Adapting to a changing climate

Yorkshire Water's Adaptation Report

2015

It's part of our Blueprint for Yorkshire

YorkshireWater

1. Executive summary

The Climate Change Act, 2008, contains the provision for critical national infrastructure providers to report to the government every few years on how they are assessing and addressing their climate change risks. Yorkshire Water first reported in 2011 and has since been invited to voluntarily update the Government about how our climate risk understanding has continued to improve since our first report, what action we have taken, and the action we plan to take in the future. This report is our response to this invitation.

Yorkshire Water is a regulated water and sewerage company with a statutory duty to provide our customers with high quality drinking water and to collect, treat and return their waste water safely to the environment. We recognise that we offer an essential public health service, as well as being custodians of the natural environment, and operators of essential infrastructure. These roles are highly dependent on weather and climate.

Our vision is "taking responsibility for the water environment for good". The essence of the vision is doing what is right; for customers, colleagues, partners, the environment and investors. We acknowledge that climate change could impact on our ability to meet our vision, and in light of this, we have published our official position on climate change, which is summarised in the following six statements;

- The climate has been changing and will continue to change
- Climate change presents risks to our strategic objectives and the services we provide
- We will quantify the climate risks that face our business
- We will develop long term plans to manage the climate change risks that face our business
- We will promote activities to address our climate change risks
- We will drive initiatives to empower every employee to reduce carbon emissions and prepare for the changing climate

In December 2013, we published our comprehensive climate change strategy and accompanying risk assessment, which includes our activity to both adapt to climate change, and the actions we are taking to mitigate (reduce) our greenhouse gas emissions. In line with Defra's guidance for reporting authorities, this report provides an overview of where we have specifically assessed the risk to assets or services from extreme weather and/or climate change. We have also included details of how we manage and reduce our impact on the natural environment, as we recognise that a healthy and well-functioning environment is, in itself, an adaptation measure. It is important to note that we do not manage climate or extreme weather risks in isolation from our other business risks. We take an "all hazards" approach to managing risk, and our primary drivers for action are usually related to ensuring delivery of our core services and protecting public health. In order to gain the fullest understanding of our plans for the future, we encourage the reader to read this report in conjunction with the summary of our five year business plan, and our climate change strategy, both available on our website.

We have grouped this report into five themes, which closely match our customer outcomes. Our customer outcomes are the priorities our customers have told us they expect and value, and which they want us to deliver over the next five years and beyond. They are:

- We provide you with water that is clean and safe to drink
- We make sure you always have enough water
- We take care of your waste water and protect you and the environment from sewer flooding
- We protect and improve the water environment
- We understand our impact on the wider environment and act responsibly
- We provide the level of customer service you expect and value
- We keep your bills as low as possible

We recognise that climate change and extreme weather have the potential to impact on all of these, so we have provided the table below which shows which climate risks could impact on each of our customer outcomes, and where in this report you can find more information about those risks which we have quantified. Each chapter describes our risk understanding, what action we have taken since our last report, and what action we are planning in the future as well as commentary regarding barriers, opportunities and interdependencies. Each section also signposts to where you can find out how we are doing against the relevant performance commitment for each climate risk area. Our performance commitments are the metrics we will use to report progress against the seven customer outcomes listed above.

Readers should take confidence from the activity set out in this report that we are effectively assessing our climate risks, and laying the necessary foundations to affordably maintain and enhance our water and waste water services for the long term. We look forward to working in partnership with our customers, government, regulators and other stakeholders to meeting the challenge posed by climate change and achieving our vision: taking responsibility for the water environment for good.

Climate Change Risk and Customer Outcome	Where to find more information	Now	2030s	2050s	2080s
We make sure you always have enough water					
Demand exceeds supply	Chapter 3				
Demand exceeds distribution	Chapter 3				
Cold causes bursts	Chapter 3				
Reservoir siltation	Business as usual risk management				
National emergency water transfer	Chapter 3 and 5				
We take care of your waste water and protect you and the environment from sewer flooding					
Overloaded sewers cause flooding	Chapter 4				
Overloaded sewers cause pollution	Chapter 4				
Outfalls restricted by sea level rise	Chapter 4				
We provide you with the level of customer service you expect and value					
Flooding of our assets	Chapter 5				
Storm surge	Chapter 5				
Coastal erosion	Chapter 5				
Reservoir failure	Chapter 5				
Landslips	Business as usual risk management				
Scour of bridges and foundations	Business as usual risk management				
Freezing treatment works	Climate change strategy				
Resilient health and safety	Business as usual risk management				
Resilient human resources	Business as usual risk management				
Resilient IT and telemetry	Chapter 5				
Resilient transport	Business as usual risk management				
Resilient supply chain, including grid electricity	Chapter 5				
Resilient energy self-generation	Business as usual risk management				
Climate Change Risk and Customer Outcome	**Where to find more information**	**Now**	**2030s**	**2050s**	**2080s**
We provide you with the level of customer service you expect and value					

Resilient asset delivery	Business as usual risk management	Green	Green	Green	Green
Resilient asset maintenance	Business as usual risk management	Green	Yellow	Red	Red
Resilient external communications	Chapter 5	Yellow	Yellow	Yellow	Yellow
Legal action	Business as usual risk management	Green	Green	Yellow	Yellow
We provide you with water that is clean and safe to drink					
Land management (particularly moorland peat)	Chapter 6	Green	Green	Red	Red
Rainfall impacts raw water quality	Chapter 6	Green	Green	Green	Green
Salinisation of water resources	Chapter 6	Green	Green	Green	Yellow
Water borne diseases	Business as usual risk management	Green	Green	Green	Green
We protect and improve the water environment					
Biodiversity	Chapter 7	Green	Green	Yellow	Yellow
Treating sewage in hot/dry	Climate change strategy	Green	Green	Yellow	Yellow
We understand our impact on the wider environment and act responsibly					
Sludge storage - land application window	Business as usual risk management	Green	Yellow	Yellow	Yellow
Sludge treatment capability	Business as usual risk management	Yellow	Yellow	Yellow	Yellow
Greenhouse gas emissions	Climate change strategy	Green	Yellow	Red	Red
We keep your bills as low as possible					
Inability to secure approval	Climate change strategy	Red	Red	Red	Red
Affordability	Climate change strategy	Green	Yellow	Red	Red
Cost of capital	Climate change strategy	Green	Yellow	Red	Red
Insurance costs	Climate change strategy	Green	Green	Red	Red
Faster asset deterioration	Climate change strategy	Green	Green	Green	Green

