Rialtas na hÉireann
Government of Ireland

Water Quality and Water Services Infrastructure

Climate Change Sectoral Adaptation Plan

Prepared under the National Adaptation Framework

Prepared by the Department of Housing, Planning and Local Government
housing.gov.ie

Acknowledgements

This plan was prepared by the Department of Housing, Planning and Local Government with technical advice and assistance from Mott MacDonald Ireland Ltd.

The plan was prepared in collaboration with a Sector Adaptation Team and in consultation with key stakeholders. The Department also received comments and input during a public consultation. This collaborative approach has been vital at each step of the adaptation process.

The Department acknowledges and expresses thanks to the following organisations for participating in a series of workshops and separate stakeholder interviews and meetings. This process provided vital input into the plan and ensured that the process was informed by a comprehensive range of cross-sectoral evidence and expertise.

An Fóram Uisce
Climate Action Regional Offices
Climate Change Advisory Council
Department of Agriculture, Food and Marine
Department of Health
Department of Communications, Climate Action and the Environment
Electricity Supply Board
Environmental Protection Agency
Geological Survey of Ireland
Inland Fisheries Ireland
Irish Water
Local authority sector
National Federation of Group Water Schemes
National Parks and Wildlife Service
Office of Public Works

Mott MacDonald (Technical Consultant working on behalf of DHPLG)

Contents

Climate Change Sectoral Adaptation Plan for the Water Quality and Water Services Infrastructure Sectors

Key points from this plan	• Protecting and improving water quality and improving water services infrastructure are major challenges in Ireland. • Climate change-induced threats will increase the scale of these challenges. • Risks to water quality and water infrastructure arise from changing rainfall patterns and different annual temperature profiles. The frequency and intensity of storms and sea level rise are also considered.
The Challenges: **Water Quality**	• High rainfall and flooding leading to mobilisation of pollutants. • Reduced dilution of contaminants in water bodies at low flow. • Drying of peatland resulting in the reduction of natural filtration of pollutants. • Increased spread and viability of pathogens, such as from livestock waste and slurry. • Changes in the distribution and viability of native, non-native and invasive flora and fauna.
The Challenges: **Water services infrastructure**	• Increased surface and sewer flooding leading to pollution, water and wastewater service interruptions. • Reduced availability of water resources. • Hot weather increasing the demand for water. • Increased drawdown from reservoirs in the autumn/winter for flood capacity, leading to resource issues. • Business continuity impacts or interruptions for water services providers.
Primary Adaptive Measures:	• Fully adopt the ‘integrated catchment management’ approach. • Improve treatment capacity and network functions for water services infrastructure. • Water resource planning and conservation – on both supply and demand sides. • Include climate measures in monitoring programmes and research. • Many of these proposed adaptation actions are already underway through existing and scheduled water sector plans and programmes.

Ministerial Foreword

Water affects all aspects of life. By protecting our water environment, we protect sources of supply for our people, our environment and our economy. As a result, it must be managed effectively for use by current and future generations.

By investing in our water services and water quality protection, we are working to protect our water resources and deliver water services to a high standard. We are now facing ever increasing demands, arising from population growth and a growing economy. We are also facing new challenges from the expected impacts of climate change.

Climate change will have diverse and wide-ranging impacts on many aspects of our environment, including ecosystems, agriculture, coastal zones and our water resources.

Observations show that Ireland is experiencing more weather extremes, along with rises in sea level, increases in average temperature and changes in precipitation patterns. This, together with the level of destruction and disruption caused by recent extreme weather events, highlights the need to prioritise climate adaptation action and plan effectively for a climate resilient future.

Presenting an assessment of key future climate risks, the plan outlines the adaptive measures available to build resilience in responding to climate change and weather related events, and other socio-economic impacts.

Many of the proposed adaptation actions are already underway and mainstreaming these measures into the operations and policies of all relevant stakeholders will be important to implementing climate action at national level. An example of these measures includes the River Basin Management Plan for Ireland 2018-2021 and Irish Water's forthcoming National Water Resource Plan. This adaptation plan is the beginning of an iterative process and adaptation planning will need to be an ongoing process.

This plan has been achieved through partnership and collaboration. I would like to thank all individuals and stakeholders who generously contributed their views as we developed this Plan, whether through the formal public consultation process, through participation at other forums or through bilateral engagements with my Department. The feedback received was invaluable and greatly helped shape and inform the final content of this Plan.

As we prepare for the impacts of climate change in the years ahead, a robust and flexible process of climate-change-adaptation planning is required in order to build a climate resilient water sector. While this will be an on-going process, this plan is an important first step in ensuring that climate change is fully mainstreamed into water policy in Ireland.

I look forward to continuing to work with all stakeholders to deliver more resilient systems, assets and operations, so that the risks to both water sectors are well managed in the face of climate change.

Eoghan Murphy, T.D.,

Minister for Housing, Planning and Local Government.

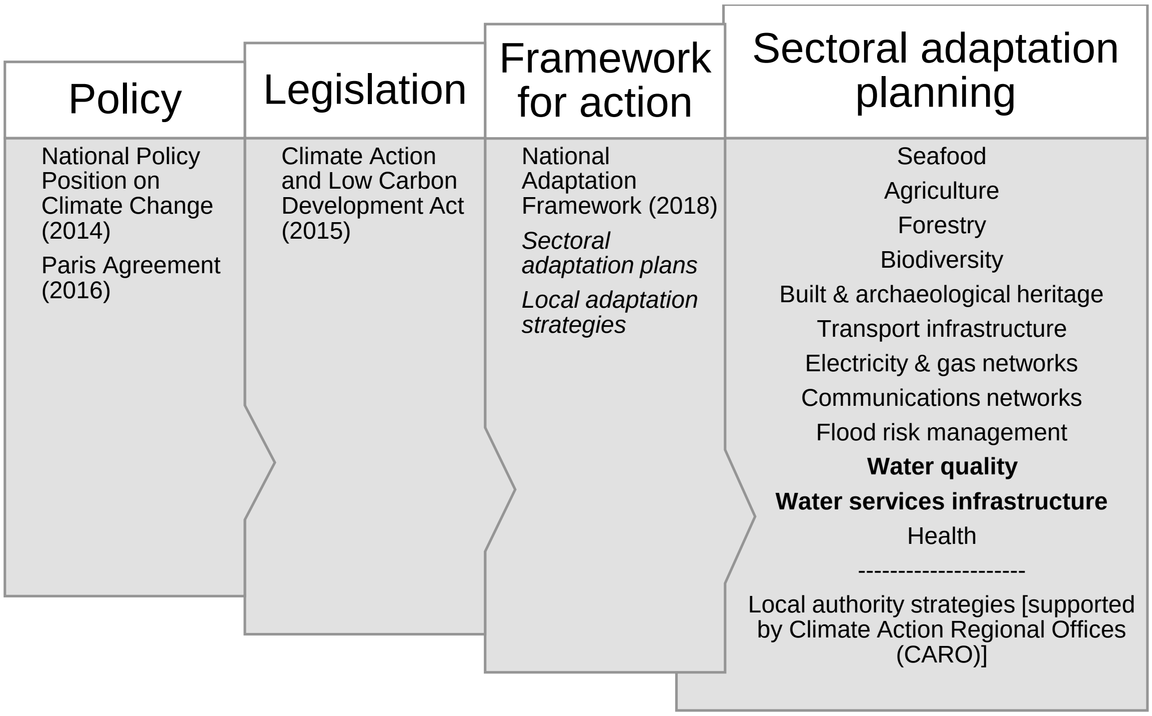
Executive summary

Human interference with the climate system is occurring and climate change poses risks for human and natural systems. This adaptation plan (the Plan) is focused on managing the risks from climate change for water quality and for water services infrastructure and describes the key risks and proposes necessary adaptive measures. The outcomes of this assessment will be used by policy makers, implementing organisations and stakeholders within the water sectors to inform further, detailed adaptation planning.

The Intergovernmental Panel on Climate Change (IPCC) reports that climate change involves complex interactions and changing likelihoods of diverse impacts. The timing and severity of impacts will vary between geographic regions.

The Minister for Housing, Planning and Local Government has prepared this Sectoral Adaptation Plan (SAP) under the National Adaptation Framework in respect of two sectors: 'water quality' and 'water services infrastructure', together called the 'water sectors'. The development of this Plan forms one part of a much larger effort by Ireland to prepare for climate change. Seven government departments covering 12 sectors have been requested to submit sectoral plans (as detailed below).

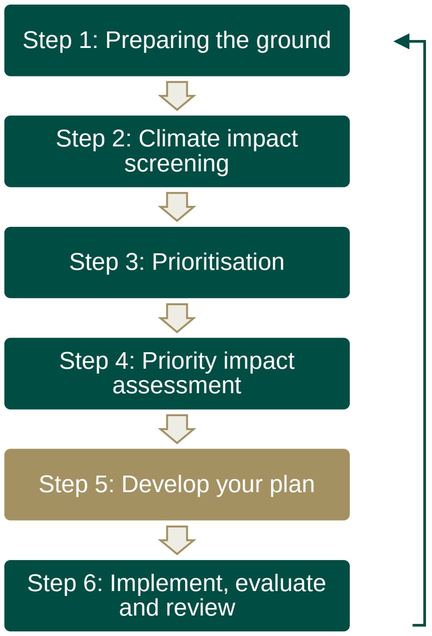
Several policy and legislative milestones addressing climate action have been put in place nationally to inform Ireland's response to climate change (as detailed below). The existing climate policy in Ireland is being strengthened by the global necessity to achieve the goals of the Paris Agreement, and to put best practice into action.



In the context of this Plan '**water quality**' refers to the biological, chemical and physical status of raw water in the environment (rather than effluent water quality or treated water for supply). **'Water services infrastructure'** refers to the integrity and performance of above and below ground infrastructure assets relevant to water and wastewater service provision. This includes water abstraction infrastructure, potable water treatment plants, pipe networks, wastewater and sludge treatment plants and discharge of treated water in both the public and private sectors.

This plan follows the Sectoral Planning Guidelines for Climate Change Adaptation [1]. These guidelines are based on international best practice and were developed in close consultation with several government departments and key stakeholders. The adaptation planning process incorporates six steps as set out in Figure 1.

Figure 1: Adaptation process



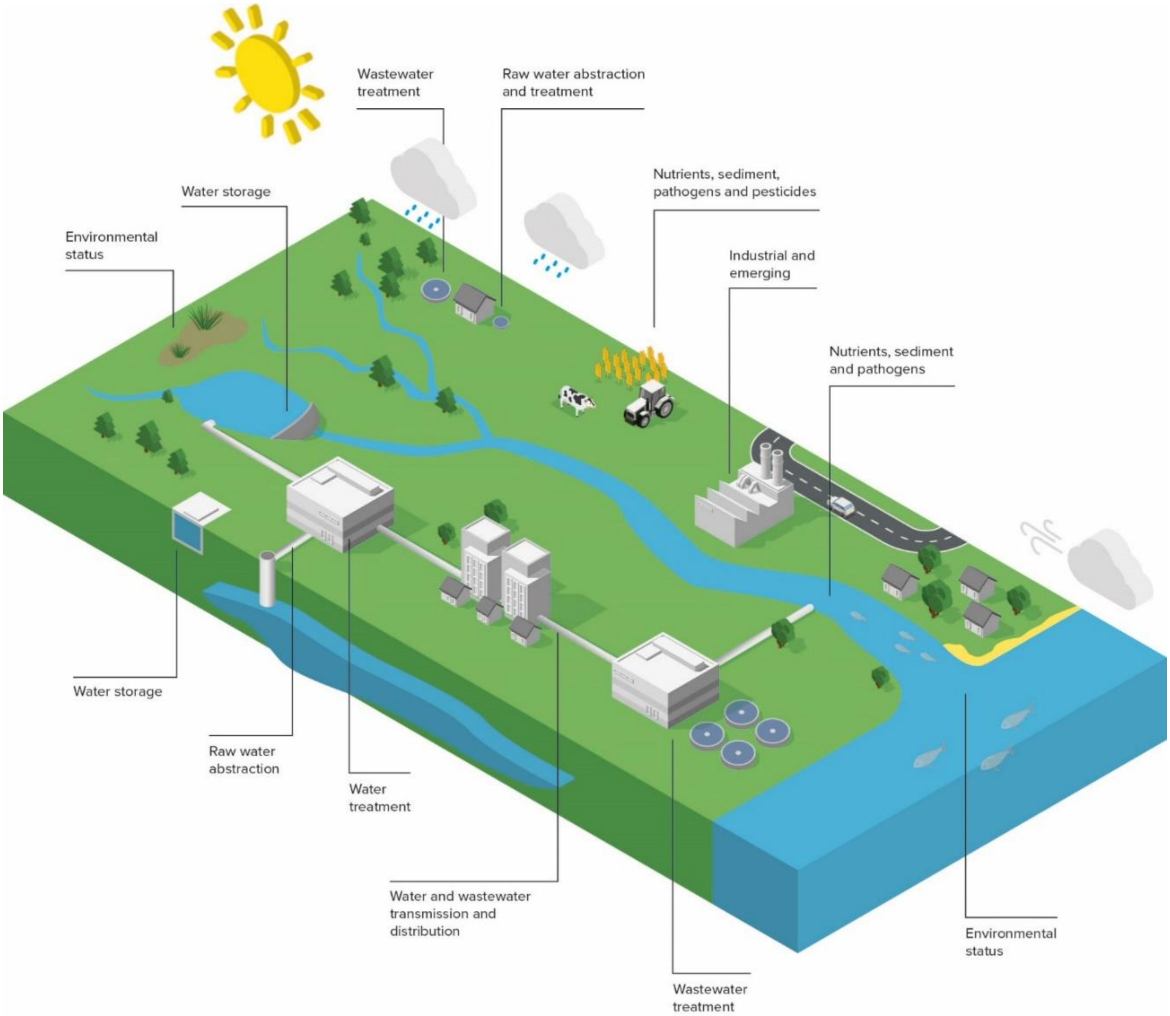
This report considers the fifth step of the adaptation planning process – the development of the Plan based on the methodologies and assessment in Steps 1 to 4.

This Plan is a national-scale plan and focuses on independent impacts on the sectors rather than the broad range of coincident and downstream impacts. As such, it considers national-level statements of observed and projected changes in climate rather than impacts on individual infrastructure assets or water quality parameters and pressures (as suggested in [1]).

In developing an understanding of current and potential future impacts, and in order to understand how risks fit into the wider social, environmental and economic context, a series of climate change statements for key stimuli (such as temperature) and a number of sub-sectors for both the water quality and water services infrastructure sectors have been described. A representation of the water quality and water services infrastructure sub-sectors considered in this assessment is presented in Figure 2. Aligned with these, a 'long-list' of sectoral impacts (outlined in Appendix A) was developed through consultation with the Sectoral Adaptation Team (SAT).

The assessment of risks, and adaptation options, is based on a summary of global (e.g. IPCC) and local (e.g. Met Éireann, Climate Ireland) climate change projections. This assessment considers the full range of climate scenarios for the medium term (2031-2060) – as adopted and described in the IPCC Fifth Assessment Report (AR5). Key statements of projected future climate change are presented below for the four key climate stimuli (temperature, precipitation, storminess and sea level).

Figure 2: Water quality and water services infrastructure sub-sectors



Source: Mott MacDonald, 2019

The process of developing the interrelationships between climate stimuli and the risk to each sub-sector (using impact chains) started with consideration of all current and potential impacts of each climate variable on each water quality and water services infrastructure sub-sector. A 'long-list' of impacts was compiled and then rationalised. For some sub-sectors, there were few foreseeable impacts and for others there were multiple impacts of a climate variable on one sub-sector. The potential magnitude of each impact in terms of economic, environmental and social impacts was then assessed and an aggregate overall magnitude was assigned for each impact. The resulting future risks to the water quality and water services infrastructure sectors were calculated for each impact based on the product of the likelihood and magnitude of impacts.

Temperature

- Long-term increase in annual average temperatures
- Chronic increase in temperature maxima, i.e. frequency/duration/magnitude of summer heatwaves
- Chronic increase in minimum temperatures, e.g. decreased intensity/frequency of cold weather events
- An increase in the average length of the growing season
- Changes in acute events (more heatwaves, fewer frost and ice days)

Precipitation

- A net decrease in total annual precipitation and event frequencies
- Projected decreases in summer precipitation, with increased frequency/duration/magnitude of summer dry/drought periods
- An increase in winter precipitation frequencies, with notable increases in winter and autumn precipitation
- Changes in antecedent precipitation intensity and distribution
- Geographical and temporal nuances in precipitation patterns from west to east

Storminess

- Decreased frequency of North Atlantic storms
- Overall intensity of storm events is more likely than not to increase, with more intense associated hazards e.g. heavy precipitation, flooding, storm surge, wind, lightning, from increased convective activity
- Hail and snow may decrease
- Net decrease in high winds, but a possible increase in extreme wind associated with more intense storms

Sea Level

- Chronic increase in sea level
- An associated net increase in storm surge and tidal flooding

Projected changes in climate were applied to the impact chains to understand the direction of changes under a future climate. This included consideration of how a changing climate might exacerbate or ameliorate current levels of impacts related to sensitivity, exposure, adaptive capacity and sectoral consequence, as well as the potential for projected changes to result in any new or emerging climate impacts and risks. Through the 'prioritisation stage' these impacts were ranked according to the risk to water quality and/or to water services infrastructure, based on the expected future likelihood and magnitude of impacts. This resulted in a list of acute priority impacts (which as such are reflected as 'sectoral priorities') and medium priority impacts which have been assigned with 'watching briefs' to capture research gaps, interdependencies and potential adaptation measures which could lead to a refinement of the impact and risk score in future iterations of this SAP.

Water quality

- **High precipitation -** Increased surface and sewer flooding (leading to mobilisation)
- **Low precipitation -** Low flows and water levels causing reduced dilution of pollutants
- **High temperatures -** Spread of / increased viability of pathogens
- **High temperatures -** Changes in species distribution and phenology, including native, non-native and invasive species
- **High temperatures -** Drying of peatland can result in a reduction of natural pollution attenuation and flood prevention, the leaching of ammonia, and peat slides (when followed by heavy precipitation)

Water services infrastructure

- **High temperatures -** Hot weather-related changes in demand (e.g. higher daily and peak demand)
- **High precipitation and increased storminess -** More frequent water/wastewater asset flooding, asset loss and potential for environmental pollution
- **High precipitation -** Increased drawdown in the autumn/winter for flood capacity, leading to resource issues in the following spring/summer
- **Low precipitation -** Reduced availability of water resources (surface water and groundwater sources)
- **Increased storminess/ high temperatures / high precipitation -** Business continuity impacts/ interruptions

A detailed assessment was undertaken of the acute priority impacts that may result in the most serious sectoral consequences or potential benefits. A summary of these acute priorities is presented above.

This Adaptation Plan has been subject to a six-week public consultation period managed by DHPLG. In total, 121 comments were received from 12 organisations. The views and feedback received covered the adaptation planning process and underlying climate science and the development of the Plan to consider interdependencies and how the Plan will be implemented.

Importantly, the comments gave additional sector-specific feedback on impacts and on how these could be considered going forward. All comments have been thoroughly considered and the consultation has informed this Plan.

The final step of adaptation planning as set out in the Sectoral Adaptation Planning Guidelines for Climate Adaptation [1] involves the implementation, monitoring, and evaluation of Plans. The Department has overall policy responsibility for water quality and water services infrastructure policy areas and sets out policy objectives and priorities, which are given effect by stakeholders such as Irish Water, the National Federation of Group Water Schemes and local authorities. This Plan will provide clarity on the nature of challenges that face the sectors and sets out a range of potential adaptive measures for consideration. It provides strategic direction across the sectors and will inform the design, resourcing and review of policies and measures.

The National Adaptation Framework (NAF) is, necessarily, a cyclical process. This Adaptation Plan is viewed as a 'live' document and the Plan will be evaluated and reviewed to account for changing science and socio-economic conditions via existing monitoring mechanisms (such as the Water Policy Advisory Committee, Irish Water governance arrangements). This will allow tracking and revision of the sectoral priorities as adaptation and mitigation efforts are made across the sectors.

1 Introduction

This Sectoral Adaptation Plan for the water quality and water services infrastructure sectors presents an assessment of key future climate risks to the sectors and describes a range of key potential adaptive measures. The outcomes of this assessment should be considered by organisations and stakeholders within the sectors in future adaptation planning.

This plan, prepared by the Department of Housing, Planning, Community and Local Government (DHPLG), falls under the National Adaptation Framework (NAF) [2] through which seven Government Departments covering 12 sectors have been requested to submit sectoral plans. The NAF also outlines the requirement for local authorities to prepare local adaptation strategies given their crucial role in addressing climate change at a local level. In line with a review of the NAF at least every five years, it is intended that all plans are viewed as 'live' documents and as such will be updated periodically to consider latest scientific and socio-economic evidence and promote ongoing engagement and discussion around climate adaptation.

1.1 Climate change

Climate change is arguably one of the most important and pervasive global threats we face in the 21st century. It is widely recognised as posing significant, increasing risks, with exponentially rising costs - to the environment, to society, and to the global economy.

Climate change is not the only ongoing pressure that will impact the water sector in Ireland. A rising population will mean an increased demand for water resources and an increase in the amount of waste requiring treatment. In addition, intensification of agriculture has brought further demands on water resources and has the potential to result in an increased load of multiple pollutants (nutrients, sediments, pesticides and other agricultural chemicals) to water bodies. These factors will also interact; increased agricultural yield will be required to feed more people. However, climate change will have overarching impacts that both contribute to these factors, for example changes in population distribution due changing weather patterns and will also worsen the impacts that these factors might have on water quality and water services infrastructure.

Specifically, changes in the global climate present a suite of direct and indirect challenges to Ireland's water quality and water services infrastructure through:

- Chronic, long-term variations to existing climate conditions, and
- Acute changes to the severity and frequency of extreme events.

An understanding of the likely risks posed by climate change to the water sector is required to enable improved planning, resilience and overall social, economic and environmental sustainability for Ireland and its citizens.

Ireland signed and ratified the Paris Agreement under the United Nations Framework Convention on Climate Change in 2016, committing the nation to a path of intended decarbonisation and improved resilience.

Prior to this Plan being produced, several key policy and legislative milestones addressing climate action (outlined in the preceding Impact Screening Report [3]) have been put in place nationally which inform Ireland's response to climate change. Their importance and urgency are underscored by the requirement to implement the Paris Agreement targets which were signed in 2016 by Ireland (and the EU). The existing climate policy landscape in Ireland is thus constantly being strengthened by the global imperative to achieve the goals of the Paris Agreement, and to put best practice into action.

While the development of this Plan forms one part of a much larger effort by Ireland to tackle this systemic global threat, it is a defining moment for the future performance of the water sector in Ireland, which underpins much of Ireland's wellbeing and economy.

1.2 Water quality and water services infrastructure in Ireland

Ireland's water resources include over 70,000km of water channels, 12,000 lakes, 850 km^2 of estuaries and 13,000km^2 of coastal waters. 82% of drinking water supplies in Ireland are sourced from surface water (i.e. rivers and lakes) and 18% from groundwater – of which 10.5% is from boreholes and 7.6% from springs [4]. There is generally a lack of storage in the Irish system – most abstractions are run-of-river with little or no in-network storage for raw or treated water.

The water sector in Ireland has changed significantly in recent years with the formation of Irish Water in 2013. Irish Water is the national water utility that is responsible for the delivery of public water and wastewater services; this responsibility was previously distributed locally across 31 local authorities. In some rural areas many small communities are not served by Irish Water's networks and rely on group and private schemes to provide water and wastewater services.

The water quality of rivers and lakes in Ireland is declining due largely to inputs of nutrients from agriculture and sewage, with the potential to cause eutrophication. E. Coli contamination of groundwater is also a problem in Ireland, and high nutrient concentrations can be a problem in areas where agriculture is a dominant land use. The quality or Ireland's bathing water generally is good; in 2017 93% of bathing waters met the minimum required standard of sufficient quality [5].

Apart from climate change, there are very significant and multiple additional pressures facing the water sector in Ireland. Ireland is currently implementing a programme of investment to improve water services to ensure that infrastructure meets basic quality and performance standards. In addition, pressures from population growth and demographic and societal change (e.g. urbanisation) are significant. Climate change impacts may compound these existing pressures and pose challenges for adaptation planning and finance [2]. There are likely to be interactions and feedbacks between climate change and these additional pressures, including both direct and indirect impacts and positive and negative relationships. The NAF [2] recognises the importance of the social and economic policy context when considering climate change impacts and adaptation actions.

This Sectoral Adaptation Plan (SAP) does not consider the impacts of these additional interacting factors in detail but focuses on the national-level impacts resultant from climate change. Socio-economic factors are captured through the use of the IPCC climate change scenarios, which include high-level socio-economic factors (although it is recognised that this does not capture Ireland specific factors in detail), and in the identification of cross-sectoral interdependencies.

1.3 Sectoral adaptation planning

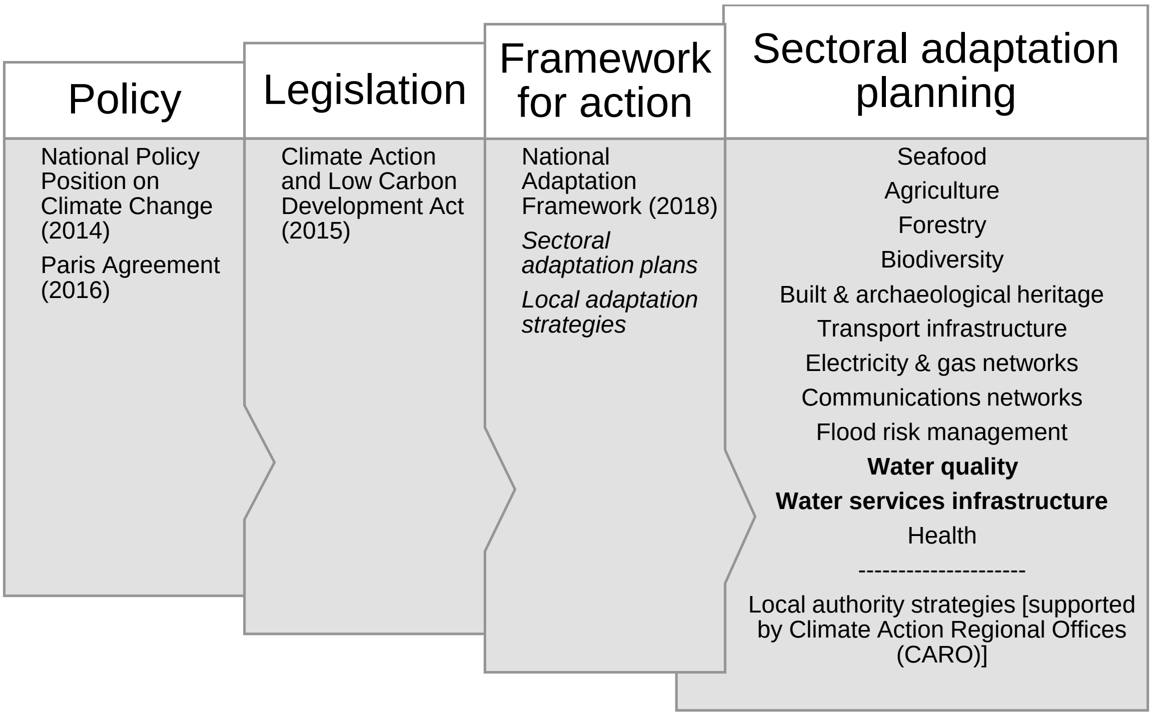
The Department of Environment, Community and Local Government (now configured as the Department of Communications, Climate Action and Environment – DCCAE) published a National Climate Change Adaptation Framework (NCCAF) in 2012 [6]. DCCAE leads and co-ordinates national adaptation policy and supports the implementation of the adaptation effort at national, sectoral and local government levels. The NCCAF was Ireland's first step in developing a comprehensive national policy position wherein climate change adaptation measures could be planned and implemented. It is a Government-approved framework which mandates the development and implementation of sectoral adaptation plans and local government adaptation strategies. In combination they form part of the national response to the physical impacts of climate change. Twelve sectors were identified in the NCCAF; Water, Emergency Planning, Seafood, Agriculture, Forestry, Biodiversity, Heritage, Transport, Energy, Communications, Flood Defence and Health.

Ireland's climate adaptation policy, first set out in the NCCAF, was subsequently revised in the National Policy Position on Climate Change (NPPCC) in 2014. The NPPCC provides a high-level policy direction for Government to adopt and implement plans to enable Ireland to pursue the transition to a low carbon, climate resilient and environmentally sustainable economy by 2050. This was known as the "national transition objective".

