashford to the tidal limit. Increases are also indicated in the Upper Stour reaches. This is due to the potential combined effects of greater discharges from the WwTW and lower river flows available for dilution. The vulnerability of the Sarre Penne and River Wantsum is also high but this is primarily due to loss of river flow as there are no Southern Water WwTWs within these reaches. The Little Stour shows low vulnerability to increased phosphate concentrations from climate change and population increase.

Figure 5-6 shows that the vulnerability of the system to increased total nitrate concentrations is less than that for phosphate, with the exception of the Great Stour downstream of Ashford and Canterbury. Full results are provided in Appendix A.

The results from the modelling should not be interpreted as a prediction of what will happen, but as an overview of how vulnerable different waterbodies may be to changes in river flow and population increases as a result of where they are located in the wider catchment (both in terms of volume of flow and also catchment sources of pollution), and in relation to the location of existing and future population centres with significant WwTW discharges.

The results are simulations of what could happen if both population increases and climate change manifest as significant impacts on river flow and quality. This has been undertaken to allow the potential vulnerability of each WFD waterbody to be considered. However, this simplistic approach does not take account of all the factors which would influence the vulnerability of waterbodies to these source pressures nor some of the adaptations and mitigations which are likely to occur, for example:

- Water industry wide trials and research has led to development of technologies which deliver significant improvements in the level of treatment and hence removal of phosphate in wastewater treated at wastewater treatment plants. Some of these technologies are already being implemented at WwTWs in Kent allowing improved discharge quality to be achieved and hence stricter permit conditions to be applied in order to protect and mitigate water quality impacts. Further implementation of such technologies could also act (at least in part) to mitigate for future population and climate change induced changes, and there is potential for further improvements in 'best available technology' which could further act to mitigate future impacts. These issues are being considered by Southern Water as part of the first Drainage and Wastewater Management Plans

(DWMP) which will identify where investment in treatment process solutions are required in line with growth proposals in its wastewater catchments.

- The analysis of impacts on river flow from climate change has only considered a statistical change in naturalised flows; this means it assumes flow reductions would be linear as rainfall patterns change. Lower flows in watercourses are often supported by wastewater discharges which are not reduced as rainfall volumes fall and hence in some waterbodies, the impact of climate change induced impacts on reduced flows will be less significant.
- A movement towards more integrated management of water could see significant changes in how water and wastewater are used as resources, particularly for major new development sites. There is an increasing awareness of the need to consider how wastewater can be reused as a resource through water recycling technologies, meaning increases in population may not always lead to a direct increase in nutrient discharges from WwTWs.

The results indicate that the Great Stour is particularly vulnerable to increases in phosphate concentrations for most of its length (downstream of Ashford) and to a lesser degree total nitrate (downstream of Canterbury) without future mitigation from improved wastewater treatment technologies. This indicates locations where catchment measures to reduce the contributions from agricultural land use and urban diffuse pollution could have a significant benefit to mitigating potential future impacts. Results presented in Appendix A demonstrate that catchment sources of phosphate range from 50% to 100%, and catchment sources of nitrate from 40% to 100% throughout the Stour catchment and hence NbS can play a significant role in reducing future impacts on water quality from these sources.

#### 5.3.4.2 Water Dependent Habitat Assessment – Surface Waterbodies

The combination of hydrological drought (WSIS2) and surface water quality pressures (WSIS3) has been compared to where habitats with a water dependency have been identified. Where a surface waterbody catchment has either (or both) a future water quality deterioration risk or risk of increased frequency of hydrological drought with a water dependent habitat, this has been illustrated in Figure 5-7. This highlights some key habitats which could be at risk of deterioration in condition including Stodmarsh SAC/Ramsar and the River Beult SSSI. An analysis of the sensitivities of the identified sites related to these future risks is included in Table 5-9.

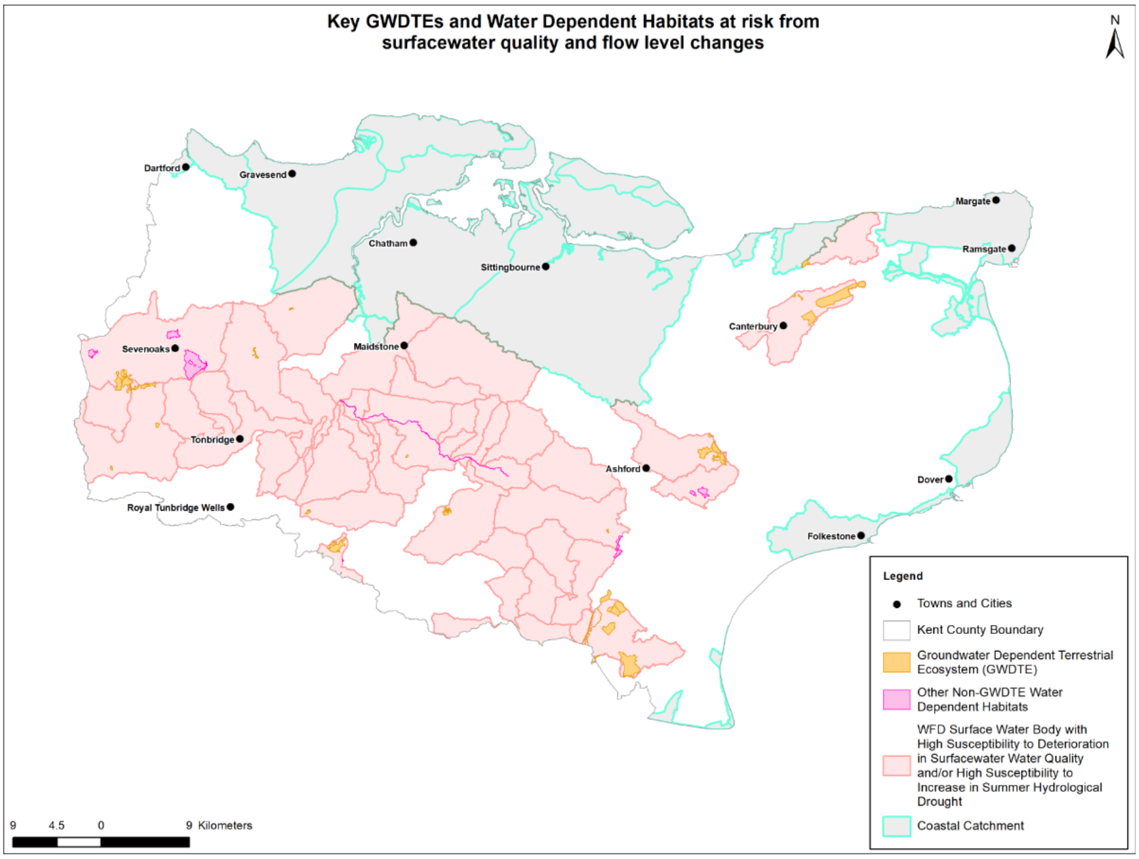


**Figure 5-7: Water Dependent Habitats at Risk from Water Quality Deterioration and/or summer hydrological drought.**

**Table 5-9: Summary of Likely Sensitivities on Water Dependent Habitats as a Result of Surface Water Quality Deterioration and/or Increase in Summer Hydrological Drought**

| Habitat Name | Designation | Risk Identified | Summary of Likely Site Sensitivities |
|---|---|---|---|
| Stodmarsh | SSSI, SAC, SPA, Ramsar | Deterioration in SW Quality | • Lagoon and reed beds sensitive to increases in nutrients which can lead to a loss of aquatic plants in favour of excessive growths of algae which may result in a fundamental shift in the way a waterbody functions, reducing plant and invertebrate abundance and diversity, both of which are important food sources for a range of wetland birds.<br>• Swamp habitats in continuity with a waterbody can be sensitive to nutritional enrichment which can lead to the excessive spread of species including reed or reed sweet grass.<br>• Floodplain fen is susceptible to river water quality. Most floodplain fens depend on an adequate supply of nutrients, however, excessive nutrient enrichment may result in a dominance of species-poor vegetation such as reed or reed sweet grass with nettles.<br>• Ditches are susceptible to increased levels of nutrients which can cause a loss of aquatic plants and increases in algal growth.<br>• Site highly sensitive to inorganic fertilisers and pesticides. |
| Brookland Wood | SSSI | Increase in Summer Hydrological Drought | • Wet woodland including alder woodland and aspen is susceptible to increases in summer hydrological drought, in addition to wood horsetail, a rare plant in Kent, which occurs in the dampest places.<br>• A few small streams flow through the wood and these support a rich community of bryophytes (mosses and liverworts) together with a few higher plants, such as opposite-leaved golden saxifrage Chrysosplenium oppositifolium, which are susceptible to increases in summer hydrological drought. |
| Sissinghurst Park Wood | SSSI | Increase in Summer Hydrological Drought and Deterioration in SW Quality | • Wet woodland including alder woodland is susceptible to increases in summer hydrological drought, occurring along the lines of small streams and in seepage areas. In the damper areas of the alder woodland there is greater diversity. |
| Wye & Crundale Downs | SSSI, SAC | Deterioration in SW Quality | • Plants and animals that occur in and around flush and spring fen habitats are dependent on water chemistry and flow rate.<br>• Site highly sensitive to inorganic fertilisers and pesticides. |
| West Blean & Thornden Woods | SSSI | Deterioration in SW Quality | • Site highly sensitive to inorganic fertilisers and pesticides. |

| Habitat Name | Designation | Risk Identified | Summary of Likely Site Sensitivities |
|---|---|---|---|
| Cowden Pound Pastures | SSSI | Increase in Summer Hydrological Drought and Deterioration in SW Quality | • Wet woodland and associated important invertebrate species and assemblages susceptible to drought conditions.<br>• Streams sensitive to changes in natural flow regime, including natural erosion and sedimentation processes, in order to meet the requirements of the full range of flora and fauna it supports.<br>• Site highly sensitive to inorganic fertilisers and pesticides. |
| Scotney Castle | SSSI | Increase in Summer Hydrological Drought | • Wet woodland and associated important invertebrate species and assemblages susceptible to drought conditions.<br>• Ponds susceptible to drought conditions which are home to several scarce invertebrates. |
| Bourne Alder Carr | SSSI | Increase in Summer Hydrological Drought | • Wet woodland and associated important invertebrate species and assemblages susceptible to drought conditions. |
| Marden Meadows | SSSI | Increase in Summer Hydrological Drought | • Damper meadows sensitive to changes in surface drainage which can cause adverse changes in the plant species composition of the sward. |
| Scords Wood & Brockhoult Mount | SSSI | Increase in Summer Hydrological Drought and Deterioration in SW Quality | • Wet woodland including oak species, beech, ash, field maple and alder is susceptible to increases in summer hydrological drought.<br>• Damper pastures sensitive to changes in surface drainage which can cause adverse changes in the plant species composition of the sward.<br>• Site highly sensitive to inorganic fertilisers and pesticides. |
| Alex Farm Pastures | SSSI | Increase in Summer Hydrological Drought and Deterioration in SW Quality | • Damper pastures sensitive to changes in surface drainage which can cause adverse changes in the plant species composition of the sward. |
| Titsey Woods | SSSI | Increase in Summer Hydrological Drought | • Wet woodland and associated important invertebrate species and assemblages susceptible to drought conditions. |
| Dungeness, Romney Marsh and Rye Bay | SSSI, SAC, Ramsar | Increase in Summer Hydrological Drought | • Saline lagoons and ditches susceptible to changes in water depth.<br>• Ponds, where great crested newts have been recorded, are sensitive to increases in summer hydrological drought. |

| Habitat Name | Designation | Risk Identified | Summary of Likely Site Sensitivities |
|---|---|---|---|
| Trottiscliffe Meadows | SSSI | Deterioration in SW Quality | • Site likely to be sensitive to pesticides including herbicides or fertilizers. |
| Chequers Wood & Old Park | SSSI | Deterioration in SW Quality | • Site highly sensitive to inorganic fertilisers and pesticides. |
| Polebrook Farm | SSSI | Increase in Summer Hydrological Drought and Deterioration in SW Quality | • Site likely to be sensitive to pesticides including herbicides or fertilizers.<br>• Damper meadows sensitive to changes in surface drainage which can cause adverse changes in the plant species composition of the sward. |
| Westerham Wood | SSSI | Increase in Summer Hydrological Drought | • Wet woodland and associated important invertebrate species and assemblages susceptible to drought conditions. |
| Sevenoaks Gravel Pits | SSSI | Increase in Summer Hydrological Drought | • Waterbodies sensitive to variations in water depths, impacting the plant and animal species present. For example, extensive shallow water and wet marginal substrates provide feeding conditions required by a variety of wintering, passage and breeding wildfowl, whilst other species may require areas of water at least 3 metres in depth.<br>• Changes to the amount of water within the waterbody can alter nutrient regimes, as well as change the available area of some habitats.<br>• Wet woodland and associated important invertebrate species and assemblages susceptible to drought conditions. |
| River Beult | SSSI | Increase in Summer Hydrological Drought and Deterioration in SW Quality | • Natural flow regime of the river or stream including the full range of flora and fauna it supports susceptible to drought and deterioration in water quality.<br>• River sensitive to pollution of the river from point and diffuse sources, including discharges of domestic and industrial effluent, runoff from agriculture, forestry and urban land and accidental pollution from industry and agriculture.<br>• Siltation of the riverbed can smother and infill coarse gravels, which can affect fish spawning success and the establishment of submerged plants such as water crowfoot, as well as having an impact on the invertebrates living in and on the riverbed.<br>• Riparian areas and the wider catchment sensitive to excessive runoff of soil particles and nutrients into the river which can result in the decline of plant, invertebrate and fish communities. |
| Combwell Wood | SSSI | Increase in Summer Hydrological Drought | • Wet woodland and associated important invertebrate species and assemblages susceptible to drought conditions. |

| Habitat Name | Designation | Risk Identified | Summary of Likely Site Sensitivities |
|---|---|---|---|
| Orlestone Forest | SSSI | Increase in Summer Hydrological Drought and Deterioration in SW Quality | • Wet woodland and associated important invertebrate species and assemblages susceptible to drought conditions. |
| Hatch Park | SSSI | Deterioration in SW Quality | • Site likely to be sensitive to pesticides including herbicides or fertilizers. |

## 5.4 Deterioration in Water Quality – Groundwater

### 5.4.1 Figure Reference

Volume 2: Mapbook Figure Reference

**Figure WSIS4 – Deterioration in Water Quality – Groundwater**

**Figure CRE6 – Risk of Increase in Summer Demand and Abstraction – Groundwater**

**Figure CRE9 – Risk of Increase in Pollutant Load from Urban Sources**

**Figure CON11 – Agricultural Pressures – Groundwater**

### 5.4.2 Rationale

As with surface waterbodies, the water quality condition of aquifers has the potential to be affected by a range of change source pressures including land use change, population change and climate change. Aquifers are particularly susceptible to changes in how agricultural land is managed through the application of pesticides and fertilisers, how soil is managed through cultivation and the types of agriculture practices. They are also vulnerable to diffuse urban pollution in runoff, saline intrusion from over-abstraction near tidal waterbodies and discharge of treated wastewater to ground in some locations.

Changes in groundwater quality are an important water system impact to consider as they have a range of potential effects and consequences on receptors, including:

- Water environment receptors - groundwater quality changes can affect habitats such as wetlands, which are directly dependent on groundwater flows and chemistry. In particular, GWDTEs have been identified as part of the WFD classification process and are a critical element to the assessment of the WFD status of groundwater bodies. GWDTEs are a category of wetlands supporting biodiverse, botanically rich ground-flora communities and which primarily derive their water supply from a groundwater body, rather than from surface water or rainfall. Additionally, where groundwater inputs support significant baseflow in rivers, the quality of groundwater plays a significant role in the low flow quality of connected river systems.
- People and places - through the need for charges to pay for investment in treatment processes for water supply and wastewater treatment undertaken by the water and sewerage supply company.

### 5.4.3 Mapping Method

This impact has been created by combining the following change response maps:

- Increase in Summer Demand and Abstraction – Groundwater.
- Increase in Pollutant Load from Urban Sources.

Mapping has also considered groundwater vulnerability and the Agricultural Pressures map which influence the susceptibility of groundwater bodies water quality deterioration risk.

For the change responses, the magnitudes were given a rating score for high, medium and low as shown in Table 5-10.

**Table 5-10: Risk Score assigned to Increase in Summer Demand and Abstraction – Groundwater and Increase in Pollutant Load from Urban Sources**

| | Low | Medium | High |
|---|---|---|---|
| Score | 1 | 2 | 3 |

For the Groundwater Vulnerability map, the figure was scored based on the vulnerability rating covering the largest percentage of groundwater body assessed using the GIS as shown in Table 5-11.

**Table 5-11: Risk Score assigned to Groundwater Vulnerability**

| | Low | Medium | High |
|---|---|---|---|
| Score | 0 | 1 | 2 |

For Agricultural Pressures context, a score was assigned based on whether a groundwater body was identified with agricultural pressures as shown in Table 5-12.

**Table 5-12: Risk Score assigned to Agricultural Pressures**

| | Yes | No |
|---|---|---|
| Score | 1 | 0 |

The scores were then combined to determine an overall risk score for Deterioration of Water Quality – Groundwater (WSIS4), using the magnitude ratings as displayed in Table 5-13.

**Table 5-13: Deterioration of Water Quality - Groundwater**

| Low | Medium | High |
|---|---|---|
| 2-4 | 5-6 | 7-9 |

### 5.4.4 Risk Assessment

The groundwater bodies with the highest risk of water quality deterioration are illustrated in Figure 5-8. This identifies where change responses combine with the highest values of groundwater vulnerability and agricultural pressures to present the highest risk susceptibility. This occurs for the West Kent Darent and Cray chalk, North Kent Tertiaries, Kent Greensand Middle waterbody and the Kent Greensand Eastern waterbodies.

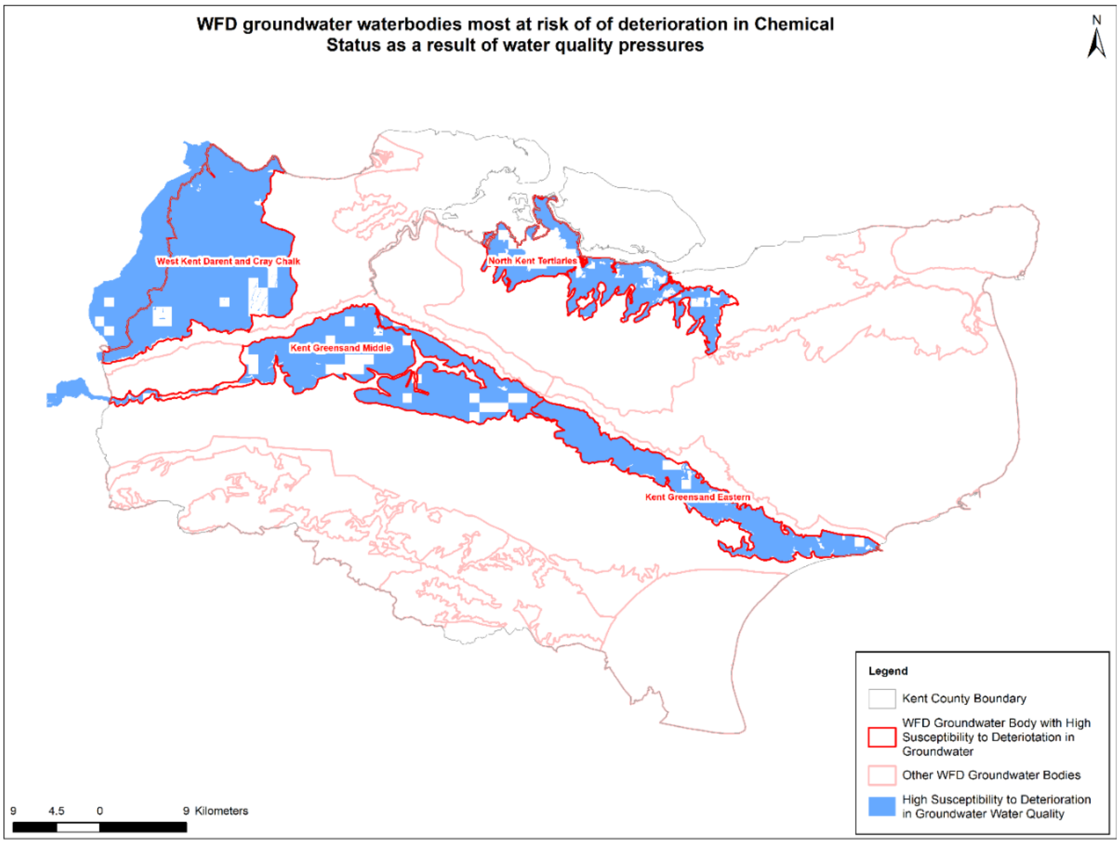

**Figure 5-8: WFD Groundwater Bodies most at risk of Deterioration in Chemical Status as a result of Water Quality Pressures**

Of these WFD groundwater bodies, North Kent Tertiaries is at ‘Good’ chemical status as of 2019 and therefore at risk of future deterioration due to water quality pressures. The other high-risk groundwater bodies are already at ‘Poor’ chemical status; however, future risk to these pressures could prevent ‘Good’ chemical status from being achieved in the future.

Potential adaptation responses to groundwater quality deterioration risk linked to NbS are discussed in Section 6.

## 5.5 Deterioration in Hydromorphological Condition – Fluvial

### 5.5.1 Figure Reference

Volume 2: Mapbook Figure Reference

**Figure WSIS5 – Deterioration in Hydromorphological Condition – Fluvial**

**Figure CRE5 – Risk of Increase in Summer Demand and Abstraction – Surface Water**

**Figure CRE7 – Increase in Risk of Soil Erosion and Degradation**

### 5.5.2 Rationale

The deterioration of hydromorphological condition of fluvial surface waterbodies has been considered as a risk owing to the combined potential change responses of lower river flows due to climate change and land use change sources and increase in soil erosion also as a result of climate change and land use risk.

There are currently several hydromorphological pressures on fluvial water systems, with anthropogenic physical alterations to watercourses and their connectivity with floodplains one of the biggest pressures, but increasing risk of soil erosion as a result of climate change and resultant sedimentation of river systems is likely to increase as a pressure within many catchments and lower flows exacerbating this sedimentation risk. Lower flows also affects the flow regime quality element of hydromorphological status as defined by the WFD classification process in England.

As with changes in river flow and surface water quality, changes in hydromorphological condition are an important water system impact to consider as it has a range of potential effects and consequences on receptors, including water environment receptors.

The future susceptibility of river systems to this impact has been derived using the following change responses:

- Increase in Soil Erosion and Degradation.
- Increase in Summer Demand and Abstraction – Surface Water.

### 5.5.3 Impact Assessment

Each change response magnitude was given a rating score for high, medium and low as shown in Table 5-14.

**Table 5-14: Risk Score assigned to each contributing change response magnitude**

| | Low | Medium | High |
|---|---|---|---|
| Score | 1 | 2 | 3 |

The scores were then combined to determine an overall risk score for the Deterioration in Hydromorphological Condition (WSIS5) using the ratings displayed in Table 5-15

**Table 5-15: Deterioration in Hydromorphological Condition Magnitude**

| Low | Medium | High |
|---|---|---|
| 1-2 | 3-4 | 5-6 |

### 5.5.4 Risk Assessment

Figure WSIS5 Illustrates the locations most at risk of hydromorphological change, showing the most concentrated high risk areas in the upper reaches of the River Darent catchment, the Lower Eden, the Little Hawden Stream and the Bourne. Other catchments with areas of high risk include the Len, the Newmill Channel, the Stour between Wye and Canterbury and its upper reaches, the Teise, and Tudeley Brook. Future soil erosion is the key change response driving this impact and waterbodies in these catchments will be at increased risk of their hydromorphological quality elements not supporting ‘Good’ status.

## 5.6 Reduction in Summer Groundwater Levels

### 5.6.1 Figure Reference

Volume 2: Mapbook Figure Reference

**Figure WSIS6 – Reduction in Summer Groundwater Levels**

**Figure CRE6 – Risk of Increase in Summer Demand and Abstraction – Groundwater**

### 5.6.2 Rationale

As reported in Section 4.4, rising temperatures and variation in rainfall patterns will change the recharge to groundwater in UK aquifers[18]. UKCP18 climate change projections show that by the 2080s, average daily rainfall in the winter months could increase by up to 0.70mm/day resulting in a 30% increase in winter rainfall volume.

Water resource climate change modelling undertaken by water companies to support production of the current WRMPs supplying Kent demonstrate that groundwater yields are likely to remain robust across for the majority of probabilistic climate change projections. However, the risk of lower summer groundwater in some years is a potential concern as a result of climate change due to the groundwater recharge season, typically September to April, potentially becoming shorter. In addition, groundwater abstraction pressure could exacerbate this risk. Therefore, the susceptibility of this risk has been created by using the Increase in Summer Demand and Abstraction – Groundwater change response scores as set out in Table 5-16.

**Table 5-16: Reduction in Summer Groundwater Levels Magnitude**

| Low | Medium | High |
|---|---|---|
| 1-2 | 3-4 | 5-6 |

### 5.6.3 Risk Assessment

Figure WSIS5 identified a medium to high risk of lower groundwater levels across most groundwater bodies in the County. Figure 5-9 identifies the WFD groundwater bodies most likely to be at risk of WFD quantitative status as a result of potential future groundwater level change covering the North Kent Tertiaries, the Easy Kent Chalk – Stour, and the West Kent Darent and Cray Chalk. Of these waterbodies, the North Kent Tertiaries and East Kent Chalk – Stour were both at 'Good' status for Quantitative Water Balance quality element as of 2019 and hence at risk of deterioration in overall status due to this future risk.

[18] https://geosmartinfo.co.uk/2019/10/groundwater-flooding-and-climate-change/

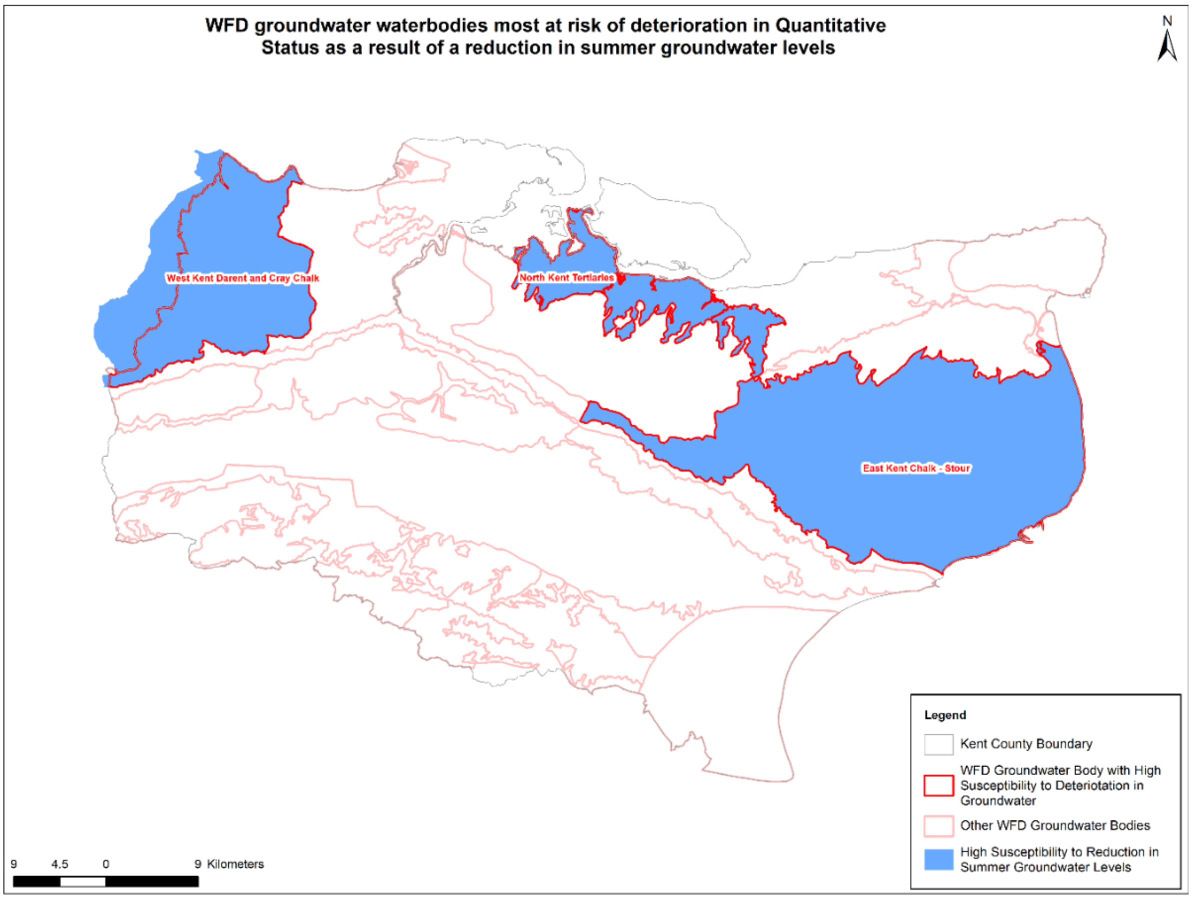


**Figure 5-9: WFD Groundwater Bodies Most at Risk from Lower Groundwater Levels**

5.6.3.1 Water Dependent Habitat Assessment

The combination of groundwater quality deterioration risk (WSIS4) and groundwater level changes (WSIS5) has been compared to where habitats with a water dependency have been identified, covering both GWDTEs classified under the WFD and other habitats with a material water dependency (as these are likely to be influenced by groundwater as well as surface water flows).