The table above lists our climate change risks mapped to our customer outcomes and shows our risk profile across three time horizons from now until the end of the century. The red, yellow and green illustrate whether we consider the risk to be high, medium or low. These scores represent our risk position in 2020, following implementation of our current five year business plan.

2. Our climate change risk assessment

This chapter describes how we have carried out a multi-phase project to understand the best available evidence for climate change and the latest projections for how the climate in our region will change in the future.

Phase 1:	Local Climate Impact Profile - to understand how past weather events have impacted Yorkshire Water.
Phase 2:	Analysis of UKCP09 against other Global Circulation Models – to understand the range of possible climate futures.
Phase 3:	Strategic Climate Change Risk Assessment – to understand how climate change could impact on Yorkshire Water.
Phase 4:	Publication of Yorkshire Water's formal position on climate change.
Phase 5:	Detailed risk assessments (see later chapters for more information).
Phase 6:	Publication of Yorkshire Water's climate change strategy.

Our position paper and strategy (including the risk assessment) are available at www.yorkshirewater.com/climate

2.1 Informing our climate risk understanding

We have continued to make progress in assessing and, where practical and cost-effective to do so, quantifying our risks from climate change and extreme weather. Since our first ARP report in 2011 we have carried out a number of projects to better understand our priority risks and what action we can take to mitigate against them. In this chapter we summarise the activity carried out to inform and develop our overarching climate change risk assessment and strategy. Our climate change strategy and risk assessment were informed by a multi-phase project, with the first three phases carried out in partnership with URS Consultants.

Phase one: Local Climate Impact Profile

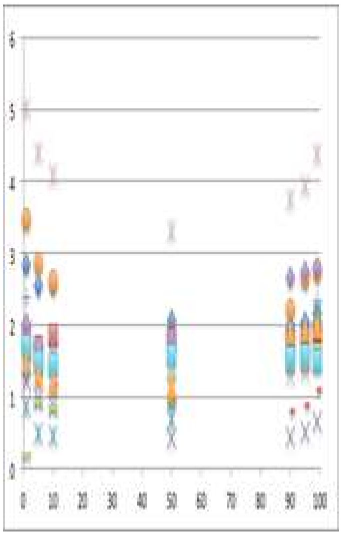
The first phase began in 2011 by carrying out a Local Climate Impact Profile (LCLIP). An LCLIP is a simple way of assessing how past weather events have affected an organisation and uses a methodology developed by the UK Climate Impact Programme[1]. To inform our LCLIP we looked back at media clippings from local and regional newspapers, analysed call centre records, interviewed staff from across the business and reviewed a number of internal reports and papers. We covered the period from 1995 to 2011 which captured a number of major weather events including drought in 1995/96, floods in 2007 and cold winters of 2009/10 and 2010/11. The findings from the LCLIP helped highlight past weather impacts and what action has been taken in response, and was used to develop our climate change risk assessment.

[1] UKCIP are the UK Climate Impact Programme, based at the University of Oxford and funded by Defra. UKCIP have developed a comprehensive set of climate change projections for the UK up to the end of the century. The latest set of projections are called UKCP09. The LCLIP methodology is available from the UKCIP website at: http://www.ukcip.org.uk/wizard/current-climate-vulnerability/lclip/

Phase two: Analysis of UKCP09 compared to other General Circulation Models

In 2012 we commissioned climate risk consultants CCRM to run an ensemble of future climate projections using each of the 16 different General Circulation Models (climate change models) which have been used in the preparation of the Intergovernmental Panel on Climate Change (IPCC)'s assessment reports. We wanted to understand how the UK's climate projections, called UKCP09 and prepared using the HadCM3 model, compared to the projections produced using other models, in order to better understand the modelled range of future climate changes. Figure 1 below shows an example of one of the outputs from this project. The chart shows the spread in results from the different models for changes in annual maximum temperature at different probability levels for the period 2046-2065. The x axis shows probability (1, 5, 10, 50, 90 and 99 percentiles) and the y axis shows the projected change in annual maximum temperature (0-6°C). Each different coloured shape shows the results from a different model. Results are for the IPCC A1B emissions scenario, which is roughly equivalent to the medium emissions scenario in UKCP09[2].

Figure 1. Analysis of UKCP09 compared to other General Circulation Models



The results from the analysis demonstrated that there is general agreement across global climate models, with more agreement for some weather parameters than others. For example, every model agrees that maximum temperature will increase, although the magnitude of the change is uncertain. The results for precipitation are less clear as it is more difficult to model. This is because snow and rainfall are driven by much smaller scale processes than temperature, and the smaller the scale of the underlying process, the more chaotic it is, and therefore harder to model. The UK climate projections (UKCP09) tend to suggest a narrower distribution of possibilities for annual precipitation compared to other climate models. However, for changes in the intensity of daily precipitation, there is almost complete unity between the models that these will become more intense, with increases suggested of up to about 18 per cent; only one or two of the projections indicate possible decreased intensities in the order of 1 or 2 per cent.