The enactment of the Climate Action and Low Carbon Development Act in 2015 was a key milestone in establishing the national transition objective on a statutory basis. To facilitate this nationwide transition, the 2015 Act prescribed the formal development and submission of national mitigation and adaptation plans to Government. It also established the institutional and governance framework for these plans. The framework identifies the key participants (i.e. Government Departmets) at sectoral level and at local level (i.e. the local government sector) that are responsible for driving the adaptation effort.

Under Section 5 of the 2015 Act, the Minister for Communications, Climate Action and Environment is required to submit a NAF to Government for approval, which must be reviewed every five years. The current NAF [2], published in 2018, specifies the national strategy for the application of adaptation, and policy measures in different national sectors and by local authorities in their administrative areas in order to reduce the risks to Ireland from the negative effects of climate change and to take advantage of any positive effects that may occur. The NAF set outs requirements for sectoral adaptation plans (including this Water Quality and Water Services Infrastructure Plan) and local adaptation plans, which are led by local authorities with support from Climate Action Regional Offices (as detailed in Figure 3).

Figure 3: Adaptation planning



Under Section 8 of the 2015 Act, a Climate Change Advisory Council (CCAC) was established in January 2016. The Council, which serves as an independent expert body providing advice and recommendations to DCCAE in relation to the preparation of the NAF and the development of SAPs. The Council has numerous reporting obligations, including ‘Annual’ and ‘Periodic Reviews’ of progress towards meeting the national transition objective; it also established an Adaptation Committee in 2016 to focus specifically on adaptation related matters. The Committee on Climate Action in the Houses of the Oireachtas has recognised the need for a cross-party consensus for action and has produced a report [7] to recommend actions for further and more immediate action.

This plan covers both water quality and water services infrastructure (as defined in Section 2.2.5). The plan identifies and prioritises the climate change impacts that have the potential to threaten achievement of policy objectives in these sectors.

In the context of this Plan ‘**water quality**’ refers to the biological, chemical and physical status of raw water in the environment (rather than effluent water quality or treated water for supply). **‘Water services infrastructure’** refers to above and below ground infrastructure assets relevant to water and wastewater service provision.

1.4 Structure of the Plan

Following the requirements and recommended structure outlined in the NAF, this SAP details the priority concerns for the water quality and water services infrastructure sectors, clearly presenting the linkages between climate change hazards and associated risks to sub-sectors, beginning the process of identifying sectoral priorities which will be developed following this study. In so doing, the interaction with the other sectors which are producing SAPs and local authority adaptation strategies are considered to identify potential conflicts and synergies. A clear analysis of Strategic Environmental Assessment (SEA) and Appropriate Assessment considerations at this stage of the sectoral adaptation planning process is included.

The detail in this report is based on information available at the time of writing. Although this report is based on the outcomes of the Impact Screening [3], the Prioritisation [4] and the Priority Impact Assessment [8] a few minor updates and refinements in the impact chains and risk scoring have been made. As such the impact chains and risk scoring in this report supersede those.

The following chapters of this Plan are structured as follows:

- **Chapter 2** summarises the previous steps in the sectoral adaptation planning process and the methodology used to derive priority impacts.
- **Chapter 3** presents the priority impact assessments for both the water quality and water services infrastructure sectors.
- **Chapter 4** summarises and discusses the outcomes of this report before signposting the next step of the adaptation planning process.
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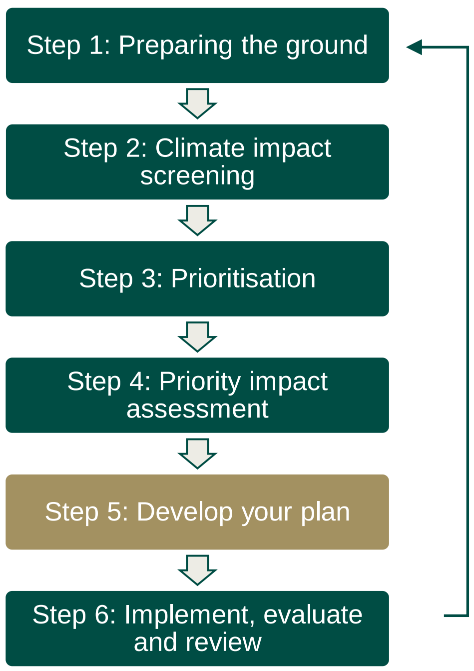
This Plan has been subject to a six-week public consultation period managed by DHPLG. In total, 121 comments were received from 12 organisations. The views and feedback received covered the adaptation planning process and underlying climate science and the development of the Plan to consider interdependencies and how the Plan will be implemented. These comments have all be thoroughly considered and the consultation has informed this final Plan.

2 Developing the Plan

The Minister for Housing, Planning and Local Government has prepared this Climate Change SAP in respect of the Water Quality and Water Services Infrastructure sectors. A stepwise approach has been followed using the DCCAE Sectoral Planning Guidelines for Climate Change Adaptation [1]. These guidelines are based on international best practice and were developed in close consultation with several government departments and key stakeholders.

The adaptation planning process incorporates six steps as follows:



This report considers the fifth step of the adaptation planning process – the development of the Plan based on the methodologies and assessment in Steps 1 to 4. Summaries of these Steps, undertaken prior to this report, are presented in this Chapter.

Being undertaken at a national scale and to enable the identification and prioritisation of adaptation, this Plan focuses on independent impacts on the sector rather than the broad range of coincident and downstream impacts. As such, this Plan considers national-level statements of observed and projected changes in climate rather than impacts on individual infrastructure assets or water quality parameters and pressures.

2.1 Preparing the ground (Step 1)

Preparing the ground focused on ensuring that the foundations for designing and delivering an effective adaptation planning process were established. This involved establishing a Sectoral Adaptation Team (SAT) to oversee and undertake the adaptation planning process, identifying stakeholders and their roles, and securing required human, technical and financial resources. The team co-ordinated and oversaw the adaptation planning process, and ensured that a broad spectrum of relevant knowledge, know-how and technical expertise were considered in the development of this Plan. Screening determinations were undertaken for SEA and Appropriate Assessment at the early stages of plan development to ensure the plan complied with the requirements of the SEA Directive and the Birds and Habitats Directives.

Collaboration and consultation with the SAT have driven the assessments at each step of the adaptation process. A series of workshops and separate stakeholder interviews for each of Steps 1 to 5 were held with the SAT between November 2018 and April 2019. This ensured that the process was informed by a comprehensive range of cross-sectoral evidence and expertise. The SAT includes representatives from several organisations, stakeholders and technical bodies, including:

- Department of Housing, Planning and Local Government
- Department of Agriculture, Food and Marine
- Department of Health
- Department of Communications, Climate Action and the Environment
- Environmental Protection Agency
- Office of Public Works
- Irish Water
- National Federation of Group Water Schemes
- Geological Survey of Ireland
- National Parks and Wildlife Service
- Local authority sector
- Climate Action Regional Offices
- Inland Fisheries Ireland
- Electricity Supply Board
- Mott MacDonald (Technical Consultant working on behalf of DHPLG)

2.2.1 Strategic Environmental Assessment and Appropriate Assessment

This assessment has been undertaken at a national-scale having regard to observed and projected changes in climate and the associated sectoral risks and impacts arising from the same.

A range of adaptive measures have been proposed which are envisaged to be implemented by a wide variety of organisations through a series of specific plans and programmes. It is through this widespread integration of these adaptive measures in water sector planning and programme making processes that effective and targeted implementation can be achieved. These national adaptive measures will need to be adopted and developed to ensure effective implementation.

Where plans and programmes are developed by plan and programme makers and, where necessary, issued for approval to consenting authorities, compliance with the SEA Directive (2001/42/EC), the Habitats Directive (92/42/EEC) and the Birds Directive (2009/147/EC) and transposing national legislation will be adhered to where relevant. In accordance with the SEA Directive, competent authorities (plan/programme makers) must subject plans and programmes in the water management sector to an environmental assessment where they are likely to have significant effects on the environment.

Article 6(3) of the Habitats Directive requires that competent authorities assess the potential impacts of plans and projects on the Natura 2000 network of European protected sites to determine whether there will be any ‘likely significant effects’ as a result of a plan’s or project’s implementation (either on its own or ‘in combination’ with other plans or projects); and, if so, whether these effects will result in any adverse effects on the site’s integrity.

Following the screening undertaken for SEA and Appropriate Assessment, the DHPLG has determined that due to the nature of this plan, and the implementation of potential adaptive measures through existing or planned plans or programmes, a full SEA and Appropriate Assessment are not required at this stage.

2.2 Climate impact screening (Step 2)

Climate impact screening identified a broad spectrum of changes and impacts which have the potential to give rise to wide and unacceptable sectoral impacts. In defining this list, past extreme events and current issues experienced by the water quality and water services infrastructure sectors were explored (Section 2.2.2). This enabled the impact screening to be reflective of risks and consequences pertinent to the sectors and the national context (considering Ireland's climate, topography, landscape, hydrology, hydrogeology, land uses and the range of water and wastewater infrastructure assets) (Sections 2.2.2 and 2.2.3).

By employing national-level information on the projected changes in Ireland's climate, an assessment was undertaken on how these changes in climate stimuli might affect the current magnitude and likelihood of each impact and the sectoral consequences of these changes. A summary of the baseline climate and recent trends is described in Section 2.2.1.

2.2.1 Climate baseline and observed trends

The climate baseline[1] and more recent observed trends are described in terms of four 'representative' variables; temperature, precipitation, storminess and sea level.

Temperature

The annual average baseline temperature in Ireland is approximately 9°C across most of the country, with lower temperatures of approximately 4°C at high elevations. Average summer temperatures are approximately 15°C and winter temperatures are approximately 5°C. Average maximum temperatures are approximately 14°C across most of Ireland, reaching approximately 19°C in the summer, again with lower maximum temperatures (approximately 5°C lower) seen at higher elevations. Annual average minimum temperatures are approximately 5°C to 6°C in most of the country, dropping to around 1°C at high elevations. In winter the average minimum temperature is around -2°C at the highest elevations, and approximately 1-2°C elsewhere.

Recent trend: Average annual temperatures for the 1991-2015 time period have been 2°C higher compared to the 1961-1990 baseline [9]. Further, the number of observed warm days and heatwaves per annum has increased while the number of cold snaps/frost days has decreased [10].

[1] 1961–1990 for temperature and precipitation, with lengthier (historic) baseline records for storm activity and sea levels based on available data

Precipitation

The western extent of Ireland receives significantly more precipitation than the east due to its exposure to the Atlantic Ocean. Annual average precipitation is greater than 2000mm in some high elevation areas on the west coast, such as in Kerry and Donegal, whilst average annual precipitation around Dublin in the east is approximately 700mm. In autumn and winter this spatial trend becomes more pronounced, with greater increases in precipitation in the west of the country compared to the east.

Recent trend: Observational records have shown an increase in average national annual precipitation over the most recent three decades (1981–2010) of approximately 5% (approximately 60mm) compared with the 30-year period 1961–1990 [10]. However, there is variation in the spatial distribution. Generally, larger increases in precipitation have been recorded in western Ireland. Drought events since 1991 have been observed to be less intense and lengthy compared to those that occurred in the previous 200 years.

Storminess

Ireland's location means that it is frequently exposed to storms from the North Atlantic, particularly in winter. There are several weather characteristics that typify storms:

- high wind speed
- high precipitation falling as rain, freezing rain, hail, or snow
- lightning (or thunderstorms).

Analysis of records from observations has shown that summer storm tracks over Europe vary significantly from year to year.

Coastal areas typically experience higher wind speeds than inland areas. The highest wind speeds in Ireland have been observed at Malin Head and Belmullet, located on the north and west coasts, respectively. These stations also experience the highest wind gusts, followed by Valentia, located on the coast on the south-west of Ireland. The highest wind speed records since 1942 in Ireland have been recorded in Limerick (131km/h with gusts of 182km/h) [11].

Data suggests that Malin Head, on the north coast, experiences significantly more days with gales than the other weather stations, followed by Belmullet on the west coast. However, Valentia on the southern west coast experiences the highest number of days with high precipitation (days with precipitation over 5mm) and Belmullet, on the west coast, experiences the most days of thunder.

Recent trend: A review of storm activity over the North Atlantic suggests there is no evidence of a sustained long-term trend [12], [13]. As with trends in observed winter precipitation, however, flooding for the period 1954–2008 has shown an increasing trend, particularly in winter flows for longer record stations [14], [15].

Sea level

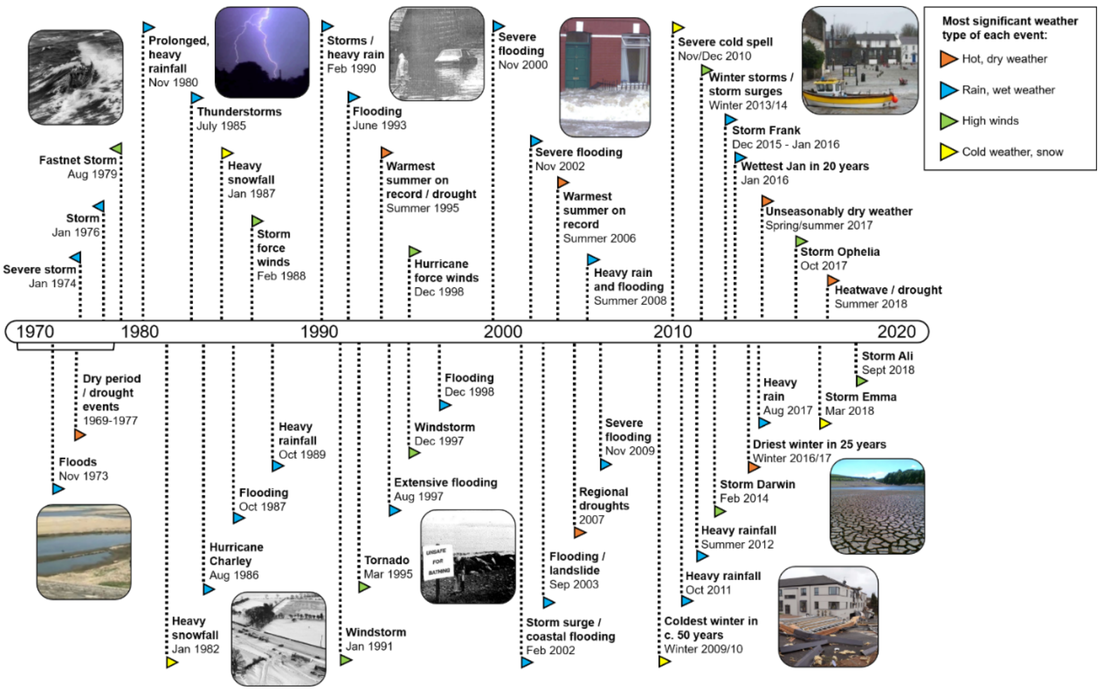
Globally, sea levels have risen by approximately 100mm since the start of the 20th century (approximately 1mm/year). When high winds coincide with high tides, resultant sea level rise (SLR) is likely to increase the impacts of storm surges.

Recent trend: Measurements from 1993 to 2015 suggest that sea level - compounded by isostatic rebound - has risen by 1-2mm/year around the west and south coasts of Ireland, and by 2-3mm/year on the east coast.

2.2.2 Extreme climatic events

To form a baseline understanding of the impact of past weather events on the water quality and water services infrastructure sectors, a summary of major observed weather events in Ireland since 1970 was prepared (Figure 4). The associated impacts on Ireland's water sector of major historic extremes have been captured in detail and are included in Appendix B, and used to inform the long-list of sectoral impacts and consequences.

Figure 4: Major historic weather events in Ireland



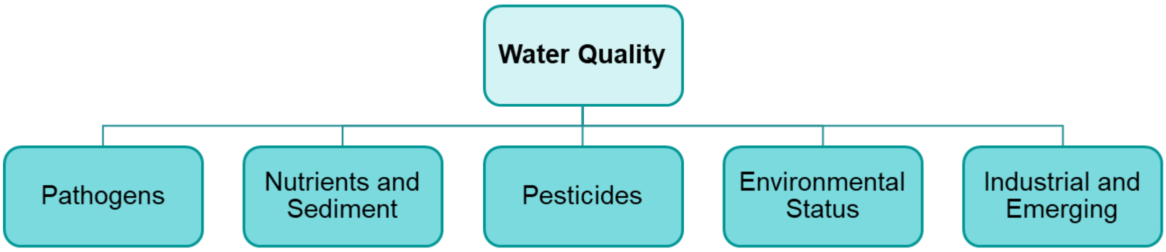
Source: Mott MacDonald (2019)

2.2.3 Sub-sectors

In developing an understanding of current and potential future impacts, several sub-sectors for both the water quality and water services infrastructure sectors have been described. Aligned with these, the long-list of sectoral impacts were developed through consultation with the SAT (Appendix A).

A breakdown of the sub-sectors that represent the water quality and water services infrastructure sectors is presented in Figure 5 and Figure 6 respectively and summarised in Figure 7. In the context of these two sectors 'water quality' refers to the biological, chemical and physical status of raw water[2] in the environment (rather than effluent water quality or treated water for supply). 'Water services infrastructure' refers to above and below ground infrastructure assets relevant to water and wastewater service provision.

Figure 5: Water quality sub-sectors



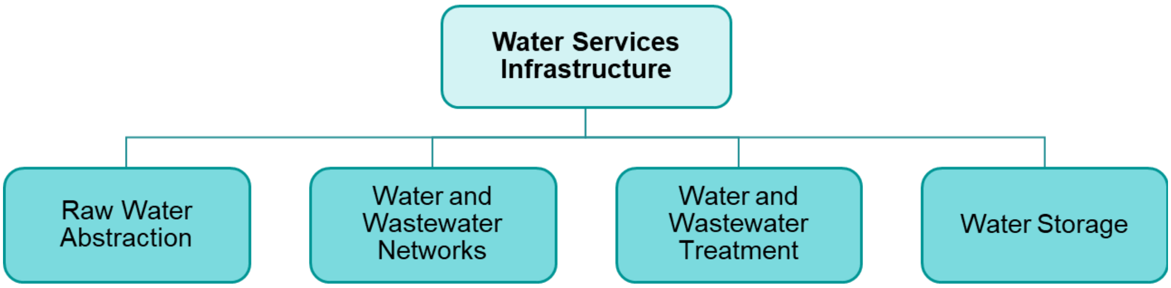
-
- Pathogens – including sources, survival, pathways and impacts on treatment. This sub-sector includes pathogens derived from agriculture, domestic and urban wastewater, urban runoff and industrial waste.
- Nutrients and sediment – including sources, pathways and impacts on treatment. This sub-sector includes nitrates, ammonia, phosphates, dissolved organic carbon and sediment, derived from domestic and urban wastewater, agriculture (e.g. fertilisers, manure, livestock excrement), urban runoff, forestry, industrial waste and historically polluted sites.
- Pesticides – including sources, degradation, pathways and impacts on treatment. The term pesticides is used to cover all plant-protection products, including herbicides,

[2] Raw water refers to water in the environment (rivers, lakes, groundwater, transitional and coastal water), or that has been abstracted from the environment that has not undergone any treatment processes. Where we refer to treated water, this is water that has been through some level of treatment process.

fungicides and molluscicides, largely from agriculture but also from forestry and industrial activities.

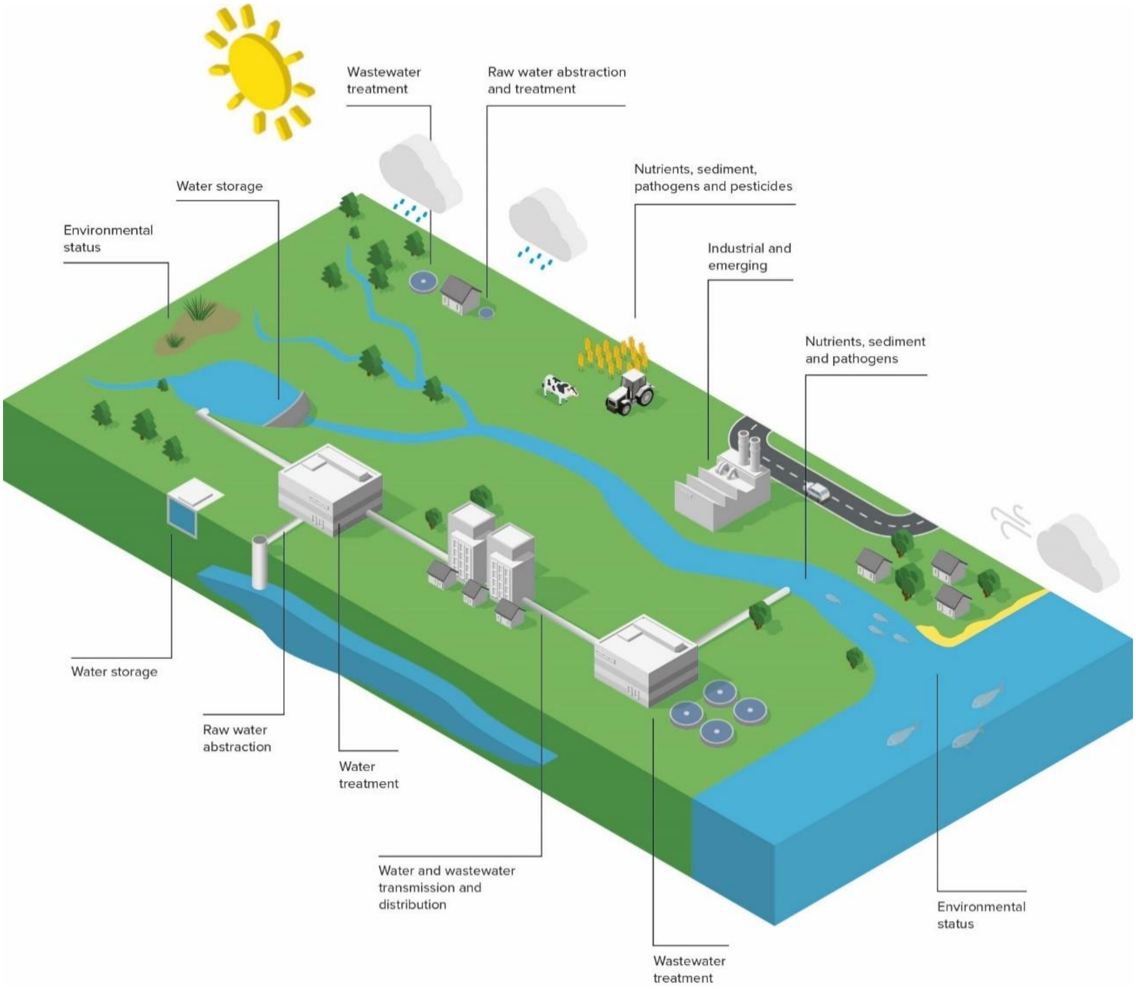
- Environmental status – capturing WFD ecological elements not captured under other sub-sectors; environmental variables directly linked to water quality (e.g. temperature, Biological Oxygen Demand, dissolved oxygen, flow), invasive species, phenology and the relationship between the environment and society
- Industrial and emerging pollutants – water quality concerns that may not be yet be measured and not be of regulatory concern but could cause impacts in the future. This includes factors such as mining, industrial cooling water, plastics, hydrocarbons and pharmaceuticals (from agricultural and human use).
-

Figure 6: Water services infrastructure sub-sectors



-
- Raw water abstraction – both regulated and unregulated from surface- and groundwater considering river flow and aquifer performance respectively.
- Water and wastewater networks (transmission and distribution) – associated assets (such as combined sewer overflows) including supply-side assets.
- Water and wastewater treatment – engineered and natural, water and wastewater treatment works and associated infrastructure and consumables, septic tanks and package plants.
- Water storage – both above and below ground reservoirs for raw or treated water, and associated infrastructure.

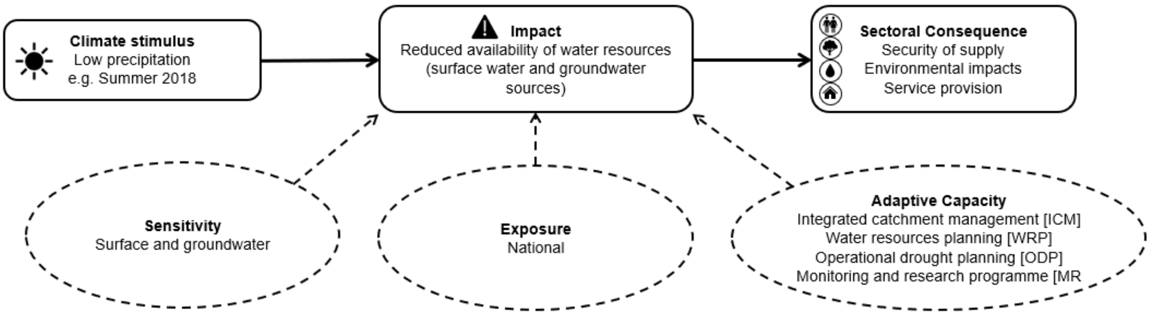
Figure 7: Water quality and water services infrastructure sub-sectors



2.2.4 Sectoral impact chains

Sectoral impact chains have been defined to capture the interrelationships between climate stimulus and sub-sector, considering sectoral sensitivity, exposure, consequences and adaptive capacity, an example of this is presented in Figure 8.

Figure 8: Example impact chain: Reduced availability of water resources



Note: This impact description is set out in full detail in Chapter 3.

As part of the impact screening exercise, a long-list of sectoral impact chains, based on current evidence, was formulated to summarise the risks posed to the water quality and water services infrastructure sectors to support understanding, systemisation and prioritisation of impacts and sectoral consequences (Appendix A). For each identified impact, an impact chain was developed to summarise the following key concepts, as set out in the DCCAE sectoral planning guidelines [1]:

- **Climate stimulus**: a series of statements of projected climate change for key stimuli to capture changes in climate variability and in the frequency and magnitude of extremes based on observed trends and modelled projections. In this assessment these have been defined as:
  - Increased/high temperature
  - Decreased/low temperature
  - Increased/high precipitation
  - Decreased/low precipitation
  - Sea level rise
  - Increased storminess[3].
- **Sensitivity**: the features/systems that are likely to be sensitive to changes in climate, for example surface water, groundwater, an ecosystem, population group, infrastructure asset.

[3] High winds, intense precipitation and other extreme storm weather, e.g. hail, lightning

- **Exposure**[4]: the spatial location of a feature/system potentially impacted upon by the climate stimulus.
- **Adaptive capacity**: the possibility for a feature/system to adapt to climate hazards through measures to reduce adverse impacts or exploit new opportunities.
- **Impacts**: impact of the climate stimulus on the system, considering sensitivity, exposure and adaptive capacity.
- **Sectoral consequence**: results from a climate impact on a feature/system and accounting for adaptive capacity.
-

The process of developing the impact chains started with consideration of all current and potential impacts of each climate variable on each water quality and water services infrastructure sub-sector. A 'long-list' of impacts was compiled (Appendix A) and then rationalised; for some sub-sectors there were no foreseeable impacts and for some there were multiple impacts of a climate variable on one sub-sector. Some were combined, e.g. high precipitation can have a similar impact on pathogens, nutrients and pesticides so these impacts were combined into one impact chain. The magnitude of the impact in terms of economic, environmental and social impacts was then assessed and an aggregate overall magnitude was assigned for each impact.

Projected changes in climate (described in Section 2.2.5) were applied to the impact chains to understand the direction of changes under a future climate. This included consideration of how a changing climate might exacerbate or ameliorate current impact magnitude, which considers sensitivity, exposure, adaptive capacity and sectoral consequence. A comparison between the impact chains reflective of the current climate, and these reflective of future climate impacts suggested that in most cases climate change will exacerbate already existing negative impacts (based on the impacts considered). One of the few exceptions is the prospect of warmer winters which could alleviate cold weather-related impacts such as freeze-thaw action affecting network assets which can lead to bursts and leakage.

These impact chains were taken forward for use in the Prioritisation step (Step 3, Section 2.3) of the adaptation planning process to prioritise future climate-related risks to the water quality and water services infrastructure sectors.

[4] It should be noted that while 'exposure' is often defined as 'national' for impact chains reflective of the current climate and that impacts could be experienced throughout Ireland, this can be still further exacerbated under the future climate. For example, areas which are already prone to flooding and which exist across the country may further increase in size under climate change.

2.2.5 Climate change projections

A summary of climate change projections against the current baseline for Ireland is necessary to inform future risks and priority adaptation options for the water quality and water services infrastructure sectors.

While detailed climate projection data exists for all climate change scenarios in the medium (2031-2060[5]) and long term[6] (2081-2100), this Plan focusses primarily on the medium-term timeframe, while the full range of emission scenarios[7] are considered (see Figure 9 for Representative Concentration pathways (RCPs) which represent the range of possible climate futures.