Where a groundwater body has either (or both) risks identified and includes a water dependent habitat, this has been illustrated in Figure 5-10. Both the North Kent Tertiaries and the West Kent Darent and Cray Chalk waterbodies are at risk from both groundwater quality and level pressures and hence, water dependent habitats in these locations are more vulnerable to future impacts. This highlights some key habitats which could be at risk of deterioration in condition including Wye and Crundale Downs SSSI and SAC, Lympne Escarpment SSSI and the Swale SSSI, SPA and Ramsar site. An analysis of the potential sensitivities as a result of these future risks is included in Table 5-17.

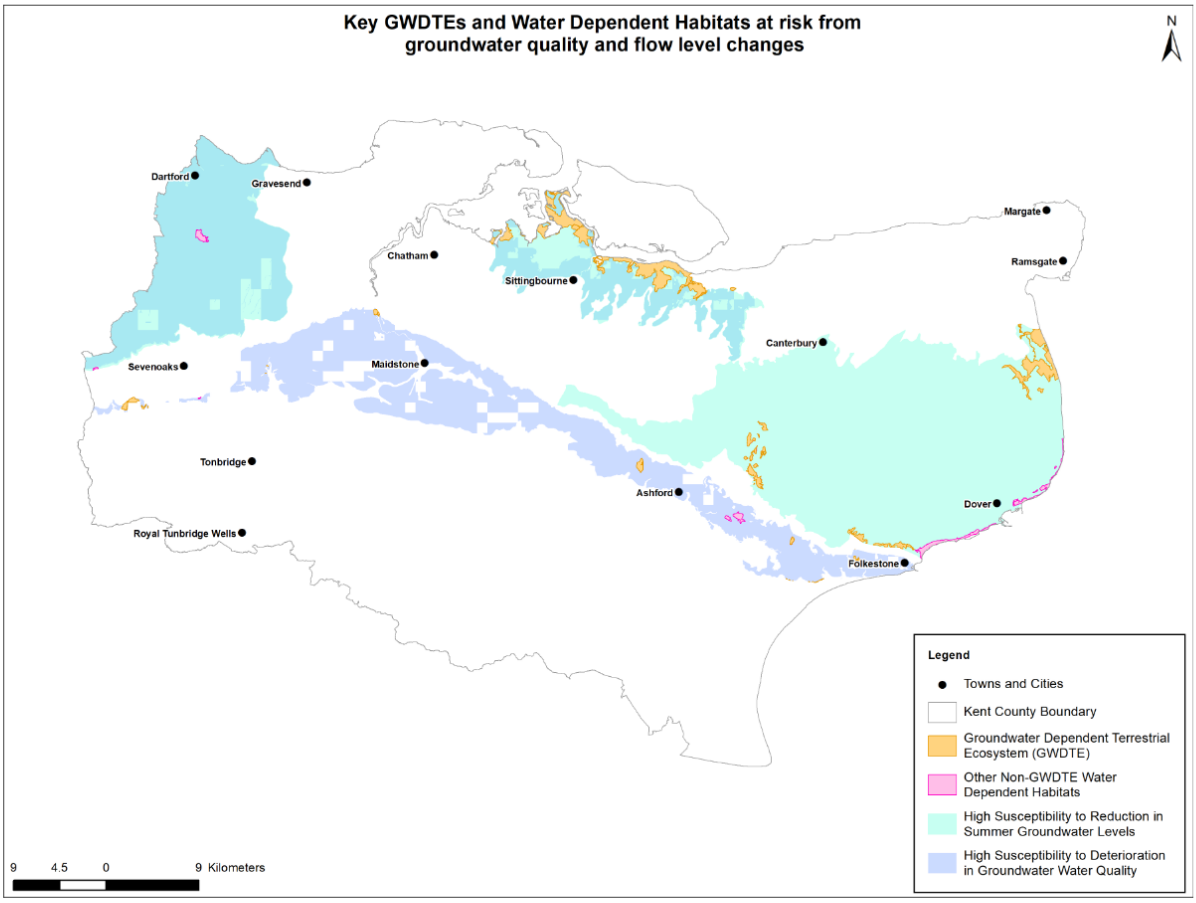


**Figure 5-10: Water Dependent Habitats at risk of Groundwater Quality Changes and Level Changes**

**Table 5-17: Water Dependent habitats and Likely Sensitivities as a result of Groundwater Risks**

| Habitat Name | Designation | Habitat Dependency | Risk Type Identified | Summary of Likely Site Sensitivities |
|---|---|---|---|---|
| Medway Estuary & Marshes | SSSI, SPA, Ramsar | GWDTE | Reduction in Summer GW Levels and Deterioration in GW Quality | • Wetland susceptible to low water levels, e.g. shallow areas of flooding provide feeding grounds for birds until late June and ditches should have a sufficient depth of water throughout the year.<br>• If water quality and sediment quality deteriorate, including the transition between freshwater and brackish water conditions, species diversity may be impacted.<br>• Site highly sensitive to inorganic fertilisers and pesticides which can cause a loss of aquatic plants and increases in species dominance and algal growth. |
| Wye & Crundale Downs | SSSI, SAC | GWDTE | Reduction in Summer GW Levels | • Wet woodland and associated important invertebrate species and assemblages susceptible to low water levels.<br>• Plants and animals that occur in and around flush and spring fen habitats are dependent on water chemistry and flow rate and the quantity and quality of the groundwater must be maintained. |
| Folkestone to Etchinghill Escarpment | SSSI, SAC | GWDTE | Reduction in Summer GW Levels | • Plants and animals that occur in and around flush and spring fen habitats are dependent on water chemistry and flow rate and the quantity and quality of the groundwater must be maintained. |
| Lympne Escarpment | SSSI | GWDTE | Deterioration in GW Quality | • Within flush and spring fen habitat groundwater sometimes breaks out on the surface and the plants and animals that occur in and around these habitats are dependent on the water chemistry and flow rate, therefore are susceptible to changes in the quantity and quality of the groundwater.<br>• Site highly sensitive to inorganic fertilisers and pesticides. |

| Habitat Name | Designation | Habitat Dependency | Risk Type Identified | Summary of Likely Site Sensitivities |
|---|---|---|---|---|
| Holborough to Burham Marshes | SSSI | GWDTE | Deterioration in GW Quality | • Floodplain vegetation may be dependent on water seepage from subterranean aquifers and therefore susceptible to deterioration in groundwater quality.<br>• Excessive nutrient enrichment may result in the replacement of the characteristic floodplain fen communities with very species-poor vegetation.<br>• In swamp habitats, appropriate water quality should be maintained as some communities are likely to be very sensitive to nutritional enrichment and outcompeted by other species.<br>• The conservation value of artificial standing waterbodies is largely determined by structural diversity and water quality. Nutrient increases can lead to a loss of aquatic plants in favour of excessive algal growth which may result in a shift in the way a waterbody functions, reducing plant and invertebrate abundance and diversity - an important food sources for wetland birds.<br>• Site highly sensitive to inorganic fertilisers and pesticides. |
| Bourne Alder Carr | SSSI | GWDTE | Deterioration in GW Quality | • The springline at the juncture of these beds is responsible for continuous flushing of the woodland with nutrient-rich water. This is significant to the botanical communities which have developed and is therefore susceptible to deterioration in groundwater quality. |
| Sandwich Bay to Hacklinge Marshes | SSSI | GWDTE | Reduction in Summer GW Levels | • Wet grasslands are susceptible to low water tables, occurring on land that is subject to periodic flooding or has a seasonally high water table and is waterlogged for much of the year. Wet grassland often supports a wide variety of plants and animals, in particular birds and invertebrates, and is an important habitat for breeding waders and wintering wildfowl. |
| Thanet Coast & Sandwich Bay | SPA, Ramsar | GWDTE | Reduction in Summer GW Levels | • Wet grasslands are susceptible to low water tables, occurring on land that is subject to periodic flooding or has a seasonally high water table and is waterlogged for much of the year. Wet grassland often supports a wide variety of plants and animals, in particular birds and invertebrates, and is an important habitat for breeding waders and wintering wildfowl. |
| Sandwich Bay | SAC | GWDTE | Reduction in Summer GW Levels | • Wet grasslands are susceptible to low water tables, occurring on land that is subject to periodic flooding or has a seasonally high water table and is waterlogged for much of the year. Wet grassland often supports a wide variety of plants and animals, in particular birds and invertebrates, and is an important habitat for breeding waders and wintering wildfowl. |

| Habitat Name | Designation | Habitat Dependency | Risk Type Identified | Summary of Likely Site Sensitivities |
|---|---|---|---|---|
| The Swale | SSSI, SPA, Ramsar | GWDTE | Reduction in Summer GW Levels and Deterioration in GW Quality | • Wet grasslands are susceptible to low water tables, occurring on land that is subject to periodic flooding or has a seasonally high water table and is waterlogged for much of the year. Wet grassland often supports a wide variety of plants and animals, in particular birds and invertebrates, and is an important habitat for breeding waders and wintering wildfowl.<br>• Most ditch systems are subject to water level control and should have a sufficient depth of water in ditches throughout the year. Ditches are susceptible to increased levels of nutrients which can cause a loss of aquatic plants and increases in algal growth.<br>• If water quality and sediment quality deteriorate, including the transition between freshwater and brackish water conditions, species diversity may be impacted.<br>• Intertidal mud and sand flats are susceptible to deterioration in water quality and sediment quality and the sediment budget within the estuarine or coastal system can be restricted by anthropogenic influences.<br>• Site highly sensitive to inorganic fertilisers and pesticides. |
| Scords Wood & Brockhoult Mount | SSSI | GWDTE | Deterioration in GW Quality | • Site highly sensitive to inorganic fertilisers and pesticides. |
| Ruxley Gravel Pits | SSSI | GWDTE | Reduction in Summer GW Levels and Deterioration in GW Quality | • The conservation value of artificial standing waterbodies is largely determined by structural diversity and water quality. Nutrient increases can lead to a loss of aquatic plants in favour of excessive algal growth which may result in a shift in the way a waterbody functions, reducing plant and invertebrate abundance and diversity - an important food sources for wetland birds.<br>• Changes to the amount of water within the waterbody (by abstracting water from inflowing streams or raising the water level) can also alter nutrient regimes, as well as change the available area of some habitats. |

| Habitat Name | Designation | Habitat Dependency | Risk Type Identified | Summary of Likely Site Sensitivities |
|---|---|---|---|---|
| Seabrook Stream | SSSI | GWDTE | Deterioration in GW Quality | • Within flush and spring fen habitat groundwater sometimes breaks out on the surface and the plants and animals that occur in and around these habitats are dependent on the water chemistry and flow rate and therefore are susceptible to changes in the quantity and quality of the groundwater.<br>• The groundwater comes from aquifers, and these may be contaminated by agricultural chemicals such as fertilisers, or by pollution leaking from landfill sites. When this has occurred, the characteristic fen vegetation of the valley mire will be replaced. |
| Hothfield Common | SSSI | GWDTE | Deterioration in GW Quality | • The groundwater within fen and valley mire habitat is often susceptible to contamination by agricultural fertilisers, or by pollution leaking from landfill sites and groundwater quality and quantity should be maintained.<br>• Swamp habitats are sensitive to worsening water quality which can lead to the excessive spread of species including reed, reed canary grass, or reed sweet grass.<br>• Site highly sensitive to inorganic fertilisers and pesticides. |
| Gibbins Brook | SSSI | GWDTE | Deterioration in GW Quality | • The groundwater within fen and valley mire habitat is often susceptible to contamination by agricultural fertilisers, or by pollution leaking from landfill sites and groundwater quality and quantity should be maintained.<br>• Swamp habitats are sensitive to worsening water quality which can lead to the excessive spread of species including reed, reed canary grass, or reed sweet grass.<br>• Site highly sensitive to inorganic fertilisers and pesticides. |
| Farningham Wood | SSSI | Non-GWDTE Water Dependent Habitat | Reduction in Summer GW Levels and Deterioration in GW Quality | • Wet woodland and associated important invertebrate species and assemblages susceptible to low water levels. |
| Westerham Wood | SSSI | Non-GWDTE Water Dependent Habitat | Reduction in Summer GW Levels and Deterioration in GW Quality | • Wet woodland and associated important invertebrate species and assemblages susceptible to low water levels. |
| Folkestone Warren | SSSI | Non-GWDTE Water Dependent Habitat | Reduction in Summer GW Levels | • Any development or activity that restricts natural processes is likely to damage the interest features of the site. Changes in drainage patterns can damage active process sites. |

# 6. Adaptation

## 6.1 Introduction

The focus of this Section is to set out the potential opportunities for NbS to address the following risks to vulnerable habitats and waterbodies and the related effects for people and places.

- **Flooding:** Increase in frequency, extent and depth.
- **Water Availability:** Increase in frequency of summer hydrological drought; and reduction in summer surface water and groundwater levels.
- **Water Quality**: Deterioration in water quality (surface water and groundwater); and reduction in waterbody hydromorphology condition.

For ease of reference, the assessment has been presented for the County's five main WFD Management Catchment areas (Medway, Great Stour, Darent, North Kent and Rother).

This section has considered a landscape scale perspective to firstly provide an overview of key areas at risk, using geo-spatial data, followed by potential NbS adaptation measures to mitigate these risks. Risk maps have been annotated to identify where selected adaptation options may be most applicable and effective.

Due to the geographical breadth of this study, it has not been possible to examine all risks and adaptation measures at a high spatial resolution. As such, the analysis considers solutions at a catchment level, using each of the WFD Management Catchments within Kent. The process highlights the key risks that are specific to each catchment and uses them as opportunities to demonstrate where NbS could be considered, to highlight opportunity for further studies, and for discussion and engagement with key stakeholders. As such, not every risk or adaptation measure applicable to each catchment has been detailed.

## 6.2 Why Nature-based Solutions?

The rationale behind the focus on NbS in this assessment is largely to explore existing and new innovative solutions to address the water-related risks to habitats and communities in Kent which are being heightened due to the change sources of climate, land-use and population change, and to demonstrate the wide range of benefits afforded by working with natural systems.

The previous 2014 Kent SRA focused predominantly on more traditional adaptation measures and how they would mitigate anthropocentric risk. As such, it was decided there would be greater value in exploring natural solutions to risks to natural systems, whilst considering these solutions with respect to co-benefits to communities. This chapter will seek to align and build upon other recent studies that involve or have been commissioned by KCC on NbS:

- Buro Happold (2021) Natural Solutions to Climate Change in Kent.
- Prowater (2021) Water Resources & Nature-based Solutions.
- AECOM (2021) Natural Flood Management Opportunities in the Upper Darent Catchment.

## 6.3 Nature-based Solutions applicable to Kent

NbS are a multidisciplinary tool for sustainably utilising the landscape and its features to address socio-environmental challenges. The services that ecosystems provide can be harnessed to tackle major global challenges like biodiversity loss and climate change. Through the sequestration of carbon, NbS can contribute to the mitigation of climate change[19], with cost-effective NbS interventions estimated to provide up to 30% of the mitigation required to constrain global warming to below 2°C by 2030[20]. While NbS have a high climate mitigation potential, these measures are also essential for supporting human systems and ecosystems to build resilience and adapt to climate change, as there are a multitude of benefits and co-benefits for ecosystems and communities. NbS can be used as standalone adaptation measures or they can be combined with traditional grey infrastructure solutions. As such, there has been a recent drive to promote, fund and implement NbS, as they offer cost effective solutions to climate change adaptation and mitigation, both of which Kent will need to apply on a broad scale to reduce climate-related risk now and in the future.

There is a strong policy and legislative framework in the UK to support and encourage NbS, which broadly align with several policies and strategies of KCC, such as the:

- Kent Environment Strategy (2016);
- Kent Nature Partnership Biodiversity Strategy, which was adopted by KCC in 2020; and,
- Kent and Medway Emissions Analysis and Pathways to Net Zero report (2020).

Included in those documents are a range of commitments and initiatives to work with nature, to preserve the ecosystems that already exist, and enhance and rejuvenate natural environment to help build resilience to climate change whilst also committing to reduce the impact on climate change from a mitigation standpoint. For example, a key commitment made in the Net Zero report is the commitment for KCC to plant 1.5 million trees. The UK government has recently developed a £15m woodland creation scheme, which specifically aims to support landowners/farmers to use woodland creation in areas where it can apply most benefit e.g. reducing flood risk, improving water quality, and supporting species recovery. With this, and other schemes to promote NbS, the business case and opportunity for NbS is being made[21].

This assessment seeks to build on the aforementioned studies that have been conducted with regards to NbS in Kent and identifies where these solutions can best be applied to achieve maximum benefit. Kent has a wide range of land-use/habitats, which come with associated opportunities for NbS. The following opportunities are not an exhaustive list of NbS but those which may be most effective at reducing the water system risks identified by this study.

### 6.3.1 Woodlands

Opportunities: Woodland corridors, woodland expansion, riparian woodland, catchment woodland, natural regeneration, active woodland management**,** under-storey planting.

- **Woodland creation and restoration**, both in the wider catchment and in floodplain/riparian zones are a key tool in NFM. Woodlands are ideal for flow attenuation, such as creation of **large woody debris (LWD)** or ‘leaky’ dams. Not removing woody debris from waterways in woodland habitats can contribute to flow attenuation. Simple timber dams, sourced from the woodland, placed across a stream can spill water onto the woodland floor, attenuating flow, slowing flood peaks and improving woodland habitat. Whilst trees can slow water, they also improve soil quality, intercept rainfall and reduce the amount of water reaching the ground: conifers lead to a 25-40% reduction and deciduous to a 10-25% reduction.

[19] Nature-Based Solutions (NBS) Facilitation Team. 2018. Compendium of Contributions Nature-Based Solutions. Available: https://wedocs.unep.org/bitstream/handle/20.500.11822/29988/Compendium_NBS.pdf?sequence=1&isAllowed=y
[20] IUCN. 2020. Global Standard for Nature-based Solutions. A user-friendly framework for the verification, design and scaling up of NbS. Available: https://portals.iucn.org/library/sites/library/files/documents/2020-020-En.pdf
[21] Forestry Commission, Department for Environment, Food & Rural Affairs, and The Rt Hon George Eustice MP. June 2021. https://www.gov.uk/government/news/landmark-15-million-woodland-creation-grant-opens-for-applications

- **Under-storey planting** can increase floodplain roughness, leading to reduced flood risk, biodiversity benefits, and carbon sequestration. Floodplains in woodlands are ideal areas to increase attenuation; by planting dense understorey species such as holly or hazel. Away from woodlands, willow-hurdles can be planted to slow floodplain flow.
- Woodlands created in appropriate locations can have multiple benefits of **slope stabilisation, reduced landslide risk, absorption of water, reduced runoff and reduced discharge peaks to decrease flooding downstream**. Decisions need to be considered on whether native deciduous species which have large biodiversity benefits, or conifer woodland which has greater carbon sequestration and interception rates but less biodiversity benefits, are selected. Woodlands can also **help improve water quality** as they can intercept pollution and sediment before it reaches watercourses. A focus in this study is on riparian woodland and catchment woodland.
- Due to water requirements of woodland, planting may only be suitable in areas not susceptible to current or future drought risk.

### 6.3.2 Biodiverse grasslands

Opportunities: Grassland creation/restoration, grassland protection, road verge naturalisation.

- Converting **arable land to grassland** (especially on steep slopes and in chalk areas), can **improve infiltration and reduce runoff to reduce flood risk**, whilst improving water quality, biodiversity and carbon sequestration.
- In some cases, conversion from woodland (especially conifer plantations to grassland) may be advantageous, especially to biodiversity, drought risk and improved groundwater recharge.
- Grassland protection, creation and restoration could be considered within coastal margins and catchments with **high flood and water quality risks,** as biodiverse grasslands have deeper rooting vegetations which benefits **soil stabilisation, reduces leaching and improves infiltration**[22].
- Benefits of grasslands are often overlooked with regards to carbon sequestration, however they are effective carbon sinks, especially in areas where drought risk prevails, and woodland would not be a suitable option.

### 6.3.3 Inland wetlands and waterways

Opportunities: Recreation of wetlands, restoration of natural river channels (e.g. barrier removal, meander channels, pools, re-grade banks), retaining and protecting existing inland wetlands, restoration of natural floodplains (e.g. species reintroduction, removal/blocking artificial drainage ditches).

- Wetlands have been reduced in Kent by straightening and canalising waterways, leading to increased downstream flood risk. Measures to reverse this trend and **increase inland wetlands will lead to increased storage capacity and provision of baseflow and extended retention time**. Allowing waterways to return to their natural state is inherently natural but can be assisted by measures such as the removal of artificial drainage ditches to restore natural process on headwater streams. More active measures may be required to restore channel and floodplain wetlands to improve channel morphology, including re-grading banks to reshape the river channel and installing shallow berms to create a meandering, self-cleaning channel.
- **Wetland creation or restoration in Flood Zones**, or upstream from Flood Zones, where land-use conditions are suitable or possible, are areas where these opportunities could be exploited. Natural floodplain restoration has become increasingly promoted in policies as this can offer key flood, drought and water quality benefits, and is seen as cost effective compared to structural interventions.

[22] Buro Happold. 2021. Natural Solutions to Climate Change in Kent.

- Wetlands role in retaining water during winter and spring fall, and releasing it into the surrounding environment, recharging the groundwater aquifers, is imperative[23]. This role of wetlands becomes even more critical with wetter winters and drier summers, where **wetlands will reduce slow-onset drought risk**[24].
- Benefits include reduced downstream flood risk, increased biodiversity, eco-tourism, reduced drought and improved carbon sequestration as a result of waterlogged anaerobic conditions which act as a carbon sink.

### 6.3.4 Agricultural land

Opportunities: regenerative farming practices, reducing livestock access to waterways, soil improvement techniques, rewilding and woodland/grassland creation.

- Whilst agriculture is not itself a NbS, moving toward agricultural practices that work with nature, such as regenerative farming practices, can tackle environmental and social risks, especially in areas like Kent where agriculture is the dominant land-use. **Regenerative farming** covers a broad spectrum of measures, such as **minimising soil disturbance, keeping soil covered and maximising plant/crop diversity and reduction in pesticides/herbicides**. They are an effective way of improving biodiversity, water quality and recharge, livelihoods, and building climate resilience.
- **Agricultural drainage** and land management techniques play a key role in the contribution to the **speed and size of flood events** as runoff from the land is hugely influenced by farming practices in the catchment[25]. Some poorly planned agricultural practices can lead to degrading soil condition, reduced infiltration and increased runoff.
- Agricultural land close to watercourses can lead to runoff and leaching of pesticides, fertiliser and herbicides leading to **eutrophication, deoxygenation, poor water quality and reduced biodiversity**.
- Soil improvement and other measures that improve soil infiltration can help **reduce drought risk by recharging aquifers and preserving drinking water supplies.**
- Simple measures to support ‘margin management’, such as **limiting livestock damage to waterways,** can be employed to help **stabilise the riverbanks and increase channel roughness.** The benefits include reduced flood risk, improved water quality (reducing sediment load and faecal matter) and improved river biodiversity by reducing overgrazing. Whilst not seen as an inherently natural measure, the **fencing off of the watercourse to livestock** allows riverbanks to naturally establish with vegetation thereby reducing erosion risk and increasing roughness.
- Where conditions are right, opportunities to **convert arable land to grassland and woodland,** where appropriate, through rewilding can have multiple benefits and is seen as key to building climate resilience in suitable areas.

### 6.3.5 Coastal wetlands and marine habitats

Opportunities: Retention and protection of coastal habitats, restoration of coastal habitats, restoration of seagrass beds, managed realignment of coastal defences, natural coastal management.

- The retention, protection and restoration of coastal wetlands have multiple benefits including **coastal defence, carbon sequestration, and increased and improved biodiversity.**

[23] Ramsar Convention Secretariat (RCS). 2018. Ramsar Briefing Note 10: Wetland Restoration for Climate Change Resilience
[24] Buro Happold. 2021. Natural Solutions to Climate Change in Kent.
[25] Environment Agency. 2011. Runoff Attenuation Features ‘A guide for all those working in catchment Management’ - https://research.ncl.ac.uk/proactive/belford/papers/Runoff_Attenuation_Features_Handbook_final.pdf

- Hard-engineered sea defences can impact the coastal systems ability to adapt to climate change and sea level rises and can lead to a reduction in coastal wetlands[26].
- Seagrass beds, native coral reefs and oyster reefs dissipate wave energy to reduce storm surges and buffer wave action, **reducing incidences of both flooding and coastal erosion and improving water quality**. Natural seagrass beds provide an essential marine habitat to **support biodiversity**, acting as a nursery ground for juvenile fish and other species. The **restoration of seagrass beds** is often highlighted as a climate solution for their high **carbon sequestration** potential and ability to support climate mitigation[27]. In addition the reefs adjust and grow in response to sea-level increases which is crucial for coastal areas around Kent.
- Saltmarsh is a distinct environment home to salt tolerant species specialised to the intertidal environment. Like seagrass beds, vegetated saltmarsh environments have the capacity to reduce wave and tidal energy by an average of 82%[28]. Saltmarshes are generally located in sheltered estuaries and commonly accompanied by mudflats. In addition to **reducing coastal erosion and flooding, saltmarshes support unique biodiversity and improve water quality, filtering runoff and metabolising excess nutrients.**

### 6.3.6 Cross-Cutting NbS

- Rewilding, the practice where control over the land is partially or fully given back to nature, can lead to the revitalisation of natural processes which can have multiple benefits. The restoration of natural grasslands and woodland creation can lead to a reduction in flood risk, improvements in soil quality, biodiversity and health as well as access and wellbeing benefits. Eco-tourism can create opportunities for improved livelihoods as rewilding schemes have surged in popularity due to Covid and its impact on people's perception and need for nature. The increase in demand for natural areas has also been driven by people's understanding and desire to address the current climate and ecological crisis. Rewilding can be passive, or it can be active, with the re-introduction of native species which have since declined or become extinct. Innovative schemes which are being trialled in several locations in the UK to reintroduce native species, such as beavers, are seen as opportunity areas for risk reduction and improved water quality and biodiversity:

  "Beavers can also offer a nature-based solution to improving the health and function of river catchments. Beaver-created wetlands can act as sponges, resulting in more constant flows and retaining water during droughts. A series of leaky beaver dams can reduce the speed of flow and help reduce the chance of flash flooding. Beaver dams can capture organic sediments, and reduce the effects of agricultural runoff and harmful chemicals such as pesticides, helping to improve water quality downstream." – RSPB[29].
- The reintroduction of a species can be a sensitive issue to some stakeholders such as farmers and landowners, with claims that beavers damage agricultural land by impeding drainage and flooding cropland. However, there is a groundswell of support for beavers as they form part of the UK's green recovery and there are new schemes being created, such as the Beaver Tenancy Association (BTA). The BTA is an innovative scheme developed by Ecosulis, and is being trialled to offer landowners the opportunity to lease land to wildlife, to help mitigate any impacts to landowners from keystone species, such as beavers, and engage landowners in the recovery of beaver populations in the UK[30].

Combining NbS across all of these habitats will allow for a landscape approach to risk reduction, which will not only reduce flood, water availability and quality risks in river channels, but will have wide ranging benefits to the ecosystems and communities within the whole catchment area.

[26] Climate Change Committee (lead author Brown, I.). 2017. UK Climate change Risk Assessment 2017: Evidence Report: Chapter 3.
[27] Oreska, M., McGlathery, K., Aoki, L., Berger, A., Berg, P., Mullins, L. 2020. The greenhouse gas offset potential from seagrass restoration.
[28] Scottish Environment Protection Agency. 2015. Natural Flood Management Handbook.
[29] Beaver Reintroduction in the UK: www.rspb.org.uk
[30] Ecosulis. 2020. The Beaver Tenancy Association.