[2] UKCP09 contains projections of future climate under three different greenhouse gas emission scenarios (low emissions, medium emissions and high emissions). The scenarios describe future releases into the atmosphere of different volumes of greenhouse gasses and are based on assumptions about future economic and population growth, technology development and other factors. The IPCC uses four future scenarios, while UKCP09 uses three.

The main conclusion drawn from this work is that no one single scenario should be used to inform decisions, and a flexible and iterative approach to adaptation is required to account for future uncertainty. We have followed this recommendation by using both the medium and high emissions scenarios, and a range of different probabilities from UKCP09 to inform our planning. We have not used the low emissions scenario as global emissions are currently tracking slightly above the high emissions scenario. Using a range of future emissions scenarios and differing probability levels is in line with the approach recommended by UKCIP, Defra and others.

Phase three: Strategic climate change risk assessment

This phase created a repeatable, documented risk assessment methodology and made use of the LCLIP assessment, data on future climate projections from UKCP09, and data on past extreme events from the Met Office. This information was used to inform a series of cross business workshops to qualitatively assess the risk to Yorkshire Water assets and services. The workshops invited business experts to examine the projected changes in climate, the likelihood of those changes causing an impact, the proximity of the impact being realised, and the severity of impact. We used our standard business risk assessment matrix (shown below) to inform the severity and also captured details of the evidence and assumptions underpinning our risk and impact understanding. For example, where we have already experienced an impact, such as an extreme flood or a period of hot weather, we have a better understanding of how, where and why it causes an impact. The risk assessment covers all aspects of the business and looks across four time horizons (now, the 2030s, 2050s and 2080s). The risk scores were then reviewed by an internal panel to standardise scores across each risk area and remove possible bias caused by more recent weather impacts scoring more highly, or by different risk perceptions amongst individuals.

Figure 2. Yorkshire Water's Business Risk Assessment Matrix.

Yorkshire Water's business risk assessment matrix

	Very Low	Low	Medium	High	Very High (Strategic Risk)
Service+	Less than 1% of YW customers affected	Between 1-2% of YW customers affected	Between 2-5% of YW customers affected	Between 5-10% of YW customers affected	More than 10% of YW customers affected
Compliance+	Non compliance leading to fines/compensation within value limits below	Non compliance leading to fines/ compensation within value limits below	Non compliance leading to fines/compensation within value limits below	Non compliance leading to fines/ compensation within value limits below	Serious non compliance leading to imprisonment/ loss of licence/regulator action/costs within value limits below
Value+	Less than £0.8m	Between £0.8m and £2m	Between £2m and £4m	Between £4m and £8m	More than £8m
People+	Employees within a local works/depot affected	Employees within an major office affected	Employees within a function affected (e.g. within treatment)	Employees within a Business or Support Unit affected	All employees affected
Society	Local media coverage and active involvement of opinion informers	Regional media coverage	Regional media coverage and active involvement of opinion formers	National media coverage	National media coverage and significant effect within City
Partners	One partner affected	More than one partner affected	One group of partners affected (e.g. networks, area partners, R&M)	More than one group of partners affected	All partners/suppliers affected

The risk assessment showed that climate change has the potential to impact across all areas of our business, with our risk profile increasing into the future as climate change becomes more severe. The assessment found that climate change will generally exacerbate existing known risks, causing them to become more severe or more frequent. The table in the executive summary section shows the full list of our climate risks, and a more detailed version is in the appendix to our climate change strategy which can be downloaded from our website.

Phase four: Position paper

In 2012 we published a paper summarising our review of the scientific evidence for climate change and setting out Yorkshire Water's official position on climate change, which is summarised in the six statements below:

- The climate has been changing and will continue to change
- Climate change presents risks to our strategic objectives and the services we provide
- We will quantify the climate risks that face our business
- We will develop long term plans to manage the climate change risks that face our business
- We will promote activities to address our climate change risks
- We will drive initiatives to empower every employee to reduce carbon emissions and prepare for the changing climate.

The position paper also contains tables of UKCP09 data for the Yorkshire region for each of the three emissions scenarios, as well as the current baseline data for number of different weather parameters, time scales and probabilities.

Phase five: Detailed risk assessments

Following the publication of our position paper, we carried out a number of projects to assess, and, in many cases, quantify our priority risks from drought, fluvial flooding, coastal erosion, extreme rainfall and storm surges. More detail on each of these assessments is set out in the relevant chapters in this report.

Phase six: Development of our climate change strategy

Following the above activity, we updated our climate change risk assessment to account for our improved understanding of many of our priority climate risks. The risk assessment formed the basis for the development of our climate change strategy. Our strategy covers our strategic risk understanding, our investment plans up to 2020 as well as our long term approach, and covers both adaptation and mitigation. The action we set out in our strategy ensures we are effectively managing today's risks and laying the necessary foundations to affordably maintain services for the long term.

We have integrated our climate change needs into our Business Plan for the period 2015-2020 and are working to embed our climate change strategy across the company. The climate change strategy and risk assessments will be reviewed and updated for our next Business Plan, which will cover the period 2020-2025.

3.Ensuring sufficient water supplies

This chapter describes how we have assessed the risk to public water drinking supply from climate change, including how we have assessed the range of uncertainty in future climate change scenarios and identified thresholds for severe multi-year droughts (Section 3.3).

Section 3.4 describe how we manage leakage and the particular impact of cold weather, and how we have identified weather and performance triggers for escalating our leakage activity.

Section 3.5 describes how we have targeted investment to improve network resilience, and reduce the risk of customer supply interruptions while section 3.7 describes the role of customers have to play in reducing their own water use and how we encourage this.

Section 3.9 and 3.10 summarises the actions we have taken and plan to take.