This climate change assessment should be read with the following principles in mind:

- In line with the precautionary principle, resilience preparation should entail adequate consideration of the 'reasonable worst-case scenario'[8], in parallel with taking actions to reduce the likelihood of the more severe projections becoming reality.
- Planning and budgetary cycles should remain adaptable whilst also keeping a long-term view - particularly when major infrastructure is being planned. However, the climate uncertainty that exists to the end of the century renders long-term planning inherently difficult because low, medium and high emission scenarios are considered equally plausible towards the end of the century (Figure 9).
- Considering this, an adaptive pathways / adaptive management approach is considered prudent in this context (beyond 2050) whereby a watching brief on all climate scenarios, associated impacts and risk values must be maintained – with adaptation actions that are appropriate and proportionate.

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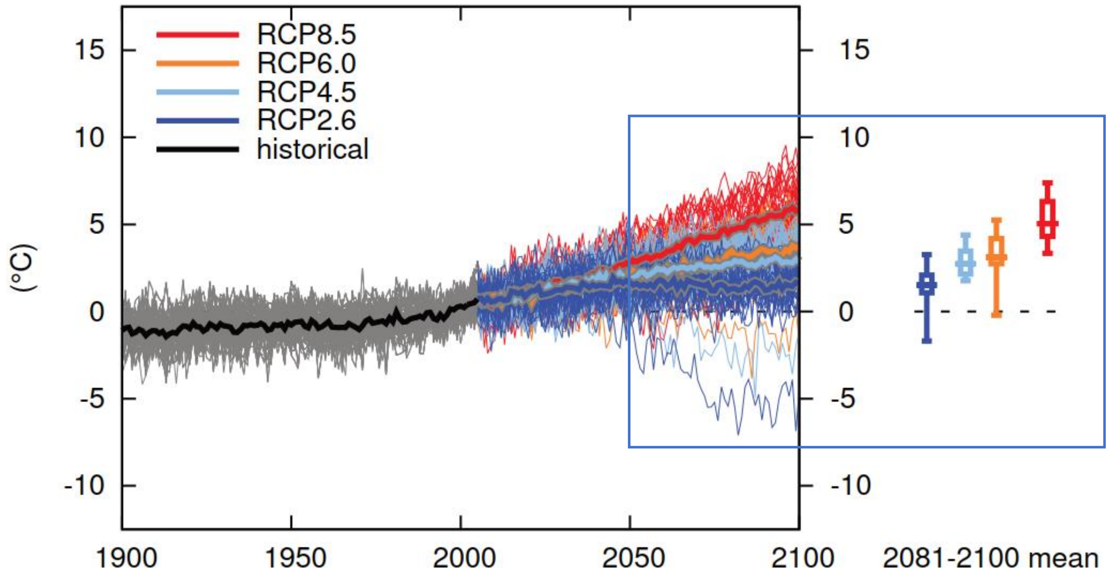
5 Referred to as the '2050s' and/or 'mid-century' going forward

6 Note: Longer term climate projections have been highlighted in the preceding Priority Impact Assessment [38] (and are summarised in this report) for the purposes of noting the aforementioned uncertainty and the need for keeping a *watching brief* with regard to the suite of priority impact chains.

7 Representing the range of emissions between RCP2.6 to RCP8.5.

8 In this context, the medium to high emission scenario range (representing the range of emissions between RCP4.5 to RCP8.5) could be considered an appropriately precautionary and plausible range to 2050 due to current relatively unabated greenhouse gas (GHG) emissions and 'committed' climate change.

Figure 9: Projected temperature change in north Europe (annual)



Source: [16]

The summaries that follow provide an indicative representation of Ireland's climatic future to mid-century. For the purposes of this report, the projected changes for each of the following climate stimuli is summarised with a qualitative outcome:

- Temperature
- Precipitation
- Storminess
- Sea level.

More (numeric) information has been captured in the preceding Priority Impact Assessment and is highlighted in the adaptation assessments that follow in Chapter 3.

A combination of research by Met Eireann (2013), Climate Ireland's Online Information Viewer and Status Tools (2018), the Environmental Protection Agency (EPA), the Irish Centre for High-End Computing (ICHEC) (funded by the EPA), research undertaken by the Climatic Research Unit of the University of East Anglia (UK) (2015), and the review undertaken by the IPCC (2013) are used to describe future changes.

It must again be emphasised that the nature of the climate system is a source of uncertainty, which is amplified by climate change. Further, this uncertainty is not uniform, particularly at a regional and sub-regional scale: while some climate variables (e.g. temperature, sea level rise) are more predictable, others (e.g. precipitation, extreme wind from storms) are less so. However, the broad scale global changes are predictable due to the physically based nature of the climate system.

Ireland's geographic location makes it particularly difficult to present very precise projection outputs with high confidence. Its climate is influenced - and therefore nuanced - by dynamics of the North Atlantic Ocean. As this can impact on the climate in unexpected ways (notwithstanding wider regional and global warming trends), the intrinsic uncertainty in climate projections must be stressed.

2.2.5.1 Temperature

Baseline annual average temperatures of 9°C could see increases in mean national annual temperatures by a minimum of 0.5°C to 1.7°C by mid-century, with more pronounced increases closer to 3°C in the south and east of the country [17].

Warming is likely to continue to be enhanced for the extreme values (i.e. hot and cold days), with highest daytime temperatures projected to rise by between 1.3 and 2.6°C in summer and lowest night-time temperatures projected to rise by between 1.4 and 3.1°C in winter - with a net increase in the frequency of heatwaves. Averaged over the whole of Ireland, the number of frost days (days when the minimum temperature is less than 0°C) is projected to decrease by between 50% - 62% across the full range of scenarios. Similarly, the number of ice days (a period of 24 hours throughout which the maximum air temperature remains below 0°C) is projected to decrease by between 73 - 82% [18].

- Long-term increase in annual average temperatures
- Chronic increase in temperature maxima, i.e. frequency/duration/magnitude of summer heatwaves, unseasonably warm winter weather, and fewer frost days
- An increase in the average length of the growing season
- Changes in acute events:
  - more heatwaves
  - fewer frost and ice days.

The projections also indicate an average increase in the length of the growing season by mid-century of approximately 35 - 40 days per year for the medium to high emission scenario range[9].

[9] Hereinafter referring to the range of emissions between RCP4.5 to RCP8.5.

2.2.5.2 Precipitation

- A net decrease in total annual precipitation and event frequencies
- Projected decreases in summer precipitation, with increased frequency/duration/magnitude of summer dry/drought periods - closely associated with higher temperatures
- An increase in winter precipitation frequencies, with notable increases in winter and autumn precipitation
- Changes in antecedent precipitation intensity and distribution, with possible increasing intensity of extreme precipitation events
- Geographical and temporal nuances in precipitation patterns from west to east (i.e. more pronounced wetting in the west in winter and more pronounced drying in the east during summer

Projected simulations for Ireland show that frequencies of heavy precipitation events will likely increase most noticeably during winter and autumn months (by approximately 20%). The percentage change in precipitation levels could increase by between 5% to 35% in the autumn and winter months under the full range of scenarios.

Conversely, dry periods are projected to increase significantly for the spring and summer months, with values ranging from 12% to 40% for the medium to high emission scenario range, and summer precipitation levels dropping by a range of 0% to -30% for all scenarios. This is expected to result in an anticipated net decrease in average annual precipitation levels (ranging between 0% and -10%) by mid-century for the medium to high emission scenario range, but with projections indicating no net loss (+10% to -10%) for the full range of emission scenarios.

'Drying' is anticipated to be more pronounced in the east of Ireland, with more pronounced 'wetting' in the west [19][10].

Increasing intensity of extreme precipitation events: As the climate warms, precipitation extremes will increase principally because a warmer atmosphere has a greater capacity to hold more water. The relationship between 'moisture-holding capacity' of the atmosphere, temperature and pressure is expressed by the Clausius-Clapeyron relation [20] which gives an approximate 7% increase in precipitation per degree Celsius of warming. Considering a precautionary, average approximately 3°C global warming by mid-century[11], the Clausius-Clapeyron relation would produce an estimated 22.5%

[10] It should be noted hereinafter, that the mention of projected regional (east-west) variations in precipitation in Ireland must be treated with the same amount of caution as for all other summarised climate projections contained in this report.

[11] This estimated 22.5% increase in precipitation intensity may require consideration when evaluating design return periods to adopt for critical infrastructure design lifespans to mid-century (considered in priority impact chains where appropriate). Seasonal variation must be duly noted.

(compound) increase in precipitation intensity against baseline extreme precipitation events.

2.2.5.3 Storminess

Current evidence and projections indicate that the overall number of North Atlantic storms may decrease by approximately 10%, but overall *intensity* has been quantified and described by the IPCC as being more likely to increase. Further, current evidence and projections predict tracks of intense storms to extend further south in the future [18].

There is, however, no firm scientific evidence or consensus as yet on the dynamics and changes to North Atlantic storms. As extreme storm events are rare, future storm-tracking research needs to be extended.

Using impact models[12], a robust signal of increasing seasonality in hydrological regimes is evident, with increases in winter and spring stream flows and a decrease in summer stream flow likely. As linked to the precipitation section, a 5% to 35% increase in the amount of water flowing through rivers is expected for the majority of catchments in the autumn and winter season by mid-century, with potential decreases of 0-30% for summer.

- Decreased frequency of North Atlantic storms (i.e. fewer North Atlantic depressions)
- Overall intensity of storm events is more likely than not to increase, with more intense associated hazards e.g. heavy precipitation, flooding, storm surge, wind, lightning, from increased convective activity
- Hail and snow may decrease
- Net decrease in high winds, but a possible increase in extreme wind associated with more intense storms.

Due to overall ground and ambient temperature warming, precipitation events in the form of snow, and possibly hail, may decrease.

In terms of wind, studies have shown significant projected decreases in the energy content of wind for the spring, summer and autumn seasons, with no significant trend in winter if current scientific evidence does not change. It could however be inferred that despite a net decrease in high winds, an increase in intense wind events (associated with more intense storms) may occur in future.

2.2.5.4 Sea level

Observed sea level rise (SLR) has been ~2-3mm per year. More recent observations and research, however, have indicated that the melting of Antarctic and Greenland land ice

[12] Where observed climate data and climate model outputs (e.g. temperature, precipitation, solar radiation) are used to forecast regional changes in variables such as freshwater availability, crop yields, coastal inundation, energy demand and forest productivity.

has been somewhat under-estimated, and this may be a conservative representation of future SLR.

While projections of global SLR under the medium to high emission scenario range are estimated at between 40mm and 60mm by mid-century, SLR is not expected to be geographically even. Projected regional SLR to mid-century, allowing for isostatic components[13], of ~250mm (Dublin/east coast of Ireland), ~440mm (Sligo/central western coasts) and ~400mm (south-west Ireland) have been projected [21].

All major cities in Ireland in coastal locations are subject to tides, and therefore any significant rise in sea levels could have major economic, social and environmental impacts due to inter alia increased coastal erosion, flooding, and damage to property and infrastructure.

- Chronic, increase in sea levels of conservatively ~2-3mm per annum
- An associated net increase in storm surge and tidal flooding.

Storm surge: Predicted changes in mean sea level will be the primary driver in magnifying the impacts of changing storm surge and wave patterns in coastal areas, coupled with more intense storm events and precipitation intensities. Observational records and analyses indicate an increase in significant wave heights of about 20cm per decade since the 1950s in the North Atlantic [22].

Expected changes in wave heights are uncertain. Recent high-resolution simulations suggest an overall decrease in the mean and extreme wave heights by mid-century [23].

However, it is expected that less frequent but higher magnitude, more destructive storm surges will be experienced at coastal locations in Ireland. These are likely to occur due to the combined effects of:

- Rising sea levels in the region
- A more-likely-than-not increased intensity of storm events and associated precipitation intensities in autumn and winter months
- Physical characteristics (e.g. low-lying topography) of the region which determine its sensitivity to storm surge, and
- Changes in fetch length which will increase wave height, exacerbated by increasing SLR

Furthermore, because there is an expected increase in the number of high-magnitude storms, larger associated surges (of > 1m) are expected by mid-century [21].

[13] Isostatic sea level change being the result of an increase or decrease in the height of the land due to counterbalancing of the earth's crust.

2.2.5.5 Longer term projections

This sub-section aims to outline the inherent uncertainty in climate projections beyond the 2050s and to the end of the century. As mentioned, this is done with a view to maintaining a watching brief on the priority climate risks which may evolve over time (as well as the moderate priority impacts described in Table 27 and Table 28). The long-term uncertainty of the future climate system means that, in certain instances, an adaptation pathway (i.e. flexible) approach should be followed.

The modelled results of two variables have been captured to the end of the century (2081-2100): surface air temperature change and relative precipitation change. These temperature and precipitation variables are considered sound proxies for understanding the different possible climatic futures.

Identifying a ‘most likely scenario’ is not possible and all future scenarios to 2100 are equally plausible. Thus, considering all emission scenarios:

- Annual mean temperature change from the baseline may range from a minimum of +0.5°C to a maximum of +4.5°C by the end of the century
- Annual mean precipitation change from the baseline may range from a minimum of -10% to a maximum of +15% by the end of the century.

As per current climate predictions to the 2050s, further increasing, chronic changes in mean temperature and precipitation to the end of the century in Ireland would result in:

- An exacerbation of hazards already associated with rising global temperatures (such as heatwaves, drought and flooding)
- A more likely than not increase in storm intensity (including acute precipitation intensity and wind intensity), and
- Increasing chronic sea level rise and acute storm surge.

2.3 Prioritisation (Step 3)

The Prioritisation step identified priority changes and impacts that in the future may result in unacceptable sectoral impacts or potential benefits. All impacts were prioritised according to the risk to water quality or to water services infrastructure, based on the expected future likelihood and magnitude of impacts.

The future likelihood and magnitude of each impact was described using the ratings presented in Table 1 and Table 2 respectively. Using the information collected and the IPCC classification of likelihoods as a guideline for 'likelihood scales' (summarised in [24] and [25]), overall likelihood ratings have been assigned to the representative climate stimuli using a scale of estimated impact return periods. These ratings represent a full range of likelihoods of climate hazards globally and regionally and as such should be viewed relative to this. Magnitude rating (1 to 3) and associated scoring was undertaken based on a combination of expert judgement and review of available evidence and literature relating to economic, environmental and social impacts. These values represent a full range of magnitudes of climate hazards in the UK (with minor amendments for Ireland) and as such should be viewed relative to this. Ultimately, the magnitude ratings selected per impact chain for each category (economic, environmental, and social) are blended to arrive at an aggregated magnitude rating (1 to 5).

Table 1: Climate stimulus likelihood rating descriptions

Score	Likelihood rating	Description of likelihood of recurring events
1	Rare	Unlikely to occur in the next 25 years, or has not occurred in the past five years
2	Unlikely	May occur once in ten years, or may have occurred in the past five years
3	Possible	Increasingly intensity, or has occurred, within the previous and next five years - but not necessarily every year
4	Likely	May occur, or has occurred, approximately once per year and in each of the previous and next five years
5	Almost Certain	Has occurred, or could occur, several times per year

Source: Mott MacDonald (2019)

Table 2: Climate impact magnitude rating descriptions

Magnitude rating (and score)	Economic	Environmental	Social
Low (1)	• Minor or very local consequences • No consequences on national or regional economy • Localised disruption of water related services • €1 million per event/year	• Short term/reversible effects on species/habitat/ landscape or ecosystem services • Localised decline in land/water/air quality • Short term loss/minor decline in quality/status of ‘designated’ sites • Adverse impact on locally important aquifer, or aquifer of unknown importance. • 50ha of valued terrestrial and aquatic habitats damaged • 100km of river, transitional and/or coastal water quality affected	• Small number affected • Small reduction in community level service provision • Within coping range of staff and citizens • 100’s affected
Medium (2)	• Widespread damage to water services infrastructure or property • An influence on regional economy • Consequences on operations and service provision initiating contingency plans • Moderate cross-sector consequences (e.g. energy, transport, health systems) • Moderate loss of employment opportunities • €10 million for a single event/year	• Important /medium term consequences on species/habitat/landscape • Medium term or moderate loss of quality/status of sites of national importance • Regional decline in land/water/air quality • Medium term or regional loss/decline in ecosystem services • Adverse impact on locally/regionally important aquifer • 500ha of valued terrestrial and aquatic habitats damaged/lost • 1000km of river, transitional and/or coastal water quality affected	• Significant numbers affected • Minor disruption to utilities • Increased inequality (e.g. through raised costs of service provision) • Consequences on health burden • Moderate reduction in community services • Moderate increased role for emergency workers • Minor impacts on individual well-being/water security • 1000’s affected • 100’s harmed • 10’s fatalities

Magnitude rating (and score)	Economic	Environmental	Social
High (3)	• Major and recurrent damage to water services infrastructure or property • Major consequences on regional and national economy • Major cross-sector consequences (e.g. energy, transport, health systems, environment, tourism, etc) • Major loss of employment opportunities • €100 million for a single event/year	• Major loss or decline in long term viability/quality/condition of species/habitat/landscape • Major or long-term decline in status condition of sites of national or international significance • Widespread decline in land/water/air quality • Widespread failure of ecosystem function or services • Major cross-sector consequences • Adverse impact on nationally important aquifer and/or vulnerable karstic systems. • 5000ha of valued terrestrial and aquatic habitats damaged/lost • 10,000km of river, transitional and/or coastal water quality affected	• Potential for many fatalities or serious harm • Major loss or disruption to utilities • Major consequences on vulnerable groups (e.g. old, young, poor) • Increase in national health burden • Large reduction in community services • Major role for emergency workers • Major impacts on individual well-being/water security • 1000's affected • 100's harmed • 10's fatalities

Source: Mott MacDonald (2018) - adapted from the CCA Sectoral Planning Guidelines, as based on the UK Climate Change Risk Assessment (2012)

The resulting future risks to the water quality and water services infrastructure sectors were calculated for each impact based on the product of the likelihood and magnitude of impacts using the risk matrix presented in Table 3. The justifications for assigning historic magnitudes are presented in [3] with watching briefs to capture research gaps, interdependencies and potential adaptation measures which could lead to a refinement of the impact and risk score in future revisions of the Adaptation Plan.

Table 3: Risk scoring matrix*: Likelihood of impact x Magnitude of impact = Risk[14]

Risk		Magnitude rating				
		1	2	3	4	5
Likelihood rating	1	1	2	3	4	5
	2	2	4	6	8	10
	3	3	6	9	12	15
	4	4	8	12	16	20
	5	5	10	15	20	25

Source: Mott MacDonald, 2019

Note: *the area indicating the acute priority risk score (a risk score >12) is indicated by a black dashed line

Impact chains with:

- Risk scores of **>12** were considered as acute priority future impacts for the water quality and water services infrastructure sectors and as such are reflected as sectoral priorities
- Risk scores of **≤12** were considered as moderate priority future impacts for the water quality and water services infrastructure sectors.

Table 4 and

Table 5 summarise the acute priority impacts for the water quality and water infrastructure sectors, respectively. Further descriptions of the 'Impact' are provided in Chapter 3. For the medium priority impact chains, a summary is presented in Appendix D.

[14] These terms are described in detail in Appendix C

Table 4: Water quality acute priority impact chains

Climate stimulus	Climate change	Impact	Risk
High precipitation	Changes in precipitation intensity and distribution (typically resulting in wetter winters particularly in the west) *Likelihood: 4*	Increased surface and sewer flooding (leading to mobilisation) *Magnitude: 4*	16
Low precipitation	Changes in precipitation intensity and distribution (typically resulting in drier summers particularly in the east) *Likelihood:4*	Low flows and water levels causing reduced dilution of pollutants *Magnitude: 4*	16
High temperatures	Increasing temperature resulting in more heatwaves, more drought and fewer frost days *Likelihood: 5*	Spread of / increased viability of pathogens *Magnitude: 3*	15
High temperatures	Increasing temperature resulting in more heatwaves, more drought and fewer frost days *Likelihood: 5*	Changes in species distribution and phenology, including native, non-native and invasive species *Magnitude: 3*	15
High temperatures	Increasing temperature resulting in more heatwaves, more drought and fewer frost days *Likelihood: 5*	Drying of peatland can result in a reduction of natural pollution attenuation and flood prevention, the leaching of ammonia, and peat slides (when followed by heavy precipitation) *Magnitude: 3*	15

Table 5: Water services infrastructure acute priority impact chains

Climate stimulus	Climate change	Impact	Risk
High temperatures	Increasing temperature resulting in more heatwaves, more drought and fewer frost days *Likelihood: 4*	Hot-weather-related changes in demand (e.g. higher daily and peak demand) *Magnitude: 5*	20
High precipitation	Changes in precipitation intensity and distribution (typically resulting in wetter winters particularly in the west) *Likelihood: 4*	More frequent water/wastewater asset flooding, asset loss and potential for environmental pollution *Magnitude: 5*	20
High precipitation	Changes in precipitation intensity and distribution (typically resulting in drier summers particularly in the east, and wetter winters particularly in the west) *Likelihood: 4*	Increased drawdown in the autumn/winter for flood capacity, leading to resource issues in the following spring/summer *Magnitude: 4*	16
Low precipitation	Changes in precipitation intensity and distribution (typically resulting in drier summers particularly in the east) *Likelihood: 4*	Reduced availability of water resources (surface water and groundwater sources) *Magnitude: 4*	16
Increased storminess	Increase in intensity of storm events (including heavy precipitation, wind, hail, lightning), but at a decreased frequency *Likelihood: 3*	More frequent water/wastewater asset flooding, asset loss and potential for environmental pollution *Magnitude: 5*	15
Increased storminess/ High temperatures / High precipitation	Increase in intensity of storm events (including heavy precipitation, wind, hail, lightning), but at a decreased frequency *Likelihood: 3-5*	Business continuity impacts/ interruptions *Magnitude: 3*	15

This prioritisation exercise demonstrated that the water quality and water services infrastructure sectors face several key future risks due to projected future climate change. It is important that along with further assessment of acute priority risks in the next Step, a watching brief is kept on key moderate priority risks as with research and monitoring the understanding of risk scores could be refined over time.

Supporting information on the prioritisation methodology is included in Appendix C.

2.4 Priority impact assessment (Step 4)

For the Priority Impact Assessment, a detailed assessment has been undertaken of the acute priority impacts that in the future may result in unacceptable sectoral impacts or potential benefits. This has been done with a view to adequately informing the identification and assessment of sectoral priorities.

The description of the future impact and sectoral consequence was informed by a detailed assessment of ongoing and projected future climate and weather-related impacts accounting for spatial and temporal variations in these and associated uncertainties (as introduced in Section 2.2.5). To give a fuller, more realistic picture of the uncertainty of future climate change, the focus is on the medium term (2050), while considering the longer term (2080 or 2100) time horizons for a range of emission scenarios. This results in the articulation of the overall direction of change.

A summary of plausible climate change and sectoral outcomes has been developed (i.e. consequences and their magnitudes) based on our understanding of current adaptive capacity, the scale and significance of future climate impacts. This systematically considers physical, institutional, operational, social, environmental, and economic consequences.

This priority impact assessment demonstrated that the water quality and water services infrastructure sectors face several key future risks due to future climate change and confirmed the outcome from the initial assessment, which formed part of Step 3 (Prioritisation). While no extreme (unacceptable) risks were identified, it is important that along with further assessment of priority risks in the next step, a watching brief is kept on the moderate priority risks as with research and monitoring the understanding of risk values could be refined over time. Sectoral consequence and associated adaptive capacity cut across the acute priority impacts described in this assessment.

2.5 Interdependencies

It must be emphasised that the mutual interaction of this plan with other sectoral (adaptation) plans for Ireland will remain an essential component of its successful implementation and overall purpose.

Water and wastewater services, and the availability of high-quality freshwater are crucial for enabling good public health, a functioning environment, and a productive economy. To limit climate-induced cascade impacts upon other sectors like agriculture, forestry, energy and health, the performance of these water service sectors must be considered in the context of other sectors – and vice versa. Thus, the implementation phase of this plan must involve consultation with other sector departments and agencies of Ireland.

To more holistically inform adaptation planning, sectoral interdependencies that were identified in the preceding Prioritisation and Impact Screening have been captured in each of the impact descriptions that follow in Chapter 3. Interdependencies with specific government departments have been identified as these are the organisations responsible for adaptation planning, but it is important to note that many (additional) organisations will be involved in the implementation of this Plan, for example the EPA, Irish Water, the National Federation of Group Water Schemes and Electricity Supply Board (ESB). Importantly, interacting United Nations (UN) Sustainable Development Goals (SDGs) have also been identified in the priority impact tables.

3 Adaptation Assessment

This Plan presents an assessment of key future climate risks to the sectors and describes a range of key potential adaptive measures. It provides strategic direction across the sectors and will inform the design, resourcing and review of policies and measures. This chapter presents an assessment of the acute priority impacts identified in the prioritisation stage for both the water quality and water infrastructure sectors. The impact assessments include a description of the impact under investigation including a description of factors that contribute to sectoral exposure and sensitivity depending on the impact being assessed. The future impact and sectoral consequences are informed by an assessment of ongoing and projected future climate and weather-related impacts while accounting for associated uncertainties, based on the work in the Impact Screening [24]. The assessment focuses primarily on the medium term (2050s) horizon, while considering the longer term at a high level for reasons of inherent uncertainty highlighted in Section 2.2.5. The assessment therefore results in the articulation of the overall direction of change to the end of the century, with more detail provided to the 2050s.

A summary of plausible climate change and sectoral outcomes has been developed (i.e. consequences and their magnitudes) based on an understanding of current adaptive capacity, the scale and significance of future climate impacts. This systematically considers physical, institutional, operational, social, environmental, and economic consequences, along with interacting socio-economics (e.g. population growth) and prevailing environmental conditions (e.g. habitat condition, soils).

To recognise alignment both between the water quality and water services infrastructure sectors and with other sectoral adaptation plans and local authority adaptation strategies, cross sectoral linkages are considered for those plans where there could be common or related impacts. Common to all linkages will be the role of national organisations such as Met Éireann and national flood forecasting and warning services which help to communicate climate risks and related impacts. In addition, it will be important, when appropriate, to engage with the private sector, for example through Local Enterprise Offices and umbrella bodies such as IBEC. This will enable businesses to integrate the findings of this plan into their planning process and be a useful consultee for cascading any actions.

These assessments are informed by professional judgement, literature review and the understanding gained through collaboration with stakeholders through the sectoral adaptation planning workshops to date. All aspects of the adaptation assessments were discussed at the planning workshops, to share findings and gain feedback to further develop the assessments, including review of identified adaptive measures and interdependencies. The views of stakeholders were integrated in the adaptation assessments presented here; where specific events or impacts are described and not specifically referenced, for example in the 'Current effects of impact' section of the assessments below, this information is based on feedback from stakeholders in the workshops.

Summaries of the definitions used for adaptive measures and sectoral consequences are presented in Table 6 and Table 7 respectively.

Table 6: Impact chain adaptive measure definitions

Adaptive measure[15]	Definition
Asset management	As per ISO 55000, the international standard for the management of assets of any kind, asset management is defined as the "coordinated activity of an organisation to realise value from assets". This includes coordinated and optimised planning, asset selection, asset acquisition/ development, asset utilisation, asset maintenance, asset life extension and asset decommissioning/renewal.
Biosecurity measures	This assessment considers the impacts of invasive species spread due to changing climate, rather than those spread due to human actions. However, biosecurity measures are still important. These measures cover steps to make sure that good hygiene practices are in place to reduce and minimise the risk of spreading invasive non-native species.
Business continuity planning	Planning to mitigate risks to the normal operation of a business/organisation.
Communication	Communication refers to outreach to citizens, customers (household and industrial), and owners and operators of private schemes and private operators. This includes warnings, (local level) awareness raising, and behavioural change campaigning as part of demand management as well as information and messaging as part of normal business operation.
Ecosystem and habitat restoration	Restoration of degraded ecosystems helps improve freshwater water quality and catchment hydrology.
Flood risk assessments and flood defences	The undertaking of studies to quantify flood risk to inform the requirement for and design of flood defences. 'Flood defences' refers to the infrastructure in place to reduce the extent, severity and duration of flooding. This can include hard, engineering solutions (e.g. flood walls) or more nature-based approaches (e.g. using leaky dams to slow the flow of water in headwaters). This also includes flood risk assessments, to inform the requirement for and design of defences.
Improved aeration and circulation	Mechanical aeration or changes to circulation of a waterbody, not wastewater treatment asset, predominantly to reduce stratification and improve water quality.

[15] Utility staff training and training for private operators is implicit for all adaptive capacity.