## 6.4 Approach to NbS Identification

Areas of high risk have been identified in Section 5. The Kent Landscape Information System[31] (KLIS) provides detailed information on Kent's landscape and biodiversity. As part of KLIS, a range of habitat opportunity has been identified, developed from field-level information on the current distribution of habitats in Kent, the distribution of protected areas and areas under agri-environment schemes. Ecological rules were used to identify the best opportunities for habitat creation. The rules are aimed at increasing valuable habitats within Kent and reducing the effects of fragmentation across the landscape; this habitat opportunity mapping has assisted in identifying areas suitable to specific NbS. In linking the high risk areas with greatest habitat opportunity areas, this assessment seeks to provide examples of potential spatial solutions to future risks. Due to the constraints of the study, these are example areas and are indicative of the further NbS required in the catchment but are not exhaustive.

•

Figure **6-1** shows the potential benefits of NbS per opportunity type. There are a wide range of methodologies for identifying and ranking benefits for NbS; however this assessment has largely based the range of benefits and scoring on the Environment Agency's 'Working with Natural Processes (WWNP) to reduce flood risk' methodology[32]. The scores have been ranked from 0 'no benefit' to 3 'maximum benefit'. The scoring is fairly generic and does not factor in local nuances, but it does enable the assessment to show where NbS could be best utilised based on the WSIS identified in this study, and the various benefits that may be applicable. The scores also reflect the long-term delivery of benefits once the NbS have been established, as there may be some adverse short-term impacts in their development e.g. woodland creation could have a negative impact on water quality.

[31] https://webapps.kent.gov.uk/KCC.KLIS.Web.Sites.Public/Default.aspx accessed April 2021
[32] Environment Agency. 2017. Working with Natural Processes to reduce flood risk. Available: https://assets.publishing.service.gov.uk/media/6036c730d3bf7f0aac939a47/Working_with_natural_processes_one_page_summaries.pdf

| **Opportunity Group** | **Woodland** | | **Biodiverse Grasslands** | | **Inland wetlands and waterways** | | **Agriculture** | | **Coastal wetlands and marine habitats** | | **Cross-Cutting** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Opportunities ID** | **W1** | **W2** | **W3** | **W4** | **W5** | **G1** | **G2** | **WW1** | **A1** | **C1** | **C2** | **RE1** |
| **Opportunity Type** | Catchment Woodland creation / restoration | Riparian Woodland creation / restoration | Woodland NFM | Woodland to grassland | Arable to woodland | Grassland restoration/ protection | Arable to grassland | Inland wetland and waterway restoration /creation | Regenerative farming practices | Restoration / creation coastal & marine habitats | Realigning coastal defences | Rewilding / species reintroduction |
| Flood (Fluvial or Coastal) Risk Reduction | 3 | 3 | 3 | 0 | 3 | 2 | 3 | 3 | 2 | 3 | 1 | 2 |
| Flood (SW or GW) Risk Reduction | 2 | 1 | 2 | 0 | 2 | 2 | 3 | 2 | 3 | 0 | 0 | 2 |
| Water Availability (SW or GW) | 0 | 0 | 2 | 3 | 1 | 2 | 2 | 3 | 2 | 0 | 0 | 2 |
| Water Quality (SW or GW) | 2 | 2 | 3 | 2 | 2 | 2 | 3 | 2 | 3 | 2 | 1 | 2 |
| Habitat & Biodiversity | 3 | 3 | 3 | 0 | 3 | 2 | 3 | 3 | 2 | 3 | 3 | 3 |
| Livelihoods & Cultural Activity | 2 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 2 | 2 | 3 |
| Health Access and Wellbeing | 3 | 1 | 0 | 0 | 3 | 2 | 2 | 2 | 1 | 2 | 2 | 3 |
| Climate Regulation | 3 | 3 | 2 | 0 | 2 | 2 | 2 | 3 | 2 | 3 | 3 | 1 |
| Air Quality | 3 | 2 | 1 | 0 | 2 | 1 | 2 | 0 | 1 | 1 | 1 | 1 |

| | |
|---|---|
| 0 | No benefit |
| 1 | Minor benefit |
| 2 | Significant benefit |
| 3 | Maximum benefit |

Source: AECOM (2021)

**Figure 6-1: Potential Benefits of NbS Per Opportunity Type**

## 6.5 Applicability of Nature-based Solutions to Key Risks

The NbS assessment has used geo-spatial datasets to identify and summarise some of the key risks in each catchment area. Various NbS have then been suggested as a means to reduce those risks and maximise the benefits from each measure to the habitats, communities and assets in the study area. For each catchment, the assessment then provides rationale for the selection of NbS that could be prioritised, as they are deemed to have the greatest potential benefit.

Whilst the rationale is provided, it is within the constraints of the limitations set out in Section 6.1 and further study to verify the assessment's recommendations may be required.

## 6.6 Medway Assessment

### 6.6.1 Catchment Landscape Context

The Medway catchment covers an area of 2,400km$^2$, emerging in High Weald and flowing into the Thames Estuary[33]. Some WFD waterbodies within the Medway catchment are not achieving 'Good' status including the Beult and Eden at Bough Beech. Across the catchment, the physico-chemical status is primarily 'moderate' with some waterbodies achieving 'high' including Alder Stream and Hammer Dyke, Leybourne Stream and Ditton Stream. Reaches of the Beult in particular suffer large seasonal variations in flow with low summer flows comprising 50-75% sewage treatment works discharge and winter flows prone to flooding[34]. In the upper areas of the Medway catchment, landcover is primarily a mixture of agriculture, with significant areas of arable land, improved grassland and semi-improved grassland with pockets of mixed or broadleaf forest. Towards the estuary, there are large areas of reedbeds, extensive salt marshes and intertidal flats interspersed with urban areas, grazing marsh pasture and course neutral grassland. The following recommendations are based on the known landcover and existing habitat types, with an understanding of the habitat opportunities.

### 6.6.2 Flood Risk Options

An increase in the frequency, extent and depth of flooding is expected to be a persistent issue throughout the Medway catchment, however flooding is projected to coalesce around specific areas including the Holborough to Burham Marshes SSSI and widely across the central catchment where several tributaries converge. Similarly, tidal areas including the Medway Estuary and Marshes SSSI are prone to an increased risk of combined fluvial/tidal flooding which extends into the nearby towns of Gillingham, Rochester and Chatham.

**Potential NbS Options**

The following NbS (shown on Figure 6-2) could potentially help with managing these risks:

1. **WW1:** Upstream **inland wetland restoration** and creation at the confluence of the River Eden and the River Medway could alleviate major flood risk in the central area of the Medway catchment which contains areas with high susceptibility to flood risk. Natural floodplain restoration and wetland creation is likely to allow increased storage capacity and retention upstream in these areas, which may reduce downstream flood risk. More centrally, south of Maidstone, KLIS indicates there is significant opportunity for floodplain restoration and wetland creation. Inland wetland and waterway restoration including removing barriers, re-grading banks and creating shallow berms and inserting gravel riffles could alleviate winter flood risk along the Beult while simultaneously improving water quality, reducing drought risk and supporting biodiversity and recreation opportunities.

2. **W1: Arable to catchment woodland** at the confluence of the River Teise and the River Bewl. This area has a high opportunity to increase woodland cover, especially in the areas not prone to drought, such as areas around Lamberhurst. This could reduce runoff and increase absorption of water, which will be key to reducing flood risk downstream especially in the winter.

[33] Medway Catchment Partnership. 2021. Catchment Mapping Portal. Available: https://theriverstrust.maps.arcgis.com/apps/MapSeries/index.html?appid=d4f79e4f327542209bff6386646f911a#:~:text=The%20River%20Medway%20Catchment%20is,the%20Eden%2C%20Teise%20and%20Beult.

[34] Natural England and Environment Agency. 2018. Improving the River Beult for People and Wildlife. Available: extension://bfdogplmndidlpjfhoijckpakkdjkkil/pdf/viewer.html?file=https%3A%2F%2Fassets.publishing.service.gov.uk%2Fgovernment%2Fuploads%2Fsystem%2Fuploads%2Fattachment_data%2Ffile%2F734379%2FImproving_the_River_Beult_SSSI_Technical_Report.pdf

3. **RE1: Wetland restoration and rewilding** could be used to reduce flood risk in multiple areas in the Medway catchment. KLIS mapping has identified opportunity areas around Paddock Wood, as 'medium and greatest' opportunity for wetland restoration and creation[35]. In addition, the area around Burham Marshes also presents an opportunity for wetland restoration through KLIS mapping, which could also reduce the risk of flooding downstream.

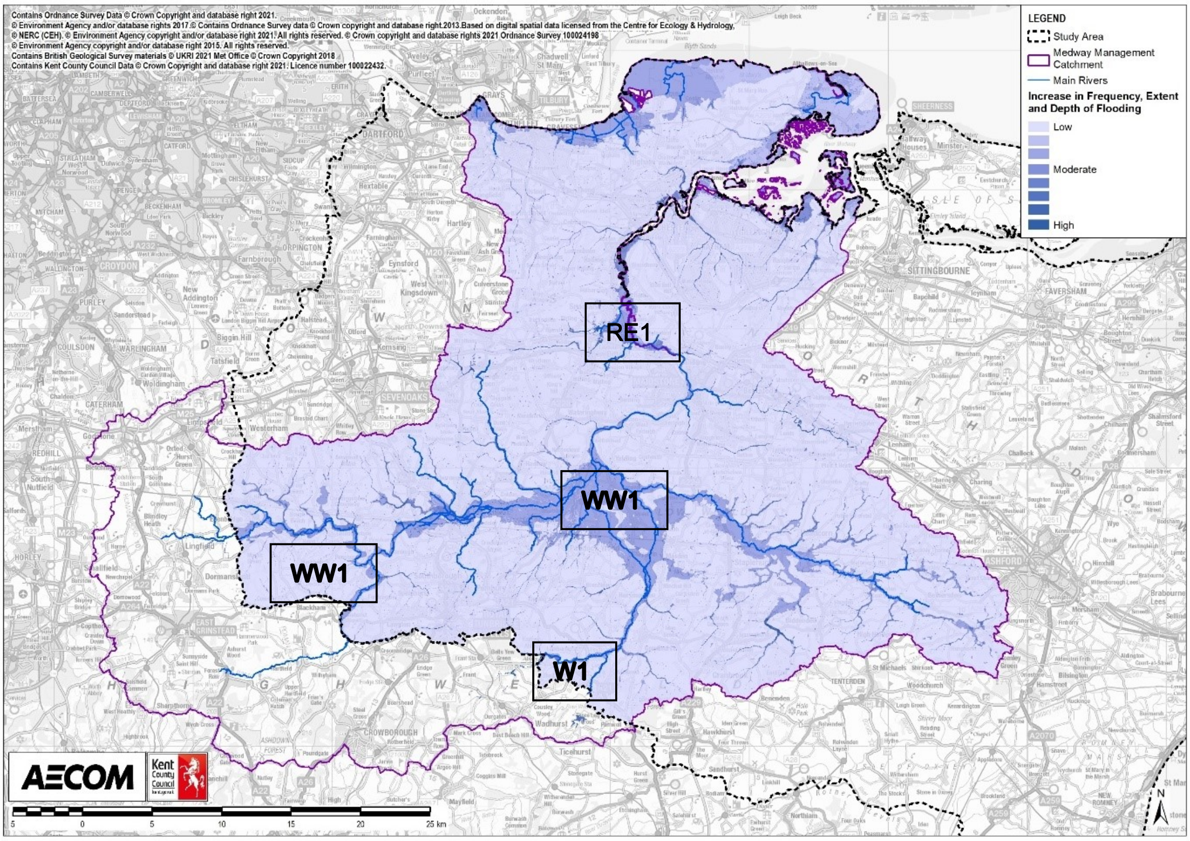


**Figure 6-2: Medway Whole Catchment Flooding - Frequency, Extent and Depth**

The WSIS map for increased frequency of flood risk identifies significant risk at Tonbridge within the Medway catchment with vulnerable receptors including high population density and infrastructure assets. Surrounding land cover exacerbates the challenge of flooding due to the high urban density. Large areas of improved grassland or arable land surround the town.

**Potential NbS Options**

The following NbS (as shown in Figure 6-3) could potentially help with managing these risks in Tonbridge and communities downstream such as Peckham and Brambridges:

1. **WW1**: Upstream measures for **inland wetland restoration** and floodplain restoration to the west of Tonbridge, where there is an array of water features such as canals with high wetland potential.

2. **G2 & G1:** There could also be benefits to converting **arable land to grassland** (G2) and to **restore or protect existing grassland** (G1) to the south and west downstream to reduce surface water runoff and reduce the peak river discharge. Grassland restoration/protection and creation downstream of Tonbridge could contribute to a reduction in flood risk in the area and in the middle and lower catchment.

3. In Tonbridge, SuDS in combination with the upstream NbS would be recommended.

[35] Kent County Council. 2021. KLIS Map. Available: https://webapps.kent.gov.uk/KCC.KLIS.Web.Sites.Public/ViewMap.aspx

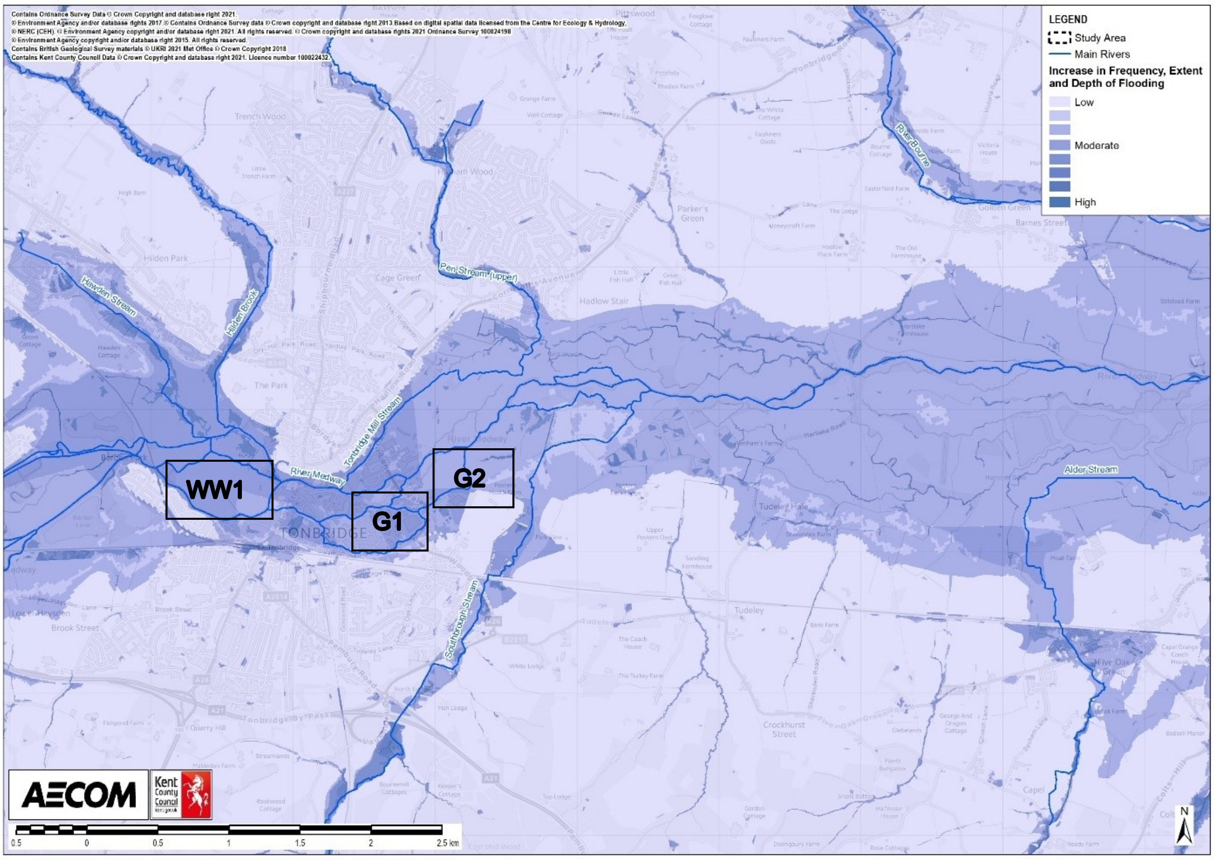


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**Figure 6-3: Tonbridge Flooding - Frequency, Extent and Depth**

### 6.6.3 Water Availability Options

Of the five catchments of the study, the Medway has the most extensive risk of summer hydrological drought, ranging across the catchment through Kent Greensand Middle, Tonbridge and up to Maidstone.

Key areas at risk are the water dependant habitats at the catchment boundary of Scords Wood and Brockhoult Mount, an SSSI habitat of wet woodland. As these habitats require sufficient water to thrive, increased summer hydrological drought combined with deteriorating groundwater puts these areas at high risk.

#### Potential NbS Options

The following NbS (as shown in Figure 6-4 and Figure 6-5) could potentially form part of a solution to managing these risks:

1. **WW1:** In the east of the catchment there are opportunities for **wetland and waterway creation and restoration**, specifically in areas around the Beult near Headcom, down to where the river connects with the Lesser Teise and Teise Rivers. Along the Beult implementing NFM and combining wetland and waterway restoration with riparian and macrophyte planting could significantly improve water quality while reducing flood risk and stabilising waterways.

2. **G1, G2, A1:** General recommendations throughout the catchment are the **restoration/protection** (G1) and **creation of biodiverse grassland from arable** (G2) alongside promotion of **regenerative farming measures** (A1). Grassland restoration/protection should be promoted in areas surrounding SSSI. The SSSI Scords Wood and Brockhoult Mount is characterised by dense woodland interspersed with grassland. Preserving existing grasslands is likely to yield multiple benefits by improving infiltration with added benefits of soil stabilisation, biodiversity gains and water quality improvements.

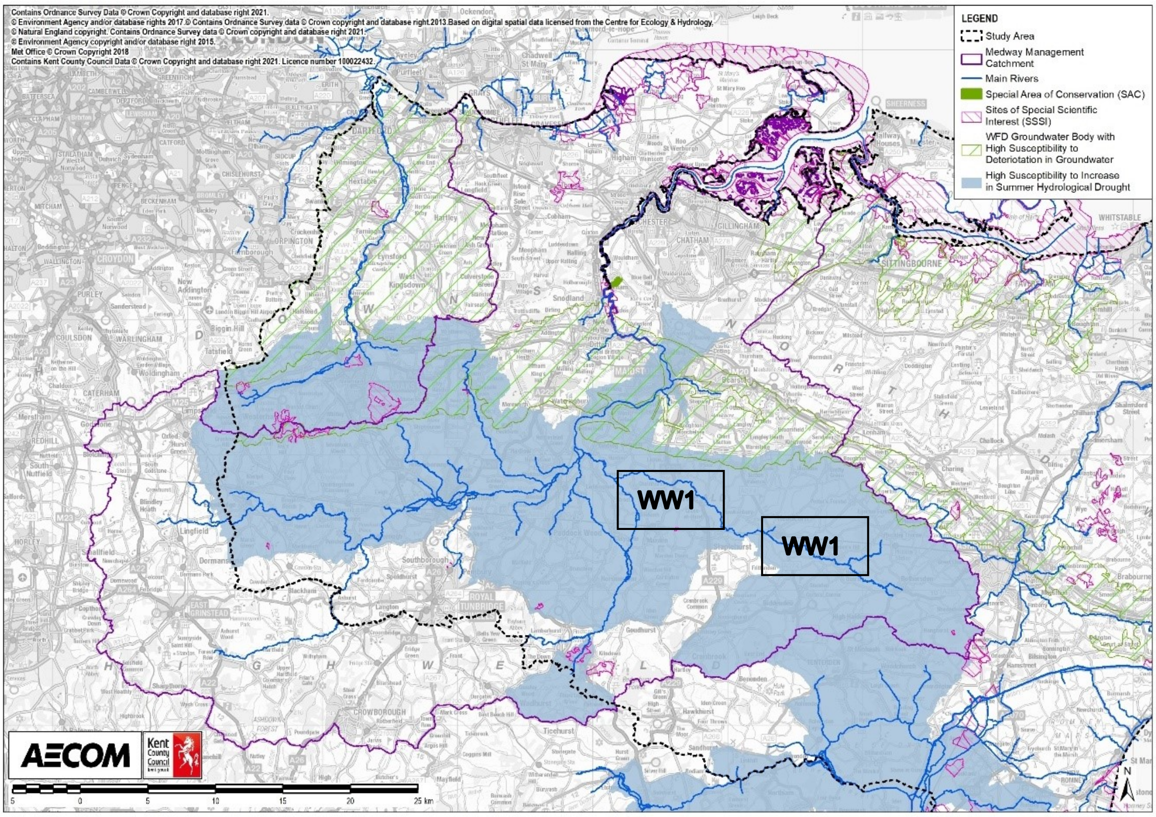


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**Figure 6-4: Medway Whole Catchment High Susceptibility to Summer Hydrological Drought**

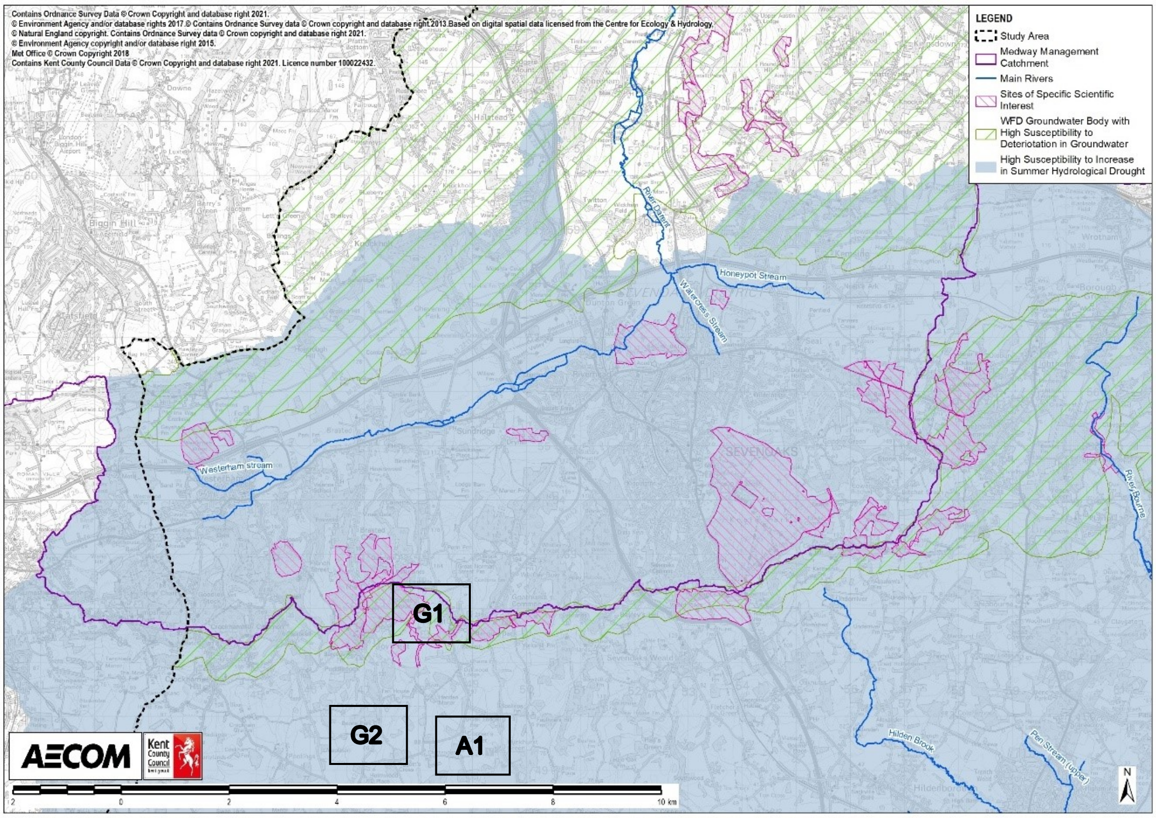


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**Figure 6-5: North West Medway High Susceptibility to Summer Hydrological Drought and Water Dependant Habitats**

### 6.6.4 Water Quality Options

Deterioration in groundwater quality can lead to detrimental effects on water dependent habitats like the Holborough to Burham Marshes and the Medway Estuary and Marshes. Both are GWDTEs dependent on high quality groundwater to preserve the habitat; the combined challenges of deterioration in quality and reduction in groundwater level precipitates water quality risk. Scords Wood & Brockhoult Mount SSSI is an area highly susceptible to deterioration in both groundwater and surface water quality in addition to hydrological drought. Further water dependent areas such as Peter's Pit have a high susceptibility to deterioration in surface water quality while Bourne Alder Carr SSSI on the Bourne has high susceptibility to deterioration in surface water quality and increase in summer hydrological drought. Groundwater availability and quality are high risk across the water dependent habitats in the River Medway catchment and require combined interventions of wetland restoration and rewilding, regenerative farming practices and inland wetland restoration/ creation to alleviate these risks.

### 6.6.5 Key Risks and Recommended NbS

Whilst there are a number of opportunity areas to apply NbS in the Medway catchment, the selected areas below (as shown in Figure 6-6), have been identified due to their ability to reduce risk in the catchment, but also because they provide a wide range of co-benefits.

1. **1.RE: Wetland restoration and rewilding** could be used as a key tool to reduce multiple risks in the Medway catchment. Implementing these measures in areas between Paddock Wood and Yalding, where the habitat and environment is suitable for its creation, could help reduce downstream flooding. The area around Burham Marshes also presents a high opportunity for wetland restoration (KLIS mapping), and there could be added benefits of utilising rewilding measures and species reintroduction, which would not just provide flood, water availability and water quality benefits, but also would reap additional cultural activity, health access and wellbeing benefits for residents in Rochester, Chatham and Maidstone. The data collected identified several areas with 'highest increase in flood risk linked to most deprived 30% of areas nationally', in these three towns, as such, upstream NbS flood risk reduction measures which could reduce peak river discharges, combined with SuDS and other Water Sensitive Urban Design (WSUD) measures in the urban areas should be a high priority. Species reintroduction, such as beavers, could contribute to the reduction of risk and improve co-benefits, and if a suitable habitat is identified in the catchment, possibly around '1.RE' to support a thriving population, then this should be explored.

2. **2.WW1:** The creation of inland **wetlands and restoration of waterways** along this stretch of the Beult, and also moving into areas around Lesser Teise are worth exploring further. They are areas of winter flooding and summer drought, and as such, these measures would allow the storage of water in the catchment during the winter/spring and slow the flow of water to allow increased groundwater and surface water levels in the summer. This could potentially help to protect drought vulnerable habitats and offer a range of co-benefits such as improved water quality, high levels of carbon sequestration (climate regulation) and improved biodiversity.

3. **3.G2**: The area west of Tonbridge has significant areas of arable land and could be an opportune area for the **restoration/protection and creation of biodiverse grassland creation from arable** land use (G2). This, alongside other rewilding measures, could let more natural processes return to these areas to help address the water availability risk. This could be supplemented with the promotion of regenerative farming practices in these areas of high summer hydrological drought risk. There are several areas in the Medway catchment which may be suitable for woodland creation, however due to the high risk of summer drought in the large parts of the catchment, other NbS have been prioritised. However, in areas with low drought risk, woodland creation could also be considered.