Section 3.11 describes how we are addressing barriers and understanding interdependencies such as the challenge of securing customer support for future bill increases, and how we are working with the Environment Agency and our neighbouring water companies to ensure long term water supplies.

The final section describes how will monitor and report our performance.

3.1 Water resource management planning

We supply around five million domestic customers and 135,000 business customers with 1200 mega litres (Ml) of drinking water per day. Our water resources are carefully managed through a well-established regulatory process which requires water companies to produce long term plans for managing drinking water supply, including the development of action plans for times of drought. These plans are developed using methodologies and guidelines produced by the Environment Agency and are carefully scrutinised by our regulators to ensure the long term supply of drinking water, at a price customers are willing to pay, without damaging the environment.

Figure 3. The Yorkshire Grid

Yorkshire's water comes from a mix of sources, which are connected by a series of major pumping stations and pipelines to form the Yorkshire Grid (shown in Figure 3). Rain is channelled into reservoirs on higher ground in the west, abstracted from rivers in the centre and pumped up through boreholes that tap into underground aquifers in the east. It is filtered, cleaned and treated at one of our 53 Water Treatment Works and piped through the distribution network to customer taps. Over 99 per cent of Yorkshire Water customers are now connected to the Grid, which allows us to move water around the region to where it is most needed, and ensures one of the most resilient water supply systems in the UK.

Our Water Resources Management Plan (WRMP) uses sophisticated modelling to account for the impact of climate change, new development, population growth and trends in water use over a 25 year timeframe. Our latest modelling finds that climate change will have a significant effect on our long-term water resources by reducing the amount of water available for supply. At the same time, population growth means that demand is forecast to rise, although this rise is largely off-set by improvements in the water efficiency of new homes and appliances. However, despite these improvements in water efficiency, Figure 4 below shows that, without action, there will be a growing deficit between supply and demand over the coming years. Fortunately, we have a wide range of options to close this gap, which are shown in Figure 5.

Figure 4. Long term water supply and demand balance

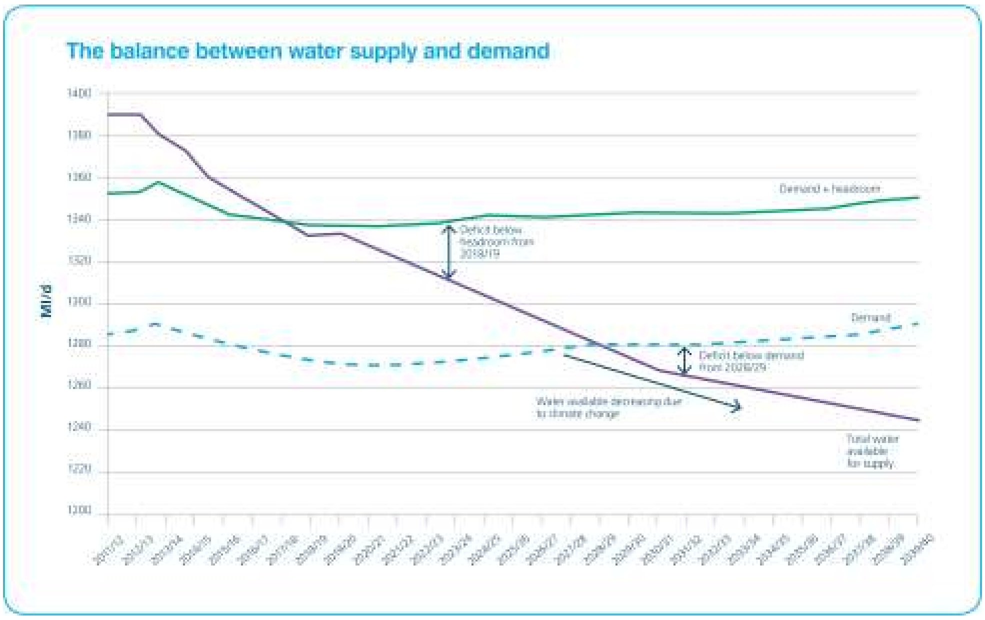
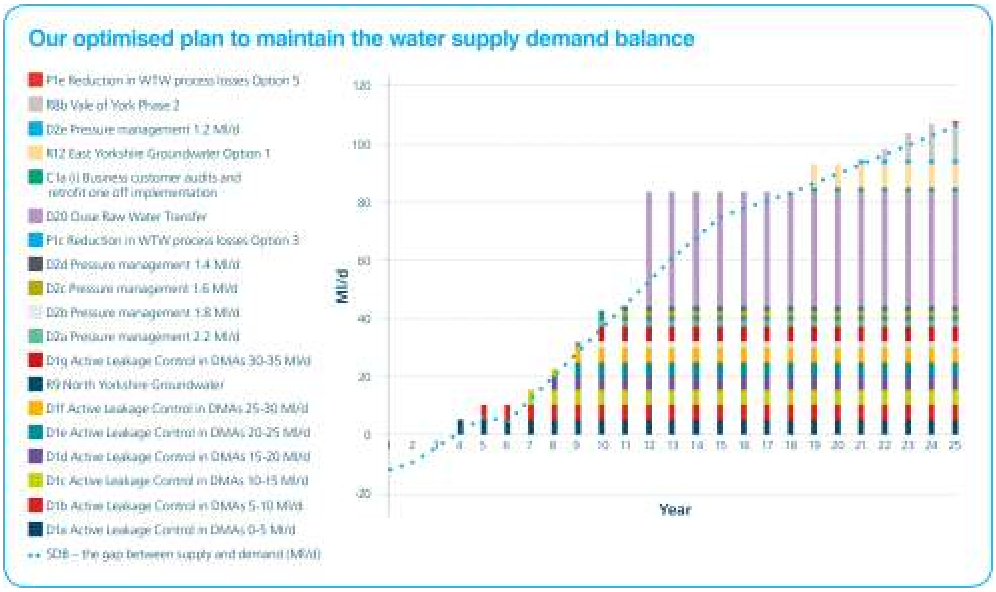


Figure 5 below shows the range of options that are available to manage the balance between water supply and demand. In line with customer expectations, and making use of the most cost-effective options first, in the near term, we will focus on demand side measures including reducing leakage, and working with customers to use less (see Section 3.4 and 3.7). In the longer term we are likely to have to implement some supply side measures. We review our plans every five years, so we can take an iterative approach and amend our activity to take into account how growth and development plans may change, the latest data about rainfall or river flows, or developments in modelling science, as well as the latest views of our customers and regulators. This ensures we are always taking the most beneficial and effective action for our customers, and for the environment, and making use of the best available information to inform our decisions.