Adaptive measure[15]	**Definition**
Improved water/wastewater treatment	Infrastructure new builds, upgrades or other improvements to increase the effectiveness and level of treatment of both raw water and wastewater and to reduce the impact of such on the environment and public health.
Integrated catchment management	Measures to improve resilience to climate change and reduce the input of pollutants to areas draining to rivers, lakes, groundwater sources and coastal areas. Integrated catchment management (ICM) measures may be implemented at the scale of a whole catchment, or be more localised, for example actions taken by one land owner. ICM includes consideration of other interacting sectors which are likely to be involved in catchment-based measures, such as agriculture and forestry. ICM is relevant in terms of reducing inputs of pathogens, sediment, nutrients and pesticides to waterbodies. ICM is also of benefit for flood and drought management using measures such as surface water management, SuDS (Sustainable Drainage Systems) and Natural Water Retention Measures (NWRM), which can have multiple benefits beyond climate change adaptation. For example, they can enhance water quality, biodiversity, sediment and soil management, and sometime can be used as amenity areas. Stakeholder engagement forms a crucial part of ICM.
Monitoring programme and research	Implementation of a programme of monitoring to understand performance of a system (e.g. in-river water quality). This may also include numerical modelling to predict impacts. The focus of this research should be on water sector related research to enhance the adaptive capacity of the sector and reduce uncertainty to inform decisions of key stakeholders.
Operation and maintenance improvements	Improvements to operation and maintenance programmes (risk-based), for example increased maintenance frequency, or storage of increased quantities of chemicals for wastewater treatment.
Operational drought planning	A plan setting out the actions water service providers will take during a drought to maintain public water supply, including temporary restrictions on water use, leakage control, drought permit applications and publicity campaigns encouraging water conservation.
Upgrade of assets	Improvements to water and wastewater infrastructure (Capital Expenditure only), for example an increase in pipe diameter or improved design standards to inform upgrades. This also includes. local/private asset level measures.
Water resource planning	Long term and strategic planning involving all relevant stakeholders to ensure the long-term balance between water supply and demand is maintained. This includes demand management options such as leakage reduction, metering, water efficiency activities and non-potable options (e.g. rainwater/ stormwater harvesting and greywater recycling) coupled with outreach/ communication (i.e. water conservation messaging and behavioural change campaigning). Supply side options can include new sources, transmission/ distribution network improvements (e.g. improved network interconnections to address the spatial variation in water resources availability) and increased storage capacity for raw and treated water.

Adaptive measure[15]	Definition
Water and wastewater network improvements	Improvements to raw water mains and sewerage networks, for example to increase the capacity, or increase resilience to leakage/bursts.

Table 7: Impact chain sectoral consequence definitions

Sectoral consequence	Definition
Asset damage/loss	Physical damage to infrastructure. This includes temporary damage which can be repaired, and permanent loss of infrastructure.
Business continuity	According to the international standard for business continuity management systems (ISO 22301), business continuity is defined as 'the capability of the organisation to continue to deliver products or services at acceptable predefined levels following a disruptive incident.'
Environmental	Risks to the chemical, physical and ecological status of the water environment, including surface water (rivers, lakes, estuaries and marine waters) and groundwater dependent ecosystems.
Operator health	Risks to the health, safety and wellbeing of operational staff, including operators of clean and wastewater assets (e.g. Irish Water staff and private supply owners), and farmers who rely on sustainable water management for their livelihoods.
Public health (and the food chain)	Risks to the health, safety and wellbeing of the general public and food chain. This includes risks through consumption of water, contamination along the food chain and exposure to environmental hazards. This includes the potential for loss of life.
Service provision/security of supply	Risks impacting on services provided by the water sector. This includes the services agreed as per Irish Water's service level agreement, including the secure supply of sufficient, safe and wholesome water for human consumption, and the treatment of wastewater. For other stakeholders, this includes water for agricultural production, and provision of infrastructure to meet clean and wastewater demands.

Water quality

The sections below detail the in-depth assessments for each individual acute priority impact identified for the water quality sector, the key climate stimuli, descriptions of the impact and potential consequences, and key adaptive measures. A summary of current drivers through which actions can subsequently be developed by the respective organisations is provided.

3.1 Increased surface and sewer flooding leading to mobilisation of pollutants

Climate stimulus: High precipitation	Sub-sector(s): Pathogens; Nutrients & sediment; Pesticides; Environmental status; Industrial & emerging
Impact: Increased mobilisation of pollutants	

Impact description:

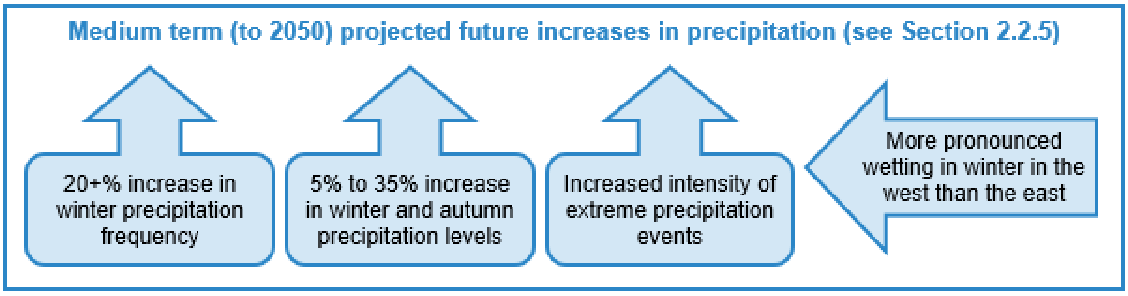
Pollutant loading from storm water runoff could increase due to more frequent and intense precipitation events. The potential sources of pollution that could be mobilised in this way include:

- Diffuse agricultural sources of pathogens and nutrients (including livestock waste, slurry, manure and fertilisers), sediment and other contaminants such as agrochemical and agricultural pharmaceutical products. For example, during heavy precipitation in August 1997, pollutants were washed into watercourses and eutrophication occurred at Lough Leane in Killarney following a major precipitation event during the growing season. There may also be other knock-on effects, for example increased flooding and/or high water tables may prompt farmers to dig new drainage facilities or clear old drainage systems, resulting in mobilisation of sediments.
- Urban and industrial pollutants, such as metals, hydrocarbons and micro-plastics. In some urban locations Dublin City Council has detected elevated levels of contamination, especially of metals, which are particularly high following the 'first flush' of contaminants in precipitation events following a dry period.
- Pollutants in wastewater networks which may be flushed through networks and discharged from Combined Sewer Overflows (CSOs) or through misconnections, including pathogens and nutrients in sewage, and industrial pollutants such as metals.

- Material containing contaminants in storage and conveyance infrastructure which may be flooded (e.g. slurry tanks, farm waste stores, septic tanks, wastewater treatment plants and network facilities, pesticide storage on farmyards).

Increased mobilisation and transport of these pollutants due to an increase in precipitation will increase the risk of contaminated sediment or water reaching freshwaters (river, lakes and groundwater), transitional and coastal water, and other areas, including homes and businesses.

Climate stimulus projection:



Impact consequences:

- Environmental risks: High pollutant concentrations and loads could negatively affect ecosystem health, impacting fish, aquatic invertebrates and vegetation, either directly through toxic effects of pollutants or indirectly through habitat damage caused by excess sediment or processes such as eutrophication caused by high nutrient loads.
- Public health risks: If pollutants are not adequately removed by the treatment processes in place and reach drinking water sources[16], or if human exposure occurs through contact with contaminated water, for example through recreational use (e.g. swimming or fishing). This risk is higher in areas with minimal treatment, for example, where water supplies are private.
- Service provision: If water cannot be adequately treated for potable use it may be diverted from supply, or Do Not Use/Boil Water notices may be required. Do Not Use/Boil Water notices could also have an increased economic impact – for example, on food businesses which may be required to invest in additional treatment technologies to avoid production losses.

[16] Throughout this report, drinking water refers to any potable water used for domestic or commercial use, for example food processing and preparation.

Key adaptive measures:

Key adaptive measures that could be considered to reduce the risks associated with this impact are:

- Monitoring programme and research [MR]: Routine monitoring of baseline pollutant concentrations, and of changes in concentration during high precipitation events will provide an evidence base to inform decision making for further measures to reduce this impact. Stormwater modelling and sewer monitoring, which Irish Water is planning under certain circumstances as part of its Business Plan, could also improve understanding of this impact and provide evidence for investment in solutions. Regular, systematic and, where appropriate, continuous monitoring, will also enable rapid response to pollution events. Research activities should coordinate with, support and learn from ongoing national research projects, including the EPA funded National Risk Assessment of Impacts of Climate Change (C-RISK) and Critical Infrastructure Vulnerability to Climate Change (CIViC) studies.
- Integrated catchment management [ICM]: In-catchment measures could provide a cost-effective, sustainable means to reduce the sources of pollutants, and to slow, limit or restrict pathways of pollutants to waterbodies. For example, agricultural pollutants such as nutrients, sediment and pesticides can be reduced by improved farming practices. Urban pollution can be reduced by implementation of Sustainable Drainage Systems (SuDS). Source protection measures such as these are being considered under the Nitrates Action Programme to improve nutrient use efficiency and break the pathways of nutrients to waterbodies, and best practice guidelines on SuDS are being developed under the River Basin Management Plan (RBMP).
- Wastewater network improvements [WNI]: Measures to reduce the risk of contamination from sewerage networks, for example:
  - increasing the capacity of existing networks and investment in hydraulically constrained treatment processes such as settling tanks
  - producing improved design standards to ensure new networks have enough capacity to carry high flows
  - identifying and fixing misconnections to ensure storm and wastewater flows are separate
  - improvements to septic tanks, and
  - implementation and enforcement of discharge licensing.

Key drivers:

Table 8 summarises the key drivers (both existing and planned) that are related to the adaptive measures above and may facilitate implementation. Table 8 also suggests linkages of this impact with other SAPs and Local Authority Adaptation Strategies, and with the UN SDGs.

Table 8: Current key drivers

Key current drivers for adaptive measures*	Cross-sectoral linkages	Related UN SDGs
• EU directives (e.g. Water Framework Directive, Floods Directive) (e) [ICM, MR] • National Water Resources Plan (p) [ICM, WNI] • NFGWS Source Protection Strategy (e) [ICM] • NFGWS 2019-2014 Strategic Plan (e) [ICM, WNI] • NFGWS Quality Assurance (HACCP) system (e) [MR, ICM] • River Basin Management Plan (e) [MR, ICM] • Irish Water Business Plan (e) [ICM, WNI] • Catchment Flood Risk Assessment and Management (e) [ICM] • DHPLG's Rural Water Programme (e) [WNI] • Irish Water's Water Services Strategic Plan (e) [ICM, WNI] • Irish Water's Drinking Water Safety Plans (p) [ICM] • Local Authority Waters Programme (LAWPro) (e) [ICM] • Agricultural Sustainability and Support Advisory Programme (e) [ICM, MR] • Environmental Requirements and Standards for Afforestation, Felling and Reforestation, and support for Woodland Creation (e) [ICM]	• Seafood (DAFM) • Agriculture (DAFM) • Forestry (DAFM) • Flood Risk Management (OPW) • Health (DOH) • Biodiversity (DCHG) • Local Authority Adaptation Strategies	

* Note: (p) planned drivers, (e) existing drivers. Abbreviations in square brackets relate to adaptive measures as described above.

3.2 Low flows and water levels causing reduced dilution of contaminants

Climate stimulus: Low precipitation	Sub-sector(s):
Impact: Reduced dilution of contaminants	Pathogens; Nutrients & sediment; Pesticides; Environmental status; Industrial & emerging

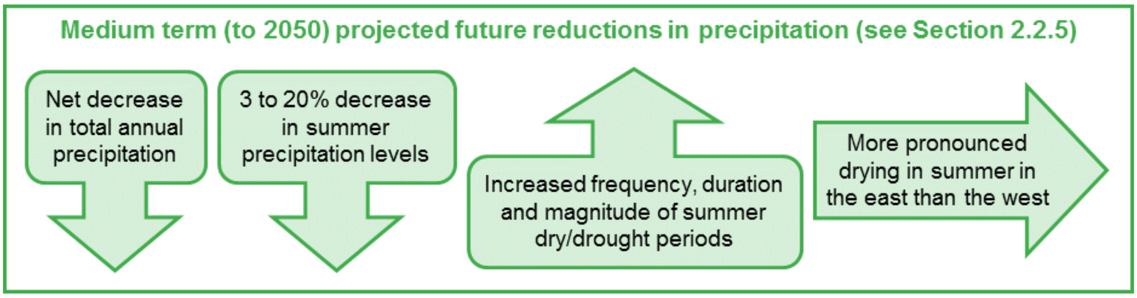
Impact description:

Lower precipitation could lead to reduced flow in rivers and a decreased volume of water in lakes and reservoirs, reducing the dilution capacity of the waterbody. This could result in elevated concentrations of pollutants reaching the affected waterbody, for example from untreated sewage discharges, spills of pesticide and industrial discharges. When groundwater levels are low, due to reduced recharge associated with reduced precipitation, there is also the potential for reduced dilution of contaminants within groundwater bodies and at springs and boreholes. When recharge and groundwater levels are low there is also the potential for increased saline intrusion into aquifers in coastal areas. In some coastal waters, particularly small embayments, low river flows into the coastal water may reduce the movement of water and flushing through the embayment, resulting in more stagnant waters and accumulation of pollutants. Deterioration of water quality due to reduced dilution will also impact water dependent habitats that are supported by connections with rivers, lakes and groundwater.

However, it should be noted that lower precipitation could also lead to reduced mobilisation and transport of these contaminants, reducing the load input to the waterbody and mitigating the impact of reduced dilution capacity in the waterbody. Lower flows (in rivers, groundwater and through lakes) could also increase the residence time of nitrates in waterbodies, resulting in increased denitrification (also increased by higher temperatures) and reduced nitrate concentrations.

In the heatwave/drought in the summer of 2018, reduction in the assimilative capacity of waters receiving discharges resulted in water quality problems. From 20th June 2018 until the end of the bathing season, bathing water in Lilliput on the shores of Lough Ennell, Co. Westmeath, was of poor quality due to elevated levels of bacteria. Water levels in the lake were low and a number of heatwave/drought related issues were suspected to contribute to the incident. In addition, high nitrate concentrations were observed in groundwater in the 2018 drought due to reduced dilution.

Climate stimulus projection:



Impact consequences:

- Public health risks: If pollutants cannot subsequently be adequately removed by the treatment processes in place and thus reach drinking water sources, or if human exposure occurs through contact with contaminated water, for example through recreational use (e.g. swimming or fishing). This risk is higher in areas with minimal treatment, for example where water supplies are private.
- Service provision: If water cannot be adequately treated for potable use it may be diverted from supply, or Do Not Use/Boil Water notices may be required.
- Environmental risks: High pollutant concentrations and loads could negatively affect ecosystem health. One potentially significant impact is the increase in nutrient concentration in rivers, lakes, reservoirs and coastal water resulting in more frequent eutrophication and algal and cyanobacterial blooms. These processes are likely to be enhanced by high temperatures, which are often associated with low precipitation. Low water levels combined with depletion of dissolved oxygen (DO) due to eutrophication and algal blooms, and the toxic effects of cyanobacteria, may result in increased fish kills and significant damage to, or local extinctions of pollution sensitive species such as freshwater pearl mussels.

Key adaptive measures:

Key adaptive measures that could be considered to reduce the risks associated with this impact are:

- Monitoring programme and research [MR]: Routine monitoring of baseline pollutant concentrations, and of increases in concentrations during dry periods will provide an evidence base to inform decision making for further measures to reduce this impact and help to understand the environmental response to reduced dilution driven by low precipitation. Regular, systematic and, where appropriate, continuous monitoring, will also enable rapid response to pollution events, allowing abstractions or discharges to be managed and adapted to limit further deterioration of water quality. Research activities should coordinate with, support and learn from ongoing national research projects, including the EPA funded National Risk Assessment of Impacts of Climate Change (C-RISK) and Critical Infrastructure Vulnerability to Climate Change (CIViC) studies.

- Integrated catchment management [ICM]: In-catchment measures could provide a cost-effective, sustainable means to reduce the sources of pollutants, and to slow, limit or restrict pathways of pollutants to waterbodies. For example, accidental spills of agricultural pollutants such as nutrients and pesticides can be reduced by improving on-farm storage of these substances and informing farmers about the potential risks, and urban pollution can be reduced by implementation of SuDS. The load of pollutants discharged to waterbodies from wastewater treatment works effluent can also be attenuated using constructed wetlands.
- Wastewater network improvements [WNI]: Measures to reduce the risk of contamination from sewerage networks, for example increasing the capacity of sewerage networks or providing storage tanks, to reduce the likelihood of spills occurring into waterbodies with low water levels (for example in an intense precipitation event following a prolonged dry period). Water treatment processes may also require improvements, as the annual deterioration of water quality due to frequent periods of low precipitation may also require additional investment and treatment upgrades to ensure that raw water is treated to a sufficient standard to produce potable water. In addition, implementation and enforcement of discharge licensing will be important to control the load of pollutants reaching water bodies.

Key drivers:

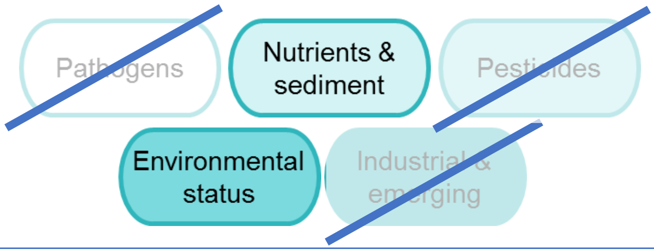
Table 9 summarises the key drivers (both existing and planned) that are related to these measures and may facilitate implementation. Table 9 also suggests linkages of this impact with other SAPs and Local Authority Adaptation Strategies, and with the UN SDGs.

Table 9: Current key drivers

Key current drivers for adaptive measures *	Cross-sectoral linkages	Related UN SDGs
• EU directives (e.g. Water Framework Directive, Floods Directive) (e) [ICM, MR] • National Water Resources Plan (p) [ICM, WNI] • NFGWS Source Protection Strategy (e) [ICM] • NFGWS 2019-2014 Strategic Plan (e) [ICM, WNI] • NFGWS Quality Assurance (HACCP) system (e) [MR, ICM] • River Basin Management Plan (e) [MR, ICM] • Irish Water Business Plan (e) [ICM, WNI] • Catchment Flood Risk Assessment and Management (e) [ICM] • DHPLG's Rural Water Programme (e) [WNI] • Irish Water's Water Services Strategic Plan (e) [ICM, WNI] • Irish Water's Drinking Water Safety Plans (p) [ICM] • Local Authority Waters Programme (LAWPro) (e) [ICM] • Agricultural Sustainability and Support Advisory Programme (e) [ICM, MR] • European watch list of additional priority substances (e) [MR]	• Agriculture (DAFM) • Forestry (DAFM) • Biodiversity (DCHG) • Health (DOH) • Local Authority Adaptation Strategies	

* Note: (p) planned drivers, (e) existing drivers. Abbreviations in square brackets relate to adaptive measures as described above.

3.3 Changes in species distribution and phenology

Climate stimulus: High temperature	Sub-sector(s):
Impact: Changes in native and non-native species distribution and phenology	

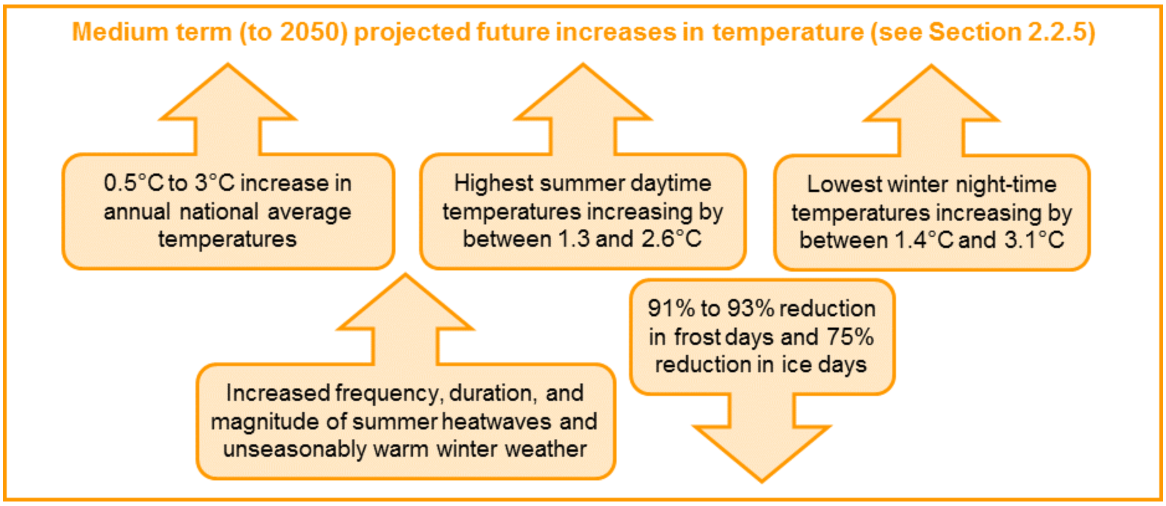
Impact description:

Changes in the distribution, population viability and phenology of native, non-native and invasive flora and fauna due to high temperatures could impact on the structure and function of marine, freshwater, and terrestrial ecosystems, affecting the ability of the aquatic environment to provide services necessary for the water quality sector. Ecological status is an important component of Water Framework Directive (WFD) classification and impacts on aquatic communities may affect achievement of Good status. Relevant to this Plan, the Draft Biodiversity Sectoral Climate Change Adaptation Plan [26] has summarised the projected climate change impacts on Ireland's biodiversity into four main categories:

- Phenology: An increase in temperature affects the timing of key life-cycle events in plant, bird and insect species. This response is likely to vary, and where there are interdependent groups of species there is the potential for mismatches in the timing of when food is available compared to when it is needed, causing disruptions in ecosystem function.
- Geographical range: Increased temperature is likely to change the range of many species, particularly where species already have distinct or narrow distributions, for example montane species or cold-water fish species that will not have areas of higher altitude/latitude to move to where temperatures are cooler. Changes in the geographical range of native or naturalised species may result in them becoming 'invasive' to a region within Ireland in which they move to where they were not previously found.
- Habitat loss: Increased temperature is likely to have a significant impact on water dependent habitats through low water levels, desiccation and erosion. Low water levels in the summer 2018 heatwave resulted in ponds drying up with impacts on newts and frogs. Ireland's habitats are already severely degraded due to past and current management activities and climate change will exacerbate the existing threats facing biodiversity.

- Invasive species. Projected shifts in temperature will likely result in the increased occurrence of invasive species and competitive pressures for Ireland's native species. This may include introduction of new pathogens and pests. The impacts above may also reduce the resilience of native Irish species to competition or predation of invasive species.

Climate stimulus projection:



Impact consequences:

Key consequences of this impact on the water quality sector include:

- Environmental risks: The environmental status and ecological quality of habitats could be affected through changes in species composition, species richness and the spread of invasive species. This may in turn impact on compliance with legislation such as the WFD, for which biological quality is an important component of WFD waterbody status, including macrophytes, phytobenthos, fish and invertebrates, all of which may be affected by the impacts described above. It is also important to consider the potential deterioration of biodiversity in terms of the intrinsic value of nature in Ireland and human well-being.
  - Water quality impacts, for example changing lake nutrient dynamics or bank erosion and sedimentation due to invasive species. The impacts described above may also impact on the resilience of aquatic habitats and ecosystems to other water quality pressures.
- Service provision: water service provision may be affected due to invasive species. Zebra mussels can block water intake pipes and have indirect impacts, for example changing nutrient cycles in lakes and causing a decline in native species.

Key adaptive measures:

Key adaptive measures that could be considered to reduce the risks associated with this impact are:

- Monitoring programme and research [MR]: Monitoring to track the spread of invasive species and to identify and monitor the changes in distribution of native species, and to allow mitigation measures to be implemented. Research will also play a key role in understanding the interconnected threats to biodiversity and the impacts that non-native and invasive species are having on the environmental status of waterbodies. Research activities should coordinate with, support and learn from ongoing national research projects, including the EPA funded National Risk Assessment of Impacts of Climate Change (C-RISK).
- Biosecurity measures [B]: Measures to limit the spread of invasive species, including good hygiene practices to minimise the risk of spreading invasive species, such as boat washing facilities, and awareness raising, for example through public information campaigns on identification and control of invasive species. Biosecurity considerations should be integrated in planning scientific and regulatory monitoring programmes and should be promoted across activities such as recreation and navigation.

Key drivers:

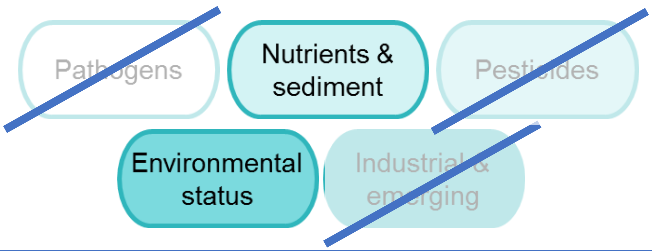
Table 10 summarises the key drivers (both existing and planned) that are related to these measures and may facilitate implementation. It also suggests linkages of this impact with other SAPs and Local Authority Adaptation Strategies, and with the UN SDGs.

Table 10: Current key drivers

Key current drivers for adaptive measures *	Cross-sectoral linkages	Related UN SDGs
• EU directives (e.g. Water Framework Directive, Floods Directive) (e) [MR, B] • River Basin Management Plan (e) [MR, B] • Local Authority Waters Programme (LAWPro) (e) [B] • Inland Fisheries Ireland biosecurity measures (IFI) (e) [B] • National Marine Planning Framework (e) [B]	• Biodiversity (DCHG) • Seafood (DAFM) • Agriculture (DAFM) • Forestry (DAFM) • Health (DOH) • Local Authority Adaptation Strategies	2 Zero hunger; 3 Good health and well-being; 13 Climate action; 14 Life below water; 15 Life on land

* Note: (p) planned drivers, (e) existing drivers. Abbreviations in square brackets relate to adaptive measures as described above.

3.4 Drying of peatland

Climate stimulus: High temperature	Sub-sector(s):
Impact: Drying of peat reducing natural pollution attenuation	

Impact description:

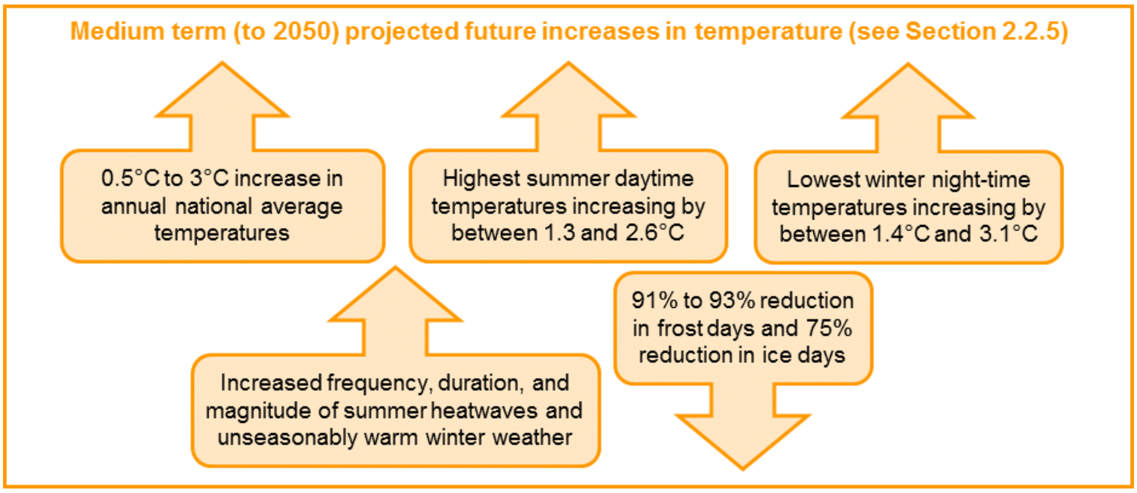
Higher air temperatures could lead to increased drying out of peatland. The water table is the primary determinant of peatland soil-organic-carbon dynamics, and sustained periods of water deficit can lead to drought conditions that reduce bog runoff and lower water levels. Peat bogs are able to adapt to changes in climate, but their resilience relies on the presence of an 'active' living peat bog surface with natural vegetation and surface patterns. This living surface has been degraded in many peat bogs through a long history of unsustainable management through drainage, land conversion to forestry and agriculture and commercial/domestic peat extraction. Although the peat extraction industry is becoming less significant in Ireland, large areas have already been affected.

Peatlands are widely distributed across Ireland, covering up to 21% of the landscape, and help support natural water resources, habitats, nutrient retention and the terrestrial carbon balance. Therefore, peatlands play an important role in ensuring environmental status and their deterioration through drying may impact on factors such as flow and services such as habitat provision. In the summer drought and heatwave event of 2018, exceptionally prolonged low water tables were recorded at Clara Bog [a Special Area of Conservation(SAC)], Abbeyleix Bog [a Natural Habitat Area (NHA)] and Girley Bog (NHA). The effects were particularly pronounced in areas of cutover bog at Girley Bog, impacting on Sphagnum translocation restoration efforts.