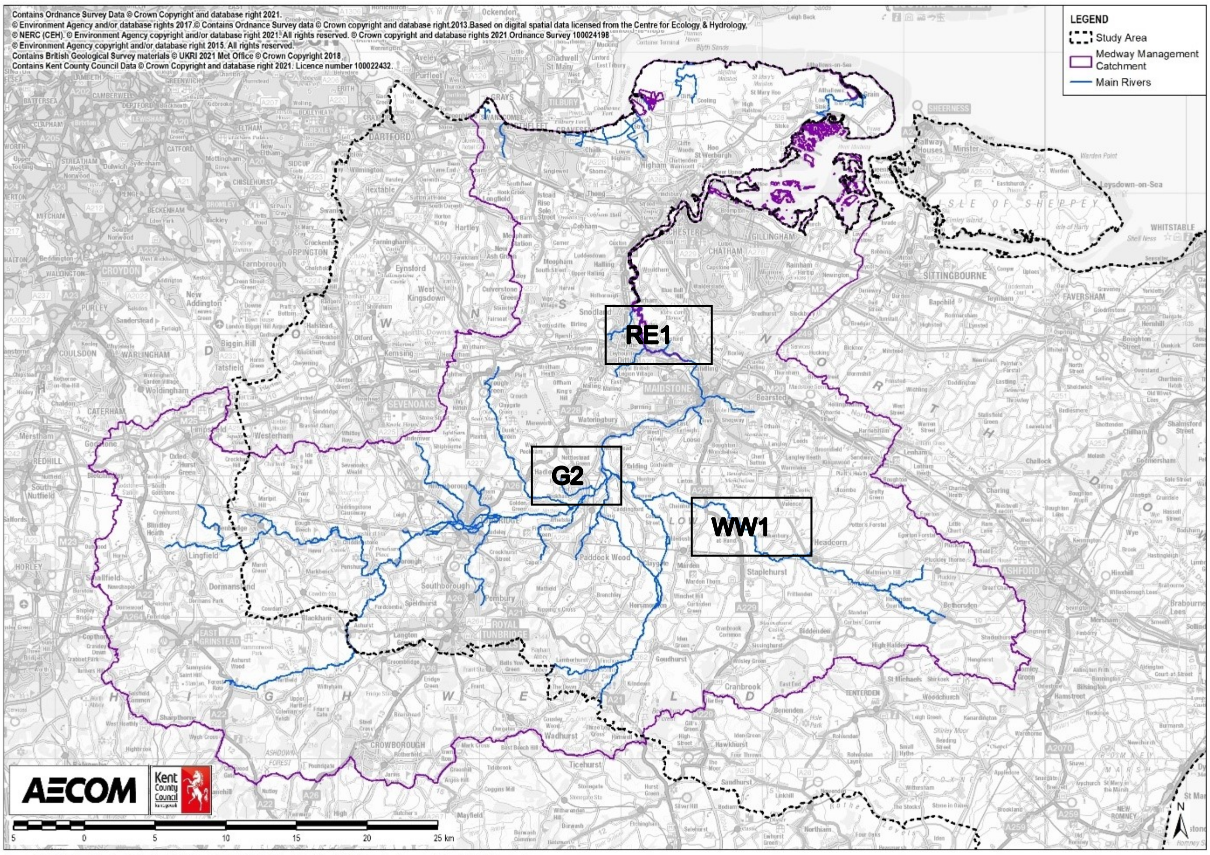


Figure 6-6: Key Recommendations for NBS in Medway Catchment

## 6.7 Stour Assessment

### 6.7.1 Catchment Landscape Context

The Stour catchment encompasses the three major rivers: the Great Stour and the East Stour which converge at Ashford, and the Little Stour which joins the Great Stour downstream of Stodmarsh SAC/Ramsar site. The source of the Great Stour originates near Lenham, a village north-west of Ashford. The East Stour rises to the south-east of Ashford near the village of Postling while the Little Stour emerges near Lyminge before joining the main river at Plucks Gutter.

The landcover at the source of the Great Stour and the East Stour is generally a combination of improved grassland and arable land with few urban settlements before flowing through the settlement of Ashford. Towards the mouth of the Great Stour, the land cover is characterised by built surfaces, semi-improved grazing marsh pasture and Atlantic salt meadows. In terms of water quality for the Great Stour catchment, two river bodies are below ‘Good’ status including Aylesford Stream and Ash Level. Across the catchment, the physico-chemical status is mostly ‘Moderate’ or ‘Good’ with North and South Streams at Northbourne achieving ‘High’.

### 6.7.2 Flood Risk Options

The WSIS of increase in frequency, extent and depth of flooding is not a consistent issue throughout the Stour catchment but is a major risk around the mouth of the river from tidal and fluvial sources. Particular areas of risk occur at the convergence of the River Wingham and the Little Stour and where the Lampen Stream joins the tidal River Stour. High risk areas of vulnerable communities in the most deprived 30% nationally occur in the inner city of Canterbury, through Dover and the town of Little Chart, north east of Ashford.

**Potential NbS Options**

The following NbS (as shown in Figure 6-7) could potentially form part of a solution to managing these risks:

1. **WW1**: **Wetland restoration** is detailed by KLIS mapping as high opportunity north of Stodmarsh National Nature Reserve by the Great Stour. On the Little Stour there is a good opportunity for wetland creation and other techniques to capture and slow run-off in heavy rain events which could reduce flood risk downstream.

2. **W2**: Large areas of arable land around Minster could provide an opportunity to be **converted to riparian woodland** to reduce flood risk. There is also an opportunity to promote wetland restoration and let natural processes reconnect the floodplain in this location.

3. **C1**: To reduce tidal flooding, restoring and **creating coastal habitats** is recommended, which could include the restoration of salt marshes and wetland which has great habitat opportunity at the mouth of the Great Stour as identified by KLIS mapping.

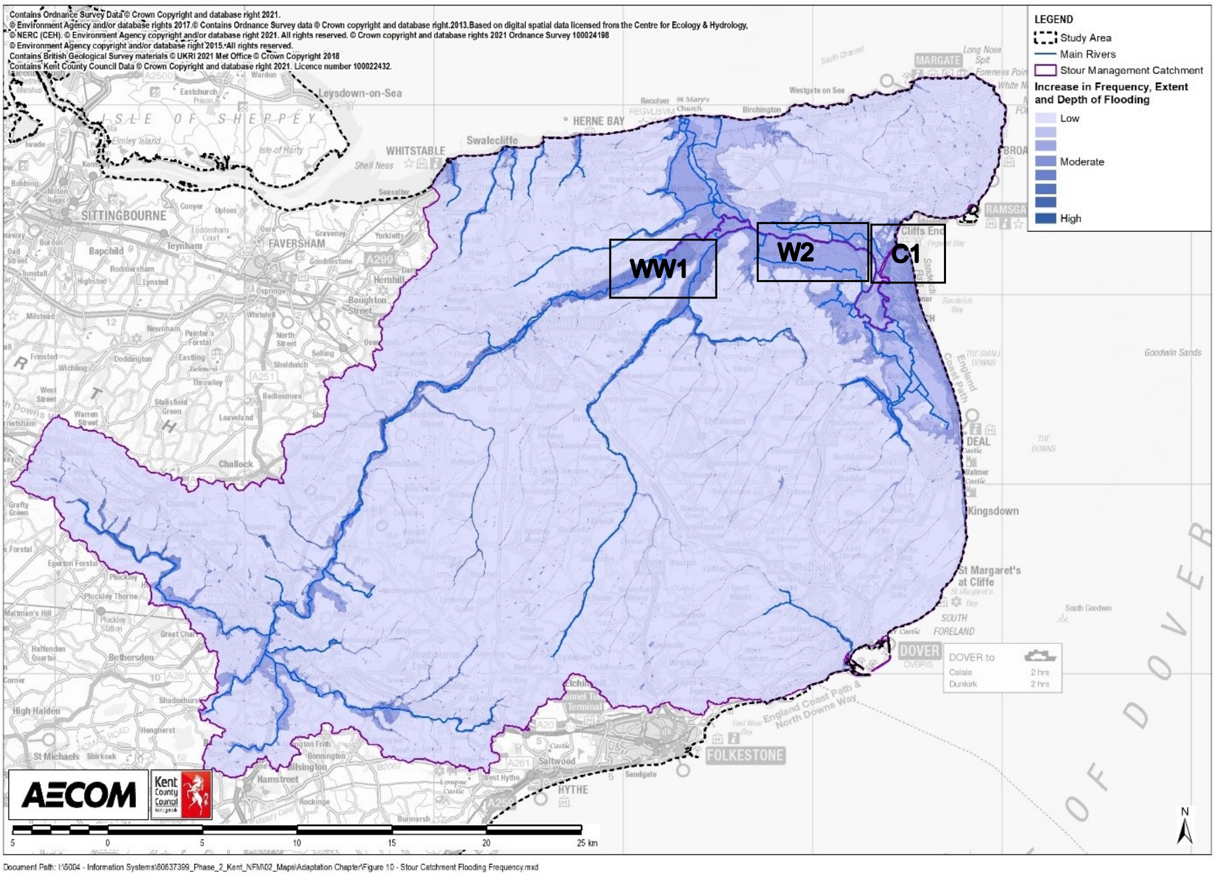


**Figure 6-7: Great Stour Whole Catchment Flooding - Frequency, Extent and Depth**

### 6.7.3 Water Availability and Quality Options

Reduction in summer groundwater levels is an extensive risk across the middle of the Great Stour catchment. In the south of the catchment, deterioration in groundwater quality is a risk from the west and across the south (Figure 6-8).

Hothfield Common is an SSSI considered as one of the last remaining areas of open heath in Kent[36]. The area has pockets of moorland and lowland dry acid grassland and therefore is highly susceptible to a deterioration in groundwater quality. Reduction in summer groundwater level affects Wye & Crundale Downs SSSI, an area of dry grassland, broad-leaf deciduous woodland and improved grassland[37]. While dry grassland generally requires little water, the areas of improved grassland and woodland are at high risk with declining summer groundwater levels.

[36] Kent Wildlife Trust. 2021. Hothfield Heathlands. Available: https://www.kentwildlifetrust.org.uk/nature-reserves/hothfield-heathlands

[37] Joint Nature Conservation Committee.2021. Wye and Crundale Downs. Available: https://www.kentwildlifetrust.org.uk/nature-reserves/hothfield-heathlands

### Potential NbS Options

The following NbS (as shown in Figure 6-9) could potentially form part of a solution to managing these risks:

1. **WW1, A1:** around Conningbrook Manor up the Great Stour to Wye, there are large amounts of arable land, which intersect with high areas of **wetland restoration** opportunity and **biodiverse grassland creation**. In this area regenerative agriculture practices could be promoted.
2. **G2**: In Wye & Crundale Downs SSSI the KLIS habitat opportunity map shows significant opportunity for chalk **grassland restoration**, and in surrounding arable areas there is medium opportunity for neutral grassland.
3. **A1, G2**: Converting **arable to grassland** to improve water quality and groundwater recharge and create biodiverse habitats is recommended in this area. Woodland creation here is not appropriate due to high drought frequency. To the west of Hothfield Common there is medium-great opportunity for wetland. Hothfield common and the surrounding areas have medium opportunity for neutral grassland conversion.

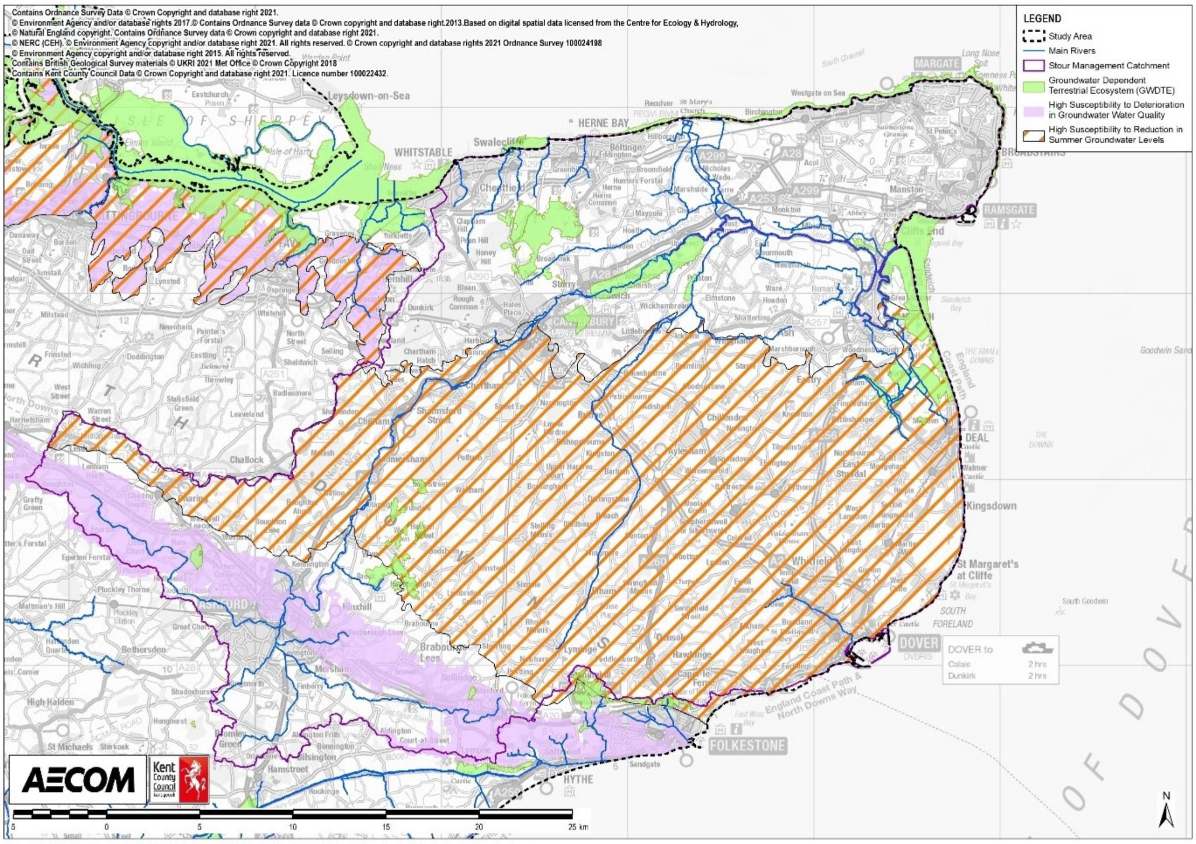


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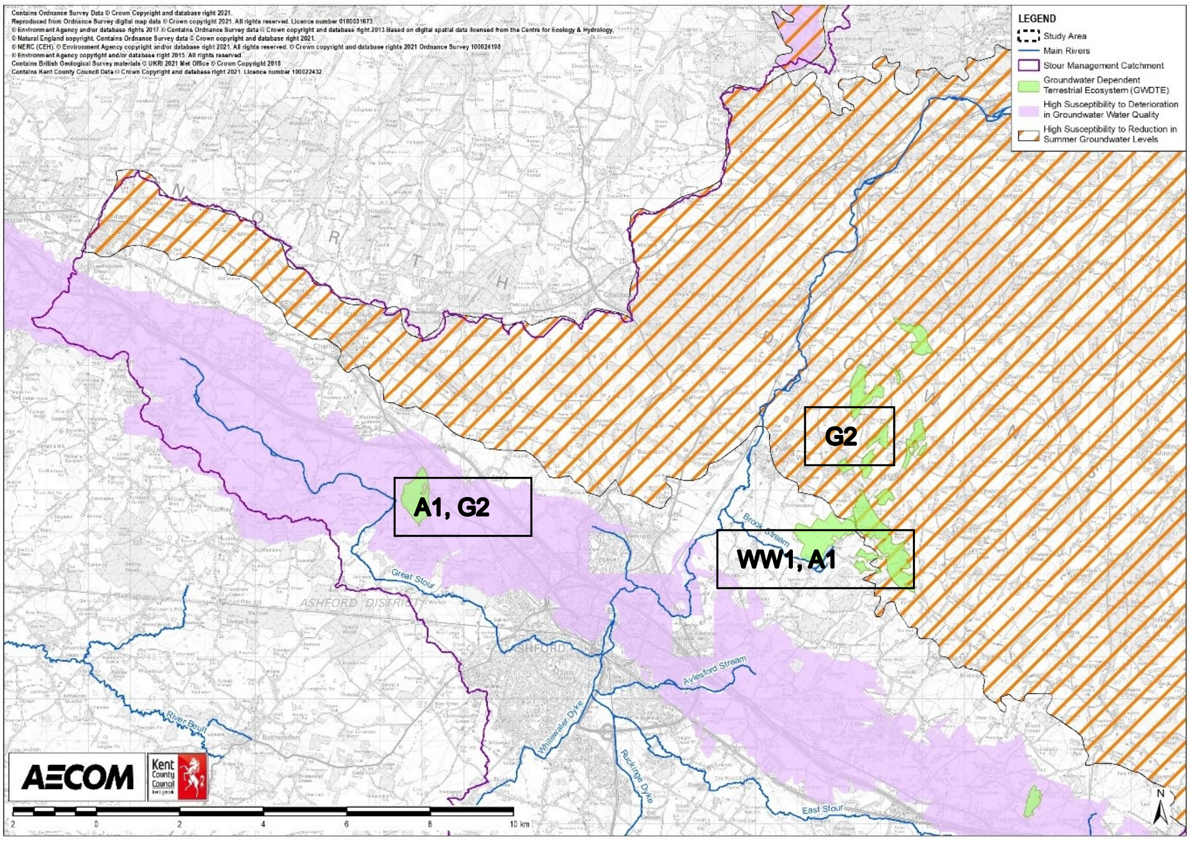
**Figure 6-8: Great Stour Whole Catchment Susceptibility to Deterioration in Groundwater Water Quality and Reduction in Summer Groundwater Levels**




### Figure 6-9: West Great Stour Sites at High Risk of Deterioration in Groundwater Water Quality or Reduction in Summer Groundwater Levels

Stodmarsh SSSI is highly susceptible to deteriorating surface water quality and summer hydrological drought, as it is characterised by marshes, heath and inland waterbodies. To the south, Chequers Wood & Old Park SSSI is characterised by lowland dry acid grassland while to the north east of Canterbury there is scrub woodland. These areas could also be susceptible to these risks. The SSSI is enclosed by residential urban areas to the north, west and south.

### Selected NbS Options

The following NbS (as shown in Figure 6-10) could potentially form part of a solution to managing these risks:

1. **G1**: To the north of Stodmarsh SSSI and areas surrounding the Chequers Wood & Old Park SSSI, there are large areas of improved grassland. As such, **grassland restoration/protection** measures could be put in place here. SuDS for both drought and water quality is recommended for urban areas around Chequers Wood & Old Park SSSI.

2. **WW1**: **Wetlands** could be extended west of Westbere Marshes to support surface water and groundwater dependent ecosystems. KLIS mapping depicts this area as high opportunity for wetland creation.

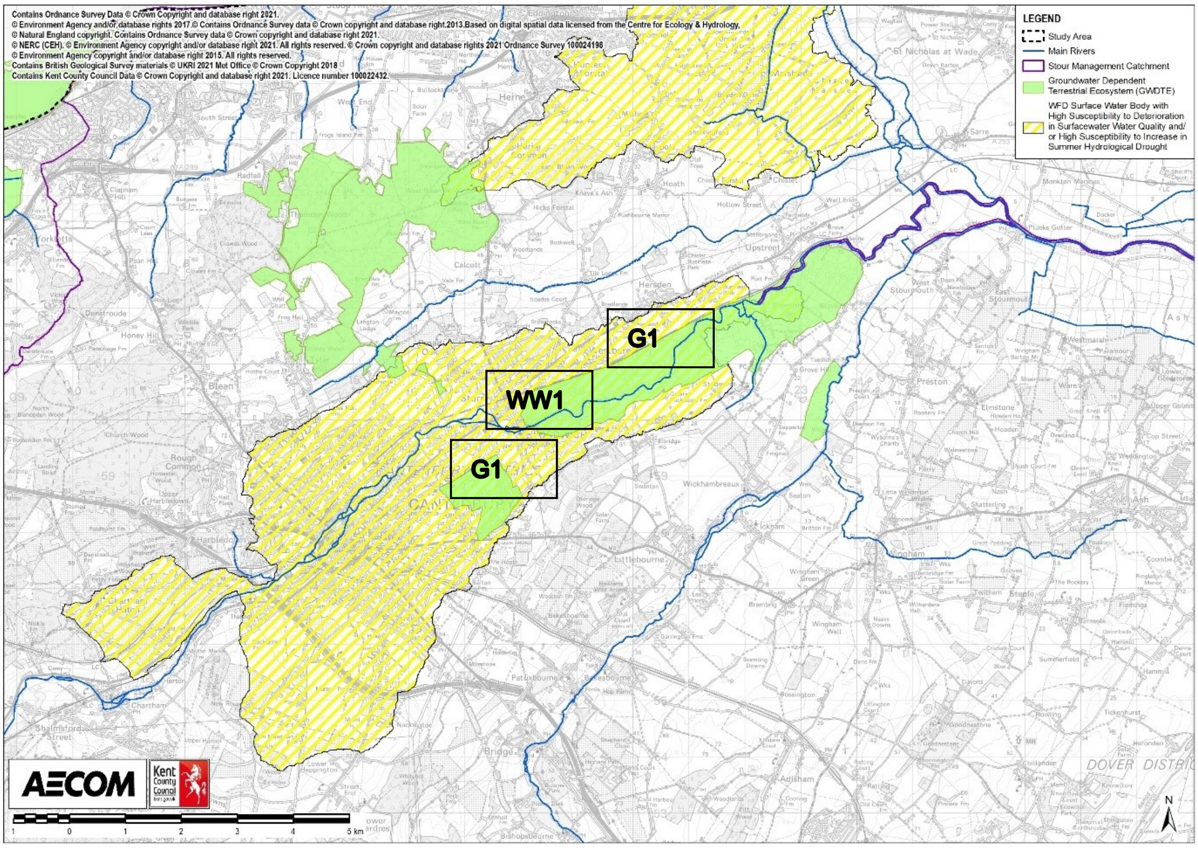



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**Figure 6-10: Great Stour WFD Surface Waterbody with High Susceptibility to Deterioration in Surface Water Quality and/or High Susceptibility to Increase in Summer Hydrological Drought**

### 6.7.4 Key Risks and Recommended NbS

Whilst there are a number of opportunity areas to apply NbS in the Stour catchment, the selected areas below (as shown in Figure 6-11) have been identified:

1. **WW1, A1, G2**: This area around Conningbrook Manor up the Great Stour to Wye has a high risk of flood, drought, poor water quality and availability. As such. a combination of **wetland creation and restoration, and grassland creation and conversion from arable land**, could be impactful to the vulnerable habitats here, but also to flood risk further downstream. Being near Ashford there are other opportunities for health and wellbeing benefits to the wider population. These measures could be supported, with chalk **grassland restoration and creation (G2)** just north in Wye & Crundale Downs SSSI and surrounding areas which could improve biodiversity and support key indicator and priority species such as the nightingale and common blue butterfly.

2. **WW1, W2:** The area around Stodmarsh has high flood and water availability risk, and high surface water quality risk. **Wetland restoration** north of Stodmarsh National Nature Reserve by the Great Stour would reduce these risks. There are also several sections of the Little Stour which could benefit from wetland creation and other natural techniques to improve attenuation. The combination of wetland creation across these two sites would benefit areas of high flood risk where these two rivers converge, around Minister and further west. Here the area has high opportunity (KLIS mapping) to convert **arable to woodland**, especially in riparian zones, which could reduce flood risk and help improve biodiversity but also act as a carbon sink (carbon regulation). Further woodland NFM measures could be applied in the future which may further reduce flood and drought risk in the area.

3. Water quality modelling of the Stour catchment in relation to increases in wastewater discharges and climate change has been undertaken and identified the Stour between Ashford and downstream of canterbury as being particularly vulnerable. Catchment source of nutrients contribute a significant proportion of current (and future) nutrient loads to the Stour and hence opportunities to consider **chalk grassland creation and conversion from arable land** could be considered in the wider catchment (between areas G2 and WW1 in Figure 6-11). Given the chalk geology of the catchment and the high

percentage of land use for arable farming in this section of the catchment, this presents a significant opportunity to reduce catchment sources of nutrient pollution. Evidence from the Environment Agency's Working With Natural Processes database[38] demonstrates significant opportunity for **floodplain reconnection** in this section of the Stour, which if combined with **restoration of floodplain wetland habitat** can provide significant water quality benefit through attenuation of nutrients within surface and groundwater lateral flow acting as a riparian buffer. Significant opportunity is shown for the Stour and its tributaries:

a. Between Ashford and Wye;

b. Downstream of Godmersham and at Chilham; and,

c. Between Chartham and Canterbury.

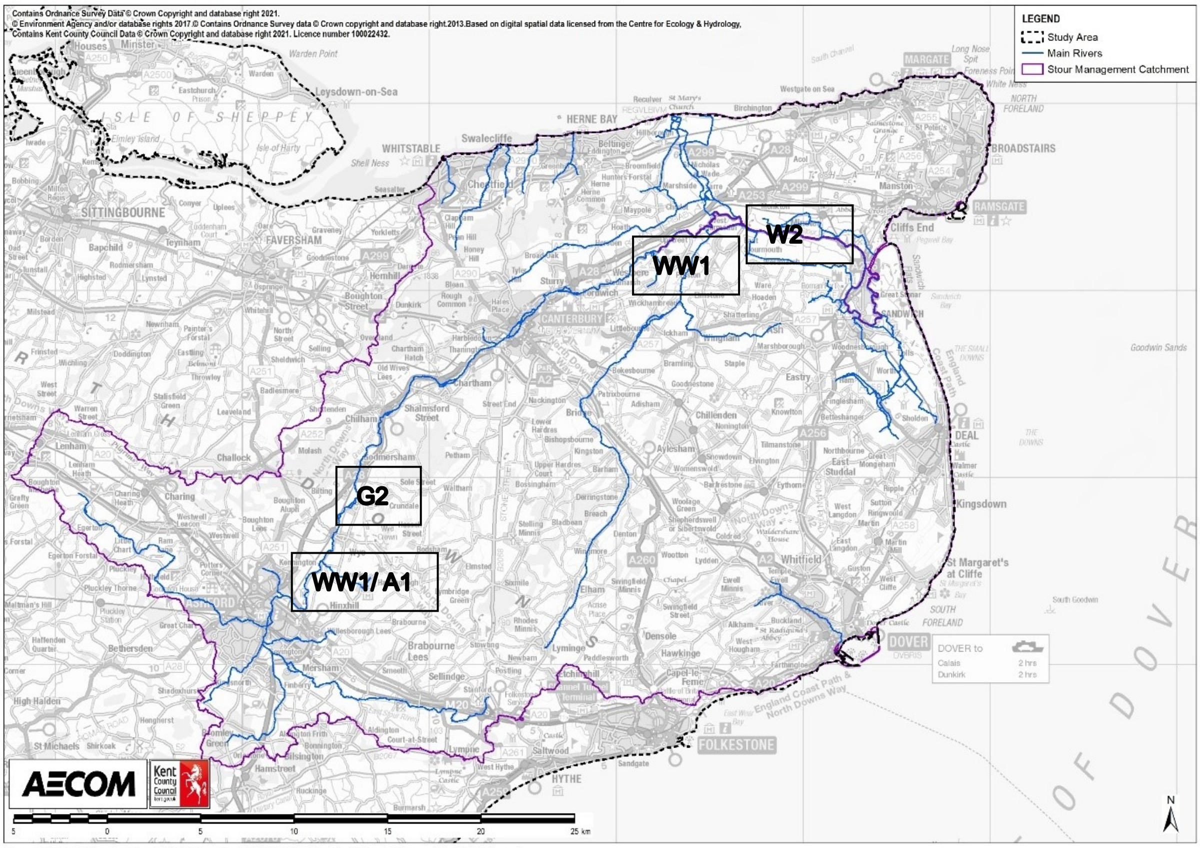


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**Figure 6-11: Key Recommendations for NbS in the Greater Stour Catchment**

# 6.8 Darent Assessment

## 6.8.1 Catchment Landscape Context

The River Darent is a 34km river flowing from the Lower Greensand hills, through the North Downs before joining the River Thames. It is one of two main rivers in the Darent and Cray catchment, supporting unique biodiversity associated with the chalk habitat[39]. The Darent has been subject to numerous adjustments including over-abstraction which has led to recent flow reduction and drought in lower reaches of the river with an impact on fisheries, communities and ecosystems. The river waterbodies of the Darent catchment are all above 'Good' water quality status and have 'High' or 'Good' physico-chemical status.

[38] Environment Agency. 2021. Working with Natural Processes to Reduce Flood Risk. Available:https://www.gov.uk/flood-and-coastal-erosion-risk-management-research-reports/working-with-natural-processes-to-reduce-flood-risk
[39] Environment Agency. 2020. Catchment Data Explorer: Darent – Summary. Available: https://environment.data.gov.uk/catchment-planning/OperationalCatchment/3121/Summary

### 6.8.2 Flood Risk Options

Flood risk is largely isolated in the catchment to the course of the main River Darent channel and in the tidal area north of Dartford. Multiple towns and villages lie in high risk areas including vulnerable communities in Darent and Dartford where flood risk coalesces with the most deprived 30% nationally.

In the upper catchment, there is high risk of flooding at the source of the river, through Westerham, Sundridge, Sevenoaks and Otford.

#### Potential NbS Options

The following NbS (as shown in Figure 6-12) could potentially form part of a solution to managing these risks:

1. **W2**: In line with AECOM's (2021) assessment, the incorporation of **riparian woodland** in the upper catchment could reduce flood risk in the high-risk areas including Sevenoaks, Sundridge and Sevenoaks Gravel Pits SSSI. With the caveat that riparian woodland should only be implemented in suitable areas which will not have a detrimental impact on sites of ancient woodland which are highly sensitive to changes in hydrology and in-keeping with native species and landscape character of the area.
2. **W1 and W3**: Opportunity mapping shows high opportunities for **catchment woodland creation** north of the river, east of the pre-established Westerham Wood through to the north of Sundridge. Combining these catchment woodland areas with woodland NFM could reduce flow and reduce risk of flooding in the ensuing settlements.
3. **RE1/W1**: **Rewilding and species introduction** is recommended in combination with **catchment woodland restoration** north of Sevenoaks. Opportunity mapping shows the area north of Sevenoaks has high potential for catchment woodland, combined with species reintroduction which could reduce flooding and peak flows.