Figure 5. WRMP options to maintain supply



3.2 Drought planning

We have a statutory requirement to produce Drought Plans, which are publically available on our website. These are produced in consultation with our regulators and set out a pre-assessed list of options that could be implemented in the event of a drought in order to protect public water drinking supply. These options have been costed and assessed for environmental impact and, in line with the approach taken in WRMPs, the Drought Plan implements demand side measures before supply side ones. Yorkshire has experienced droughts in 1995/96, 2003 and 2011/12 however we have not had to restrict water use since 1996 due to our investment in the Grid and the range of water resources we have in the region. Our modelling suggests that it is only multi-year droughts which would be likely to lead to customer restrictions, and that these events are extremely rare (see Section 3.3).

We continuously monitor our water resources and produce a weekly Water Situation Report which we share with the Environment Agency. These reports show water stocks compared to various control or trigger lines. When stocks in any part of the system cross the trigger line, we will open formal liaison with the Environment Agency and monitor the water situation on a regular basis. The trigger is set so that it is crossed well before any area is in potential drought and its purpose is to provide an early indication of problems that may develop later. Once the trigger has been crossed, we implement our drought plan procedures and work with the Environment Agency to manage the situation as it develops, including de-escalating as water stocks recover.

3.3 Informing our risk understanding – water resources planning

Over the last five years we have carried out a number of projects to inform our drought and water resource management planning and improve our understanding of climate change impacts, which are described below. These projects have helped us understand the range of likely futures our region could experience, identifying specific thresholds for severe droughts, and identifying where uncertainties remain and what further research is necessary to inform our activity.

1. Climate change evidence and trend analysis

In 2012 we undertook a comprehensive trend analysis of several long term empirical datasets available for the Yorkshire region. Around 100 years' worth of rainfall, river flow and temperature data were subjected to seven different statistical tests to identify if any evidence for past and current climate change trends could be identified. The results for the rainfall and flow datasets were mixed, with few statistically significant trends in either series, however there was a statistically significant upward trend in the Central England Temperatures (CET) data. These results are in line with other analysis which has suggested detection of anthropogenic climate change at regional scales is not generally expected for several decades to come, due to natural variability and other confounding factors (Fowler and Wilby, 2010)[3]. This highlights the need to regularly review the available evidence and the importance of maintaining long term monitoring. By continuing to make use of our historical data series and the latest climate projections, we can respond steadily to climate changes over the coming decades, integrating new evidence as it emerges.

[3] Fowler, H., J. and Wilby, R., L. Detecting changes in seasonal precipitation extremes using regional climate model projections: Implications for managing fluvial flood risk. WATER RESOURCES RESEARCH, VOL. 46, 2010.

2. Using UKCP09 in water resources modelling

This project built on UK Water Industry Research (UKWIR) analysis and subsequent Environment Agency guidance to review different options for using UKCP09 to assess the impacts of climate change on the volume of water available for public drinking water supply (known as deployable output, DO). The project allowed us to calculate factors which represent the effects of climate change on river flows and reservoir inflows. We were then able to use these factors in our water resource models to calculate future deployable output. Our analysis showed that the median climate change scenario resulted in a loss of 127.53 Ml/d by 2035 in the Grid surface water zone, with the uncertainty in this value reflected in the loss of between 45.11 Ml/d and 292.77 Ml/d in the 90th and 10th percentiles. This has been built into our plans to maintain the supply demand balance, as described in Section 3.1 above. More detail on how we have used UKCP09 for water resource planning can be found in the Technical Submission: Climate Change Effect on Deployable Output report which accompanies our Water Resource Management Plan. Our Water Resource Management Plan is available on our website and we can supply copies of the Technical Submission on request.

3. Duration modelling: impact of multi-year drought events on resources and assets

This project examined long term rainfall records along with projections of future climate change, to first establish a definition for "severe" droughts, and then to assess the current and future frequency of these droughts occurring, and what the likely impact could be on Yorkshire Water. Based on analysis of historical droughts, and in line with other academic studies, the project identified a Drought Severity Index of 20 per cent as the threshold for a "severe" drought[4]. The project then developed simulated monthly rainfall statistics based on observed rainfall data, and combined these with data from UKCP09 to establish the current probability of severe droughts and how these may change in the future. In order to account for uncertainty in the distribution of future climate outcomes, the project used both the 50th percentile and the 10th percentile of projected change in rainfall under the medium emissions scenario.

The results for the simulated current climate show that the probability of a severe one year drought is between 1 in 20 to 1 in 10 years (5 to 10 per cent annual chance of happening) with slight differences in probabilities between different parts of the region. The probability of a severe two year drought is around 1 in 100 years (1 per cent annual chance). The probability of a severe three year drought is estimated to be in excess of 1 in 400 years (0.0025 per cent annual chance). We can only estimate the probability of a severe three year drought as there are no such events in the historical rainfall record, which began in the 1860s, so it is difficult to calculate the probability of such an event occurring.