Peat has a natural capacity to filter pollutants in the water that flows through it, and to attenuate flood flows. Increased drying of peatlands could reduce the capacity of these areas to provide these services, with impacts on water quality and hydrology. In addition, research suggests that drinking water fed by peatlands supports the equivalent of more than 4 million people in the Republic of Ireland [27], and drying of peatland may reduce the quality and volume of water available for supply.

Lowered water tables due to climate change can modify hydrological conditions leading to increased nutrient and sediment transport to rivers and lakes resulting in significant water quality problems and toxic impacts for freshwater ecology, such as fish. This is particularly the case for degraded peatlands, which comprise most of the Irish peatland resource, as these systems can no longer retain water, nutrients and sediment as they do in undisturbed settings. Warmer temperatures also increase the rates of microbial decomposition and could cause an increase in dissolved organic carbon (DOC) in water released from the peatland. In County Monaghan, it has been observed that runoff from peat bogs following peat harvesting is lower when the bog is saturated, but that as the bog dries out runoff increases, resulting in additional desludging costs at the water source affected by the bog runoff [28].

Climate stimulus projection:



Impact consequences:

Key consequences of this impact on the water quality sector include:

- Environmental risks: Along with the environmental impacts of water quality deterioration on aquatic ecosystems, drying of peatland is also likely to impact the native vegetation and biodiversity of peatland habitats. Peatland habitats (raised bog and blanket bog) have been identified as one of the Irish habitats at most risk from climate change.
- Public health risks: If pollutants are not adequately removed by the treatment processes in place and reach drinking water sources;
- Service provision: If water cannot be adequately treated for potable use it may be diverted from supply, or Do Not Use/Boil Water notices may be required.

Key adaptive measures:

Key adaptive measures that could be considered to reduce the risks associated with this impact are:

- Monitoring programme and research [MR]: Research into peatlands and their restoration is ongoing. Research activities should coordinate with, support and learn from ongoing projects, including:
  - EPA funded National Risk Assessment of Impacts of Climate Change (C-RISK);
  - Strategies to improve Water quality from Managed Peatlands (SWAMP) project, investigating the impacts from Bord na Móna production sites;

- Vulnerability Assessment of Peatlands: Exploration of Impacts and Adaptation Options in Relation to Climate Change and Extreme Events (VAPOR); and
- Bord na Móna ongoing research into the 'after-life' options for their peatlands.
- Further coordination across the country and different organisations could help to drive this research forward and ensure investment in peatland research, restoration and management is prioritised at a national level.

- Ecosystem and habitat restoration [EHR]: Restoration of degraded peatland is key to ensure that the resilience of these environments to the impacts of climate change is maintained and enhanced. Restoration and conservation of peatland habitats is likely to result in benefits to water quality, as well as improvements to water availability, flood attenuation and carbon storage. Peatland (bog) restoration is ongoing in Ireland, through EU Life funded restoration projects and under the Bord na Móna Biodiversity Action Plan. It will be important to continue these efforts and coordinate restoration project examples and research at a national level to share best practice and provide a collaborative driving force.

Key drivers:

Table 11 summarises the key drivers (both existing and planned) that are related to these measures and may facilitate implementation. This also suggests linkages of this impact with other SAPs and Local Authority Adaptation Strategies, and with the UN SDGs.

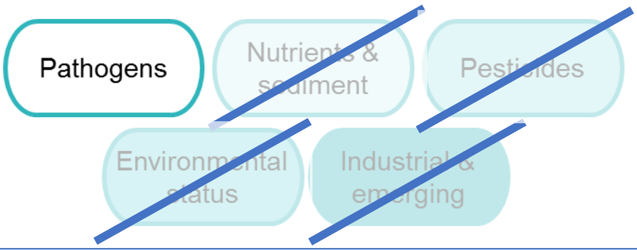
Table 11: Current key drivers

Key current drivers for adaptive measures *	Cross-sectoral linkages	Related UN SDGs
• EU directives (e.g. Water Framework Directive, Floods Directive) (e) [MR, EHR] • Bord na Móna Sustainability 2030 Strategy (e) [MR, EHR] • NPWS National Peatlands Strategy (e) [MR, EHR] • NPWS National Raised Bog SAC Management Plan 2017-2022 (e) [MR, EHR]	• Biodiversity (DCHG) • Built and Archaeological Heritage (DCHG) • Flood Risk Management (OPW) • Health (DOH) • Local Authority Adaptation Strategies	

Key current drivers for adaptive measures *	Cross-sectoral linkages	Related UN SDGs
• River Basin Management Plan (e) [MR, EHR] • Catchment Flood Risk Assessment and Management (e) [EHR] • Irish Peatland Conservation Council (e) [MR, EHR]		

* Note: (p) planned drivers, (e) existing drivers. Abbreviations in square brackets relate to adaptive measures as described above.

3.5 Spread of / increased viability of pathogens

Climate stimulus: High temperature	Sub-sector(s):
Impact: Increased pathogen pollution	

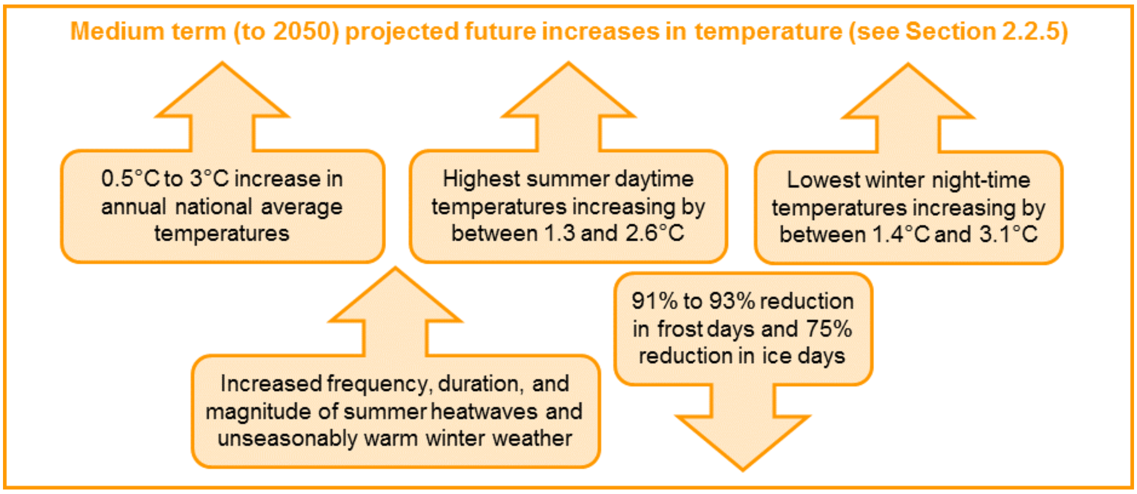
Impact description:

Higher temperatures could increase the viability of pathogens, from both rural (livestock and domestic wastewater treatment systems) and urban sources (wastewater discharges). In the heatwave/drought of summer 2018, there were parametric water quality breaches and a possible large waterborne outbreak. From 20th June 2018 until the end of the bathing season, bathing water in Lilliput on the shores of Lough Ennell, Co. Westmeath, was of poor quality due to elevated levels of bacteria. Several heatwave/drought related issues were suspected to contribute to the incident.

It is important to note that the survival rates of pathogens vary between different types (bacteria, protozoans and viruses) due to differing sensitivities to changes in heat, moisture, oxygen, light, nutrients, bacterial community composition and salinity. Higher temperatures may provide more favourable conditions for some naturally occurring organisms in coastal systems, whilst some pathogens can survive for long periods in low temperatures and the rate of die-off in the environment actually increases with increasing temperatures. The combination of the factors described above will be different in different environments, for example in faecal waste, in the soil profile, in rivers, lakes, groundwater and coastal waters, and in sewerage networks. The interactions and impact of each of these variables on pathogen survival means that the link with increased temperature is not straightforward [29] [30].

The spread of, and contact with, pathogens may increase with increasing temperatures. Warmer weather is likely to result in changes to grazing periods for livestock, and increased temperatures may increase bacterial and protozoan pathogen loads in animals [30]. High temperatures may also increase the risk of human exposure. For example, in warm summers the frequency and period of recreational use of waterbodies (for example swimming and fishing) is likely to increase. Hot weather is also likely to result in an increase in water consumption rates, and where drinking water quality is poor this will increase the risk of ingesting contaminated water [30].

Climate stimulus projection:



Impact consequences:

Key consequences of this impact on the water quality sector include:

- Environmental risks: High pathogen concentrations and loads could negatively affect ecosystem health, impacting fish aquatic invertebrates and vegetation, either directly through toxic effects of pollutants or indirectly through processes such as eutrophication and DO depletion.
- Public health risks: If pathogens are not adequately removed by the treatment processes in place and reach drinking water sources, or if human exposure occurs through contact with contaminated water, for example through recreational use (e.g. swimming or fishing) This risk is higher in areas with minimal treatment, for example where water supplies are private.

- Service provision: If water cannot be adequately treated for potable use it may be diverted from supply, or Do Not Use/Boil Water notices may be required.

Key adaptive measures:

Key adaptive measures that could be considered to reduce the risks associated with this impact are:

- Monitoring programme and research [MR]: Due to the complexities and interactions between factors affecting pathogen viability there is considerable uncertainty around this impact. Therefore, further monitoring and research to improve understanding of this impact would be valuable. Monitoring to record baseline concentrations of pathogens and increases in concentrations during dry periods will provide an evidence base to inform decision making for further measures to reduce this impact and help to understand the environmental response of pathogens to high temperature. Regular, systematic and, where appropriate, continuous monitoring, including following extreme temperature and precipitation events, will also enable rapid response to pollution events, allowing abstractions, discharges and recreational use of waterbodies to be managed and adapted to limit further deterioration of water quality.
- Integrated catchment management [ICM]: In-catchment measures could provide a cost-effective, sustainable means to reduce the sources of pathogens, and to slow, limit or restrict pathways to waterbodies. For example, the spread of pathogens from livestock sources to surface water bodies can be reduced by improved farming practices, sediment traps and riparian buffer strips.
- Improved water treatment [IWT]: Higher pathogen concentrations may change the raw water risk and quality category, requiring a higher level of treatment and intensified operations and maintenance activities to mitigate the risk.

Key drivers:

Table 12 summarises the key drivers (both existing and planned) that are related to these measures and may facilitate implementation. It also suggests linkages of this impact with other SAPs and Local Authority Adaptation Strategies, and with the UN SDGs.

Table 12: Current key drivers

Key current drivers for adaptive measures *	Cross-sectoral linkages	Related UN SDGs
• EU directives (e.g. Water Framework Directive, Floods Directive) (e) [ICM, MR]	• Health (DOH)	2 ZERO HUNGER; 3 GOOD HEALTH AND WELL-BEING

Key current drivers for adaptive measures *	Cross-sectoral linkages	Related UN SDGs
• National Water Resources Plan (p) [ICM, IWT] • NFGWS Source Protection Strategy (e) [ICM] • NFGWS 2019-2014 Strategic Plan (e) [ICM, WNI] • NFGWS Quality Assurance (HACCP) system (e) [MR, ICM] • River Basin Management Plan (e) [MR, ICM] • Irish Water Business Plan (e) [ICM, WNI] • Catchment Flood Risk Assessment and Management (e) [ICM] • DHPLG's Rural Water Programme (e) [IWT] • Irish Water's Water Services Strategic Plan (e) [ICM, IWT] • Irish Water's Drinking Water Safety Plans (p) [ICM] • Local Authority Waters Programme (LAWPro) (e) [ICM] • Agricultural Sustainability and Support Advisory Programme (e) [ICM, MR]	• Agriculture (DAFM) • Seafood (DAFM) • Biodiversity (DCHG) • Local Authority Adaptation Strategies	

* Note: (p) planned drivers, (e) existing drivers. Abbreviations in square brackets relate to adaptive measures as described above.

Water services infrastructure

The sections below detail the in-depth assessments for each individual acute priority impact identified for the water services infrastructure sector, the key climate stimuli, descriptions of the impact and potential consequences, and key adaptive measures. A summary of current drivers through which actions can subsequently be developed by the respective organisations is provided.

3.6 Hot-weather-related changes in demand

Climate stimulus: High temperatures	Sub-sector(s):
Impact: Increased water demand	Raw water abstraction; Water and wastewater networks; ~~Water & wastewater treatment~~; Water storage

Impact description:

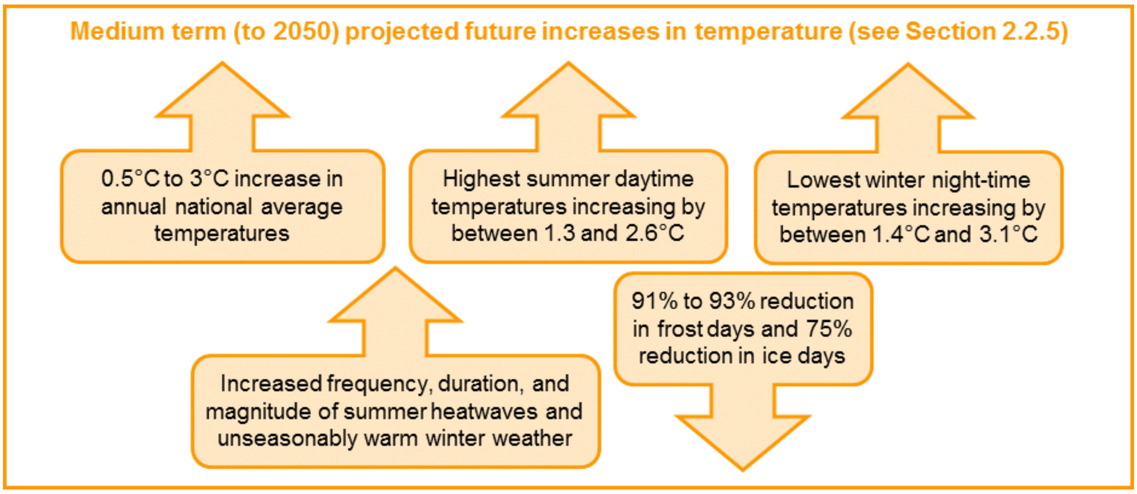
High temperatures could lead to an increase in household water demand (with respect to personal hygiene, washing, domestic garden watering and other external uses of water), industrial and agricultural demand for potable water. Changes in, and changing patterns of, demand can put increased strain on water transmission and distribution networks, as well as on supply (abstraction and storage). It should be noted that warm weather driven peak demand can, but does not have to, coincide with drought conditions. This is further addressed in the impact chain on the ‘reduced availability of water resources’.

A National Water Resources Plan is currently under preparation by Irish Water. This will indicate how far existing sources of supply are to the limits of what can be abstracted without causing adverse environmental impacts, with increases in demand having recently caused supply shortages and usage restrictions.

As detailed by Irish Water, the existing water supply sources serving Dublin and surrounding environs can currently supply 623 Million litres per day (Mld) at full production capacity under stressed conditions, against current average day demand of 540Mld. When international norms of provision for Peaks, Headroom and Supply Outage are applied, the true position is one of latent deficit.

For example, during Summer 2018 prolonged hot weather caused a significant increase in water usage across the country. In the Greater Dublin Area, Irish Water can sustainably and safely produce 623Mld.   On the 28th of June 2018, 24-hours demand reached 615 megalitres (ML). This level of demand meant drawing from treated water storage to maintain full supply. This option can only be maintained for a limited period of a few weeks. Nationally, average water demand increased within 10 days by 15% from 1,650Ml per day to 1,900Ml per day [51]. By the end of June, Irish Water reported 100 water supply schemes at risk.

Climate stimulus projection:



Impact consequences

Key consequences of this impact on the water services infrastructure sector include:

- Environmental risks: Changes in the consumptive pattern could lead to increased competition for water resources and behavioural changes in the way people access water supplies. For example, farmers investing in irrigation or increasingly going to the river to hydrate cattle may increase the consumptive pressure on surface water resources, while also increasing the risk of pollution of waterbodies (which at the same time may be used for human consumption). In case the existing fresh water resources are insufficient, increased demand could lead to the abstraction of new/ alternative sources (e.g. aquifers which have not been used in the past).
- Service provision: Increased temperature could lead to increasing household demand, which in turn could cause supply shortages, increased treatment/pumping requirements and energy use. This could have both increasing financial and carbon implications. Security of supply (i.e. increases in demand and/ or reduced availability of freshwater resources) related issues could have increasing impacts on private households and the economy. Supply side options to mitigate such impacts are very likely to incur additional costs.

Key adaptive measures:

Key adaptive measures that could be considered to reduce the risks associated with this impact are:

- Integrated catchment management [ICM] and water resource planning [WRP]: Effective water resources planning, which is in line with ICM principles, is essential to maintain the long-term balance between supply and demand. The impacts of increasing demand can be addressed through a combination of (risk based) long-term planning and operational planning approaches. The National Water Resources Plan, which is being prepared by Irish Water and is currently at draft stage, will constitute the principal long-term planning mechanism addressing interconnectivity between schemes and public water supplies to improve resilience of supply. This could be further supported by strategic peak demand planning. At utility level, operational planning can deal with more immediate assessment and management of risk.
- Monitoring programme and research [MR]: activities such as groundwater mapping to understand the extent and viability of the resource. For example, a 3D geological map of the wider Dublin area is currently being developed by Geological Survey of Ireland (GSI) for this purpose. Research activities should coordinate with, support and learn from ongoing national research projects, including the EPA funded National Risk Assessment of Impacts of Climate Change (C-RISK) and Critical Infrastructure Vulnerability to Climate Change (CIViC) studies.
- Appropriate water resources planning frameworks (e.g. abstraction licensing and/or drought planning) are crucial to maintain and manage the water supply and demand balance in a sustainable way. Demand management activities are also important; a recent report by Ofwat, the economic regulator of the UK water industry, suggested that an “average household consumption of between 50 and 70l/head/day could be achieved in 50 years without a reduction in the level of utility or quality of water use” [31]. Specific research for Ireland, taking into account local water network and demand characteristics, is needed in order to identify appropriate scenarios for changes in average household demand in Ireland.

Key drivers:

Table 13 summarises the key drivers (both existing and planned) that are related to these measures and may facilitate implementation. It also suggests linkages of this impact with other SAPs and Local Authority Adaptation Strategies, and with the UN SDGs.

Table 13: Current key drivers

Key current drivers for adaptive measures *	Cross-sectoral linkages	Related UN SDGs
• EU directives (e.g. Water Framework Directive, Floods Directive) (e) [ICM; WRP, MR]	• Agriculture (DAFM)	
• National Water Resources Plan (p) [ICM; WRP]	• Forestry (DAFM)	
• NFGWS 2019-2014 Strategic Plan (e) [ICM, WRP]	• Biodiversity (DAHG)	
• River Basin Management Plan (e) [ICM, WRP]	• Energy (DCCAE)	
• Irish Water Business Plan (e) [WRP]	• Communications (DCCAE)	
• Catchment Flood Risk Assessment and Management (e) [ICM]	• Local Authority Adaptation Strategies	
• DHPLG's Rural Water Programme (e) [WRP]		•
• Irish Water's Water Services Strategic Plan (e) [WRP]		•
• Abstraction licensing (p) [WRP]		•
		•

* Note: (p) planned drivers, (e) existing drivers. Abbreviations in square brackets relate to adaptive measures as described above.

3.7 More frequent water/wastewater asset flooding, asset loss and potential for environmental pollution

Climate stimulus: High precipitation	Sub-sector(s):
	Raw water abstraction; Water and wastewater networks; ~~Water & wastewater treatment~~; Water storage
Impact: Asset flooding, loss and potential for pollution	

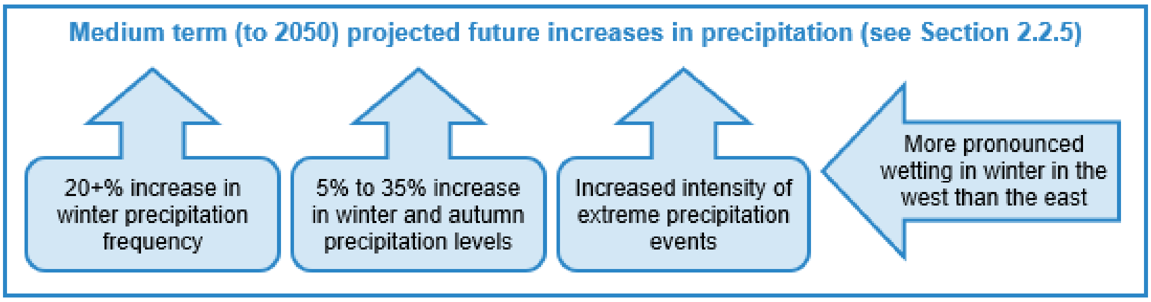
Impact description:

High precipitation could increase the frequency of pluvial/ fluvial/ groundwater flooding of water and wastewater assets leading to asset loss. This includes:

- flooding of water abstraction, storage, treatment and network assets (including private assets).
- flooding of wastewater network and treatment assets. Flooding of wastewater assets could lead to uncontrolled overflow into the environment (e.g. from failing pump stations and surcharging in wastewater networks and treatment plants). This could lead to the conveyance of pollutants into surface water and through groundwater into aquifers, contaminating water resources. In rural areas this can also include the inundation of decentralised wastewater solutions and on-site slurry systems during flooding events.

Climate change is likely to have a significant impact on flood risk as the magnitude of flooding can be directly linked to changes in future precipitation duration and intensity. In August 2017 heavy precipitation caused significant damage to road and bridge infrastructure with some direct impacts on associated water and wastewater assets and pipework: this included 17 significant water network incidents that involved pipes being affected because of flood damage to roads, bridges and waterways and six wastewater treatment plants affected by asset flooding.

Climate stimulus projection:



Impact consequences:

Key consequences of this impact on the water services infrastructure sector include:

- Asset damage/loss and environmental risks: Increased flooding could severely damage water and wastewater infrastructure (potentially leading to asset loss) and lead to contamination of waterbodies and the environment.
- Public health risks: Where drinking water resources (e.g. rivers or reservoirs) are impacted by flooding this could also have direct public health consequences. For example, due to pollutants being washed into reservoirs.

- Service provision and business continuity: Where assets are damaged/lost this could interrupt business continuity and service provision. Business continuity related impacts (e.g. the disruption of the electricity network impacting on pumping and treatment processes) are covered in the impact chain ‘business continuity impacts/interruptions’. Increased flooding of service trenches could also inhibit the ability to repair leaks. Furthermore, increased infiltration to the wastewater network due to flooding could increase wastewater pumping requirements, energy consumption and associated carbon emissions. In addition, more dilute flows can reduce treatment efficiency and additional treatment trains may be required to treat the same loads. If not addressed appropriately increased flood risk is likely to have substantial financial implications due to increased Operational Expenditure and Capital Expenditure; for example, for additional storm overflow infrastructure.

Increased flood risk could be a concern for group schemes, private supplies (some of which already experience flooding) and domestic wastewater management. Flooding can cause contaminants from various sources (including domestic wastewater facilities) to be flushed into small private wells which may not be monitored.

Key adaptive measures:

Key adaptive measures that could be considered to reduce the risks associated with this impact are:

- Integrated catchment management [ICM]: Flooding is a natural process, which depends on a variety of factors including some which are of anthropogenic origin (e.g. land use changes such as urbanisation and deforestation[17]). Whilst flood risk will never be removed it can be manged to reduce risk to human life and infrastructure. This includes ICM approaches such as sustainable land management practices and nature-based solutions. Nature based solutions such as Natural Water Retention Measures (NWRM) can have multiple benefits beyond climate change adaptation. For example, they can enhance water quality, biodiversity, sediment and soil management, and generate amenity benefits.
- Flood risk assessments and flood defences: At a policy level, flood risk assessments and flood risk management plans (FRMPs) constitute an appropriate mechanism to address flood risk. These plans identify the known risk from flooding in the communities most at risk and set out the Government’s agreed objectives to target and take forward feasible action and resources. Given the nature of flooding (i.e. a

[17] Deforestation refers to permanent forest removal and is different to clear-fells which are replanted

natural process which is sensitive to a variety of factors including changing land use), land use planning is crucial in addressing increasing flood risk. Here, the DHPLG and local authorities already play an important role through their planning functions. Therefore, as suggested by the recent report of the Joint Committee on Climate Action on 'Climate Change: A Cross-Party Consensus for Action', "climate change considerations should be addressed across all local authority plans, policies and activities including through their existing Strategic Policy Committees (SPCs) and a dedicated new Climate Change SPC for climate action. Each local authority should have a one-stop-shop or other suitable structure for provision of the necessary information."

- Monitoring programme and research [MR]: Monitoring programmes and research play a key role in understanding flood risk and improve the adaptive capacity – for example, based on data and evidence, the capacity could be further improved by supporting stronger linkages between flood risk, source protection zone planning and Drinking Water Safety Plans. Research activities should coordinate with, support and learn from ongoing national research projects, including the EPA funded National Risk Assessment of Impacts of Climate Change (C-RISK) and Critical Infrastructure Vulnerability to Climate Change (CIViC) studies.
- Asset management [AM] and upgrade of assets [AU]: The adaptive capacity can be improved by screening the asset base to identify and upgrade assets potentially 'at-risk', using historical records and undertaking detailed, asset specific studies of flood risk to determine criticality, vulnerability and risk. This could involve developing site specific hydrological and hydraulic models and combining the outputs of these with specific knowledge of elevations of critical equipment on site. This also applies at local and private level, where improved planning, regulation and communication [COM] to consider risks could help to mitigate against well flooding that could lead to water quality breaches, especially in low-lying areas.

Key drivers:

Table 14 summarises the key drivers (both existing and planned) that are related to these measures and may facilitate implementation. It also suggests linkages of this impact with other SAPs and Local Authority Adaptation Strategies, and with the UN SDGs.

Table 14: Current key drivers

Key current drivers for adaptive measures *	Cross-sectoral linkages	Related UN SDGs
• EU directives (e.g. Water Framework Directive, Floods Directive) (e) [ICM; WRP, MR] • National Water Resources Plan (p) [ICM] • NFGWS Source Protection Strategy (e) [ICM] • NFGWS 2019-2014 Strategic Plan (e) [ICM, AM] • NFGWS Quality Assurance (HACCP) system (e) [MR, ICM, AM] • River Basin Management Plan (e) [ICM, MR] • National Flood Risk Management Plans [ICM] • Catchment Flood Risk Assessment and Management (e) [ICM] • EPA project: Natural Water Retention measures (e) [ICM] • Environmental Requirements and Standards for Afforestation, Felling & Reforestation, and support for Woodland Creation [ICM] (e) • DHPLG's Rural Water Programme (e) [LPALM] • Irish Water Business Plan (e) [aspects of ICM, AM] • Irish Water's Water Services Strategic Plan (e) [aspects of ICM, AM] • DHPLG and OPW: Guidelines on the Planning System and Flood Risk Management (e) [ICM]	• Seafood (DAFM) • Biodiversity (DAHG) • Communications (DCCAE) • Flood Risk Management (OPW) • Health (DOH) • Local Authority Adaptation Strategies	

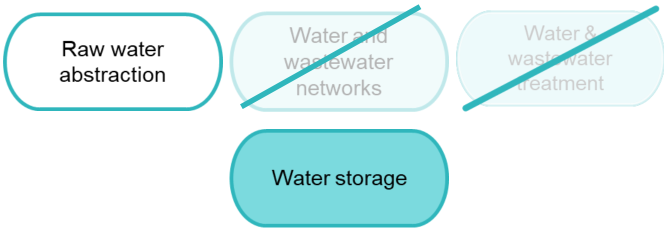
* Note: (p) planned drivers, (e) existing drivers. Abbreviations in square brackets relate to adaptive measures as described above.

3.8 Increased drawdown in the autumn/winter for flood capacity, leading to resource issues in the following spring/summer

Climate stimulus: High precipitation

Impact: Water shortages

Sub-sector(s):

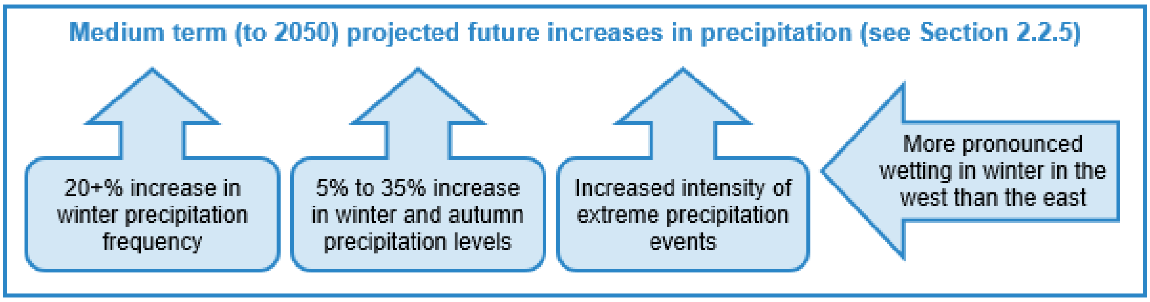


Impact description:

High precipitation could lead to the lowering of the maximum operational level of reservoirs to increase storage for potential flood waters. However, should low precipitation follow, this could lead to water shortages later in the year, or in the following year.