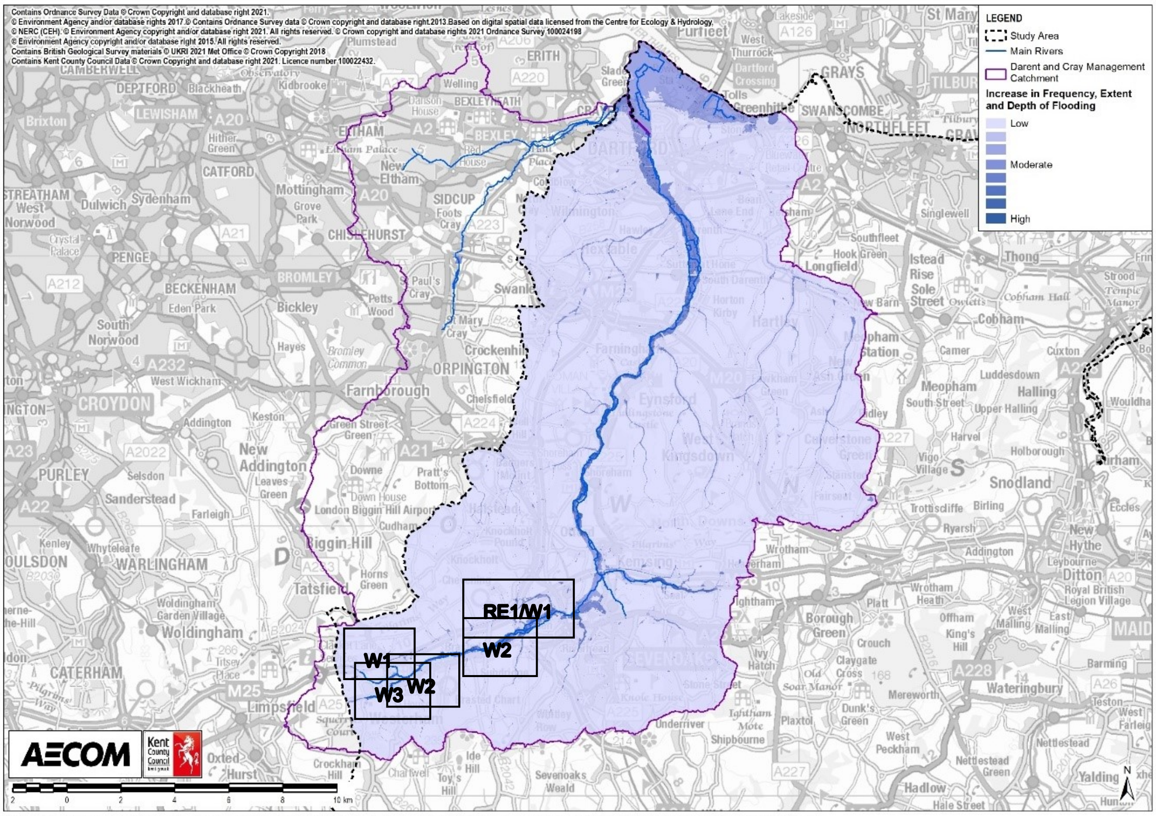


**Figure 6-12: Darent Whole Catchment Flooding - Frequency, Extent and Depth**

### 6.8.3 Water Availability Options

Summer hydrological drought risk is concentrated in the south of the catchment, this mostly affects Sevenoaks including areas of woodland such as Knole Park.

### Potential NbS Options

The following NbS (as shown in Figure 6-13) could potentially form part of a solution to managing these risks:

1. **A1/G2**: **converting arable land to grassland** north of Westerham Wood could improve water availability. Where this is not possible, implementing **regenerative farming** north of Westerham Wood could reduce water stress and risk of drought to water dependent areas.

2. **WW1**: **Wetland creation** in areas from Edenbridge and down the River Eden to Chiddingstone, in addition to north of the Sevenoaks Gravel Pits SSSI.

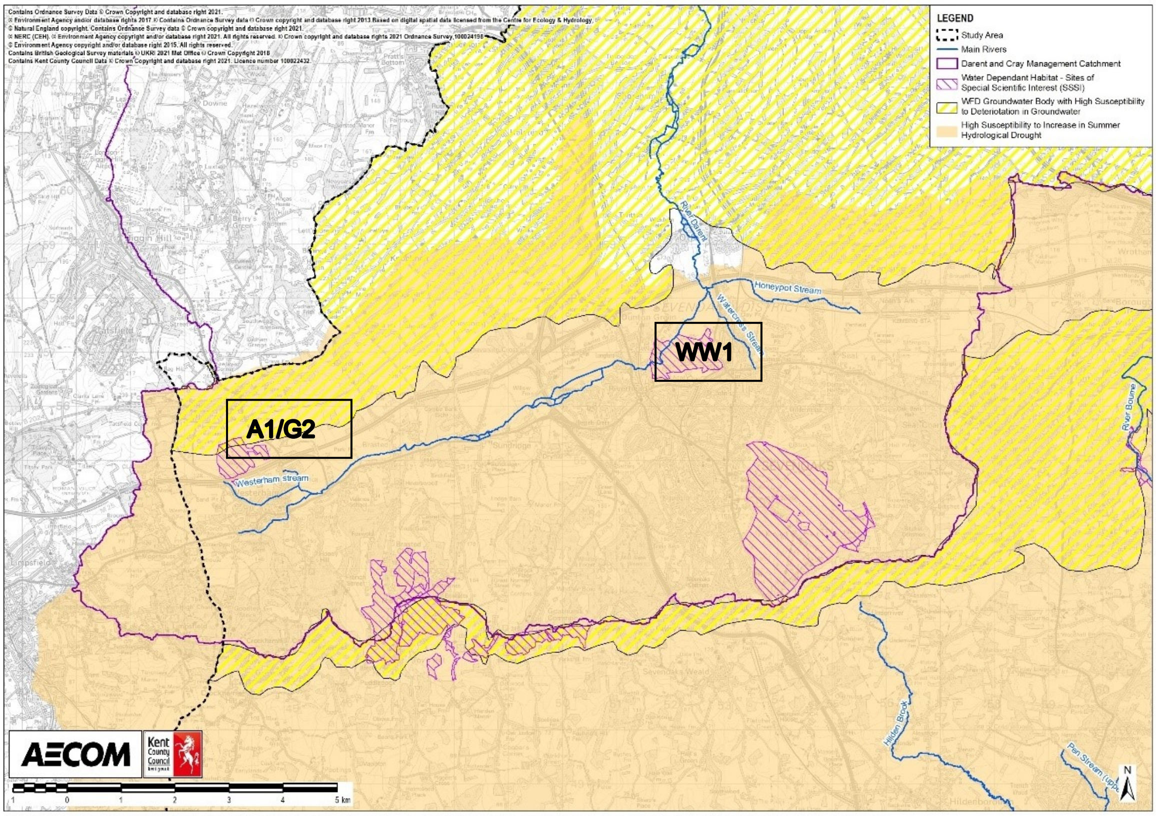


**Figure 6-13: Upper Reaches of the Darent Catchment with High Susceptibility to Increase in Summer Hydrological Drought and Water Dependant Habitats**

## 6.8.4 Water Quality Options

Deterioration in groundwater quality is a risk throughout the north and middle of the catchment largely due to land use change, loss of grasslands and pollution from urban sources. To mitigate these risks it is suggested that, where possible, regenerative agriculture be implemented and arable land converted to grassland. As identified by KLIS, areas with high opportunity for wetland restoration, like Farningham, should seek to restore wetlands to improve water quality while mitigating the risk of drought in the area.

## 6.8.5 Key Risks and Recommended NbS

Whilst there are a number of opportunity areas to apply NbS in the Darent catchment, the selected areas below (as shown in Figure 6-14) have been identified:

1. **RE1/W1**: Whilst further investigation into the specific habitats in the **riparian zones** north of Sevenoaks along the River Darent would need to be conducted, along with an assessment of any detrimental impacts, this area could be a suitable location for the **reintroduction of keystone species**, such as beavers. The benefits of a reintroduction program combined with catchment woodland creation and restoration, could be particularly pronounced in this area. The proximity to Sevenoaks could lead to improved health access, wellbeing and cultural activity, and eco-tourism could feature as a means to improve livelihood opportunities. Water availability risk is not as pronounced in the areas north of Sevenoaks as it is further south, which supports the case for woodland creation. In addition, surface water and groundwater quality

is a risk that faces these areas and those further downstream. As such, these NbS measures could help mitigate these risks. In addition, both measures may also help reduce downstream flood risk.

2. **W2/W3**: Extending **riparian woodland** in the upper catchment in the areas detailed, but especially in areas adjacent to the Westerham Wood SSSI, is likely to help mitigate flood risk both here and downstream where the risk is considerable. It could also have biodiversity and habitat benefits and build the resilience of the SSSI if implemented effectively and in-keeping with the ancient woodland. **Woodland NFM** such as leaky dams, and other woodland NFM measures could further reduce flood risk and are likely to increase river habitat and flow variability which will be particularly beneficial to fish species such as the Trout and Bullhead. Riparian woodland and woodland NFM could also help support the storage and attenuation of water to mitigate water availability risk, whilst also improving climate regulation, air quality and health access and wellbeing. However, there are concerns about over-abstraction of the Darent and it should be noted that the benefits and costs of woodland creation should be assessed based on water availability risks, as woodland creation may compound that risk.

3. **WW1**: There are several areas in the catchment that have been identified as suitable for **wetland creation**, such as areas around Edenbridge and down the River Eden to Chiddingstone. One key area that has been identified is from the Sevenoaks Gravel Pits SSSI up the river to Otford, which may help improve water availability to this water dependent habitat, with benefits of biodiversity gains and climate regulation. Health access and wellbeing could also be added benefits considering the areas close proximity to Sevenoaks and Otford.

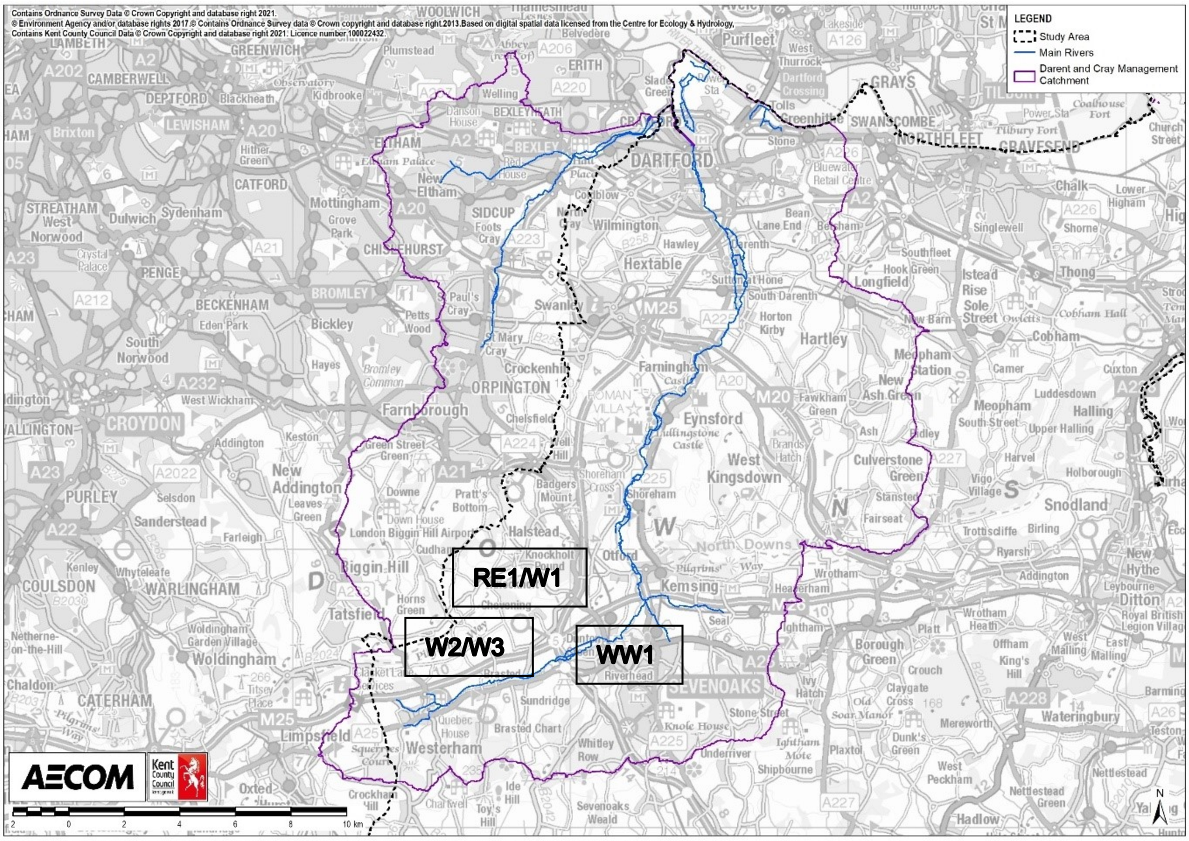


Figure 6-14: Key Recommendations for NbS in the Darent Catchment

## 6.9 North Kent Assessment

### 6.9.1 Catchment Landscape Context

The Swale is a dynamic estuarine environment, distinguished by the tidal mixing of salt and freshwater. Currents deliver nutrients to support a diverse and rich marine and intertidal habitat, supporting large populations. The landcover is defined by grazing marshes, with standing open water areas and ditches, mudflats, salt marshes and reedbeds[40]. These areas provide the habitat for an abundance of flora and fauna including wildfowl and waders, invertebrates, and plants. The coastline also features a sea wall, intended for flood defence, which has established unique habitats of grassland with flora characteristic of saltmarsh[41]. In the North Kent catchment, the river waterbodies are all above 'Good' water quality status. The only river waterbody with available data is White Drain which achieved a 'Moderate' status.

### 6.9.2 Flooding Risk Options

Areas at risk of flooding are largely isolated to the coastal areas of the North Kent catchment, with both tidal and fluvial flooding influencing the risk. The southern coast of the Isle of Sheppey and the north coast of the mainland are the areas most at risk, and concentrated immediately around the smaller watercourses draining to the Swale associated with surface water flood risk around the towns of Sittingbourne and Faversham. **Error! Reference source not found.** shows the link between deprivation and flooding with extensive risk areas for the most deprived 30% nationally located throughout Sittingbourne and rural areas through Conyer to Luddenham. Arable areas interspersed between marshes are also at risk of flooding.

#### Potential NbS Options

The following NbS (as shown in Figure 6-15) could potentially form part of a solution to managing these risks:

1. **C1**: To the north of Sittingbourne, west of the Swale, improved grassland and urban development has replaced natural habitats. Returning these sites to natural intertidal habitats, including **restoring saltmarshes and mudflats,** will likely reduce tidal flood risk to Sittingbourne and the surrounding areas.

2. **C1s**: There is a lack of opportunity mapping for **seagrass restoration** however, Natural England identified five known sites of seagrass in the Swale, with four located along the coast of the Isle of Sheppey. Therefore, with the appropriate marine conditions, seagrass could be restored north of Sittingbourne to reduce tidal flood risk.

3. **C1/WW1**: A combination of **coastal restoration and wetland creation** to the north of Faversham, with saltmarsh and mudflat restoration and protection at Nagden marshes is recommended to reduce the risk of flooding to Faversham and sensitive areas. KLIS depicts this area as high opportunity for wetland creation.

[40] Medway Swale Estuary Partnership. 2021. Estuary Habitats. Available: https://msep.org.uk/the-estuary/natural-environment/
[41] Medway Swale Estuary Partnership. 2021. Estuary Habitats. Available: https://msep.org.uk/the-estuary/natural-environment/

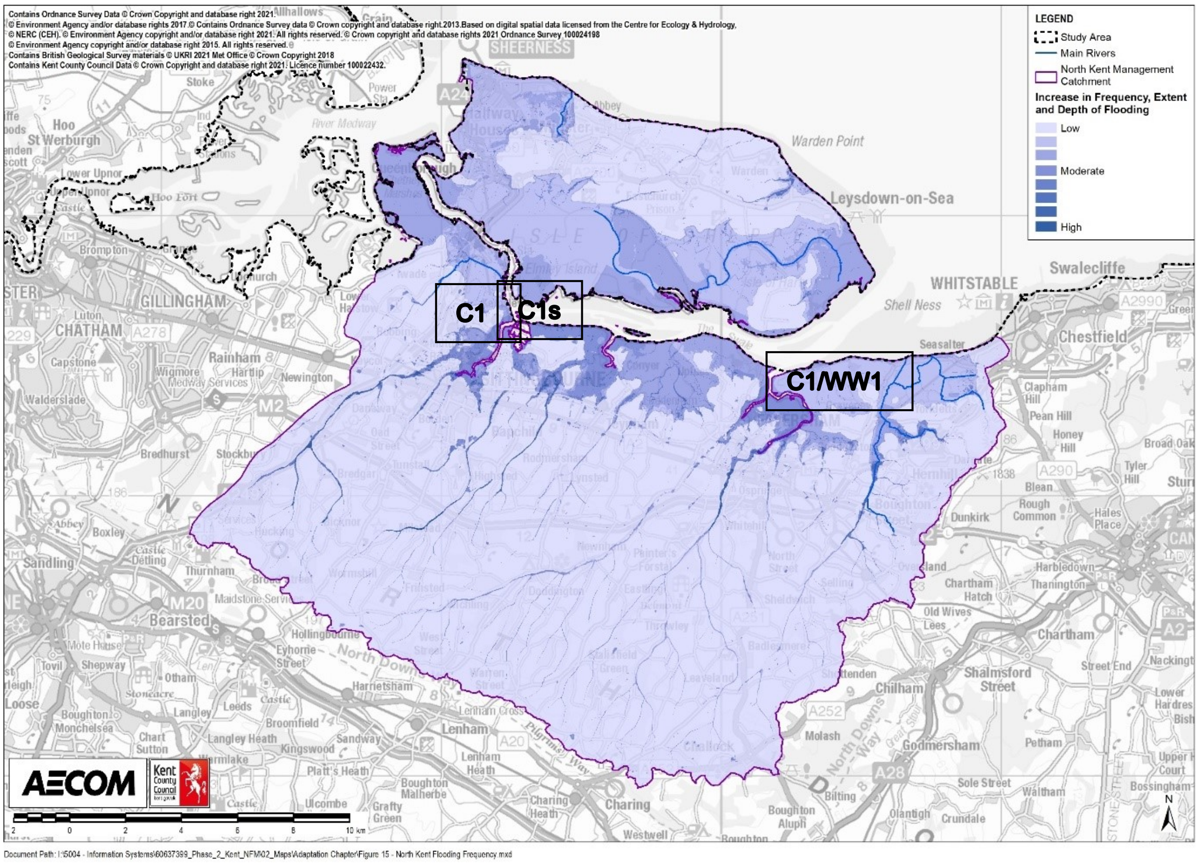


Figure 6-15: North Kent Whole Catchment Flooding - Frequency, Extent and Depth

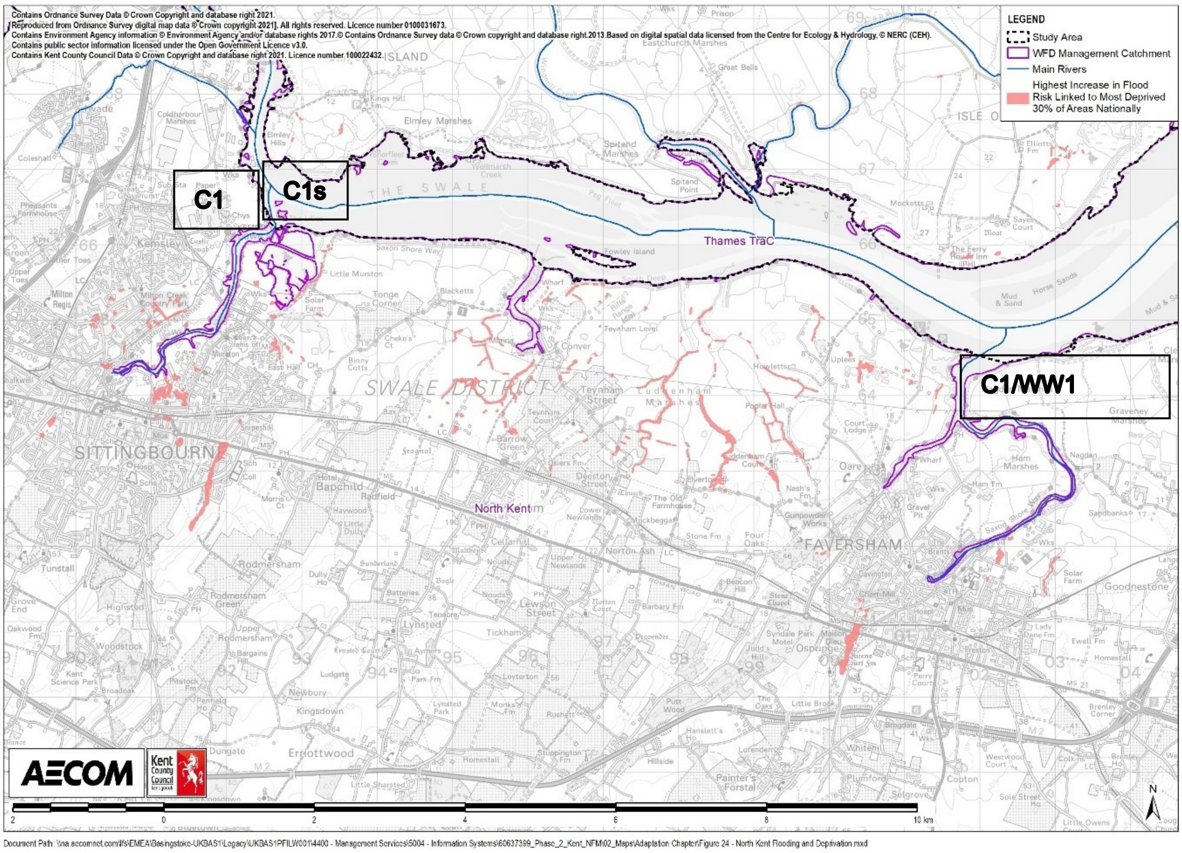


Figure 6-16: North Kent Flooding and Deprivation in Sittingbourne

### 6.9.3 Water Quality Options

The North Kent catchment hosts extensive SSSIs including the Swale which is highly sensitive to water availability and quality. Along the coastline this SSSI is at risk of both deteriorating groundwater quality and deteriorating groundwater levels which would likely impact this sensitive habitat (

Figure 6-17). NbS could supplement interventions to reduce pollution and effluents from urban areas.

**Potential NbS Options**

The following NbS (as shown in Figure 6-18) could potentially form part of a solution to managing these risks:

1. **G2**: There are significant areas of arable land surrounding Faversham, and areas identified as G2 have been recommended for **arable to grassland conversion**, especially areas north of Oare and immediately east of Faversham. In KLIS opportunity mapping these areas are identified as high habitat opportunity for neutral and acid grassland.
2. **G1**: These are areas of grassland, and it is suggested that these are **protected** and if depleted are restored, due to the benefits of grassland to water quality.
3. **A1**: **Regenerative farming practices** could be promoted for arable land around Faversham, especially upstream to the south of Faversham, which could have a big impact on water quality and water availability in these areas which are sensitive to poor water availability and quality.

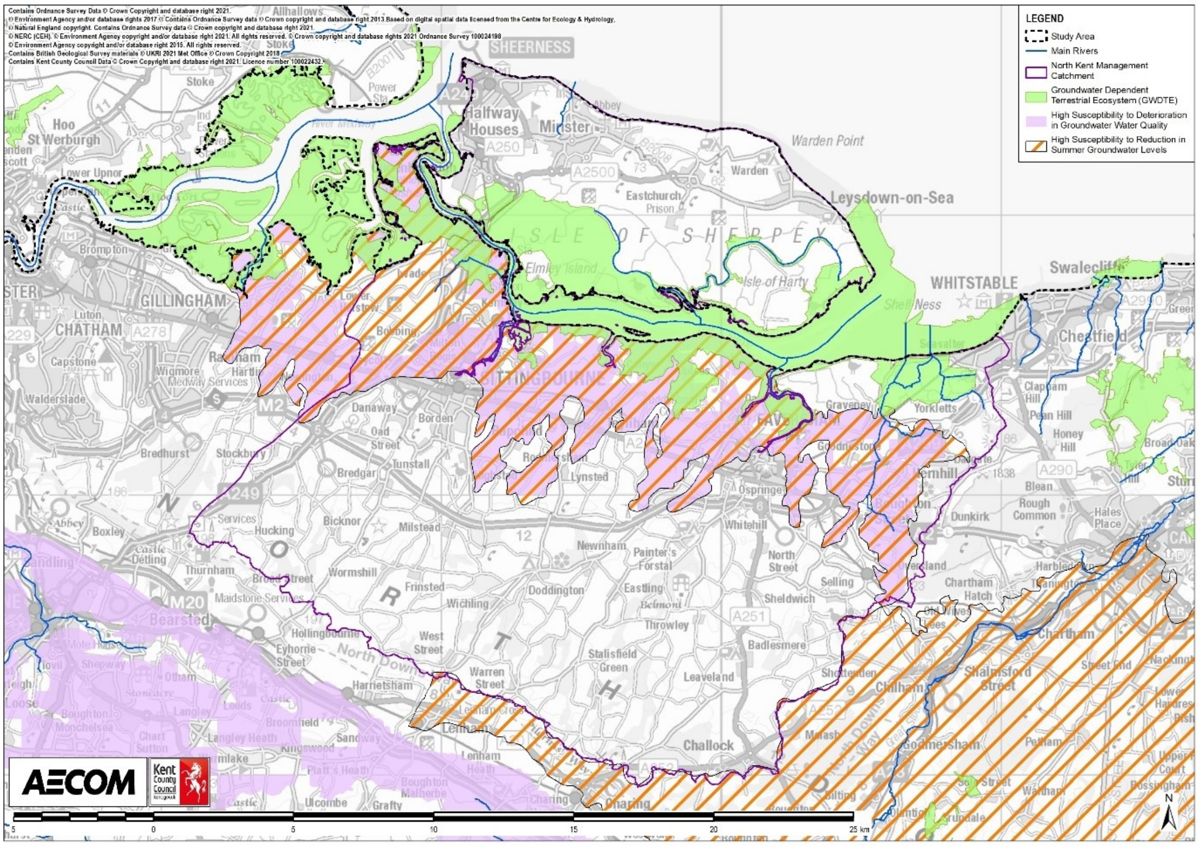


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**Figure 6-17: North Kent Whole Catchment High Risk of Deterioration in Groundwater Water Quality and/or Reduction in Summer Groundwater Levels**

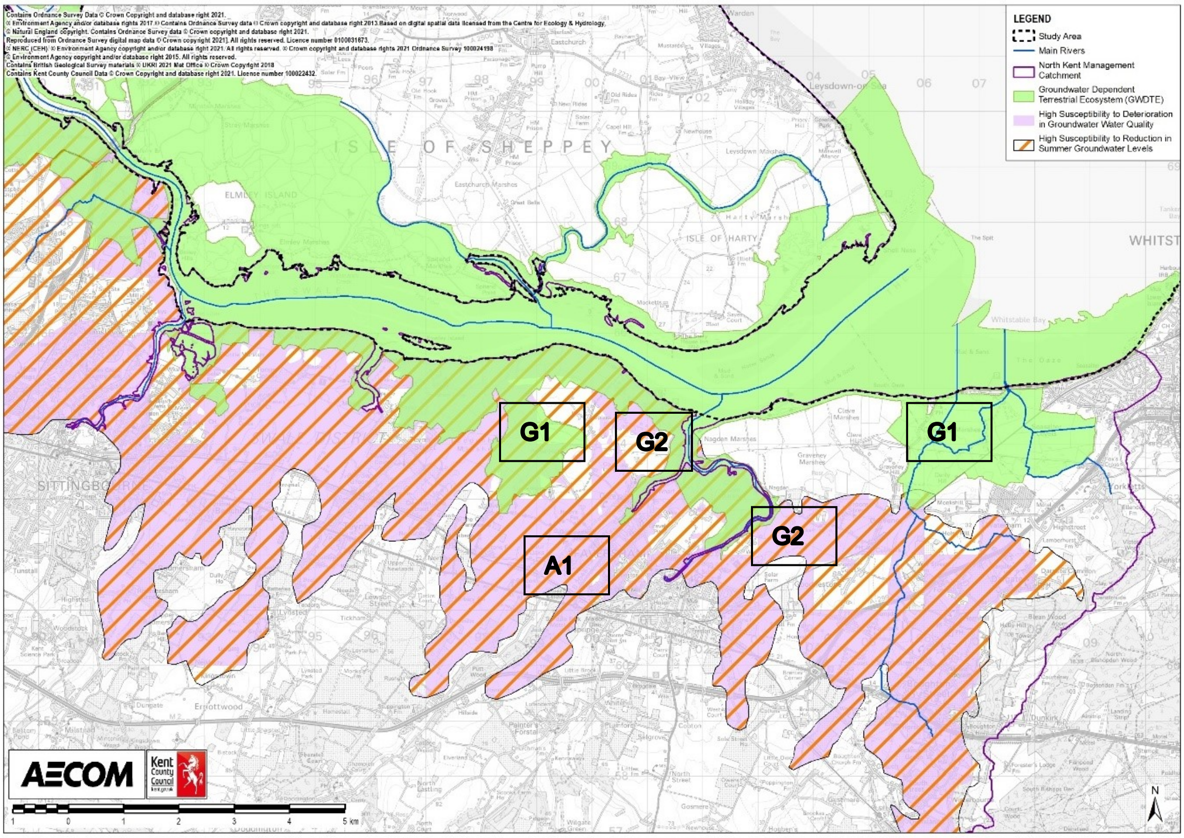



Figure 6-18: North Kent Catchment. Swale SSSI High Risk of Deterioration in Groundwater Quality

## 6.9.4 Key Risks and Recommended NbS

Whilst there are a number of opportunity areas to apply NbS in the North Kent catchment, the selected areas below (as shown in Figure 6-19) have been identified:

1. **C1/C1s:** This area around Sittingbourne is a prime location to implement marine and coastal NbS. It is an area of significant coastal flood risk, which has been compounded by urban sprawl. Where possible, **converting arable land to mudflats and saltmarsh** could mitigate some of the coastal flood risk. This is particularly pertinent in areas where flood risk and deprivation intersect, as these areas are more vulnerable to current and future flood risk. However, further study to assess the impact of conversion from arable to coastal habitats needs to be conducted to assess the impact on livelihood opportunities.