The results from the simulated future climate show that there is little discernible difference in the frequency of multi-year drought between the simulated current and future climate at the 50th percentile. This may be due to a number of factors, including the inherent difficulties in representing rare and extreme events in models, or a compensatory effect from projected wetter winters and heavier rainfall events which may serve to stifle any developing drought situation from the previous season(s). The results based on changes at the 10th percentile are more pronounced, with results suggesting that severe two year droughts could become twice as frequent, occurring as often as every 1 in 50 years (2 per cent annual chance).

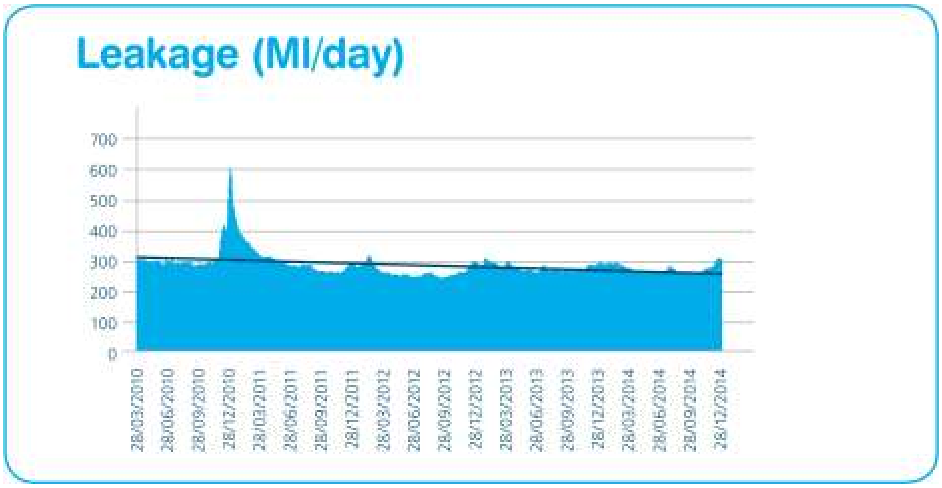
[4] The Drought Severity Index (DSI) at a given location for any given month expresses the accumulated precipitation deficit as a percentage of the mean annual rainfall. The larger the DSI percentage, the greater the severity of drought. A DSI of 20 per cent, for example, means that the cumulative rainfall deficit has reached 20 per cent of the total rainfall that falls, on average, at that location. All previous long duration droughts in the Yorkshire region have had a DSI of at least 20 per cent.

3.4 Leakage

Managing leakage is important as it helps avoid waste and reduces pressure on water resources. Leakage is treated water that is lost from the distribution system. It includes water lost from our distribution network (which makes up around two thirds of leakage) and supply pipe losses from consumers' pipes (for which the customer is legally responsible, and which makes up around a third of leakage). Some leakage is inevitable as all pipe joints are susceptible to seepage, and pipes can be damaged by freezing weather, or by the weight of traffic on roads. Annual targets for reducing leakage are set at the sustainable economic level of leakage (SELL) using methodologies produced by our regulators, the Environment Agency and Ofwat. The SELL is based on the principle that the cost of reducing leaks should be less than the cost of replacing that water from another source. In other words, it is not economically feasible to eliminate leakage entirely because the cost of finding and fixing small leaks can be excessive compared to the volume of water lost. We find and fix 25,500 above ground leaks per year, and around 4,500 below ground leaks, and have halved the volume of water lost through leakage since 1995. Our leakage performance is reported in our annual Risk and Compliance Statement available on our website.

Cold weather is the most influential factor on leakage from cast iron pipes, which make up the majority of our distribution network, whereas dry weather is most likely to cause leaks from cement asbestos pipes, of which we have far fewer. Figure 6 below shows how leakage varies with the seasons, with a significant peak shown in the winter of 20010/11. Analysis by the Met Office suggests that the snowy conditions across the Yorkshire region during November and December 2010 were the most significant and widespread since 1981, with some indications that they were the second most severe conditions in the last 50 years at this time of year[5].

Figure 6. Total leakage 2010-2015 with trend line



We monitor leakage, and customer interruptions on a daily basis all year round. Any variation (positive or negative) from the target is reported to our Board on a weekly basis. Over the spring and summer we try to generate headroom in our leakage target so that we have extra contingency in the event of a severe winter. Our Winter Plan describes how we take a stepped approach that escalates as necessary to ensure an effective operational response to cold weather. There are three trigger levels in the Winter Plan – Winter Operations, Winter Escalation and Winter Emergency. The trigger

5 Analysis of weather conditions during November/December 2010 in the Yorkshire Water region. Met Office, 2011.

levels for each of these are based on performance against the leakage target (ahead, on track, or behind), temperature and the number of repair and maintenance jobs that are outstanding. The triggers for each stage in our Winter Plan are shown the in the table below.

Figure 7. Winter Plan Trigger Levels

Winter plan trigger levels

	Triggers							
	Regional Demand (Rate of Change)	Regional Burst – Leak contacts (Rate of Change)	Regional Bursts (Frequency)	Regional Bursts (Rate of Change)	Ex Works Water Temperature	Distribution Water Temperature	Minimum Daily Air Temperature	Rapid Air Temperature change (Temperature Gradient) - min or max -
Normal Operations	<5% / wk	<5% / wk	<425	<5% / wk	>10°C	>7°C	>0°C	<3:1 per 24hrs (e.g. + 5°C in 48hrs)
Winter Operations	>5% / wk	>5% / wk	>425	>5% / wk	<10°C	<7°C	<0°C	<3:1 per 24hrs (e.g. + 7°C in 48hrs)
Winter Escalation	>10% / wk	>10% / wk	>500	>10% / wk	<7°C	<5°C	<-5°C	>5:1 per 24hrs (e.g. + 10°C in 48hrs)
Winter Emergency	>25% / wk	>25% / wk	>625	>25% / wk	<5°C	<3°C	<-10°C	>7:1 per 24hrs (e.g. + 15°C in 48hrs)