Historically, reservoir operators have lowered reservoir water levels to accommodate flood waters. Releasing additional flows from reservoirs can lead to knock on problems later in the year, or in the following year should low precipitation follow (i.e. water shortages). For example, increased drawdown in the autumn/winter for flood capacity can lead to water resource issues in the following spring/summer. In 2009 the Electricity Supply Board (ESB), which operates reservoirs across Ireland, had to release water from Inniscarra Reservoir, which contributed to low water levels during the summer of the same year. Also, during summer 2018, inflows to the upper and middle catchments of the River Lee reduced to the extent that water levels behind Inniscarra dam dropped below the spillway level and the compensation flow had to be pumped over the dam and into the Lower Lee.

Climate stimulus projection:



Impact consequences:

Key consequences of this impact on the water services infrastructure sector include:

- Security of supply and service provision: Increased drawdown of reservoirs to increase flood capacity could cause water shortages impacting the security of supply and service provision. Hence, the consequences of this impact are comparable to the consequences of 'hot-weather-related changes in demand' and 'reduced availability of water resources' due to low precipitation: if surface water resources (i.e. primarily rivers, but may include some reservoir storage) are insufficient this could lead to the increased abstraction from other sources such as groundwater (e.g. aquifers which have not been used in the past). Supply shortages and interruptions could have increasing impacts on private households and the economy. Supply side options to mitigate such impacts are very likely to incur additional costs for the service provider.
- Moreover, an increase in precipitation and a potential exacerbation of flood risk leading to increased drawdown of reservoirs to increase flood capacity could pose an increasing challenge to reservoir management and dam safety. Potential adaptation measures to increase flood capacity of reservoirs are likely to incur significant costs.

Key adaptive measures:

Key adaptive measures that could be considered to reduce the risks associated with this impact are:

- Water resource planning [WRP] and integrated catchment management [ICM]: Potential water shortages can be addressed by risk-based water resources planning considering a diversification in supply and various demand management measures. Furthermore, ICM to manage river flows could mitigate this impact. Where there is interconnectivity between different sectors, for example water and energy, coordination amongst all stakeholders should be ensured.

- Flood risk assessments and flood defences [FRAFD]: It is important to understand reservoir specific flood risk as operational reservoir levels are lowered in response to anticipated flood water. Therefore, site-specific flood risk assessments (including a reassessment to take account of climate change impacts) should be conducted. A review of design flood values and Probable Maximum Flood values (PMF) can be further supported by a condition assessment of the existing reservoir infrastructure (including smaller dams). The outcomes of the flood risk assessment should then inform asset management / asset upgrades.
- Asset management [AM]: The upgrading of assets to increase storage capacity could further mitigate this impact. For any asset related measure, it is important to note that reservoir management and dam safety should be considered in conjunction.

Key drivers:

Table 15 summarises the key drivers (existing and planned) that are related to these measures and may facilitate implementation. Table 15 also suggests linkages of this impact with other SAPs and Local Authority Adaptation Strategies, and with the UN SDGs.

Table 15: Current key drivers

Key current drivers for adaptive measures *	Cross-sectoral linkages	Related UN SDGs
• EU directives (e.g. Water Framework Directive, Floods Directive) (e) [ICM, WRP] • National Water Resources Plan (p) [WRP] • NFGWS 2019-2014 Strategic Plan (e) [ICM, AM, WRP] • NFGWS Quality Assurance (HACCP) system (e) [MR, ICM, AM] • River Basin Management Plan (e) [ICM] • Irish Water Business Plan (e) [AM] • Catchment Flood Risk Assessment and Management (e) [ICM] • Irish Water's Water Services Strategic Plan (e) [AM] • Dam safety legislation (p) [AM]	• Energy (DCCAE) • Communications (DCCAE) • Flood Risk Management (OPW) • Local Authority Adaptation Strategies	

Note: (p) planned drivers, (e) existing drivers. Abbreviations in square brackets relate to adaptive measures as described above.

3.9 Reduced availability of water resources (surface water and groundwater sources)

Climate stimulus: Low precipitation	**Sub-sector(s):** Raw water abstraction; Water and wastewater networks; Water & wastewater treatment; Water storage
Impact: Reduced water resource availability	

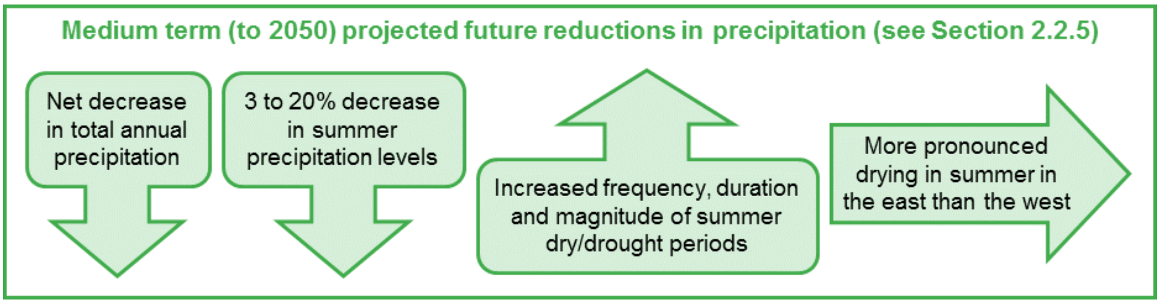
Impact description:

Low precipitation, particularly during consecutive seasons, with corresponding increases in year-round evapotranspiration could reduce river flow, reservoir refill capability and groundwater recharge.

Low precipitation could lead to supply shortages – Irish Water abstracts raw water from over 1,200 individual water sources, including lakes, rivers, streams, springs and groundwater aquifers. All these sources are reliant on enough precipitation to recharge them [51]. Most surface water sources are run-of-river without storage and may be susceptible to relatively short dry periods.

In Summer 2018 prolonged hot and dry weather put significant strain on water resources across Ireland. The drought conditions had two principal effects on water supplies. Firstly, water resources diminished, reducing the water available for abstraction. Secondly, demand levels increased in many sectors, with greater than normal volumes of water being used by customers. Out of 790 water treatment plants that make up the public water supply, using the SPI index (a drought index, which assess the current rainfall relative to the historical record), 87% of the supplies were in areas experiencing drought or extreme drought conditions [32].

Climate stimulus projection:



Impact consequences:

Key consequences of this impact on the water services infrastructure sector include:

- Environmental risks: If new resources are not sufficiently monitored and understood there can be a risk of over abstraction. Furthermore, in case public supplies are deemed unreliable this could encourage the drilling of wells to replace or supplement public water services. This could pose risks as the drilling of wells is unregulated outside of the public sector. Currently, there are no statutory requirements/ regulations on how to drill a well (although development works would be subject to the requirements as set out in the Planning and Development Act, 2000 and associated regulations), although, since November 2018 there is a 25m^3/day threshold for registering wells.
- Security of supply: Lower precipitation in summer is likely to put increasing strain on the water transmission and distribution network, as well as on supply. This can affect the security of supply and service provision. Security of supply related issues (i.e. reduced availability of freshwater resources) could lead to the abstraction of new/ alternative sources (e.g. aquifers which have not been used in the past). For example, for Dublin and the Midlands, Irish Water has concluded that existing water supply sources do not have the capacity or resilience to meet future requirements of homes and businesses [33].
- Service provision: supply interruptions could have increasing impacts on private households and the economy. Supply side options to mitigate such impacts are very likely to incur additional costs for the service provider.

Key adaptive measures:

Key adaptive measures that could be considered to reduce the risks associated with this impact are:

- Water resource planning [WRP] and operational drought planning [ODP]: Reduced availability of water resources is a key risk for any water services supplier (including group water schemes and private supplies), with a clear potential impact on service levels. This risk can be addressed through long-term water resources planning (e.g. the National Water Resources Plan (NWRP)[18] which is currently at draft stage, and the RBMP), and through operational (drought) planning, which seeks to deal with more immediate assessment and management of risk. The benefits of these will be maximised by ensuring multi-sector collaboration between sectors which rely on water resources and emphasising connectivity between water resource schemes (as is addressed in the NWRP). This can include issuing water conservation orders, deployment of additional 'find and fix' leakage teams, enhanced pressure management, water tankering and (media) communication to encourage water conservation. At utility level the supply-demand balance can be improved by either bringing additional sources into supply or conserving existing sources and/or controlling demand.
- Integrated catchment management [ICM]: Outcomes can be further improved when any option taken forward forms part of an ICM approach (which is in line with the provisions of the WFD and RBMP). Based on a good understanding of catchments and the magnitude of the respective abstractions in relation to the catchment characteristics, this should include working with local suppliers (i.e. group water schemes and private supplies) and users across all sectors. This allows to consider the more indirect impacts of reduced availability of water resources on agriculture, energy or industry. The required evidence base can be further supported by abstraction mapping, groundwater recharge mapping and groundwater/ surface water modelling activities. Where there is interconnectivity between water and energy services coordination with the ESB should be ensured.

Key drivers:

Table 16 summarises the key drivers (both existing and planned) that are related to these measures and may facilitate implementation. Table 16 also suggests linkages of this impact with other SAPs and Local Authority Adaptation Strategies, and with the UN SDGs.

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[18] As part of the National Water Resources Plan, Irish Water is developing full supply demand balance analysis for each individual water supply, to assess the capacity to meet the future requirements for homes and business in a sustainable and resilient manner.

Table 16: Current key drivers

<table>
<tr><th>Key current drivers for adaptive measures *</th><th>Cross-sectoral linkages</th><th>Related UN SDGs</th></tr>
<tr><td>

- EU directives (e.g. Water Framework Directive, Floods Directive) (e) [ICM; WRP, MR]
- National Water Resources Plan (p) [ICM; WRP]
- NFGWS 2019-2014 Strategic Plan (e) [ICM, WRP]
- NFGWS Quality Assurance (HACCP) system (e) [MR, ICM, AM]
- River Basin Management Plan (e) [ICM, WRP]
- Irish Water Business Plan (e) [WRP]
- Catchment Flood Risk Assessment and Management (e) [ICM]
- DHPLG’s Rural Water Programme (e) [WRP]
- Irish Water’s Water Services Strategic Plan (e) [WRP]
- Abstraction licensing (p) [WRP]
- Greater Dublin Area Water Restriction Management Scale (ODP)

</td><td>

- Agriculture (DAFM)
- Forestry (DAFM)
- Seafood (DAFM)
- Biodiversity (DAHG)
- Energy (DCCAE)
- Communications (DCCAE)
- Local Authority Adaptation Strategies

</td><td>

</td></tr>
</table>

* Note: (p) planned drivers, (e) existing drivers. Abbreviations in square brackets relate to adaptive measures as described above.

3.10 More frequent water/wastewater asset flooding, asset loss and potential for environmental pollution

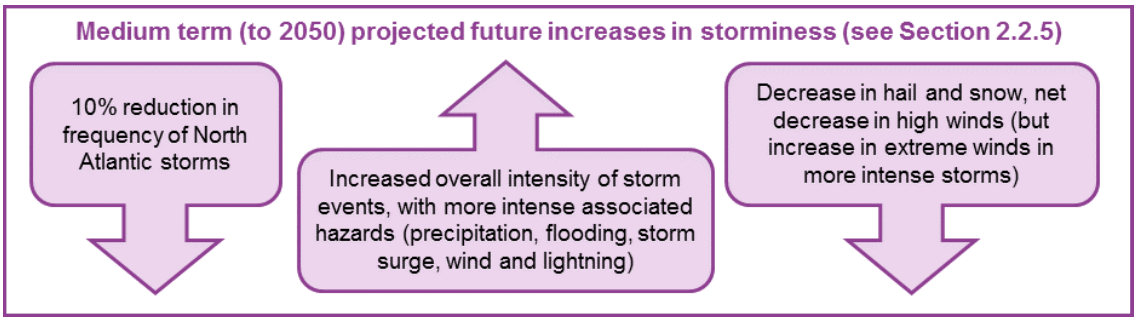
Climate stimulus: Increased storminess	**Sub-sector(s):** Raw water abstraction; Water and wastewater networks; Water & wastewater treatment; Water storage
Impact: Asset flooding and damage	

Impact description:

Increased storminess could increase the frequency of flooding (including pluvial/ fluvial/ flash and coastal flooding), high wind and ground/mass movement related damage of water/ wastewater assets. This includes:

- Flooding of water abstraction, storage, treatment and network assets (including private assets).
- Flooding of wastewater network and treatment assets. Flooding of wastewater assets could lead to uncontrolled overflow into the environment due to failing pump stations and surcharging in wastewater networks and treatment plants. This could lead to the conveyance of pollutants into surface water and through groundwater into aquifers, contaminating water resources. Furthermore, saline intrusion to the wastewater network from saline groundwater infiltration or coastal flooding may impact wastewater treatment processes.
- Damage of water abstraction, storage, treatment and network assets due to high winds and gales (this includes direct damage by high winds, airborne debris and falling trees).
- Damage of water abstraction, storage, treatment and network assets due to ground/ mass movements (this includes any form of storm induced subsidence and bulk movements of soil and/or rock debris down slopes).

Climate stimulus projection:



Impact consequences:

Key consequences of this impact on the water services infrastructure sector include:

- Asset damage/loss and environmental risks: High winds and increased flooding could severely damage water and wastewater infrastructure (potentially leading to asset loss) and lead to the contamination of waterbodies and the environment.
- Public health risks: Where drinking water resources (e.g. reservoirs) are impacted by flooding this could also have direct public health consequences. For example, due to pollutants being washed into reservoirs.
- Service provision and business continuity: Where assets are damaged/lost this could interrupt business continuity and service provision. Business continuity related impacts (e.g. the disruption of the electricity network impacting on pumping and treatment processes) are covered in the impact chain on business continuity. Increased flooding of service trenches could also inhibit the ability to repair leaks. Furthermore, increased infiltration to the wastewater network due to flooding could increase wastewater pumping requirements, energy consumption and associated carbon emissions. In addition, more dilute flows can reduce treatment efficiency as additional treatment trains may be required to treat the same loads. If not addressed appropriately increased flood risk is likely to have substantial financial implications due to increased Operational Expenditure and Capital Expenditure; for example, for additional storm overflow infrastructure.
- Increases in flood risk and high winds could be a concern for group water schemes, private supplies (some of which already experience flooding) and domestic wastewater management. Flooding can cause contaminants from various sources (including domestic wastewater facilities) being flushed into small private wells which

may not be monitored. It is estimated that there are more than 100,000 private boreholes, dug wells and springs in use [34].

Key adaptive measures:

Key adaptive measures that could be considered to reduce the risks associated with this impact are:

- Integrated catchment management [ICM]: Flooding is a natural process, which depends on a variety of factors including some which are of anthropogenic origin (e.g. land use changes such as urbanisation and deforestation). Whilst flood risk will never be removed it can be manged to reduce risk to human life and infrastructure. This includes ICM approaches such as sustainable land management practices and nature-based solutions. Nature based solutions such as NWRM can have multiple benefits beyond climate change adaptation. For example, they can enhance water quality, biodiversity, sediment and soil management, and sometimes can provide amenity benefit.
- Flood risk assessments and flood defences: At a policy level, flood risk assessments and flood risk management plans (FRMPs) constitute an appropriate mechanism to address flood risk. These plans identify the known risk from flooding in the communities most at risk and set out the Government's agreed objectives to target and take forward feasible action and resources. Given the nature of flooding (i.e. a natural process which is sensitive to a variety of factors including changing land use), land use planning is crucial in addressing increasing flood risk. Here, the DHPLG and local authorities already play an important role through their planning functions. Therefore, as suggested by the recent report of the Joint Committee on Climate Action on 'Climate Change: A Cross-Party Consensus for Action', "climate change considerations should be addressed across all local authority plans, policies and activities including through their existing SPCs and a dedicated new Climate Change SPC for climate action. Each local authority should have a one-stop-shop or other suitable structure for provision of the necessary information."
- Monitoring programme and research [MR]: Monitoring and research programmes play a key role in understanding risks associated with storminess (including flooding, strong winds, lightning, and hail) and improve the adaptive capacity – for example, based on data and evidence, the capacity could be further improved by supporting stronger linkages between flood risk, source protection zone planning and Drinking Water Safety Plans and revisioning design standards in relation to high winds. Research activities should coordinate with, support and learn from ongoing national research projects, including the EPA funded National Risk Assessment of Impacts of

Climate Change (C-RISK) and Critical Infrastructure Vulnerability to Climate Change (CIViC) studies.

- Asset management [AM] and upgrade of assets [AU]: The adaptive capacity can be improved by screening the asset base to identify and upgrade assets potentially 'at-risk' from storminess – using historical records and undertaking detailed, asset specific studies regarding storminess (including flooding, strong winds, lightning, and hail) to determine criticality, vulnerability and risk. This could involve developing site specific hydrological and hydraulic models and combining the outputs of these with specific knowledge of elevations of critical equipment on site. This also applies at local and private level, where improved planning, regulation and communication [COM] to consider risks could help to mitigate against well flooding that could lead to water quality breaches, especially in low-lying areas.

Key drivers:

Table 17 summarises the key drivers (both existing and planned) that are related to these measures and may facilitate implementation. It also suggests linkages of this impact with other SAPs and Local Authority Adaptation Strategies, and with the UN SDGs.

Table 17: Current key drivers

Key current drivers for adaptive measures *	Cross-sectoral linkages	Related UN SDGs
• EU directives (e.g. Water Framework Directive, Floods Directive) (e) [ICM; WRP, MR] • National Water Resources Plan (p) [ICM] • NFGWS Source Protection Strategy (e) [ICM] • NFGWS 2019-2014 Strategic Plan (e) [ICM, WRP] • NFGWS Quality Assurance (HACCP) system (e) [MR, ICM, AM] • River Basin Management Plan (e) [ICM, MR] • National Flood Risk Management Plans (e) [ICM] • Catchment Flood Risk Assessment and Management (e) [ICM] • EPA project: Natural Water Retention measures (e) [ICM]	• Seafood (DAFM) • Biodiversity (DAHG) • Communications (DCCAE) • Flood Risk Management (OPW) • Health (DOH) • Local Authority Adaptation Strategies	

Key current drivers for adaptive measures *	Cross-sectoral linkages	Related UN SDGs
• Environmental Requirements and Standards for Afforestation, Felling & Reforestation, and support for Woodland Creation (e) [ICM] • DHPLG's Rural Water Programme (e) [WRP] • Irish Water Business Plan (e) [aspects of ICM, AM] • Irish Water's Water Services Strategic Plan (e) [aspects of ICM, AM] • OPW: Irish Coastal Protection Strategy Study (e) [ICM] • DEHLG and OPW: Guidelines on the Planning System and Flood Risk Management (e) [ICM]		

* Note: (p) planned drivers, (e) existing drivers. Abbreviations in square brackets relate to adaptive measures as described above.

3.11 Business continuity impacts/ interruptions

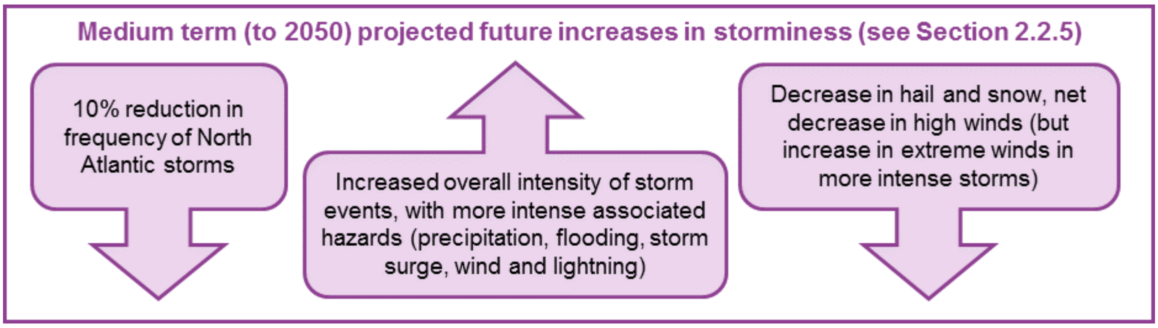
Climate stimulus: Increased storminess / High precipitation/ High temperatures 	Sub-sector(s): Raw water abstraction; Water and wastewater networks; Water & wastewater treatment; Water storage
Impact: Disruption to business continuity	

Impact description:

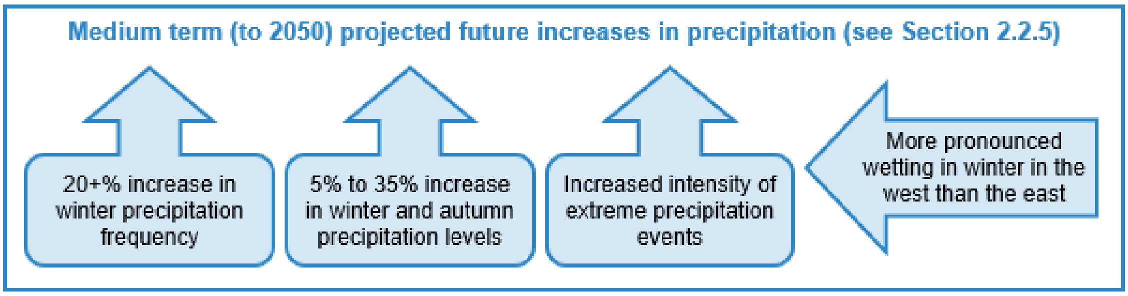
Increased storminess, high precipitation and high temperatures could impact business continuity[19]. Increased storminess (including strong winds, lightning, hail), high precipitation and high temperatures could lead to:

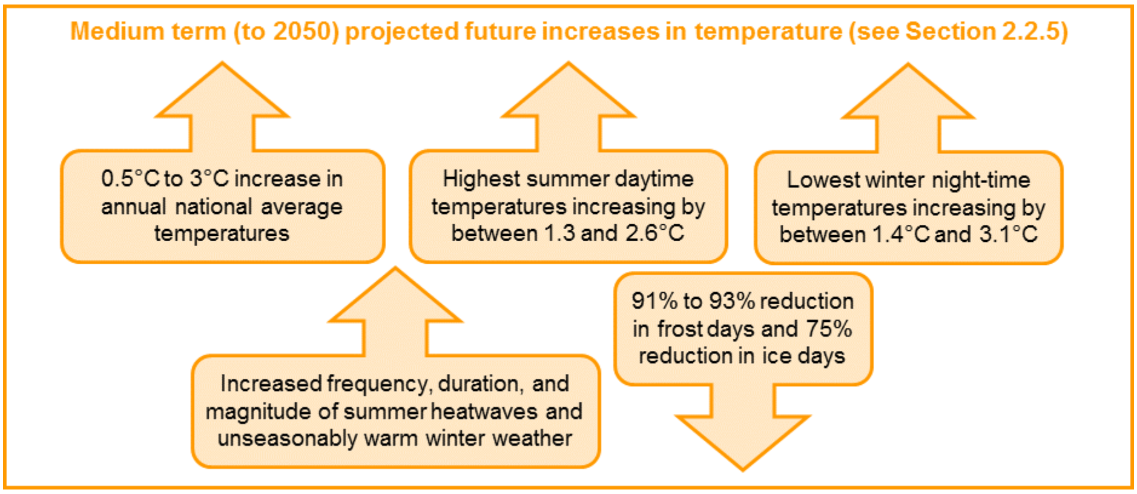
- loss/ partial loss of one or multiple sites
- power loss
- failure of ICT systems and services
- restriction on transport (consumables and staff)
- absence of staff, or the denial of access to sites
- failure of a major supplier, partner or other utility service (e.g. electricity network, online services).

Climate stimulus projection:



[19] According to the international standard for business continuity management systems (ISO 22301), business continuity is defined as 'the capability of the organisation to continue to deliver products or services at acceptable predefined levels following a disruptive incident.'





Impact consequences

Key consequences of this impact on the water services infrastructure sector include:

- Service provision and business continuity: It is expected that more severe storms will exacerbate business continuity impacts. This is likely to lead to disruptions to service provision due to asset damage/ loss, power outages, unsafe working conditions and supply chain interruptions. To ensure that responses are aligned, emergency planning and contingency planning should be a collaborative process. Any existing emergency plans should be reviewed and if necessary updated to ensure that they recognise the risks associated with climate change and more extreme weather events. This could also lead to increased Operational Expenditure and Capital Expenditure spending - for example purchasing back-up generators and/or providing alternate power supplies. If not appropriately addressed business continuity impacts could have significant knock-on effects for society, assets, the economy and the environment.

Key adaptive measures

Key adaptive measures that could be considered to reduce the risks associated with this impact are:

- Business continuity planning [BCP]: To address potential business continuity impacts/ interruptions a risk-based approach can improve the resilience of the business to disruption and can improve the ability to continue time critical business activities. An effective business continuity framework enables a service provider to maintain essential functions when the business is disrupted. Such a framework should address the full suite of potential interruptions (e.g. loss of sites, denial of access to sites, power outages, and supply chain related issues etc.). It should be noted that some business continuity management related aspects are also addressed by the Drinking Water Incident Response Plans, which Water Service Authorities are required to draft.
- Operation and maintenance improvements [OM] and asset management [AM]: Operation and maintenance improvements and asset upgrading including contingency measures for power outages can further improve a utility's resilience to business continuity impacts.
- Communication [COM]: In case of business continuity impacts/ interruptions communications with the public (considering vulnerable customers) is essential. For group water schemes advice notices can provide support on how to deal with certain events.

Key drivers:

Table 18 summarises the key drivers (both existing and planned) that are related to these measures and may facilitate implementation. Table 18 also suggests linkages of this impact with other SAPs and Local Authority Adaptation Strategies, and with the UN SDGs.

Table 18: Water services infrastructure: Business continuity impacts/ interruptions

Key current drivers for adaptive measures *	Cross-sectoral linkages	Related UN SDGs
• Irish Water business continuity framework (p) [BCP]	• Transport (DTTAS) • Energy (DCCAE)	

Key current drivers for adaptive measures *	Cross-sectoral linkages	Related UN SDGs
• Irish Water Business Plan (e) [OM, AM] • NFGWS 2019-2014 Strategic Plan (e) [OM, AM] • Irish Water's Water Services Strategic Plan (e) [OM, AM]	• Communications (DCCAE) • Flood Risk Management (OPW) • Health (DOH) • Local Authority Adaptation Strategies	 •

* Note: (p) planned drivers, (e) existing drivers. Abbreviations in brackets relate to measures as described above.

4 Plan Implementation and Monitoring

The final step of adaptation planning (Step 6) following this assessment involves implementation, monitoring, and evaluation. This will ensure that the Plan informs the design, resourcing and review of policies and measures, and provides strategic direction across the water quality and water services infrastructure sectors. Given the cyclical process defined under the NAF it is essential that this Adaptation Plan is viewed as a 'live' document and is regularly evaluated and reviewed to account for changing science and socio-economic conditions and to allow tracking and revision of the sectoral priorities as adaptation and mitigation planning and efforts are made.

4.1 Planning for action

To signpost the key cross-cutting aspects between the water quality and water services infrastructure sectors Table 19 provides an overview of the sectoral consequences relevant to the respective impact chains and Table 20 sets out the adaptive measures relevant to the respective priority impact chains. This summary allows for the identification of key sectoral actions by organisations and stakeholders throughout the water quality and water services infrastructure sectors.

- By considering these sectoral consequences and adaptive measures in future planning the residual risk associated with each impact can be minimised and it will allow for the development of goals and objectives that will allow the ongoing implementation and evaluation of adaptation efforts. This should further consider ease of implementation, cost of implementation, effectiveness of action, timeline of results, stakeholders to be involved and associated actions for implementation.

There are some key factors that must be considered throughout the implementation of this Adaptation Plan:

- As highlighted in the Introduction (Chapter 1) and in the NAF [2] social and economic policy context must be considered when considering climate change impacts and adaptation actions
- Interdependencies between the different sectors and their adaptation plans (as highlighted in Chapter 3) must be considered throughout the planning process, and each plan must ensure active engagement with other related sectors, and
- The interactions between the water quality and water services infrastructure sectors must be considered when implementing specific actions. For example, any measure implemented to provide adaptation for an aspect of water services infrastructure should not negatively impact water quality, and vice versa. The sectors should be viewed throughout the process as two elements of one overarching water sector.