   There may also be scope for seagrass and other key marine habitats to be restored and created. The pre-existing sites that have been identified here indicate adequate habitat opportunities for seagrass beds. **Restoration of further seagrass** sites close to areas at high risk from tidal flooding like Sittingbourne could dissipate wave energy and help mitigate the risk. These measures would likely benefit biodiversity, which could be linked to improved livelihoods and improved cultural activity. These marine habitats also sequeste carbon from the atmosphere and therefore have significant climate regulation benefits.

2. **G2: Conversion of land use to neutral and acidic grassland** in this area could improve water quality and availability compared to arable land use, whilst also providing an opportunity to improve biodiversity. Located near Faversham, this could reap health access and wellbeing benefits for the communities in close proximity. Other benefits such as climate regulation and improved air quality also add weight to the case for NbS in this area.

3. **A1**: This area is located upstream of Faversham and is dominated by agricultural land use. It is also in an area at risk of deterioration in groundwater quality. Promotion of **regenerative farming practices**, and where possible rewilding to habitats such as biodiverse grasslands, could be actively encouraged and incentivised. Whilst helping to mitigate the water quality issues, it would also benefit climate regulation and biodiversity.

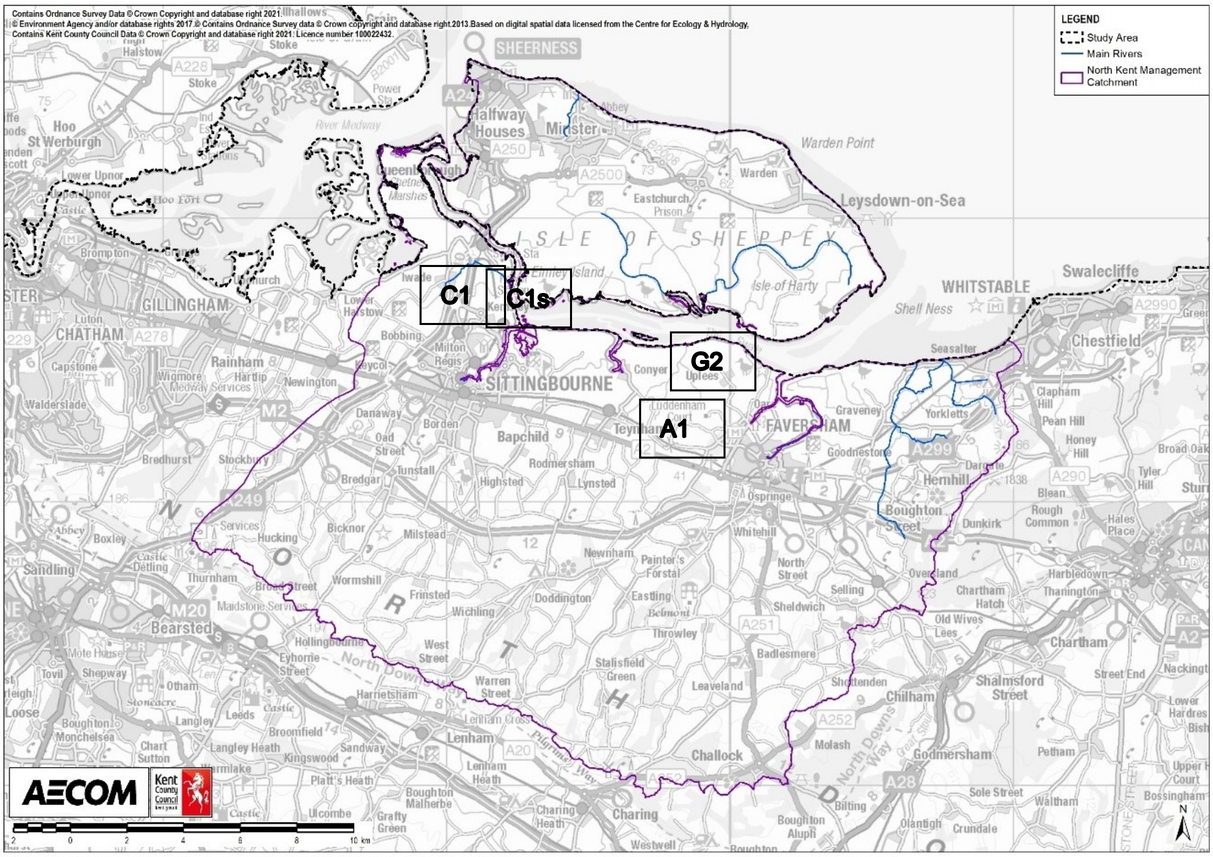



Figure 6-19: Key Recommendations for NbS in the north Kent Catchment

## 6.10 Rother Assessment

### 6.10.1 Catchment Landscape Context

The Rother catchment is comprised of a series of rivers, man-made canals and ditches. The source of the River Rother is found near Mayfield in East Sussex and reaches the sea at Rye Harbour[42]. The landcover at the source is initially characterised by steep river valleys before reaching the marshes at Romney Marsh and finally shingle ridges of Dungeness. Large areas of the catchment are protected as SSSIs or SPAs for biodiversity and landscape provision. In the Rother catchment, the river waterbodies are all above ‘Good’ water quality status. In addition, all WFD river waterbodies have a ‘Moderate’ physico-chemical status with the exceptions of Upper Newmill Channel and Newmill Channel downstream of A28 which achieve ‘Good’ status.

### 6.10.2 Flood Risk Options

While extensive, flooding in the Rother catchment is generally confined to natural habitat areas such as marsh with few settlements and therefore forms part of a natural process of tidal inundation which supports specific ecosystems and species. Other major risk areas can be found around the Royal Military Canal which divides the catchment and in the centre of the catchment where various channels converge such as the Reading Sewer, the Newmill Channel and the main River Rother. Smaller risk areas which directly impact communities are found in the towns of Folkestone and Hythe, where flood risks intersects with areas of deprivation.

**Potential NbS Options**

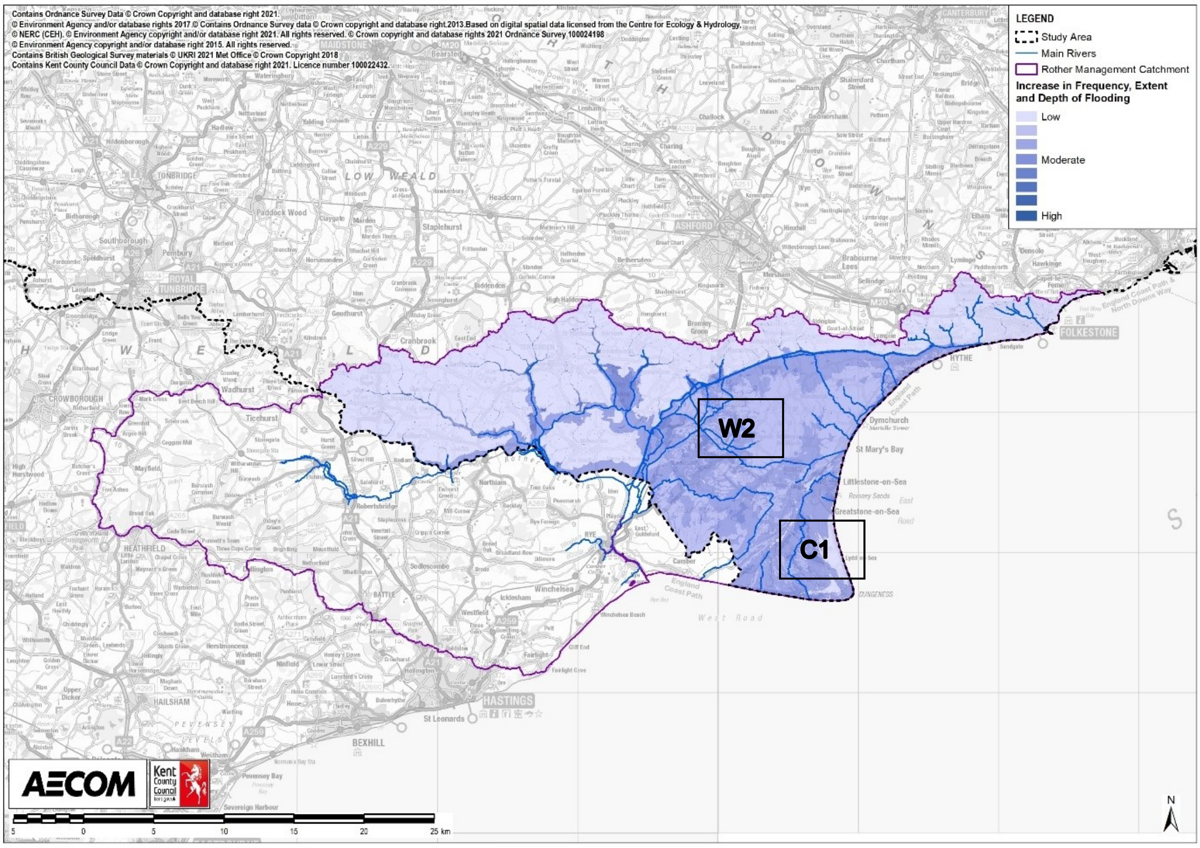
The following NbS (as shown in Figure 6-20) could potentially form part of a solution to managing these risks:

1. **C1**: Whilst KLIS mapping does not identify coastal opportunities, this assessment has identified opportunity here for **coastal habitats to be protected and restored**, including salt marshes, wetlands

[42] Winchester, C. 2015. Rother & Romney Catchment Plan: Research Synthesis. Available: extension://bfdogplmndidlpjfhoijckpakkdjkkil/pdf/viewer.html?file=https%3A%2F%2Fwww.highweald.org%2Fdownloads%2Fpublications%2Fuk-landscape-research-reports%2F1540-rother-romneycatchmentplanresearchsynthesis%2Ffile.html

and mudflats. Offshore, kelp restoration, seagrass restoration or oyster reef restoration can dissipate wave energy to reduce tidal flooding near urban settlements and infrastructure.

2. **W2**: KLIS mapping identifies large swathes of this area as high opportunity for **riparian woodland creation**. The area already has large wetland habitats which should be protected and promoted, alongside the creation of woodland to maximise benefits. It could be beneficial to prioritise woodland creation in areas north and west of Brenzett, to avoid areas of higher drought risk further south.




Document Path: I:\5004 - Information Systems\60637399_Phase_2_Kent_NFM\02_Maps\Adaptation Chapter\Figure 16 - Rother Flooding Frequency.mxd

Figure 6-20: Rother Whole Catchment Flooding Extent, Frequency and Depth

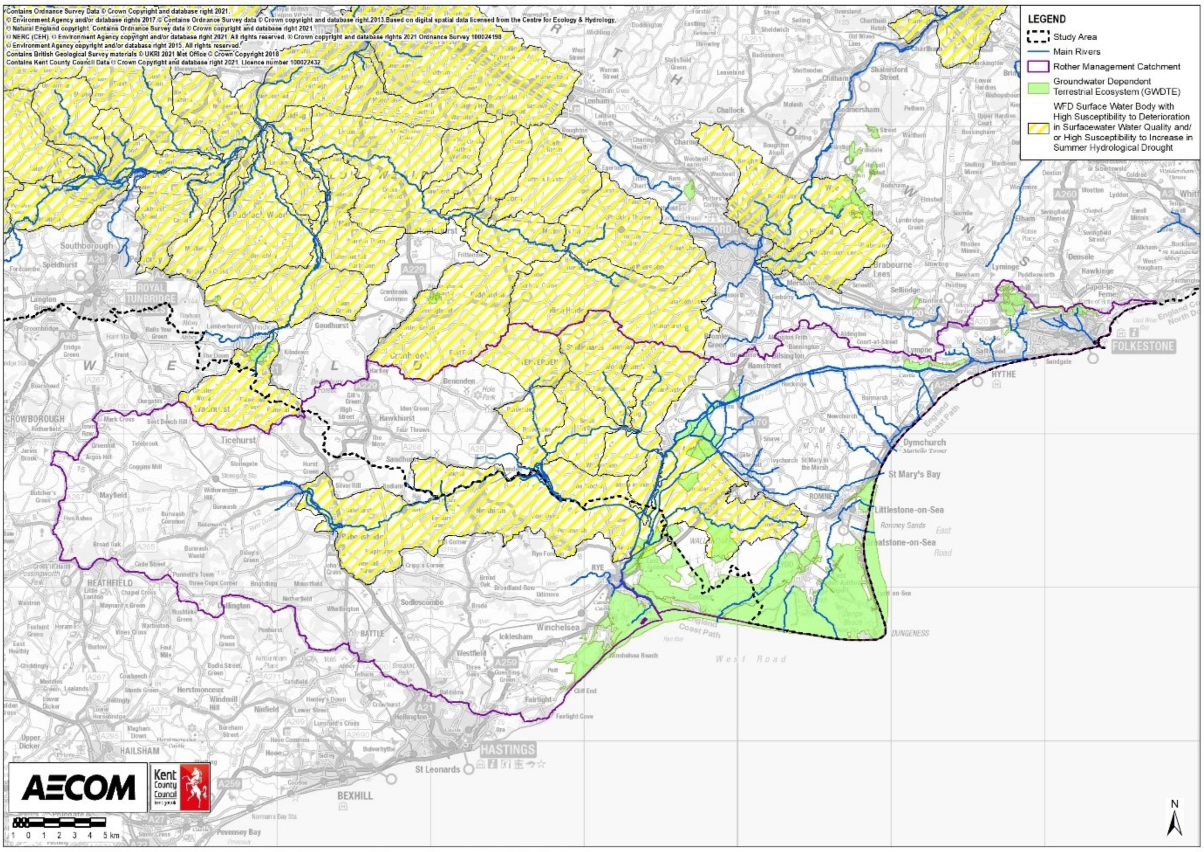
### 6.10.3 Water Availability and Quality Options

In the Rother catchment, deterioration in surface water quality and increase in summer hydrological drought are a challenge across the central catchment (Figure 6-21). As the Rother catchment hosts multiple SSSIs and SPAs this catchment is sensitive to a deterioration in water quality and availability. Therefore, these hazard areas intersect with certain GWDTEs such as Dungeness, Romney Marsh and Rye Bay Ramsar, SPA and SSSI (Figure 6-22), a designated site which stretches from the coast at Dungeness into smaller pockets towards the centre of the catchment.

#### Potential NbS Options

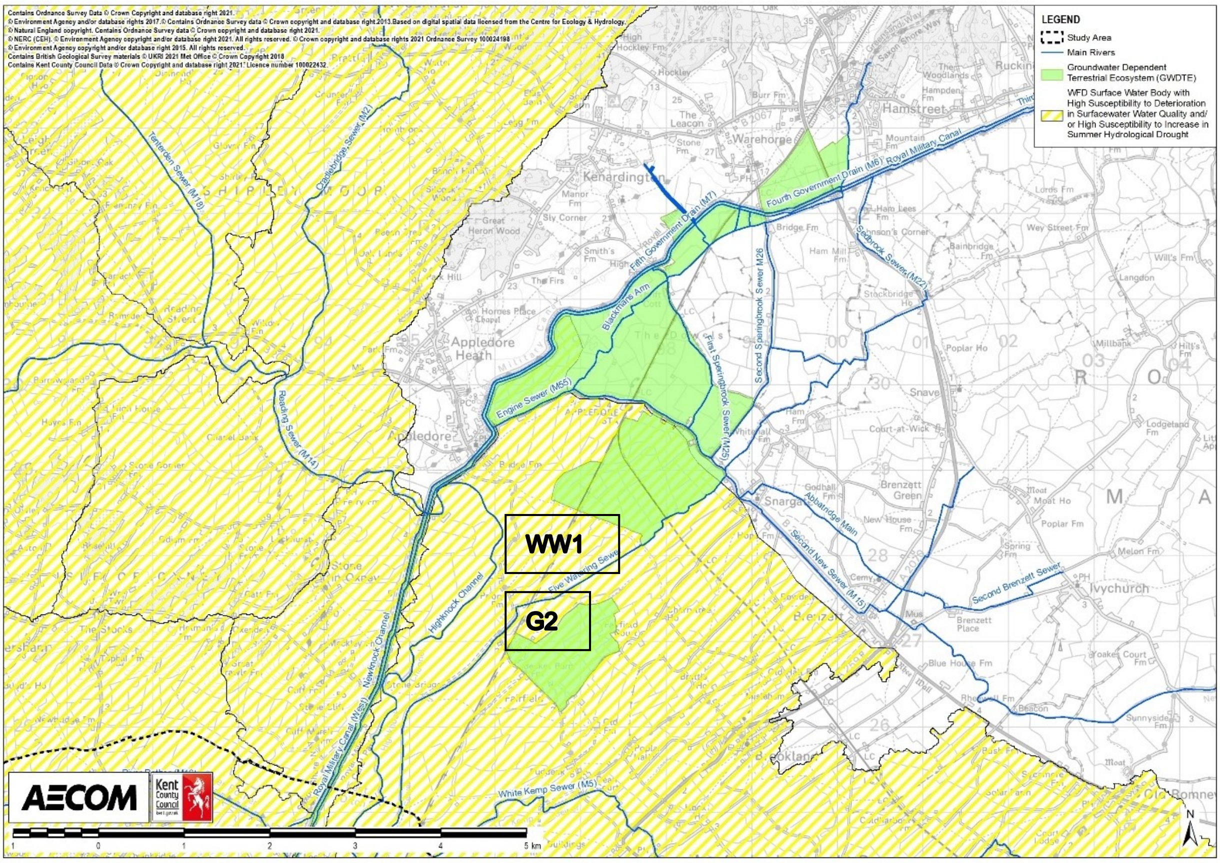
The following NbS (as shown in Figure 6-22) could potentially form part of a solution to managing these risks:

1. **G2 and WW1**: Where possible **arable to grassland conversion** could be considered in this area, which has also been identified in KLIS mapping as high opportunity for wetland creation.




Document Path: I:\5004 - Information Systems\60637399_Phase_2_Kent_NFM\02_Maps\Adaptation Chapter\Figure 17 - Rother Surface Water Quality and Summer Drought.mxd

**Figure 6-21: Rother WFD Surface Waterbody with High Susceptibility to Deterioration in Surface Water Quality and/or High Susceptibility to Increase in Summer Hydrological Drought**




Document Path: I:\5004 - Information Systems\60637399_Phase_2_Kent_NFM\02_Maps\Adaptation Chapter\Figure 18 - Rother Sites Surface Water Quality and Summer Drought.mxd

**Figure 6-22: Rother GWDTE Dungeness, Romney Marsh and Rye Bay (SSSI) Susceptibility to Deterioration in Surface Water Quality and/or High Susceptibility to Increase in Summer Hydrological Drought**

### 6.10.4 Key Risks and Recommended NbS

Whilst there are a number of opportunity areas to apply NbS in the Rother catchment, the selected areas below (as shown in Figure 6-23) have been identified:

1. **WW1, G2**: There are a range of water quality, availability and flood risks in this catchment, therefore a mixture of wetland creation and **arable conversion to biodiverse grasslands**, could help mitigate some of those risks. The area has a high number of convening canals and man-made waterways, so the creation of wetlands has been identified as high opportunity. An assessment on the benefits of these waterways, compared to the benefits of wetland restoration and allowing natural processes to be promoted, or ways in which they could be integrated, should be considered.

2. **C1**: This south east area of the catchment has high rates of coastal erosion, as such there could be opportunity for **restoration and creation for coastal habitats** such as salt marshes, wetlands and mudflats. In addition, certain measures which dissipate wave energy such as kelp restoration, seagrass restoration or oyster reef restoration could be considered if the habitats are suitable. There is no KLIS mapping of coastal opportunities, so further study would be required. Enhancing these habitats could lead to a range of benefits from increased biodiversity, improved health access and wellbeing, and it could lead to a reduction in coastal flood risk to urban settlements.

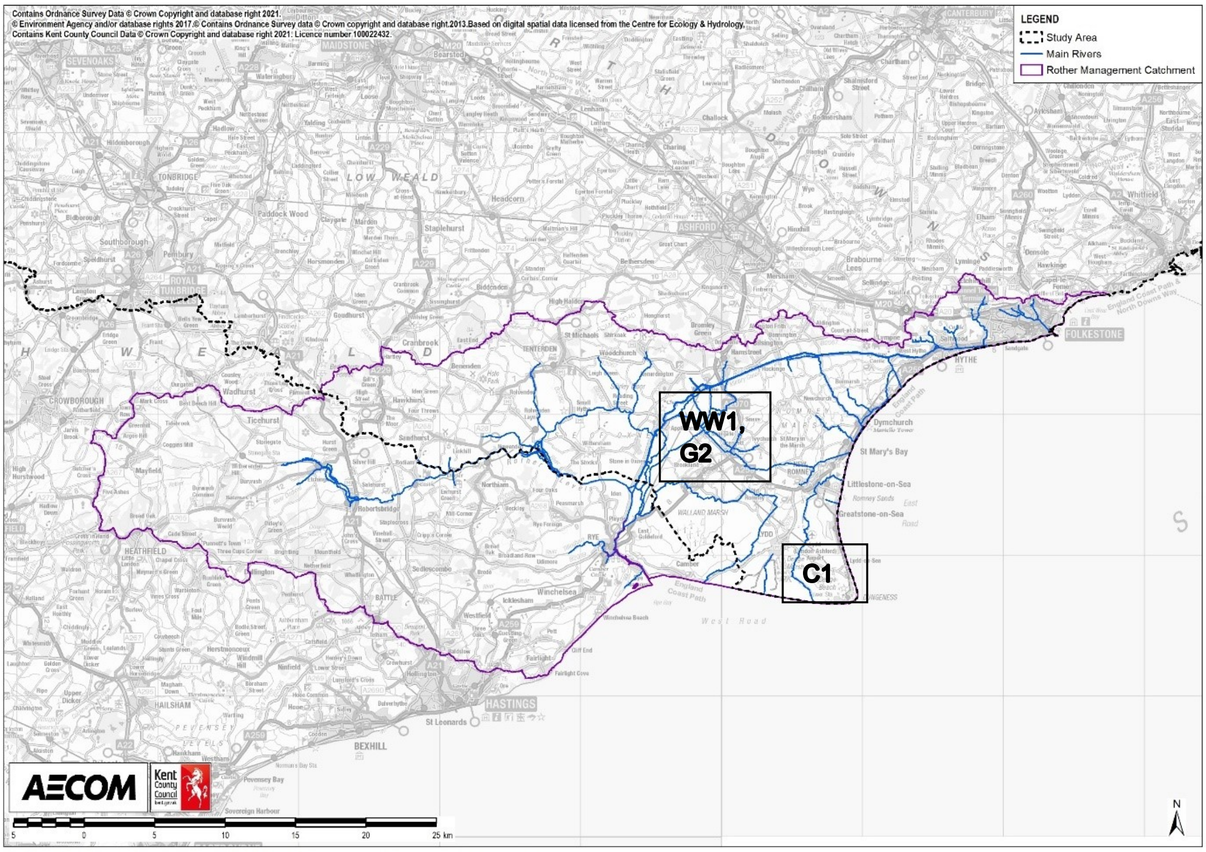


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**Figure 6-23: Key Recommendations for NbS in the Rother Catchment**

## 6.11 Key Considerations

Whilst this assessment seeks to apply a spatial lens to where NbS can be best applied to achieve maximum benefits both to the habitats and assets, there are several caveats which should be considered to ensure the suitability and effectiveness of these solutions, and where they can best be applied:

- The recommended NbS provided per catchment in this assessment are a summary of some of the solutions that could be investigated further to address key risks in the catchment. The solutions are not exhaustive, and a more granular catchment level assessment should be conducted which would detail some of the nuances specific to each given catchment. This assessment should be used to stimulate further enquiry into how and where NbS can be applied.
- Stakeholder engagement will need to be undertaken to ensure the inclusion of local views and knowledge is encapsulated in assessing the suitability of NbS. This engagement will help ensure that any adverse impacts of these solutions are considered and mitigated, and that opportunities to strengthen the solutions are encompassed in the design and development. The recommendations from this desk-based study will need to be verified, and the spatial mapping will need to be refined to account for local nuances.
- Additional feasibility studies will need to be undertaken, such as the 'Natural Flood Management opportunities in the Upper Darent Catchment' study[43], to ensure that environmental variables such as soil quality, topography and hydromorphology are accurately evaluated to assess the effectiveness of a particular solution. In addition, local factors, such as land ownership, have not been considered in this assessment due to various constraints, and this will be one of the determining factors for a given solution. These studies will help provide a cost-benefit analysis, which will identify likely build and maintenance costs, detail on legislative requirements and further investigative work that is required.
- This assessment has spatially mapped NbS opportunities, however it has not looked at the timescale of the benefits of NbS. Stakeholder engagement and further study will be required to map out the immediate and long-term NbS opportunities within each catchment to ensure they adequately address immediate and long term risks.
- Where land-use changes are suggested, additional assessment needs to be undertaken to consider wider impacts e.g. woodland creation on agricultural land may be suitable for low-grade agricultural land but may not be suitable for high-grade agricultural land. Equally grasslands may be more suitable than woodland in some cases. Landowners and farmers should be engaged to identify agricultural land that has depleted or is unproductive to strengthen the case for NbS and to maximise benefits.
- For the opportunity mapping, key resources such as the KLIS mapping tool, and other datasets provided by KCC were used to supplement the assessment. This should be verified, and where possible the use of historical land use maps, local knowledge and additional habitat survey data should be applied to assess where habitat creation would best be applied.
- Whilst there will be many benefits to communities detailed in the NbS that have been recommended, the built environment has not been a focus for the interventions, which has been more tailored to vulnerable habitats. In addition, whilst there are many areas of coastal flood risk in several catchments, due to the lack of coastal habitat opportunity data, it was difficult to infer where coastal NbS could best be applied. A separate study should be commissioned to look at where coastal measures such a flood defence realignment and creation/restoration of coastal and marine habitats should best be applied to greatest effect. In addition, lack of opportunity mapping for peat restoration meant that it was not a focus of the assessment, however this measure has multiple benefits such as reduction in flood risk and climate regulation, and should be applied where there is sufficient opportunity.

[43]AECOM. 2021. Natural Flood Management Opportunities in the Upper Darent Catchment

# 7. Recommendations

The updated 2021 Kent SRA for water provides an update to the range and scale of risks initially assessed in the 2014 SRA. In completing this study, several areas for further development have been identified which could be considered for inclusion in future revisions to the SRA. Additionally, data source availability will increase with time and this should also be considered in any future updates.