3.5 Network resilience

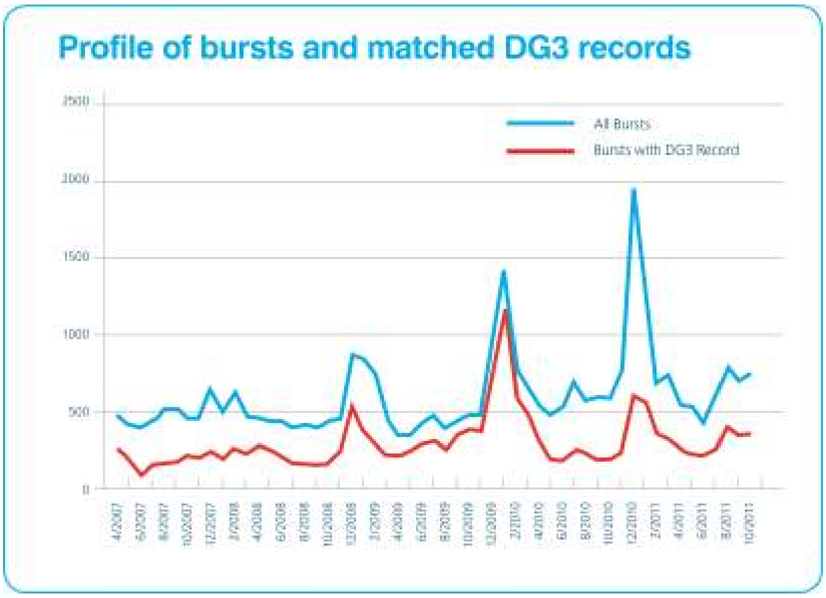
Closely related to our leakage activity is the work we undertake to manage and improve the resilience of our distribution network. This is made up of over 31,000 km of pipes along with hundreds of pumping stations and storage reservoirs which ensure our customers have a steady supply of high quality drinking water.

Climate change and extreme weather can impact on our network in a number of ways; cold weather causes pipes to become brittle and burst, intense rainfall causes landslips which can expose and damage pipes, high river flows causes scour and damage to bridge crossings, and dry weather causes the ground to shrink and move, affecting pipes and other structures.

The main indicator of network resilience is how frequently customers experience an interruption to their supply, something we try very hard to avoid. All water companies must report to Ofwat how many minutes, on average, customers supply is interrupted. To ensure comparability across the sector, this indicator is calculated by taking the number of properties which have a three hour or more interruption and dividing this by the total number of connected properties. We publish this information in our annual Risk and Compliance Statement, which is available on our website. For the last few years, our performance against this indicator has steadily improved, and is currently stable at just under 10 minutes of supply interruption per property. This figure is an average across all the properties we supply, so in actual fact the vast majority of properties did not experience any interruption to supply, but a small number (around 3 per cent) experienced an interruption to supply that lasted more than three hours.

Interruptions to supply are generally caused by bursts, but can also be a result of planned maintenance work or damage caused by third parties such as road works or other utilities. In recent years we have reduced the risk of a burst causing an interruption to supply by improving the resilience of our network, for example, by improving our ability to re-route supplies from alternative sources. This is demonstrated by Figure 8 below which plots bursts against customer interruptions (DG3 records) and which shows that despite a very high number of bursts during the cold winter of 2010/11, far fewer customers lost supply than during the previous cold winter of 2009/10, due to our investment in network resilience.

Figure 8. Bursts and customer interruptions



3.6 Informing our risk understanding – leakage and network resilience

1. Pressure transients

Pressure transients (also called water hammers) are surges in water pressure caused when pumps or valves are switched on or off too quickly which sends a wave of pressure along the network. This causes stress on pipework and valves and can result in bursts or other damage. In AMP5[6] we have carried out research with the University of Sheffield to demonstrate the extent of pressure transients, and how they are caused. In AMP6 we are deploying special transient loggers to investigate how, when and why these transients happen so we can manage them and reduce the impact on the network.

2. Winter dashboard

We have developed a water temperature predictive model which uses forecast air temperature and current water temperature to predict the point at which the water temperature will drop below the level at which we see an impact on the network resulting in increased leakage and network failure. A daily dashboard has been constructed which clearly displays the predicted date of trigger threshold crossover. The prediction provides seven days' notice and there are separate thresholds and monitors for river and reservoir water sources. The dashboard is used to inform our winter planning which is described in Section 3.4 above.

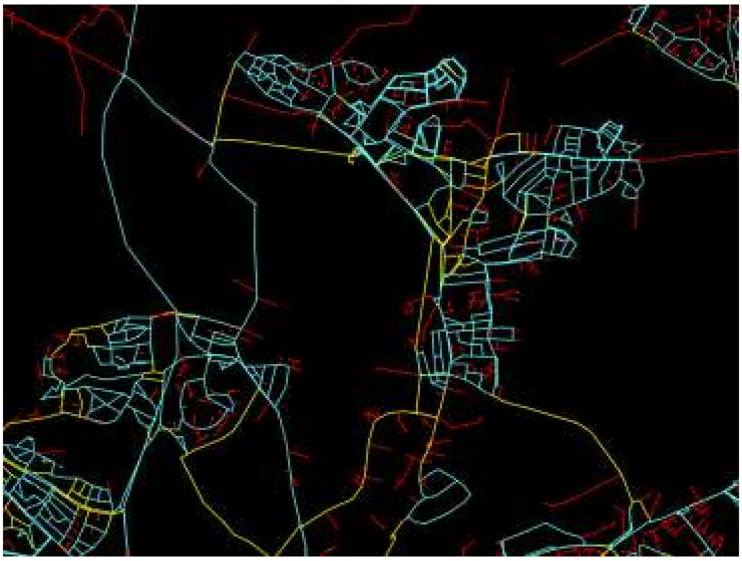
[6] AMP5 is the fifth Asset Management Period and ran from 2010-2015, AMP6 is 2015-2020