- Aligned with these key factors, potential adaptive measures should be used by the sector to consider goals and objectives to promote action. These should be time-bound, and their ownership be clear to ensure that action is timely and achieves the defined outcomes.

Table 19: Sectoral consequences matrix for the water quality and water services infrastructure sectors

	Impact chain / sectoral consequences[20]	Public Health	Environmental	Security of supply	Asset damage / loss	Service provision	Business continuity
Water quality	Increased surface and sewer flooding leading to mobilisation of pollutants	✓	✓			✓	
	Reduced dilution of contaminants	✓	✓			✓	
	Spread of / increased viability of pathogens	✓	✓			✓	
	Changes in species distribution and phenology		✓		✓	✓	
	Drying of peatland	✓	✓			✓	
Water service infrastructure	Hot-weather-related changes in demand (e.g. higher daily and peak demand)		✓	✓		✓	
	More frequent water/wastewater asset flooding, asset loss and potential for environmental pollution (high precipitation)	✓	✓		✓	✓	✓
	Increased drawdown in the autumn/winter for flood capacity, leading to resource issues in the following spring/summer			✓		✓	
	Reduced availability of water resources (surface water and groundwater sources)		✓	✓		✓	
	More frequent water/wastewater asset flooding, asset loss and potential for environmental pollution (increased storminess)	✓	✓		✓	✓	✓
	Business continuity impacts/ interruptions					✓	✓

[20] Definitions provided in Chapter 3

Table 20: Adaptive capacity matrix for the water quality and water services infrastructure sectors

Impact chain		Communication	Monitoring programme and research	Integrated catchment management*	Water resources planning	Ecosystem and habitat restoration	Biosecurity measures	Flood risk assessment and defences	Asset management	Upgrade of assets	Water transmission/ distribution network	Improved water and wastewater treatment	Operation and maintenance improvements	Business continuity planning
		Adaptive measure[21]												
Water quality	Increased surface and sewer flooding leading to mobilisation of pollutants	✓	✓	✓				✓			✓			
	Reduced dilution of contaminants	✓	✓	✓				✓			✓			
	Changes in species distribution and phenology	✓	✓	✓			✓							
	Drying of peatland		✓	✓		✓								
	Spread of / increased viability of pathogens	✓	✓	✓								✓		

[21] Definitions provided in Chapter 3

	Impact chain	Adaptive measure[22]												
		Communication	Monitoring programme and research	Integrated catchment management*	Water resources planning	Ecosystem and habitat restoration	Biosecurity measures	Flood risk assessment and defences	Asset management	Upgrade of assets	Improve Water transmission/ distribution network	Improved water and wastewater treatment	Operation and maintenance improvements	Business continuity planning
Water service infrastructure	Hot-weather-related changes in demand (e.g. higher daily and peak demand)	✓	✓	✓	✓						✓			
	More frequent water/wastewater asset flooding, asset loss and potential for environmental pollution (high precipitation)		✓	✓				✓	✓	✓	✓			✓
	Increased drawdown in the autumn/winter for flood capacity, leading to resource issues in the following spring/summer			✓	✓			✓	✓	✓				
	Reduced availability of water resources (surface water and groundwater sources)	✓		✓	✓						✓			
	More frequent water/wastewater asset flooding, asset loss and potential for environmental pollution (increased storminess)		✓	✓				✓	✓	✓	✓			✓
	Business continuity impacts/ interruptions	✓							✓	✓			✓	✓

* Note: Peatland restoration is included within Integrated Catchment Management adaptive capacity

[22] Definitions provided in Chapter 3

4.2 Implementation

This assessment will inform DHPLG's policy and funding decisions and provide strategic direction across these sectors. As can be seen in Chapter 3, many policy initiatives and drivers are currently in place and have climate benefits on the water quality and water services infrastructure sectors.

The outcomes of this assessment will be used by policy makers, implementing organisations and stakeholders within the water sector to inform further, detailed adaptation planning. A summary of the potential adaptive measures for each priority impact is detailed in Table 21 aligned with the key departments and organisations whose engagement will be essential for implementation. Common to all adaptive measures will be integration with ongoing adaptation efforts and engagement through the local authorities and alignment with their adaptation strategies will be crucial.

There is a requirement for all stakeholders within the water quality and water services infrastructure sectors to examine and implement the required adaptation pathways to enable resources to be mobilised and hence efficiently build resilience to climate change impacts. A pathways approach seeks to appropriately structure adaptation decision-making for the short and (more uncertain) long term. Such pathways will have to be placed in context with other sectoral plans being implemented to ensure cross sector compatibility.

This Adaptation Plan is viewed as a 'live' document and the Plan will be evaluated and reviewed to account for changing science and socio-economic conditions via existing monitoring mechanisms (such as the Water Policy Advisory Committee, Irish Water governance arrangements). This will allow tracking and revision of the sectoral priorities as adaptation and mitigation efforts are made across the sectors.

Table 21: Implementing potential adaptive measures

Impact	Adaptive measure to address impact	Key departments and organisations
Increased surface and sewer flooding leading to mobilisation of pollutants	Implementation of a monitoring programme and research	DHPLG, OPW, DAFM, DOH, Academia
	Improved integrated catchment management	DHPLG. OPW, DAFM, DCHG
	Increased capacity across the wastewater network	DHPLG, Irish Water, NFGWS
Low flows and water levels causing reduced dilution of contaminants	Implementation of monitoring programme and undertaking research to enhance understanding of climate-related changes.	DHPLG, EPA, Academia, DOH, IFI

Impact	Adaptive measure to address impact	Key departments and organisations
	Improved integrated catchment management	DHPLG, EPA, DAFM
	Increased capacity and improved management across the wastewater network	DHPLG, Irish Water, NFGWS
Changes in species distribution and phenology	Implementation of monitoring programme and research to understand changes in distribution	DAFM, DCHG, Academia
	Integration of biosecurity measures into planning and regulatory monitoring programme	DAFM, DCHG
Drying of peatland	Supplement and coordinate existing monitoring programmes and research	DCHG, DHPLG, OPW, EPA
	Develop plans for ecosystem and habitat restoration	DCHG, EPA
Spread of / increased viability of pathogens	Implement cross-sectoral monitoring programme and research	DOH, DHPLG, DAFM, Academia
	Implement mitigation through integrated catchment management	DHPLG, OPW, DAFM, DCHG
	Implement improved water treatment	Irish Water, NFGWS, DHPLG, Academia
Hot-weather-related changes in demand	Implement integrated catchment management aligned with wider water resource planning options development	DHPLG, Irish Water
	Integrate monitoring programmes and research	DHPLG, Irish Water, Academia, GSI
	Develop appropriate water resources planning frameworks	Irish Water, NFGWS, DHPLG
More frequent water/wastewater asset flooding, asset loss and potential for environmental pollution	Develop integrated catchment management and nature-based solutions	DHPLG, OPW, DAHG
	Integrate climate change into flood risk assessments for planning and flood defence design	Irish Water, NFGWS, OPW, DAFM
	Undertake monitoring and research	DOH, EPA, Academia
	Improved asset management and upgrade of assets of ‘at-risk’ infrastructure	Irish Water, NFGWS
	Improved communication	DHPLG, OPW, Irish Water, NFGWS, DCCAE
Increased drawdown in the autumn/winter for flood capacity, leading to resource	Integrate water resource planning and integrated catchment management	Irish Water, ESB, DHPLG
	Review specifications for flood risk assessments and flood defences	OPW, ESB, DHPLG

Impact	Adaptive measure to address impact	Key departments and organisations
issues in the following spring/summer	Improved asset management and planning	Irish Water, ESB, DCCAE
	Integrate water resource planning and integrated catchment management	Irish Water, GSI, NFGWS
Reduced availability of water resources (surface water and groundwater sources)	Integrate water resource planning and operational drought planning	Irish Water, EPA, NFGWS, GSI
	Improved integrated catchment management	DAFM, OPW, DHPLG
More frequent water/wastewater asset flooding, asset loss and potential for environmental pollution	Develop integrated catchment management and nature-based solutions	DAFM, OPW, Irish Water, NFGWS
	Integrate climate change into flood risk assessments for planning and flood defence design	DAFM, OPW, Irish Water, NFGWS
	Undertake monitoring and research	Irish Water, NFGWS
	Improved asset management and upgrade of assets of 'at-risk' infrastructure	DAFM, DAHG, DCCAE, NFGWS, DHPLG
	Improved communication	Irish Water, NFGWS, DHPLG, DOH
Business continuity impacts/ interruptions	Improved business continuity planning	Irish Water, NFGWS, DTTAS, OPW
	Implement operation and maintenance improvements and asset management	DCCAE, DOH, DHPLG
	Improved communication	DHPLG, OPW, DAFM, DOH, Academia

Glossary of Key Terms

Term	Description
Acute	Severe and/or intense (weather) extremes or ‘shocks’ experienced in a given location.
Adaptation*	In human systems, the process of adjustment to actual or expected climate and its effects, to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects – whereby human intervention may facilitate adjustment to expected climate and its effects.
Adaptation pathway	A management approach designed to schedule adaptation decision-making. It identifies decisions that need to be taken in the short term and those that may be taken in future, in support of strategic, flexible, resource efficient and structured decision-making.
Adaptive capacity*	The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences.
Baseline*	The baseline (or reference) is the state against which change is measured.
Business continuity	According to the international standard for business continuity management systems (ISO 22301), business continuity is defined as “the capability of the organisation to continue to deliver products or services at acceptable predefined levels following a disruptive incident.”
Chronic	(Climate) conditions persisting for a long time, thus detracting from a climatic baseline for a given location.
Climate*	Climate in a narrow sense is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization. The relevant quantities are most often surface variables such as temperature, precipitation and wind. Climate in a wider sense is the state, including a statistical description, of the climate system.
Climate change*	A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.
Climate projection*	Simulated responses of the climate system to a range of scenarios of future emissions or concentrations of greenhouse gases and aerosols, generally derived using climate models. Climate projections are distinguished from climate predictions by their dependence on the emission/concentration/radiative forcing scenario used, which is in turn based on assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realised.
Climate hazard*	The potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources.

Term	Description
Climate stimuli*	Changes in climate variability and in the frequency and magnitude of extremes based on observed trends and modelled projections.
Emission scenario*	A plausible representation of the future development of emissions of substances that are potentially radiatively active (e.g., greenhouse gases, aerosols), based on a coherent and internally consistent set of assumptions about driving forces (such as demographic and socioeconomic development, technological change, energy and land use) and their key relationships. Concentration scenarios, derived from emission scenarios, are used as input to a climate model to compute climate projections.
Exposure*	The presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected.
Greenhouse gas*	Gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of terrestrial radiation emitted by the earth's surface, the atmosphere itself, and by clouds. This property causes the greenhouse effect.
Impact*	Effects on natural and human systems. Impacts are also referred to as consequences and outcomes. The impacts of climate change on geophysical systems, including floods, droughts, and sea level rise, are a subset of impacts called physical impacts.
Impact assessment*	The practice of identifying and evaluating, in monetary and/or non-monetary terms, the effects of climate change on natural and human systems.
Impact chain	Captures the interrelationships between climate stimulus and sub-sector, considering sectoral sensitivity, exposure and adaptive capacity.
Land use*	Land use refers to the total arrangements, activities and inputs undertaken in a certain land cover type (a set of human actions). The term land use is also used in the sense of the social and economic purposes for which land is managed (e.g., grazing, timber extraction and conservation).
Mitigation*	A human intervention to reduce the sources or enhance the sinks of greenhouse gases.
Operational drought planning	A plan setting out the actions water service providers will take during a drought to maintain public water supply, including temporary restrictions on water use, leakage control, drought permit applications and publicity campaigns encouraging water conservation.
Paris Agreement	At COP 21 in Paris, on 12 December 2015, Parties to the United Nations Framework Convention on Climate Change reached a landmark agreement to combat climate change and to accelerate and intensify the actions and investments needed for a sustainable low carbon future. The Paris Agreement central aim is to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius. Additionally, the agreement aims to strengthen the ability of countries to deal with the impacts of climate change [36].
Phenology*	The relationship between biological phenomena that recur periodically (e.g., development stages, migration) and climate and seasonal changes.

Term	Description
Raw water	Raw water refers to water in the environment (rivers, lakes, groundwater, transitional and coastal water), or that has been abstracted from the environment that has not undergone any treatment processes. Where this Plan refers to treated water, this is water that has been through some level of treatment process.
Risk	For this Plan, risk refers to the product of the likelihood and magnitude of impacts.
Sea level rise	Increase in sea level and associated increase in storm surges/tidal flooding.
Sectoral consequence	Results from a climate impact on a feature/system and accounting for adaptive capacity.
Sensitivity	The features/systems that are likely to be sensitive to changes in climate, for example surface water, groundwater, an ecosystem, population group, infrastructure asset.
Storminess	High winds, intense precipitation and other extreme storm weather, e.g. hail, lightning.
United Nations Framework Convention on Climate Change*	The Convention was adopted on 9 May 1992 in New York and signed at the 1992 Earth Summit in Rio de Janeiro by more than 150 countries and the European Community. Its ultimate objective is the 'stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system'.
Vulnerability*	The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.
Water quality	In the context of this Plan 'water quality' refers to the biological, chemical and physical status of raw water in the environment (rather than effluent water quality or treated water for supply).
Water services infrastructure	In the context of this Plan 'water services infrastructure' refers to above and below ground infrastructure assets relevant to water and wastewater service provision.

Note: * description as per IPCC Glossary definition, there are a range of different definitions of vulnerability in the literature [37]

Table of Abbreviations

Abbreviation	Description
AM	Asset Management
AU	Asset Upgrade
CCAC	Climate Change Advisory Council
CIViC	Critical Infrastructure Vulnerability to Climate Change
C-RISK	National Risk Assessment of Impacts of Climate Change
EUCSO	Combined Sewer Overflow
DAFM	Department of Agriculture, Food and the Marine
DCCAE	Department of Communications, Climate Action and Environment
DCHG	Department of Culture, Heritage and the Gaeltacht
DHPLG	Department of Housing, Planning and Local Government
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DOH	Department of Health
DTTAS	Department of Transport Tourism and Sport
EHR	Ecosystem and Habitat Restoration
EPA	Environmental Protection Agency
ESB	Electricity Supply Board
EU	European Union
GHG	Greenhouse Gas
HACCP	Hazard Analysis and Critical Control Point system
ICM	Integrated Catchment Management
ICT	Information and Communications Technology
IFI	Inland Fisheries Ireland
IPCC	Intergovernmental Panel on Climate change
LAWPro	Local Authority Waters Programme
MR	Monitoring programme and research
NAF	National Adaptation Framework

Abbreviation	Description
NCCAF	National Climate Change Adaptation Framework
NHA	Natural Habitat Area
NPPCC	National Policy Position on Climate Change
NWRP	National Water Resources Plan
OPW	Office of Public Works
RBMP	River Basin Management Plan
SAC	Special Area of Conservation
SAP	Sectoral Adaptation Plan
SAT	Sectoral Adaptation Team
SDG	Sustainable Development Goal
SEA	Strategic Environmental Assessment
SLR	Sea Level Rise
SPCs	Strategic Policy Committees
SPI	Standardized Precipitation Index
SuDS	Sustainable Drainage Systems
UN	United Nations
WFD	Water Framework Directive
WNI	Wastewater network improvements
WRP	Water Resources Planning

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6 Appendices

A. ‘Long-list’ of sectoral impacts

Aligned with the water quality and water services infrastructure sub-sectors considered in this assessment, a ‘long-list’ of sectoral impacts was developed through consultation with the SAT during the Priority Impact Assessment Stage is detailed in Table 22 and Table 23 respectively for each sector. It should be noted that this long-list is taken from the preceding report [38] and should be viewed as such, given that the descriptions of some of these impacts have not been reviewed in the latter stages of adaptation planning.

Table 22: Water Quality

Sub-sector	Climate stimulus	Climate change	Impact
Pathogens	High temperatures	Increasing temperature resulting in more heatwaves, more drought and fewer frost days	Spread of / increased viability of pathogens
Pathogens / nutrients and sediment / pesticides / industrial and emerging pollutants	High temperatures	Increasing temperature resulting in more heatwaves, more drought and fewer frost days	Drying induced ground movement and hot weather induced thermal expansion of pipes resulting in pipe cracking and leakage
	Low temperatures	Increasing temperature resulting in more heatwaves, more drought and fewer frost days	Freeze and thaw induced ground movement resulting in pipe cracking and leakage
Pathogens / nutrients and sediment / pesticides	High temperatures	Increasing temperature resulting in more heatwaves, more drought and fewer frost days	Soil shrinkage/ cracks creating rapid transport pathways
Pathogens / Nutrients and sediment / Pesticides	High temperatures	Increasing temperature resulting in more heatwaves, more drought and fewer frost days	Amended grazing and cropping seasons and changing crop types leading to changes in application
Pesticides	High temperatures	Increasing temperature resulting in more heatwaves, more drought and fewer frost days	Changes in, and distribution of pests leading to changes in application
Pathogens / nutrients and sediment / pesticides / industrial and emerging pollutants	High precipitation	Changes in precipitation intensity and distribution (typically resulting in wetter winters particularly in the west)	Increased flow through natural pathways (leading to increased transport)
Pathogens / nutrients and sediment/ pesticides / industrial and emerging pollutants	High precipitation	Changes in precipitation intensity and distribution (typically resulting in wetter winters particularly in the west)	Increased surface and sewer flooding (leading to mobilisation)
Pathogens / nutrients and sediment / pesticides / industrial and emerging pollutants	Low precipitation	Changes in precipitation intensity and distribution (typically resulting in drier summers particularly in the east)	Low flows and water levels causing reduced dilution (and reduced assimilative capacity) of contaminants from both point and diffuse sources
Pathogens / nutrients and sediment / pesticides	Sea level rise	Chronic, increasing sea level rise and storm surge levels	Mobilisation from land surfaces through tidal flooding/storm surges

Sub-sector	Climate stimulus	Climate change	Impact
Pathogens / nutrients and sediment / pesticides / industrial and emerging pollutants	Increased storminess	Increase in intensity of storm events (including heavy precipitation, wind, hail, lightning), but at a decreased frequency	Flushes of pollutants to waterbodies
Nutrients and sediment	High temperatures	Increasing temperature resulting in more heatwaves, more drought and fewer frost days	Change in lake nutrient dynamics (for example leading to algal blooms/ eutrophication) and lower water quality
	High precipitation	Changes in precipitation intensity and distribution (typically resulting in wetter winters particularly in the west)	
Environmental status	High temperatures	Increasing temperature resulting in more heatwaves, more drought and fewer frost days	Changes in species distribution and phenology, including invasive native and non-native species
Environmental status	High temperatures	Increasing temperature resulting in more heatwaves, more drought and fewer frost days	Drying of peat can result in a reduction of natural pollution attenuation and flood prevention, the leaching of ammonia, dissolved organic carbon and peat slides (when followed by heavy precipitation)
	Low precipitation	Changes in precipitation intensity and distribution (typically resulting in drier summers particularly in the east)	
Environmental status	Low precipitation	Changes in precipitation intensity and distribution (typically resulting in drier summers particularly in the east)	Low flows, resulting in deterioration of water quality and ecological impacts
Environmental status	Sea level rise	Chronic, increasing sea level rise and storm surge levels	Saline intrusion of groundwater
Environmental status	High temperatures	Increasing temperature resulting in more heatwaves, more drought and fewer frost days	Reduced assimilative capacity of waters receiving thermal discharges (which can be further compounded by low flows)
Industrial and emerging pollutants	High temperatures	Increasing temperature resulting in more heatwaves, more drought and fewer frost days	Heat and drought induced fires (changes in run off chemistry due to chemicals related to firefighting, subsequent changes in nutrient run-off)
Pesticides	High temperatures	Increasing temperature resulting in more heatwaves, more drought and fewer frost days	Increased rate of pesticide volatilisation/ degradation
Environmental status	High precipitation	Changes in precipitation intensity and distribution (typically resulting in wetter winters particularly in the west)	Increased dissolution of carbonate geology, e.g. limestone
Industrial and emerging pollutants	Low temperatures	Increasing temperature resulting in more heatwaves, more drought and fewer frost days	Road salting/gritting

Source: [38]

Table 23: Water Services Infrastructure

Sub-sector	Climate stimulus	Climate change	Impact
Raw water abstraction / Water storage	High temperatures	Increasing temperature resulting in more heatwaves, more drought and fewer frost days	Hot weather-related changes in demand (e.g. higher daily and peak demand)
	Low temperatures	Increasing temperature resulting in more heatwaves, more drought and fewer frost days	Cold related changes in demand (e.g. higher daily and peak demand)
Raw water abstraction / Water storage / Water and wastewater treatment / Water and wastewater networks	High precipitation	Changes in precipitation intensity and distribution (typically resulting in wetter winters particularly in the west)	More frequent water/wastewater asset flooding, asset loss and potential for environmental pollution
	Increased storminess	Increase in intensity of storm events (including heavy precipitation, wind, hail, lightning), but at a decreased frequency	
Raw water abstraction / Water storage	High precipitation	Changes in precipitation intensity and distribution (typically resulting in wetter winters particularly in the west)	Increased stress on dam/reservoir infrastructure due to changes in water level operational parameters, potentially leading to water shortage
Raw water abstraction / Water storage	High precipitation	Changes in precipitation intensity and distribution (typically resulting in drier summers particularly in the east, and wetter winters particularly in the west)	Increased drawdown in the autumn/winter for flood capacity, leading to resource issues in the following spring/summer
Raw water abstraction / Water storage	Low precipitation	Changes in precipitation intensity and distribution (typically resulting in drier summers particularly in the east, and wetter winters particularly in the west)	Increased stress on dam/reservoir infrastructure due to changes in water level operational parameters, potentially leading to water shortage
Raw water abstraction / Water storage / Water and wastewater treatment / Water and wastewater networks	Low precipitation	Changes in precipitation intensity and distribution (typically resulting in drier summers particularly in the east, and wetter winters particularly in the west)	Reduced availability of water resources (surface water and groundwater sources)
Raw water abstraction / Water storage / Water and wastewater treatment / Water and wastewater networks	Increased storminess / High temperatures / High precipitation **	Increase in intensity of storm events (including heavy precipitation, wind, hail, lightning), but at a decreased frequency	Business continuity (level of service) impacts/ interruptions
Water and wastewater treatment	High temperatures	Increasing temperature resulting in more heatwaves, more drought and fewer frost days	Accelerated deterioration of structures, buildings, machinery, equipment
	Low temperatures	Increasing temperature resulting in more heatwaves, more drought and fewer frost days	Deterioration of structures, buildings, machinery, equipment
Water and wastewater treatment	High precipitation	Changes in precipitation intensity and distribution (typically resulting in drier summers particularly in the east, and wetter winters particularly in the west)	Increased turbidity, odour and taste issues

Sub-sector	Climate stimulus	Climate change	Impact
	Increased storminess	Increase in intensity of storm events (including heavy precipitation, wind, hail, lightning), but at a decreased frequency	
Water and wastewater treatment	High temperatures	Increasing temperature resulting in more heatwaves, more drought and fewer frost days	Treatment process and treatment efficiency impacts, odour creation/ dispersion and operations
	Low temperatures	Increasing temperature resulting in more heatwaves, more drought and fewer frost days	
Water and wastewater treatment / Water and wastewater networks	Sea level rise	Chronic, increasing sea level rise and storm surge levels	Direct asset flooding and/or coastal erosion leading to planned retreat and asset loss
Water and wastewater networks	Sea level rise	Chronic, increasing sea level rise and storm surge levels	Saline intrusion causing more rapid asset deterioration
Raw water abstraction / Water storage	Low precipitation	Changes in precipitation intensity and distribution (typically resulting in drier summers particularly in the east, and wetter winters particularly in the west	Loss of, or intermittent supply from reservoirs
Water and wastewater networks	High temperatures	Increasing temperature resulting in more heatwaves, more drought and fewer frost days	Changes in water chemistry, more biofilm and microorganisms in the water supply system Increased potential for odour creation and septicity in the wastewater network
Water and wastewater networks	High temperatures	Increasing temperature resulting in more heatwaves, more drought and fewer frost days	More soil moisture deficit driven leaks and bursts
	Low temperatures	Increasing temperature resulting in more heatwaves, more drought and fewer frost days	Freeze and thaw processes impacting network infrastructure
Water and wastewater networks	Low precipitation	Changes in precipitation intensity and distribution (typically resulting in drier summers particularly in the east, and wetter winters particularly in the west)	Debris being flushed from service reservoirs and towers into the system
Water and wastewater networks	Low precipitation	Changes in precipitation intensity and distribution (typically resulting in drier summers particularly in the east, and wetter winters particularly in the west)	Decrease in water quantity leading pipe failure due to de-pressurisation
Water and wastewater networks	Increased storminess	Increase in intensity of storm events (including heavy precipitation, wind, hail, lightning), but at a decreased frequency	Greater soil movement, more water/wastewater pipe movement and bursts

Sub-sector	Climate stimulus	Climate change	Impact
Water and wastewater networks	Low precipitation	Changes in precipitation intensity and distribution (typically resulting in drier summers particularly in the east, and wetter winters particularly in the west)	Lower flow rates leading to deposition and blockages, and odour issues
Water and wastewater treatment	Increased storminess	Increase in intensity of storm events (including heavy precipitation, wind, hail, lightning), but at a decreased frequency	Increase in volumes arriving at works
Water and wastewater treatment	Low precipitation	Changes in precipitation intensity and distribution (typically resulting in drier summers particularly in the east)	Low flows and water levels causing reduced assimilative capacity for wastewater discharges (changes to discharge management)

Source: [38]

B. Summary of extreme weather events and impacts

Weather event	Date (most recent first)	Description	Impacts
Storm Ali	September 2018	• Widespread strong winds and heavy rain. • High winds were the cause of most damage. • Maximum wind gust speeds of 90mph recorded at Mace Head, against 'normal' wind gust maxima of 35-45mph.	• High winds caused power outages (mostly due to fallen trees) and at the height of the storm more than 180,000 customers were without power. • Power outages resulted in approximately 10,000 customers without water supply. • Power outage prevented water from being pumped to Garristown Reservoir, resulting in depleted water levels. • Two people were killed due to high winds. • Travel disruption; air travel, trains and ferries.

Weather event	Date (most recent first)	Description	Impacts
Heatwave/ drought	Summer 2018	• All precipitation totals below long-term average for the season. • All 3 summer months had below average precipitation with June and July being the driest months. • Absolute drought conditions prevailed from late June until mid-July at stations in the East, Midlands, West and South, whilst partial drought conditions in the South from early June until late July. • All mean seasonal air temperatures across the country were above their long-term average. • Many stations reported heat waves by the end of June. Heat waves continued into July in some places. • The season's highest temperature was recorded at Shannon Airport at the end of June at 32°C. • Apart from Malin Head all stations had above average sunshine in June and July.	• High water demands due to hot weather causing depleted reservoir levels. • 22 groundwater sources with demand or supply issues at the height of the warm weather with a total of 10 sources having to locate supplementary water from alternative sources to maintain supplies for periods. • Water Conservation Order (Hosepipe ban) across the country (July-Sept in some areas) and requests to conserve water. • Non-weather-related pipe bursts at the same time as depleted resources resulted in water outages. • High water temperature/Dissolved Oxygen depletion leading to fish distress. • Depleted water levels in reservoirs caused manganese deposits to become more concentrated in parts of the network. No health risk but caused discolouration of the water. • Parametric water quality breaches and possible large waterborne outbreak. • Low rivers flows resulted in reduced assimilative capacity of receiving waters and increased pressure on wastewater treatment. • Increased blockages in wastewater collection network due to ragging etc. • High road temperatures, including some road surfaces melting, causing road closures. • Forest fires, roads closed due to smoke.

Weather event	Date (most recent first)	Description	Impacts
Storm Emma	March 2018	• Widespread heavy falls of drifting snow occurred on 1st, 2nd, and 3rd March. • Heaviest snow in the east and southeast with accumulations of up to 69cm in the Wicklow mountains. • Fairly widespread snow occurred also on the 18th.	• Freezing temperatures leading to burst water mains. • High water uses registered, thought to be due to taps being left running in homes and on farms. • High demand and pipe leaks/bursts put pressure on water treatment plants and led to reservoir level depletion. • Operational issues at treatment plants, including compromised disinfection systems. Boil Water Notices issued as precaution. • Contamination of raw water due to burst pipes (hydrocarbons). • Access issues - operators were not able to access pump stations, reservoirs, treatment plants etc. particularly in remote areas. • Freezing valves affected treatment processes and freezing pumps affected collection and distribution. • Low temperatures caused de-nitrification issues at treatment plants. • Many groundwater sources required generators to pump water and treat supplies. • Difficulties with chemicals stored outside.