## 7.1 Data Availability

- Estimates of population increases used in the Kent SRA update were based on data available at a Local Planning Authority scale. Up-to-date ward level population data would ideally be used to inform the risk of population increases on deterioration in water quality as this would allow more location specific impacts on WwTW discharges to be considered. This could be coupled with the release of the first round of finalised DWMP which should identify catchments with greatest risk and pressure and where Southern Water are proposing to invest in the medium to long term.
- Analysis and research by the Environment Agency on the likely effects of UKCP18 rainfall projections on hydrological change (particularly high flows and flood risk) was not available for input to the Kent SRA update. Guidance on how river flows and sea level change may increase with climate change based on UKCP18 outputs were released by the Environment Agency in late July 2021 which will allow modelled future simulations to be undertaken for the impact on fluvial and tidal flood risk.
- UKCP18 impacts on river flows and aquifer levels will be fully accounted for in updates to both water company, and regional water company resilience plans and WRMPs due for publication in 2024. This will allow a more detailed analysis of the potential impact of the most up-to-date climate change projections on lower summer river flows and groundwater levels and should be considered in any future update to the SRA.
- It would be useful to improve NbS opportunity mapping for Kent. Whilst the current KLIS data does provide mapping for habitat opportunities, extending this to other NbS typologies would be valuable. This is particularly pertinent with regards to the coastal NbS opportunity mapping, which was not readily available. Bringing together data from key stakeholders in this area and making that data more accessible would benefit future studies of this nature.

## 7.2 Further Analysis

- The impact of temperature increases with climate change on DO in watercourses could be considered in future updates. Higher summer temperatures leading to warmer average water temperatures in rivers, lakes and estuaries could lower the DO capacity of these systems which could impact on the range of fish species, and other aquatic species which would be able to use the systems as habitats. This should be considered in future updates to the SRA.
- The modelling of water quality impacts focused on the Stour catchment; however, through the Kent SRA update, other catchments (the Medway in particular) have also been shown to be vulnerable to the risk of lower summer river flows and hence a similar catchment modelling exercise as completed for the Stour would be beneficial for these catchments. This would allow a more detailed analysis of where NbS to reduce catchment sources of nutrients could be considered.
- In order to quantify the potential benefits of different NbS principles, the use of SAGIS modelling (over and above the use of SIMCAT) could be considered in future updates. Modelling with SAGIS would allow the disaggregation of sources of phosphate and nitrate into the most vulnerable waterbodies and would allow the assessment of relative impacts of changes to land use which could result from the implementation of NbS.
- Changes in land use were not directly used as a spatial indicator for change sources in either the 2014 SRA or the Kent SRA update. Additional analysis would be required to provide a quantitative and spatial prediction of how land use could change across Kent based on different policy and land management drivers; this analysis could be used to indicate where (and what type of) land use changes are most likely and how they may result from future influence associated with change sources such as catchment and urban diffuse pollution sources, increases in surface water runoff and changes to infiltration to aquifers.
- Since the Kent SRA update commenced, information on the sources of potential NbS interventions has continued to increase in volume as the importance of working with natural processes and a "catchment first" approach is realised with respect to achieving the Government's outcomes in the 25 year Environment Plan and targets for net zero carbon industries (particularly the water industry). Potential for NbS is now considered

across a range of plans and programmes, including emerging regional water resilience plans and DWMPs, updates to WRMPs (to be released in 2024), catchment partnership plans, Flood Management Plans, Local Flood Risk Management Strategies and other initiatives. A comprehensive database of NbS identified through these plans and programmes could be developed in a GIS and combined with updated risk assessments to provide a tool which spatially identifies suitable NbS for different types of risk. This would require a collaboration with a number of key stakeholders.

# Appendix A River Stour Catchment Modelling Summary

Information from the Environment Agency SAGIS (Source Apportionment using GIS) dataset and the SIMCAT (SIMulation of CATchments) catchment water quality model have been combined to provide insight into phosphate and total nitrate sources and potential future trends within the Stour WFD (Water Framework Directive) Management Catchment.

The SIMCAT model uses quantitative information on river flows, effluent flows, effluent quality, and observed water quality monitoring data to simulate the movement of contaminants through a catchment system. SIMCAT can be used to test different future scenarios in terms of impact on water quality, e.g. reductions in river flow due to climate change and changes in effluent flows and loads.

## SIMCAT Modelling – Baseline Situation

The Environment Agency SIMCAT model for the Stour Management Catchment was obtained and updated using up to date river flow data[44] and recent (up to 2019) WwTW effluent flow and quality data[45]. The model was calibrated using observed water quality data from river water sampling (data available up to 2020 for some points). The model has been used to determine a simulated current baseline and then assesses potential future changes to that simulated baseline in both phosphate concentrations and nitrate concentrations as a result of changing pressure sources.

### Phosphate

The model outputs for water quality were used to provide a reach-by-reach check of watercourse status in terms of phosphate (as orthophosphate) concentration compared with WFD status class limits for this nutrient (Figure A1). This shows the current (2019-2020) simulated situation with regards to water quality in the modelled reaches. The model was also used to calculate the relative contribution of catchment sources to overall phosphate loading (Figure A2).

The information on catchment pollution sources provided by SIMCAT is not considered of sufficient resolution to accurately distinguish between the different catchment sources, and therefore these have been grouped for the purposes of this assessment. Future catchment mitigation options would need to be informed by water quality sampling to verify the model results and identify specific pollutant pathways and sources for mitigation.

The simulated baseline situation uses observed data up to 2020. The situation from 2021 is expected to differ slightly compared with the period represented in the observed water quality data because stricter limits for phosphate concentrations on discharges have been (or will be) implemented via revised discharge permits at the following Southern Water WwTW[46]:

- Charing WwTW: permit revised from 1mg/l to 0.5mg/l;
- Herne Bay WwTW: permit revised from 2mg/l to 0.3mg/l;
- Lenham WwTW: permit revised from 1mg/l to 0.5mg/l;
- Newnham Valley: previous permit had no phosphate limit, the new permit contains a limit of 1mg/l;
- Sellindge WwTW: permit revised from 1mg/l to 0.5mg/l; and,
- Wingham (Dambridge) WwTW: permit revised from 2mg/l to 0.25mg/l.

The model has been used to assess the impact of the new permits in terms of WFD phosphate status. This shows that the expected reduction in phosphate discharges from WwTW would only be sufficient to change the status of the modelled reach of the River Wingham upstream of the confluence with the Little Stour (reach 719 in Figure A1). The status of this watercourse is expected to improve from ‘Poor’ to ‘Moderate’ status. The changes in the other WwTW permit are insufficient to improve the status class of other watercourse reaches without additional

[44] Flow percentile data taken from National River Flow Archive (https://nrfa.ceh.ac.uk/data/search)
[45] Water flow data downloaded from https://www.southernwater.co.uk/our-performance/flow-and-spill-reporting, March 2019. Effluent quality data provided by Southern Water
[46] Southern Water CSMG Investigation Scoping Report – Stodmarsh SAC, August 2020. All new permit limits are for Annual Average compliance.

reductions in other sources. The change in status has not been reflected in Figure A1 due to uncertainties of the exact timing of the improvements planned at the WwTW but have been reflected in the modelling of future scenarios to assess the potential impact of future population growth and climate change in addition to the changes already planned at the WwTW.

### Nitrate

The model outputs have been used to show the catchment variation in total nitrate[47] concentrations (Figure A3) and the relative contribution of catchment sources (Figure A4). Nitrate discharges from WwTW could potentially be limited by future improvements in wastewater treatment technology but other catchment sources would require different approaches depending on the specific pollution pathway. The information on catchment pollution sources provided by SIMCAT is not considered of sufficient resolution to accurately distinguish between the different catchment sources and therefore these have been grouped for the purposes of this assessment. Future catchment mitigation options would need to be informed by water quality sampling to verify the model results and identify specific pollutant pathways and sources for mitigation.

## SIMCAT Modelling - Simulated Baseline Analysis

The results in Figure A1 show moderate water quality status for phosphate in the majority of modelled reaches, with ‘Poor’ status in the Great Stour downstream of Canterbury (to West Stourmouth), the River Wingham, two small tributaries and Swalecliffe brook in Whitstable. ‘Good’ status is achieved in the upper reaches of the East Stour and the Little Stour as well as in Whitehall Dyke, Minster and Monkton Marshes, and Chislet North Stream. No modelled reaches achieve ‘High’ status with regards to phosphate concentrations. The majority of the phosphate load in the Stour catchment downstream of Ashford, as well as the River Wingham and the lower Little Stour originates from WwTWs.

The results in Figure A3 show the range of total nitrate concentrations in the modelled watercourses. Concentrations are particularly low in Chislet North Stream and particularly high in the Stour between Ashford and Canterbury and in the Ash Levels and Hogwell Sewer. Figure A4 shows that catchment contributions are the dominant source of total nitrate for most watercourses. However, WwTW are a significant source of nitrate to the Stour, estimated to be contributing 50-60% of nitrate modelled in the Stour at Ashford, 30-40% downstream of Ashford and 40-50% downstream of Canterbury. WwTW also provide a 20-30% of total nitrate in the River Wingham[48].

It should be noted that the model outputs for baseline WFD status are simulations which will (for some waterbodies) differ from the observed WFD status which are determined from targeted monitoring over WFD cycles. A simulated baseline was required to take into account the effect of recent WwTW discharge permit conditions on river quality, and to create a baseline from which to simulate the relative differences that increases in discharge (from population increases) and changes in river flow (from climate change) may have on river quality.

[47] NB, there is no WFD status limit for total nitrate in rivers
[48] It should be noted that this is based on the baseline model as provided by the Environment Agency and may not reflect measured contributions

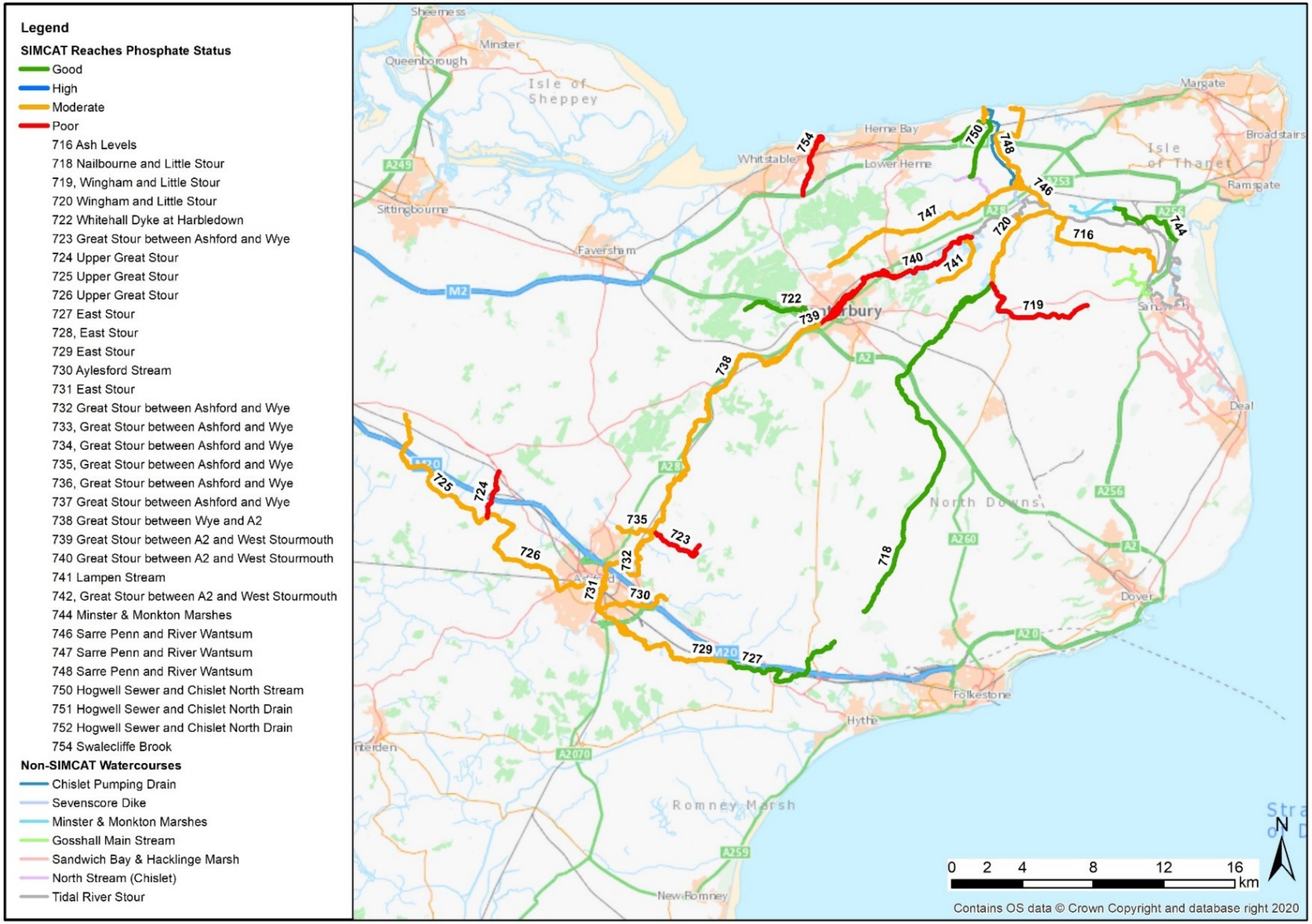


**Figure A1: 2020 Simulated Watercourse Phosphate Status Classification (SIMCAT model results)**

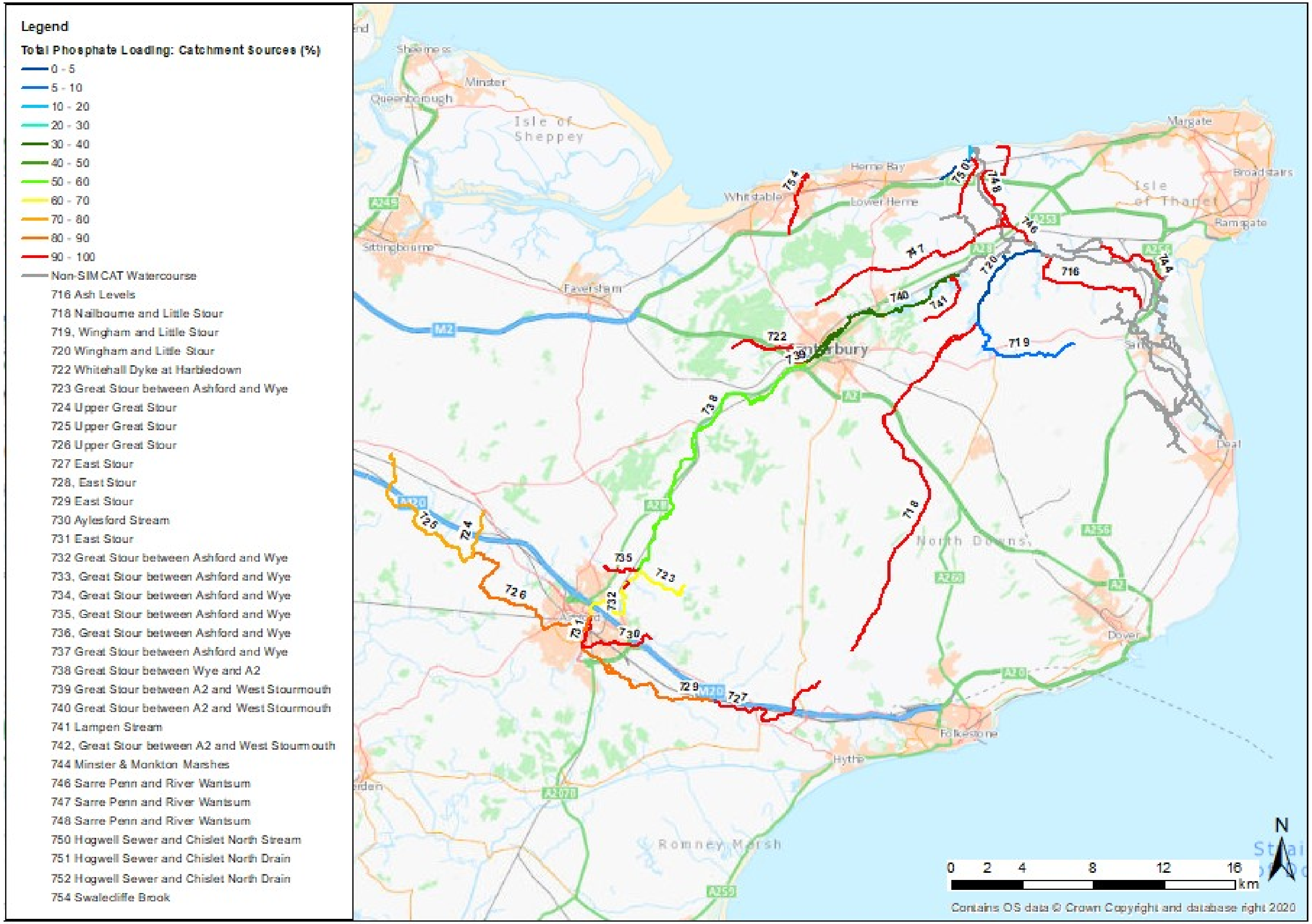


**Figure A2: Proportion of Total Phosphate Contribution to WFD Waterbodies from Catchment Sources (SIMCAT Model Results)**

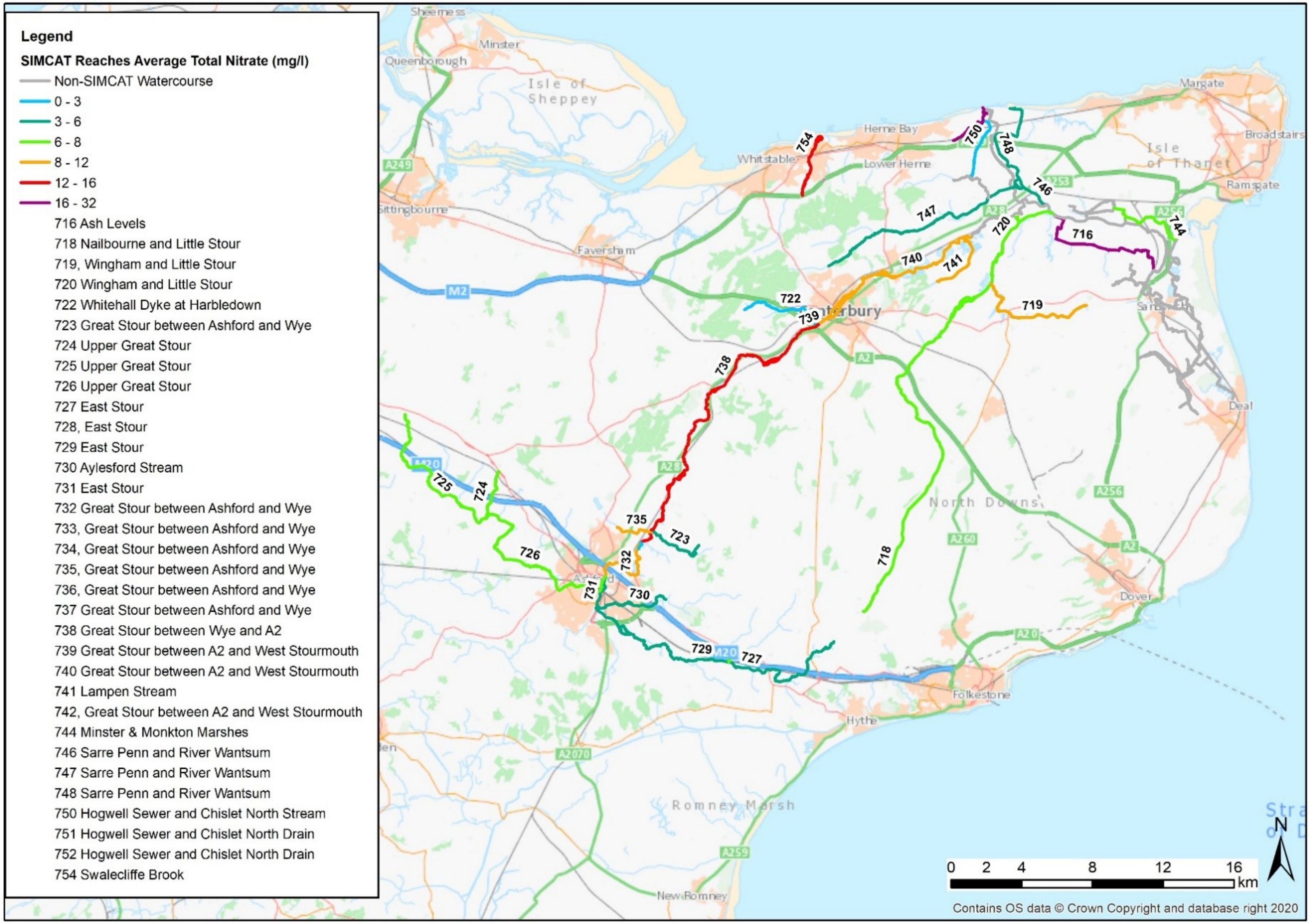


**Figure A3: 2020 Simulated Watercourse Total Nitrate Concentration (mg/l, SIMCAT model results)**

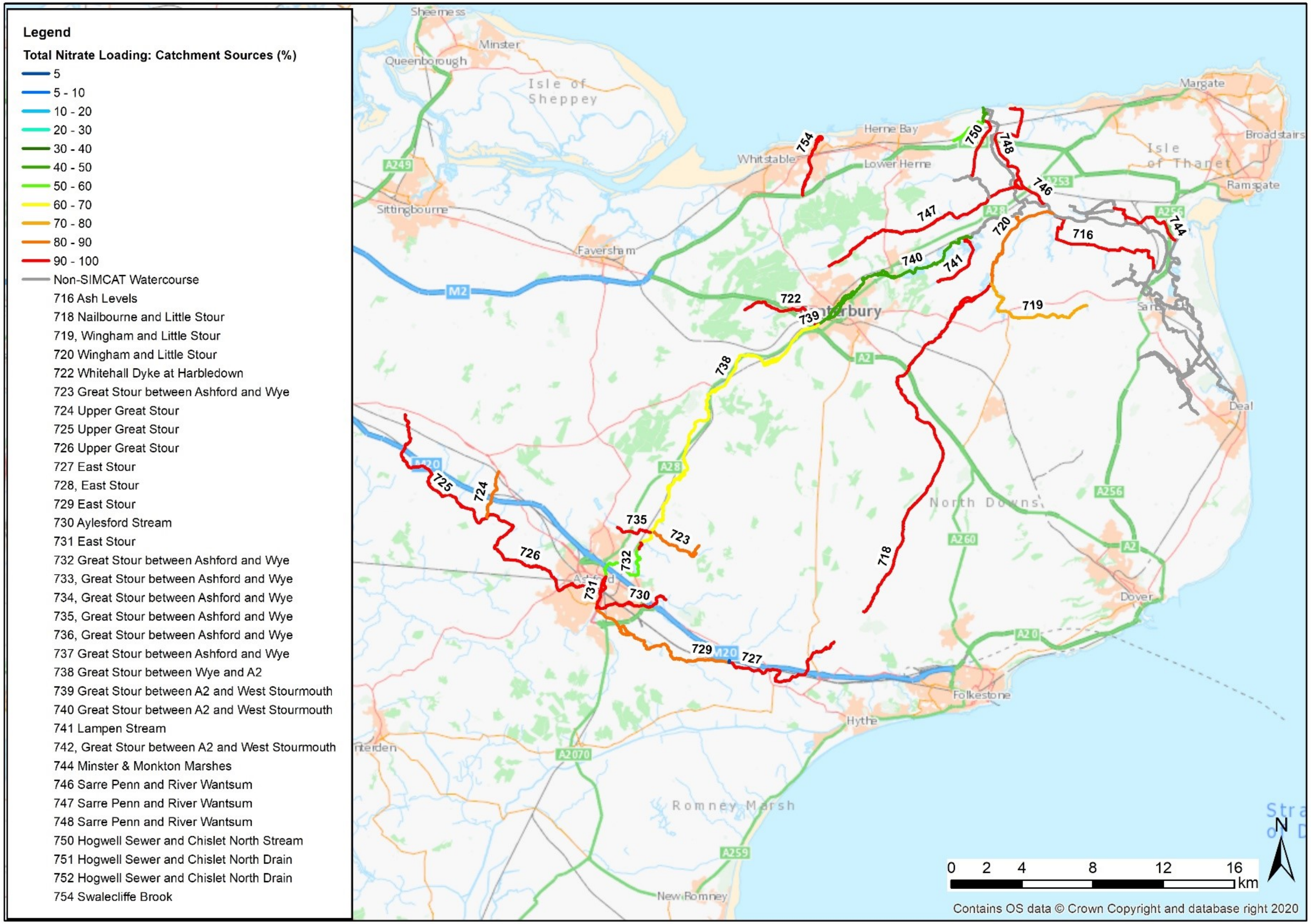


Figure A4: Proportion of Total Nitrate Contribution to WFD Waterbodies from Catchment Sources (SIMCAT Model Results)

## SIMCAT Modelling – Future Scenarios

The SIMCAT model has been adjusted as described below to assess the sensitivity of phosphate and total nitrate concentrations in the modelled watercourses to population growth and climate change.

### Modelling of Population Growth

Population growth has been represented in the model by increasing flows and overall loads from water company owned WwTWs. These WwTWs account for the majority of the treated sewage discharges into the water environment. There are a number of private wastewater treatment plants within the catchment but their effluent flow rate is small by comparison.

The effluent flow rate in the SIMCAT model is represented using the mean and standard deviation flow in the observed data. The current model calculates these parameters using daily flow data from 2015 to 2019 to ensure that a number of years of data are taken into account; relying only on data from 2019 could be misleading if this was not a typical year for any WwTW and data from 2020 was not yet available at the time of this study.

The impact of future growth was assessed using the following assumptions:

- Future flows from some WwTWs are estimated for development periods up to 2045 in a recent (2020) Southern Water Investigation Scoping Report for Stodmarsh SAC. Future populations figures were provided for Ashford, Canterbury, Charing, Chilham, Chartham, Lenham, Nats Lane Brook, Sellinge, Westbere and Wye WwTWs, along with populations figures for 2020. These figures have been used to scale the existing mean and standard deviation flows for the projected increase in population at these WwTWs.
- Future flows were not estimated for Newnham and Herne Bay WwTWs as these WwTWs do not discharge upstream of Stodmarsh SAC[49]. Future flows for these WwTWs have therefore been assessed using the assumption that flows at these WwTWs increase up to the current consented dry weather flow (DWF) limit. This results in an increase in flow of 22% from Herne Bay and 21% for Newnham WwTW, which is within the range of increased flow estimate from the other WwTWs for which future population information is available (8-25%). Further, some previous studies[50] indicate that Newnham WwTW is currently operating above the DWF limit and the limit may be exceeded by future development at Herne Bay, so assuming that the limit is met in future at both sites is not unrealistic.
- Assuming that flows increase up to the consented DWF limit would result in a very large increase in flow at Wingham Dambridge (67%). Future flows for this site are provided in the Dover WCS51 up to 2025 and Kent Water for Sustainable Growth Study up to 2031. These reports do not provide sufficient information to extrapolate growth trends to 2045, so future flows from this WwTW have been increased by the average increase of all other WwTWs (17%). This allows for growth of the same order of magnitude within the Wingham Dambridge WwTW catchment as in the catchment of other WwTWs.

The SIMCAT model was re-run using the higher effluent flows and the percentage change in phosphate and total nitrate concentrations is shown for each reach in Figures A5 and A6.

Figure A5 shows that the most vulnerable watercourse reach to increased phosphate concentrations due to population change is the Great Stour downstream of Canterbury (WFD waterbody Great Stour between A2 and West Stourmouth). Overall, however, the change in phosphate concentrations is fairly small (less than 5% for all but one modelled reach).

Figure A6 shows that watercourse concentration of total nitrate is generally not sensitive to population change, with watercourses showing an increase of 0-5%. This is because catchment sources provide the majority of the total nitrate loading in the Great Stour catchment.