Weather event	Date (most recent first)	Description	Impacts
Storm Ophelia	October 2017	• Windstorm - Gales and strong gales were reported at many stations on 16th October. • Violent storm force winds reported in Cork. • Highest gusts were 84 knots (155km/hr (highest on record at this station) also highest 10-minute mean wind spend was 62 knots.	• Wind damage including roofs blown off, trees felled, buildings damaged. • High winds caused extensive power outages affecting treatment plants and pumping stations - over 100,000 customers were without water. • Weather conditions mean that repairs delayed due to unsafe working conditions - operators instructed not to attend work during storm. • Power failures resulted in loss of treatment capacity. • Some Boil Water Notices due to treatment risks associated with power failures affecting disinfection systems. • Power outages at wastewater plants and pumping stations resulting in discharge of untreated or partially treated sewage to receiving waters. • Coastal flooding in some areas (Galway, Limerick).

Weather event	Date (most recent first)	Description	Impacts
Heavy precipitation	August 2017	• Heavy precipitation in Donegal. • Over 70mm of rain fell in 9-hour period on 22nd August, equivalent to 63% August average total precipitation.	• Significant damage was caused to roads and bridge infrastructure with some direct impact on associated water and wastewater pipework. • 17 significant water network incidents that involved pipes being affected as a result of flood damage to roads, bridges and waterways and 6 wastewater treatment plants affected by flooding. • Flooding of some wastewater treatment plants. • Bathing water prohibition notice issued following excess precipitation, leading to concern of elevated levels of bacteria in bathing water.
Driest Winter in 25 years, followed by dry spring/ summer	Winter / Spring / Summer 2017	• Country-wide below LTA winter precipitation, with the majority of stations reporting between half and three-quarters of their normal seasonal total. • All seasonal mean temperatures were above their LTA, with over half of stations reporting at least 1°C or more above normal with some of these reporting it as their mildest winter in 10 years.	• Reservoir levels depleted. • Several Water Conservation Orders issued and requests to conserve water.

Weather event	Date (most recent first)	Description	Impacts
Storm Darwin	February 2014	• Maximum sustained wind and gust speeds were 120km/h and 160km/h respectively. • Most severe winds were experienced in Galway, Clare, Limerick, Kerry and Cork but also strong winds were noticeable around the N7 motorway corridor from Limerick to Dublin.	• More than 100,000 people without clean drinking water due to power outages. • Approximately 8000ha forest were damaged. • Considerable damage to housing and other buildings. • More than 215,000 homes lost power and there was extreme flooding along the coasts and major damage caused to buildings.
Winter 2013 / 2014	2013-14	• Exceptional run of winter storms - storm force winds on 12 different days, precipitation 150%-200% of LTA which fell on already saturated/waterlogged ground.	• Storms impacted severely on the national electricity network - Most of the faults resulted from the very high wind speeds but lightning strikes were also a significant factor resulting in loss of supply. • Serious widespread damage and flooding during the latter half of December 2013 and into the middle of February 2014. • Significant disruptions to water supply were experienced due to the power outages - reservoirs typically ran dry after a day without re-supply. • The south west, and Kerry in particular, was worst hit in this regard. • Boil Water Notices were issued in several areas because of fears of ingress of groundwater into water distribution pipe networks. • Extreme weather in 2012/13 impacted on water quality.
Heavy precipitation	Summer 2012	• Heavy precipitation	• Extreme weather in 2012/13 impacted on water quality. • Significant waterborne disease in Midlands associated with regulated and "exempt" wells.

Weather event	Date (most recent first)	Description	Impacts
Heavy precipitation in the greater Dublin Area	October 2011	• Heavy precipitation in the greater Dublin region causing flooding in some eastern areas. • 82.2mm precipitation at Casemont Aerodrome (greatest October daily precipitation since records began in 1954). • Maximum 9-hour precipitation at Dublin Airport (68mm) (annual probability of 1 in 100).	• Flooding in many parts of Dublin and the east coast • Flooding roads and causing lengthy traffic delays. • Many homes and businesses under water. • Two deaths attributed to precipitation event. • Millions of euros worth of damage to homes, businesses, and infrastructure.
Extreme cold spell	Nov/Dec 2010	• Both Dublin Airport (-8.4°C) and Casement Aerodrome -9.1°C) had their lowest November temperatures on record. • Significant snow accumulation (20 - 27cm at Dublin Airport and Casement Aerodrome) and record low December temperatures. • Freezing conditions penetrated into the ground.	• Extra potholes and burst water pipes. • Severe winter weather brought widespread transport disruption, school closures, power failures, the postponement of sporting events and 25 deaths. • Partial freezing of major rivers such as the River Barrow
Cold weather	Winter 2009 / 2010	• A total of 70 to 80 ground frosts at inland stations. • Between 20 to 30 days with snow in many places - snow accumulation minor except on higher ground. • Total number of rain days during winter period was 44 to 62 (10% lower than normal)	• Burst water pipes causing interruptions to water supply.

Weather event	Date (most recent first)	Description	Impacts
Precipitation November 2009	November 2009	• Severe flooding in many parts of the country. • Precipitation totals for November were the highest on record at most stations. • Valentia's total of 360mm was its highest of any month since observations began in 1866. Between 17 and 30 wet days observed (normal range 13 to 20).	• Pluvial and fluvial flooding. • Flooding of wastewater collection network due to combined sewers and numerous combined storm overflows from network. • Pressure on pumps due to high volume of flow in networks. • Major clean up required.
Heavy rain / flooding	August 1997	• Extensive flooding in the southeast and south - 200mm of precipitation between the 3rd and 7th August in places. • Rivers in the south overflowed / burst their banks.	• Pollutants were washed into waterways, e.g. at Cahore, Wexford. • Eutrophication of Lough Leane in Killarney following a major precipitation event during growing season. • Flooding of farmland seriously damaged crops.
Summer weather	Summer 1995	• Mean air temperature over two degrees above normal in most places. • Temperature rose to above 30ºC on a number of days. • Driest summer on record at Malin Head, Casement Aerodrome and Cork Airport. • At Dublin (Phoenix Park) 65.2mm of precipitation over summer months - lowest since 1887.	• Drought conditions resulting in issue of Water Conservation Orders. • Fish kills - 84 compared to 32/33 in previous two years. Five fish kills directly attributed to drought conditions (low water, streams drying out), low dissolved oxygen). • Potato farmers suffering due to water shortages - difficulty irrigating crops. • Karst waters particularly vulnerable to drought.

Weather event	Date (most recent first)	Description	Impacts
Dry period	1969-1977	• More than 50% less than average precipitation in east / southeast Oct 1974, Jan May, June, December 1975, April, June August 1976.	• Deficit of precipitation with serious consequences for crops and supply of water for industrial and domestic use. • Lack of rain in 1975/76 resulted in high demand. High demand in 1975 resulted in depleted reservoirs and aquifers, followed by dry winter, then further high demand in 1976 summer. • Restrictions on use of water introduced in both summers.
Drought episodes	1765-1970	• Drought rich periods identified in 250-year drought catalogue [39]: • 1784-1786 • 1800-1809 • 1813-1815 • 1826-1827 • 1838-1839 • 1854-1860 • 1884-1896 • 1904-1912 • 1921-1923 • 1932-1935 • 1952-1954	• Drought catalogue notes the following impacts in these drought periods: • Reservoirs, lakes, ponds, springs, well and streams drying up. • Impacts on agriculture including potato and cereal crop failures, pasture scarcity with impacts on livestock, low milk yields. • Famine and disease occurred in the most extreme droughts (e.g. 1784-1786). • Water shortages and restrictions in cities. • Sewerage systems blocked due to lack of water, with public health concerns. • Impacts on industry, e.g. textile and flour industries, due to lack of water power for mills/factories. Embargo on distilling and grain exports. • Low hydroelectricity outputs. • Reduced quantity of salmon, oysters and eels due to insufficient flow over weirs.

C. Prioritisation methodology

C.1 Likelihood

Based on the future climate changes captured in the Impact Screening [40], the qualitative likelihood of impacts is rated based on a uniform scale as presented in Table 1. Using the information collected and the Intergovernmental Panel on Climate Change (IPCC) classification of likelihoods as a guideline for 'likelihood scales' (summarised in [40] and [16]), overall likelihood ratings have been assigned to the representative climate variables using a scale of estimated impact return periods. These ratings represent a full range of likelihoods of climate hazards globally and regionally and as such should be viewed relative to this.

The application of Table 1 to the classification of changing climate variable likelihoods is captured in Table 24.

Table 24: Classification of changing climate variable likelihoods and associated scoring

Climate variable	High level statement of projected change to 2050**	Qualitative IPCC classification of likelihoods [16]	Corresponding overall likelihood rating based on Table 1	Associated Score
Temperature	Increasing temperature resulting in more heatwaves, more drought and fewer frost days Note: The impact of increasing temperature on low temperature regimes is incorporated within this 'high temperature' impact category	Very likely – Virtually certain	Almost certain	5
Precipitation	Changes in precipitation levels, intensity and distribution (typically resulting in drier summers particularly in the east, and wetter winters particularly in the west)	Likely - Very likely	Likely	4
Storminess	Increase in intensity of storm events (including heavy precipitation, wind, hail, lightning), but at a decreased frequency	More likely than not	Possible*	3*
Sea level rise	Chronic, increasing sea level rise and storm surge levels	More likely than not - Virtually certain	Likely	4

Source: [38]

* In the case of storminess – a 'Possible – 3' scoring has been assigned due to data limitations and uncertainty in attributing increased intensity/decreased frequency to climate change on an annual basis. In spite of observed data, extremes like storms, wind or changes in their characteristics are not captured/resolved by Global Climate Models with as much certainty as temperature, precipitation and sea level rise.

**These statements are based on the High representative concentration pathway to 2050, however to 2050 all pathways (low, medium and high) follow a similar trajectory and as such the high-level statements and likelihood scores are valid for all pathways and therefore would not have an impact on the Prioritisation.

C.2 Magnitude

As captured in the Impact Screening [40], the potential magnitude of future climate impacts was rated based on a uniform scale (Table 25). Magnitude ratings and associated scoring was undertaken based on a combination of expert judgement and review of available evidence and literature relating to economic, environmental and social magnitudes (Table 2Table 2). These values represent a full range of magnitudes of climate hazards in the UK (with minor amendments for Ireland) and as such should be viewed relative to this.

Table 25: Magnitude of impact ratings and scoring

Magnitude Rating Description	Low	Low-Medium	Medium	Medium-High	High
Scoring	1	2	3	4	5

Source: [38]

C.3 Risk

The resulting future risk to the water quality and water services infrastructure sectors is calculated based on a combination of the likelihood and magnitude of impacts using the risk matrix in Table 3, which aids in categorising the level of risk as either insignificant, low, moderate, high or extreme (Table 3, with definitions contained in Table 26).

Table 26: Risk category definitions

Score	Associated risk rating	Consequence on sector
1-5	Insignificant	No, or negligible, vulnerability to specific climate risk(s). Remedial action not required.
6-10	Low	A low level of vulnerability to specific climate risk(s). Remedial action or adaptation may be required but is not a priority. Maintain a watching brief.
11-15	Moderate	A moderate level of vulnerability to specific climate risk(s). Mitigating action or adaptation could improve resilience, although an appropriate level of resilience is provided. If not a priority, maintain a watching brief.
16-20	High	A significant level of vulnerability to specific climate risk(s). Mitigating action or adaptation is recommended.
21-25	Extreme	An extreme level of vulnerability to specific climate risk(s). Mitigating action or adaptation is highly recommended.

D. Medium priority impact chains

In the Prioritisation Step, impact chains with risk scores of **≤12** were assigned as moderate priority impacts. For each of these impacts a moderate future risk has been recognised and as such watching briefs have been assigned to each to capture research gaps, interdependencies and potential adaptation measures which could lead to a refinement of the impact and risk score in future revisions of this Adaptation Plan. Justification for the risk scoring attributed to each moderate priority is provided in the Prioritisation Report [38] and key watching briefs are presented in Table 27 and Table 28 for the water quality and water services infrastructure sectors respectively.

Table 27: Water quality moderate priorities

Impact	Watching brief
Impact: Freeze and thaw induced ground movement resulting in pipe cracking and leakage **Climate stimulus:** low temperatures **Sub-sector(s):** Pathogens / nutrients and sediment / pesticides / industrial and emerging pollutants Magnitude: 2 Likelihood: 5 Risk: 10	• Due to a decrease in frost days an amelioration is expected. • This presents an opportunity for a decreased impact and locally improved water quality. • There is a clear relationship with the impact described below, maintaining assets and adapting design standard to a changing climate.
Impact: Drying induces ground movement and hot-weather-induced thermal expansion of pipes resulting in pipe cracking and leakage **Climate stimulus:** high temperatures **Sub-sector(s):** Pathogens / nutrients and sediment / pesticides / industrial and emerging pollutants Magnitude: 2 Likelihood: 5 Risk: 10	• Despite this being a known impact of high temperatures, the current and ongoing improvement in, and design of the pipe network suggests that the future magnitude should be lower. • It is recognised that there is variation across the country on the quality of the pipe network and as such there may be localised areas where this impact needs consideration.

Impact	Watching brief
Impact: Soil shrinkage/ cracks creating rapid transport pathways **Climate stimulus:** high temperatures **Sub-sector(s):** Pathogens / nutrients and sediment/ pesticides Magnitude: 2 Likelihood: 5 Risk: 10	• It is expected that dependent on soils this impact will only occur locally. • This impact could be further compounded by land use and land management changes so integrated catchment management measures that relate to the RBMP and acute priority impacts identified in this assessment should be considered. • Further research could be undertaken to fully understand risk associated with this impact.
Impact: Amended grazing and cropping seasons and changing crop types leading to changes in application **Climate stimulus:** high temperatures **Sub-sector(s):** Pathogens / nutrients and sediment / Pesticides Magnitude: 2 Likelihood: 5 Risk: 10	• It is recognising that there have been some historic (and possibly localised) impacts due to changes in cropping and grazing. • Given the dynamic nature of agriculture it cannot be stated with certainty that the magnitude of such changes would be higher than this in the future. • Coordination with the Agriculture, Forest and Seafood Climate Change Sectoral Adaptation Plan is considered vital in adapting and mitigating to any future impacts on water quality.
Impact: Changes in type, and distribution of pests leading to changes in pesticide application at source **Climate stimulus:** high temperatures Sub-sector(s): Pesticides Magnitude: 2 Likelihood: 5 Risk: 10	• Although there is a clear risk that this impact will be realised with a changing climate, this is potentially a localised risk which could be mitigated, for example through integrated catchment management. • It is also possible that there could be an aspect of amelioration related to this impact depending on the type of pest. • Coordination with the Agriculture, Forest and Seafood Climate Change Sectoral Adaptation Plan is considered vital in adapting and mitigating to any future impacts on water quality.
Impact: Increased flow through natural pathways (leading to increased transport) **Climate stimulus:** high temperatures **Sub-sector(s):** Pathogens / nutrients and sediment / pesticides / industrial and emerging pollutants Magnitude: 3 Likelihood: 4 Risk: 12	• Based on the historic magnitude the future risk is moderate. • In the west of Ireland in particular where karstic geology dominates there may be localised more significant impacts, especially where karstic pathways are not understood. Continued research and mapping of these would help to identify specific waterbodies and dependent habitats at risk.

Impact	Watching brief
Impact: Mobilisation from land surfaces through tidal flooding/storm surges Climate stimulus: sea level rise **Sub-sector(s):** Pathogens / nutrients and sediment / Pesticides Magnitude: 3 Likelihood: 4 Risk: 12	• This impact is not expected to cause widespread water quality failures or significant economic or social damage, so the risk is moderate. • Appropriate land use (and sea-level rise) planning would be recommended to mitigate future risks.
Impact: Flushes of pollutants to waterbodies **Climate stimulus:** increased storminess **Sub-sector(s):** Pathogens / nutrients and sediment / pesticides / Environmental status / industrial and emerging pollutants Magnitude: 4 Likelihood: 3 Risk: 12	• Although the future magnitude of this impact is expected to be high given the predicted intense nature of storms, the medium possibility of this stimulus results in a moderate priority. • It is acknowledged that further climate science research on the likelihood of increased storminess attributed to climate change could help to refine this likelihood score. • There is a relationship with adaptive capacity related to water quality impacts due to increased surface and sewer flooding which are considered an acute priority.
Impact: Change in lake nutrient dynamics (for example leading to algal blooms/eutrophication) and lower water quality **Climate stimulus:** high precipitation and high temperatures **Sub-sector(s):** Nutrients and sediment **Magnitude:** 3 (high precipitation), 2 (high temperatures) **Likelihood:** 4 (high precipitation), 5 (high temperatures) **Risk:** 12 (high precipitation), 10 (high temperatures)	• There have been historic occurrences of eutrophication impacting on lake water quality in Ireland, however given the number of water framework directive (WFD) lakes that could be adversely impacted and the associated social and economic impacts this risk score has been derived. • The causes of eutrophication and algal blooms in lakes are complicated as they are often driven by nutrient enrichment but may be exacerbated by high temperatures. • As such, the compounding impact of multiple climate stimuli under a changing climate should be considered and form part of an integrated catchment management programme when managing lake waterbodies, as proposed through other, acute priorities.

Impact	Watching brief
Impact: Drying of peatland can result in the leaching of ammonia, dissolved organic carbon and reduction of natural pollution attenuation and flood prevention **Climate stimulus:** low precipitation **Sub-sector(s):** Environmental status Magnitude: 3 Likelihood: 4 Risk: 12	• Although this impact has been included as a priority under a high temperature future, the lower likelihood of low precipitation results in a moderate risk. • Adaptation actions in response to high temperatures could possibly have a benefit for this impact chain also.
Impact: Low flows, resulting in deterioration of water quality and ecological impacts **Climate stimulus:** low precipitation **Sub-sector(s):** Environmental status Magnitude: 3 Likelihood: 4 Risk: 12	• This impact has been included as a priority under the low precipitation climate stimulus for the pathogens /nutrients and sediment /pesticides /industrial and emerging pollutants sub-sectors. • Adaptation actions in response to high temperatures could have a benefit for this impact chain also.
Impact: Saline intrusion of groundwater Climate stimulus: sea level rise **Sub-sector(s):** Environmental status Magnitude: 2 Likelihood: 4 Risk: 8	• There is limited information available on the extent of saline intrusion across Ireland. • Increased water level and quality monitoring would be suggested to better understand the risks of saline intrusion on groundwater.
Impact: Reduced assimilative capacity of waters receiving thermal discharges (which could be further compounded by low flows) **Climate stimulus:** high temperatures **Sub-sector(s):** Environmental status Magnitude: 2 Likelihood: 5 Risk: 10	• Based on the current understanding of the distribution of such discharges it is expected that this impact will only occur locally and is unlikely to have high social or economic impacts. • A more detailed understanding of the distribution of such discharges and research on their effect, including how this is being considered in the energy sector, could help to refine this scoring.

Impact	Watching brief
Impact: Heat and drought induced fires (changes in run off chemistry due to ash and chemicals related to firefighting, subsequent changes in nutrient run-off) **Climate stimulus:** high temperatures **Sub-sector(s):** Industrial and emerging pollutants / Environmental status Magnitude: 2 Likelihood: 5 Risk: 10	• Due to the localised nature of fires and minimal evidence from historic events the future impact was deemed to be medium to high. • It is recognised that there is a relationship with adaptive capacity related to water quality impacts which consider the drying of peatland from high temperatures given that the areas most at risk to increased incidences of fire are the upland blanket bog areas, with impacts on biodiversity, air quality and water quality (burning of peat and mobilisation of peat-silt and carbon to water courses).
Impact: Increased rate of pesticide volatilisation/degradation **Climate stimulus:** high temperatures Sub-sector(s): Pesticides Magnitude: 2 Likelihood: 5 Risk: 10	• The effects of higher temperatures on pesticide volatilisation/degradation is unclear and would require further research (across sectors as this impact is multi-sectoral), to better understand the magnitude of this risk.
Impact: Increased dissolution of carbonate geology, e.g. limestone **Climate stimulus:** high precipitation **Sub-sector(s):** Environmental status Magnitude: 2 Likelihood: 4 Risk: 8	• Current dissolution of limestone is understood to be very low. Therefore, it is not expected that precipitation increases will have a significant impact on this geological process and subsequently on water quality.
Impact: Road salting/gritting **Climate stimulus:** low temperatures **Sub-sector(s):** Industrial and emerging pollutants Magnitude: 1 Likelihood: 5 Risk: 5	• Although road salting is expected to still be required in the future, this is not a priority impact chain as due to a decrease in frost days an amelioration is expected due to reduced frequency of salting/gritting.

Source: [38]

Table 28: Water services infrastructure moderate priorities

Impact	Watching brief
Impact: Changes in demand (e.g. higher daily and peak demand) **Climate stimulus:** low temperatures **Sub-sector(s):** Raw water abstraction / Water storage Magnitude: 1 Likelihood: 5 Risk: 5	• Not a priority as due to a decrease in frost days an amelioration in the demand for water to prevent freezing in pipework is expected.
Impact: Increased stress on dam/reservoir infrastructure due to changes in water level operational parameters, potentially leading to water shortage **Climate stimulus:** high precipitation and low precipitation **Sub-sector(s):** Raw water abstraction / Water storage Magnitude: 3 Likelihood: 4 Risk: 12	• This impact reflects the risk of losing a locally or regionally significant water source should a dam fail, and storage be lost. • Although not explicitly incorporated in this calculation of risk, it is recognised that there are standards and mitigations already in place to minimise the 'real' likelihood of dam failure that should be maintained and developed in-line with the climate science relating to high precipitation as it evolves.
Impact: Accelerated deterioration of structures, buildings, machinery, equipment **Climate stimulus:** high temperatures **Sub-sector(s):** Water and wastewater treatment Magnitude: 2 Likelihood: 5 Risk: 10	• The overall magnitude of this impact was rated as low to medium as it relates to its economic impact only, with no or minimal social and environmental impact. • This could though be particularly pertinent to older infrastructure which may have been built to different standards and/or not as designed and to different treatment equipment which may have different tolerances to changes in temperature. This would typically be considered in design standard updates and when assessing specific equipment.
Impact: Accelerated deterioration of structures, buildings, machinery, equipment **Climate stimulus:** low temperatures **Sub-sector(s):** Water and wastewater treatment Magnitude: 1 Likelihood: 5 Risk: 5	• Not a priority impact chain as due to a decrease in frost days an amelioration in the lifespan of structures is expected.

Impact	Watching brief
Impact: Increased turbidity, odour and taste issues **Climate stimulus:** high precipitation **Sub-sector(s):** Water and wastewater treatment Magnitude: 3 Likelihood: 4 Risk: 12	• It is expected that this impact is only locally relevant and temporally limited.
Impact: Increased turbidity, odour and taste issues **Climate stimulus:** Increased storminess **Sub-sector(s):** Water and wastewater treatment Magnitude: 3 Likelihood: 3 Risk: 9	• It is expected that this impact is only locally relevant and temporally limited. • It is recognised that further climate science research on the likelihood of increased storminess attributed to climate change could help to refine this likelihood score.
Impact: Treatment process and treatment efficiency impacts, odour creation/ dispersion and operations **Climate stimulus:** high temperatures **Sub-sector(s):** Water and wastewater treatment Magnitude: 2 Likelihood: 5 Risk: 10	• It is expected that increasing temperatures will have a minor impact on treatment efficiency and odour creation. • It should be noted that currently odour creation is perceived as an issue. Therefore, it is expected that investments in odour treatment technology are likely to occur anyway, due to increasing societal sensitivity rather than climate change related impacts
Impact: Treatment process and treatment efficiency impacts, odour creation/ dispersion and operations **Climate stimulus:** low temperatures **Sub-sector(s):** Water and wastewater treatment Magnitude: 2 Likelihood: 5 Risk: 10	• Not a priority impact chain as due to a decrease in frost days an amelioration is expected.

Impact	Watching brief
Impact: Direct asset flooding and/or coastal erosion leading to planned retreat and asset loss Climate stimulus: sea level rise **Sub-sector(s):** Water and wastewater treatment / Water and wastewater networks Magnitude: 3 Likelihood: 4 Risk: 12	• It is recognised that there are water services infrastructure at risk from chronic sea level rise but given the duration of the onset of this the overall risk is expected to be moderate. • Consideration in planning new and upgraded assets should consider this risk (especially at the regional level where risks may be higher than in other regions). This should be aligned with the National Planning Framework [41] and protecting Ireland's coastal resource and supporting adaptation measures proposed in response to it.
Impact: Saline intrusion causing more rapid asset deterioration and impacting aquifers Climate stimulus: sea level rise **Sub-sector(s):** Water and wastewater networks Magnitude: 2 Likelihood: 4 Risk: 8	• There is limited information available on the extent of saline intrusion in groundwater across Ireland and the impact of it on transmission assets. • Increased monitoring would be suggested to better understand the risks of saline intrusion on groundwater.
Impact: Loss of or intermittent supply from reservoirs **Climate stimulus:** low precipitation **Sub-sector(s):** Raw water abstraction / Water storage Magnitude: 3 Likelihood: 4 Risk: 12	• This risk rating reflects the relative importance of reservoirs as part of the national water supply and it should be noted that resilience of supply is a common feature within the priority impact chains. • Adaptation in this regard would directly impact to reduce the risk of this chain.
Impact: Changes in water chemistry, more biofilm and microorganisms in the water supply system **Climate stimulus:** high temperatures **Sub-sector(s):** Water and wastewater networks Magnitude: 2 Likelihood: 5 Risk: 10	• It is expected that this impact is only locally relevant and temporally limited.

Impact	Watching brief
Impact: Increased potential for odour creation and septicity in the wastewater network **Climate stimulus:** high temperatures **Sub-sector(s):** Water and wastewater networks Magnitude: 2 Likelihood: 5 Risk: 10	• The magnitude of this impact is unclear and would require further research.
Impact: Freeze and thaw processes impacting network infrastructure, such as bursts **Climate stimulus:** low temperatures **Sub-sector(s):** Water and wastewater networks Magnitude: 1 Likelihood: 5 Risk: 5	• This is not a priority impact chain as due to a decrease in frost days an amelioration is expected due to decrease freeze and thaw action.
Impact: More soil moisture deficit driven leaks and bursts **Climate stimulus:** high temperatures **Sub-sector(s):** Water and wastewater networks Magnitude: 2 Likelihood: 5 Risk: 10	• Despite this being a known impact of high temperatures, the current and ongoing improvement in, and design of the pipe network suggests that the future magnitude should be lower. • It is recognised that there is variation across the country on the quality of the pipe network and as such there may be localised areas where this impact needs consideration.
Impact: Debris being flushed from service reservoirs and towers into the system **Climate stimulus:** low precipitation **Sub-sector(s):** Water and wastewater networks Magnitude: 2 Likelihood: 4 Risk: 8	• It is expected that this impact is only locally relevant and temporally limited.

Impact	Watching brief
Impact: Decrease in water quantity leading pipe failure due to de-pressurisation **Climate stimulus:** low precipitation **Sub-sector(s):** Water and wastewater networks Magnitude: 2 Likelihood: 4 Risk: 8	• It is expected that this impact is only locally relevant and temporally limited.
Impact: Greater soil movement, more water/wastewater pipe movement and bursts **Climate stimulus:** increased storminess **Sub-sector(s):** Water and wastewater networks Magnitude: 3 Likelihood: 3 Risk: 9	• It is expected that this impact is only locally relevant and temporally limited.
Impact: Lower flow rates leading to deposition and blockages, and odour issues **Climate stimulus:** low precipitation **Sub-sector(s):** Water and wastewater networks Magnitude: 3 Likelihood: 4 Risk: 12	• It is expected that this impact is only locally relevant and temporally limited. • A monitoring and inspection regime would be advised to warn against potential localised risks.
Impact: Increase in volumes arriving at works **Climate stimulus:** increased storminess **Sub-sector(s):** Water and wastewater treatment Magnitude: 4 Likelihood: 3 Risk: 12	• Although the future magnitude of this impact is expected to be medium to high given the predicted intense nature of storms, the medium possibility of this stimulus resulting in a moderate priority. • This impact should be considered as part of normal design procedures in the development of any treatment asset. • It is recognised that further climate science research on the likelihood of increased storminess attributed to climate change could help to refine this score.

Impact	Watching brief
Impact: Low flows and water levels causing reduced assimilative capacity for wastewater discharges (changes to discharge management) **Climate stimulus:** low precipitation **Sub-sector(s):** Water and wastewater treatment Magnitude: 3 Likelihood: 4 Risk: 12	• This impact links to the water quality impacts attributed to low precipitation and low flows which have been highlighted as a priority impact. • This water services infrastructure impact is expected to have a lesser magnitude as impacts will be more localised and a level of mitigation is generally in place. • When assessing the water quality impact, the wider catchment and operational considerations with low flows should be considered.

Source: [38]

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