[49] The subject of the Southern Water study from which the data was taken
[50] Kent Water for Sustainable Growth Study, AECOM for Kent County Council, May 2016, report ref 60487848
[51] Dover District Council Water Cycle Study Final Report, ENTEC, January 2009

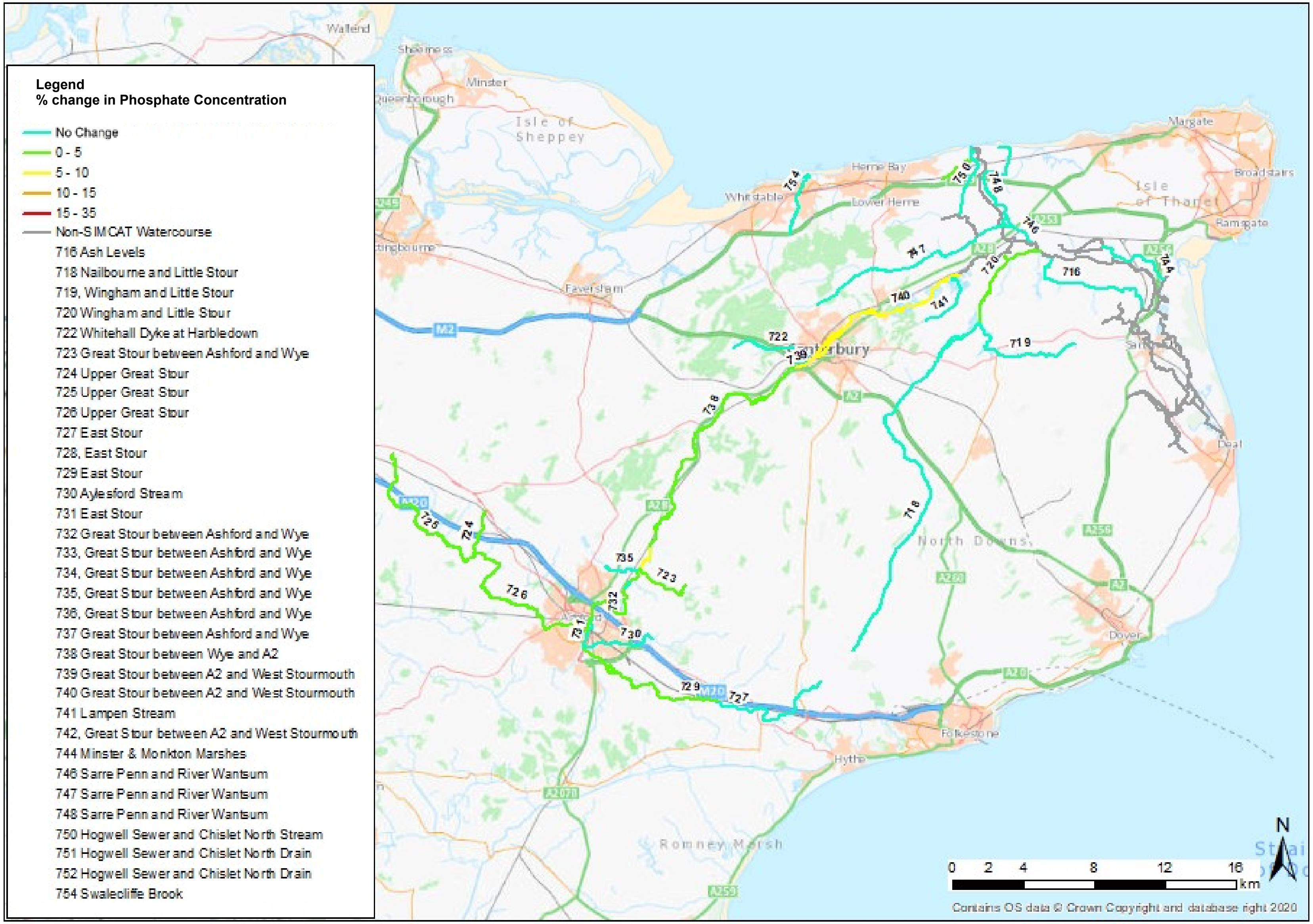


**Figure A5: Future Scenario Modelling: Potential Percentage Change in Phosphate Concentrations Due to Population Increase**

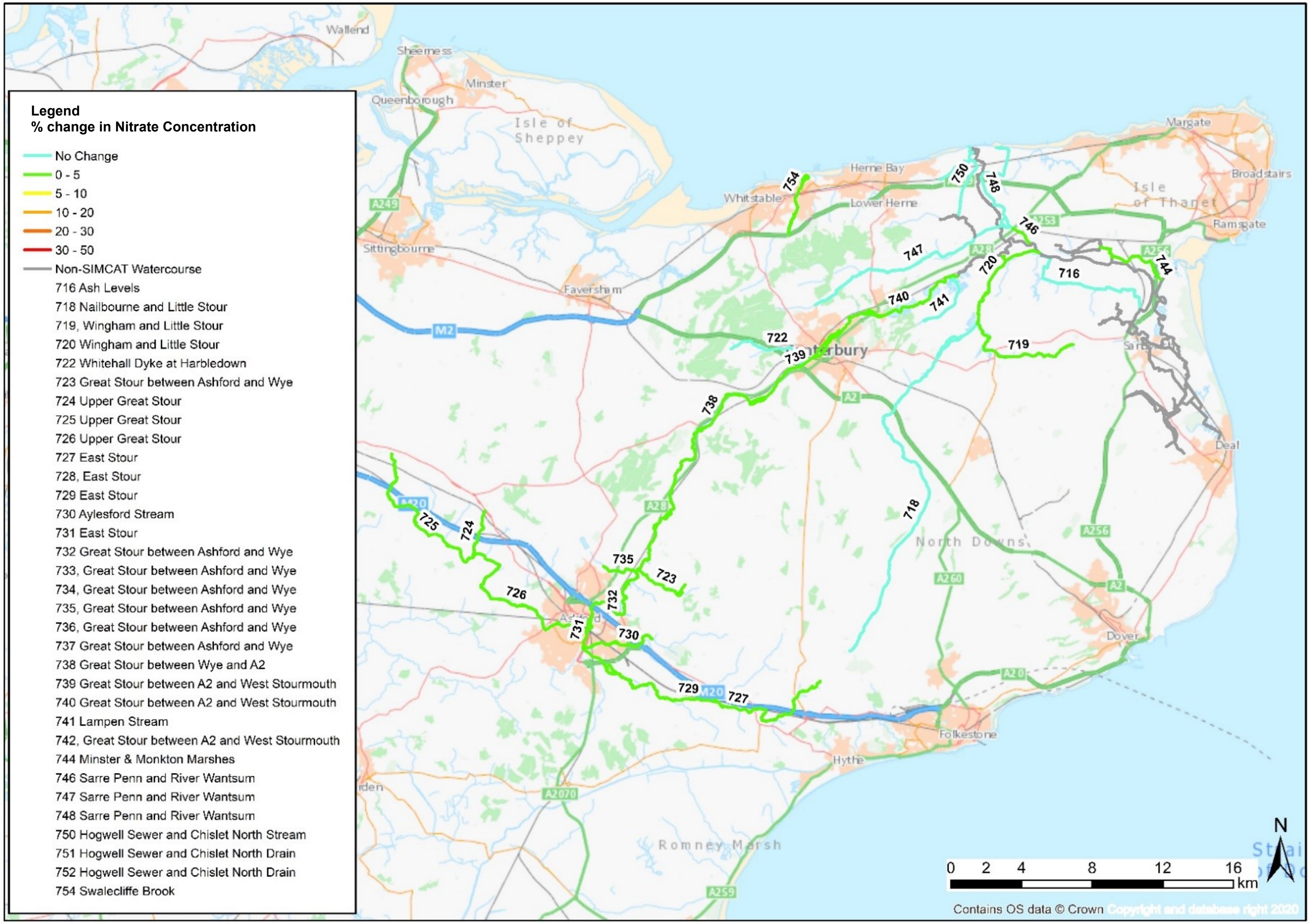


**Figure A6: Future Scenario Modelling: Potential Percentage Change on Total Nitrate Concentrations due to Population Increase**

## Modelling of Climate Change

Climate change is expected to result in a reduction in rainfall and river flow across Kent with some catchments likely to experience a larger impact than others. Risk assessment mapping for this study has shown the majority of waterbodies within the Stour catchment are likely to be at a medium to high risk of experiencing lower summer river flows. This impact is represented in SIMCAT with reference to the annual mean and $Q_{95}$ conditions and these two parameters have been amended as set out below to assess the vulnerability of water quality in the Great Stour catchment to climate change induced lower river flows.

The Future Flows Project[52] shows the expected range of changes to key river flow conditions across the UK based on the UK Climate Predictions developed in 2009 (UKCP09). The range of predictions was assessed against the outputs of the updated 2018 predictions (UKCP18) by Lindsey et al in 2020[53] and found to result in broadly similar outcomes. The UKCP09 predictions show a decrease in mean annual flow in the 2050s of 20%, with most modelled scenarios showing a decrease in mean flows in the southeast of England and one model showing a decrease in mean flow of up to 40%. The comparison between the UKCP09 predictions and the UKCP18 predictions was carried out using specific river catchments to ensure consistency of data: the UKCP18 models predicted slightly greater reduction of annual mean river flows for the two catchments closest to Kent (the River Thames and the River Itchen), although the range of predictions for both sets of models do overlap. Taking both studies into account, the mean gauged river flows in the SIMCAT model have been reduced by 25% to account for the effects of climate change.

The impacts of climate change on low flows is expected to be more significant than for mean flows because mean flows take into account the effects of large storms which are expected to become more frequent in future. The $Q_{95}$ flow condition reflects only the impacts of climate change in terms of drier summers and more frequent droughts. All UKCP09 models show a reduction in the $Q_{95}$ river flow in the southeast of England for the 2050s. The scale of the decrease is variable, but generally does not exceed 60%. The maps show the decrease in the Kent area to be in the 20-40% reduction bracket, and this is confirmed by the UKCP18 data for the Thames and Itchen catchments. On this basis, the $Q_{95}$ value has been reduced by 30% in the climate change SIMCAT model: this is a central value which is consistent with the UKCP18 outputs.

Figures A7 and A8 show the vulnerability of river water quality to increased phosphate and total nitrate concentrations due to reduced river flows. Figure A7 shows that the main River Stour waterbodies are vulnerable to increased phosphate concentrations from upstream of Ashford to the tidal limit, whereas the upper reaches and tributaries such as the Little Stour are likely to be less affected. Sarre Penn and the River Wantsum are also vulnerable as these watercourses have smaller catchments, so a future reduction would further reduce the dilution capacity for pollutants in these watercourses.

Figure A8 shows the impact of climate change on total nitrate concentrations in the modelled watercourses. As with phosphate outputs the River Stour, Sarre Penn and the River Wantsum are most vulnerable to increased concentrations, but there is slightly greater impact on the Upper Stour, East Stour, Minster and Monkton Marshes and Swalecliffe Brook.

[52] https://www.ceh.ac.uk/services/future-flows-maps-and-datasets

[53] Kay, Alison Lindsey; Watts, Glenn; Wells, Steven C.; Allen, Stuart. 2020. *The impact of climate change on U.K. river flows: a preliminary comparison of two generations of probabilistic climate projections.* Hydrological Processes, 34 (4). 1081-1088, available at https://doi.org/10.1002/hyp.13644

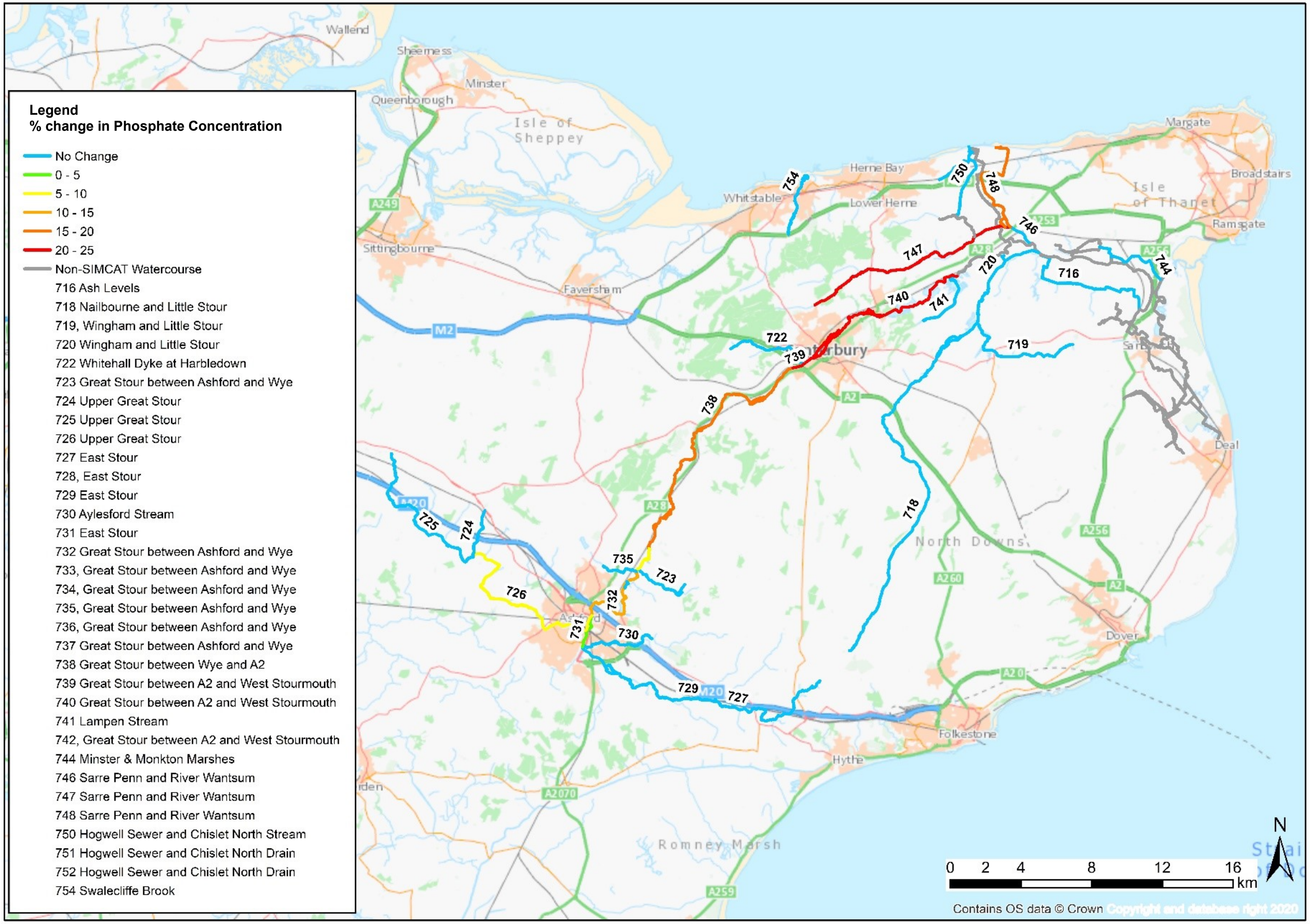


**Figure A7: Future Scenario Modelling: Potential Percentage Change in Phosphate Concentrations due to Climate Change Induced Lower River Flows**

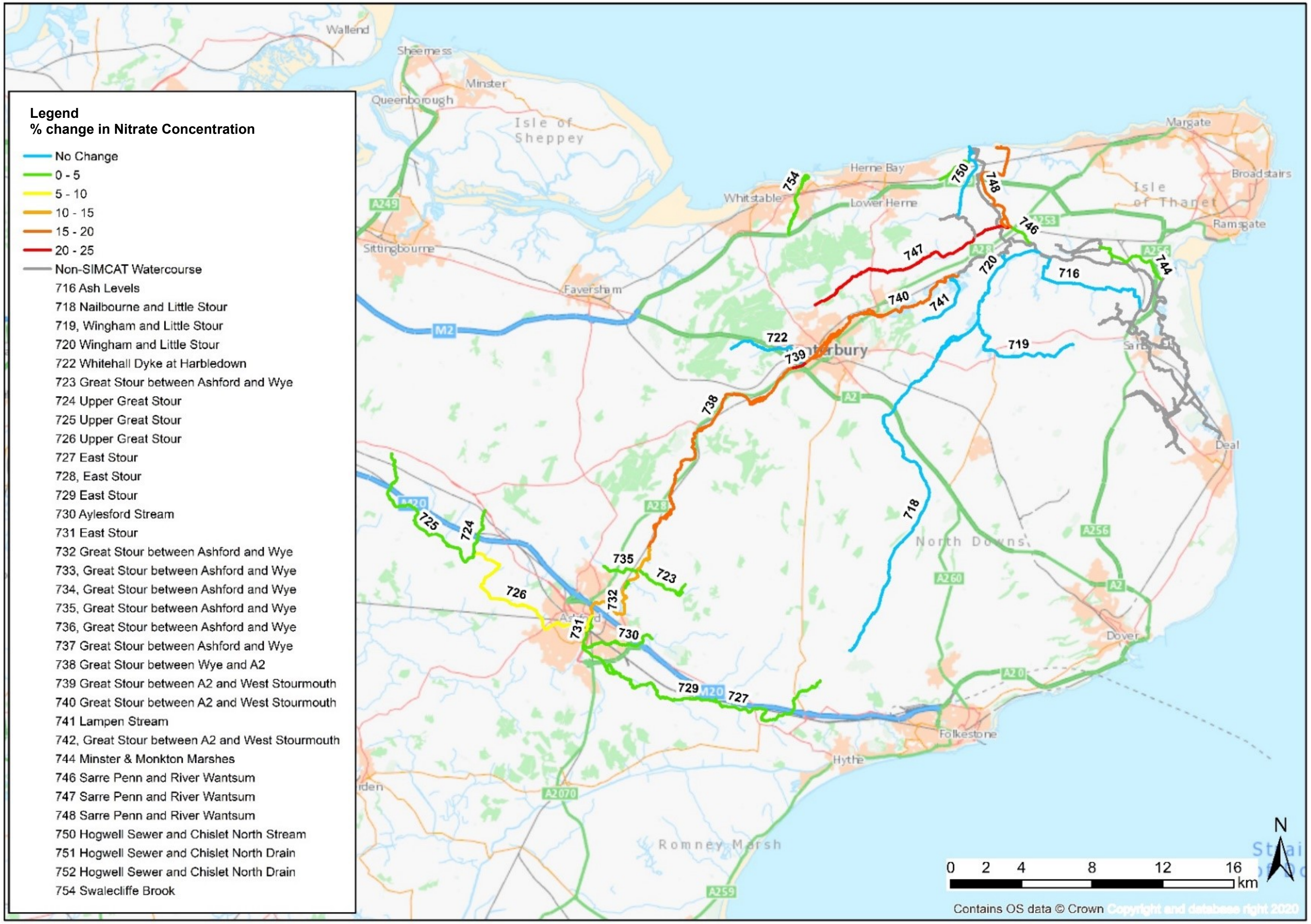


**Figure A8: Future Scenario Modelling: Potential Percentage Change in Total Nitrate Concentrations due to Climate Change Induced Lower River Flows**

## Modelling of Cumulative Impacts

The combined effects of climate change and population increases have been modelled by adjusting both the WwTW effluent flows and the river flows as set out above. The combined impact on water quality is shown in Figures A9 and A10. Figure A9 shows that the vulnerability of the River Stour to increased phosphate concentrations significantly increases when lower river flows and increases in population are combined, with the whole of the main Great Stour waterbodies affected from Ashford to the tidal limit and increases seen in the Upper Stour reaches. This is due to the combined effects of greater discharges from the WwTW and lower river flows available for dilution. The impact on the Sarre Penne and River Wantsum is also significant but this is primarily due to loss of river flow as there are no Southern Water WwTW within these reaches. The Little Stour shows low vulnerability to increased phosphate concentrations from climate change and population increase.

Figure A10 shows that the vulnerability of the system to increased total nitrate concentrations is less than that for phosphate, with the exception of the Great Stour downstream of Ashford and Canterbury.

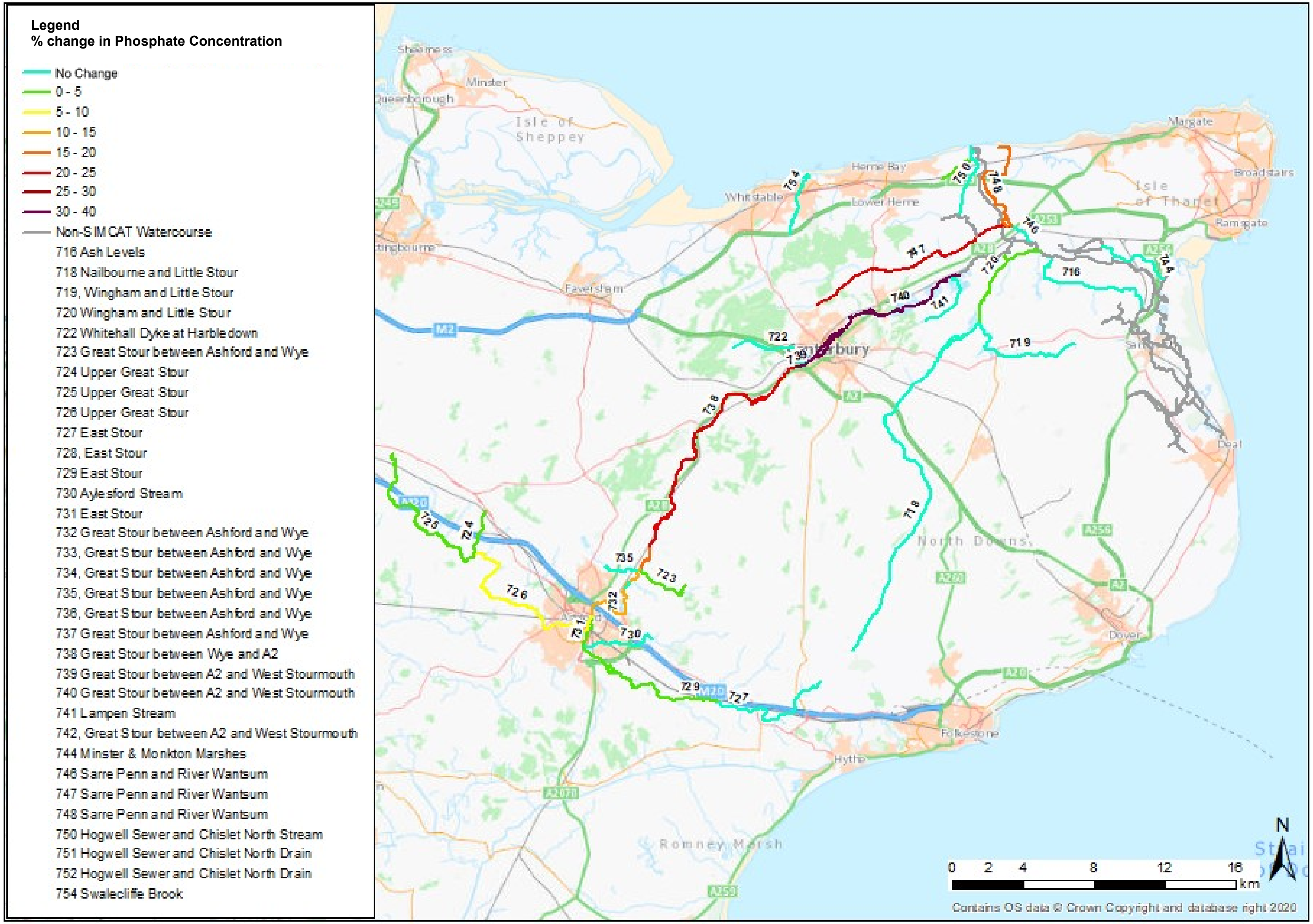


**Figure A9: Future Scenario Modelling: Potential Percentage Change in Phosphate Concentrations due to Combined Impacts (Population Increase & Climate Change)**

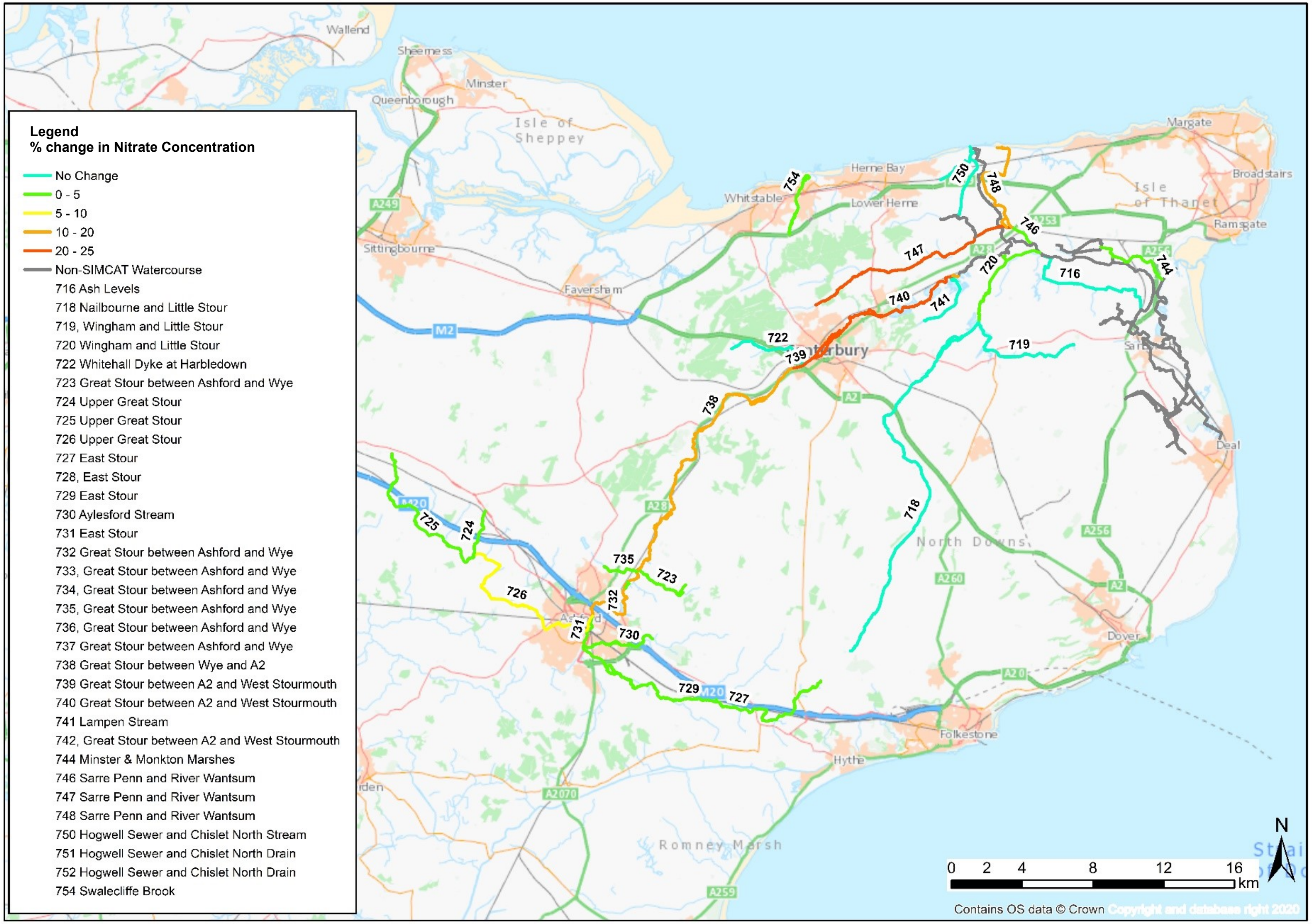


Figure A10: Future Scenario Modelling: Potential Percentage Change in Total Nitrate Concentrations due to Combined Impacts (Population Increase & Climate Change)

# Appendix B – Accessible Alternative for Figure 2-1

**This appendix is an alternative format of Figure 2-1 that is digitally accessible.**

**Key to follow:**

- **Change Response**
  - Change Response
    - Water System Impact Susceptibility

- **Population increase**
  - Increase in pollution load from treated wastewater
    - Deterioration in water quality (SW and GW and Coast)
- **Farming practice changes (policy)**
  - Increase in soil erosion and degradation
    - Increase in frequency, extent and depth of flooding
  - Increase in pollutant load from agricultural diffuse sources
    - Deterioration in water quality (SW and GW and Coast)
- **Increased urbanisation**
  - Increase in pollution load from urban sources
    - Deterioration in water quality (SW and GW and Coast)
- **Decrease in summer rainfall**
  - Lower waterbody distribution
    - Deterioration in water quality (SW and GW and Coast)
  - Reduced summer surface water runoff
    - Deterioration in water quality (SW and GW and Coast)
    - Reduction in waterbody hydromorph condition
- **Increase in winter rainfall**
  - Increased winter surface water runoff
    - Increase in frequency, extent and depth of flooding
  - Increase in flood defence overtopping or breach risk
    - Increase in frequency, extent and depth of flooding
- **Increase in summer temperature**
  - Increase in demand and abstraction
    - Increase in frequency of summer hydrological drought
    - Reduction in summer GW levels
    - Reduction in waterbody hydromorph condition
- **Sea level rise**
  - Increase in rate of coastal erosion
    - Increase in frequency, extent and depth of flooding
  - Increase in flood defence overtopping or breach risk
    - Increase in frequency, extent and depth of flooding

# Appendix C – Accessible Alternative for Figure 2-2

**This appendix is an alternative format of Figure 2-2 that is digitally accessible.**

- Change Source
- Change Response
- Water System Impact Susceptibility (WSIS)
    - Effects (on receptors)
    - Adaptation
    - Increase in winter rainfall
    - Sea level rise
        - Increased winter surface water runoff
        - Increased risk of defence breach
        - Increased rate of coastal erosion
            - Susceptibility to increase in frequency and extend of flooding
                - Agriculture (loss of productive land)
                - Business and Community (Property Damage Infrastructure investment)
                    - Adaptation