3. VASTnet

We have worked with Leeds University to develop a neural network tool called VASTnet. The tool uses Complex Network Theory and Graph Theory to analyse the connectivity and resilience of our water distribution network. The tool allows us to identify how many properties are served by a particular main and what options are available if that main should fail. For example, in some cases, supply to properties could be restored from an alternative connection, or by opening boundary valves. In other cases there is no alternative supply option, so the VASTnet tool has allowed us to identify these vulnerable properties and target these areas for investment.

An example output from the VASTnet tool is shown below. The properties served by the yellow mains could be supplied by opening boundary valves and allowing water in from a different distribution zone. The properties served by the blue mains can be served from an alternative direction, while the properties served by the red mains have no alternative supply options should they fail.

Figure 9. VASTnet output



4. Criticality study

In addition to the VASTnet tool we have also carried out a desk based criticality study of our trunk mains to identify those mains with a low probability of failure but which would have a high impact on customer supply. These are mains which serve a large population but which are difficult to either isolate, or access for repair. To improve the resilience of these key mains we have allocated investment to duplicate sections of main at critical points (e.g. major crossings), installation of cross connections (to provide alternative supplies) and installation of pressure management valves as part of a by-pass solution.

5. Longwood metering trial

Since 2012 we have been running a detailed study of two areas in West Yorkshire, to gain an understanding of the different factors affecting leakage. The study installed external meters and automated meter readers to gather flow data from as many properties as possible, along with information about the size of the property and whether it has a garden. Customers were initially made aware of the trial and informed the meters were not for billing purposes, but beyond this, the trial has tried to be as unobtrusive as possible, to avoid it influencing or changing customer behaviour in any way.

The first phase of the study analysed daily flow data to establish the extent of supply pipe leakage. Supply pipes are the section of pipe which is within the boundary of the customer's property. Although these are the responsibility of the customer to repair, we currently offer a free one-off repair service as a goodwill gesture. The study found that almost all the supply pipes (77 per cent) had some leakage, but that just three leaky pipes contributed almost all the total volume of water being lost. However, the volumes of water leaking meant that none of these leaks would currently be classed as economical to repair as they are still relatively small[7]. This information has allowed us to improve our understanding of where and when leaks are occurring, enabling us to better target resources and improve the calculations used to determine our Sustainable Economic Level of Leakage (SELL).

The second phase of the study examined how pressure management affects leakage rates. Pressure management involves the use of valves to lower the pressure in pipes, which means there is less stress on joints and less water lost if a burst occurs. The results from the pressure management study showed that it can reduce leakage, however it is very dependent on the configuration of each specific distribution management area (these are discrete, largely self-contained, water supply zones).

A third phase is planned for AMP6. The objective of this phase will be to understand and quantify the impact of the free water saving packs we offer on customers' water use over a year. This will enable a much more accurate understanding of how much water is actually saved, whether the packs offer value for money, or whether we should provide alternative products.

3.7 Water efficiency

As a water company we have a statutory duty to promote the efficient use of water by our customers. Our water efficiency campaigns highlight the ease of saving water through simple lifestyle changes, and include the following elements:

- Provision of cistern devices to households, businesses and community groups on demand.
- Free water saving packs available to household customers via our website which include tap aerators, shower timers and cistern devices.
- Retrofit water saving devices available to purchase via our website.
- Discounted water butts available to purchase via our website.
- Water efficiency information on our website and on leaflets included in letters to customers.
- Green classroom school pack and visits to our education centres.
- Water audits at non household customers and installation of water saving devices.
- Water usage investigations by our customer service team for high use customers, or customers whose usage changes suddenly.
- Free supply pipe repairs for customers.
- Proactive monitoring of large commercial customers and notification of any sudden changes in use.

[7] The principle underpinning leakage repair is that it must be cheaper to fix the leak than it is to get the water from elsewhere, to avoid unnecessarily disrupting customers by digging up roads and gardens fixing small leaks when resources could be better spent elsewhere.

- Water efficiency stalls with free water saving packs for customers in city centres and at rural events such as the Yorkshire Show.

Installing a water meter typically reduces customers' water use because of the increased financial incentive to save water. Around 40 per cent of our customers currently have a water meter installed, which we provide free on request. However, metering is expensive compared to unmeasured billing and would significantly increase customer bills due to the cost of installing new meters, replacing them every 10 to 15 years, and the ongoing operating costs associated with servicing a measured account. This cost, along with a policy of providing customers with a choice, means that we currently have a demand-led, opt-in policy on metering. We expect around 40,000 customers per year will opt to have a water meter installed, up to 2020, with numbers reducing to 15,000 per year by 2030 as the number of unmetered properties declines. By 2040 we forecast around 60 per cent of customers will have opted to have a meter installed, which along with the requirement for all new build homes to have a meter, will bring the proportion of metered customers to around 80 per cent over the next 25 years.

We will continue to provide water efficiency advice and support to our customers, and also investigate ways in which Yorkshire Water can reduce its own use of water. We have recently installed a rainwater harvesting system at our main offices in Bradford which is used to flush the toilets, and have an ongoing internal programme to identify which of our sites have a high water use, and target activity accordingly. We are also committed to including more innovative water reduction schemes in our next WRMP options appraisal, such as grey water recycling and rain water harvesting.

The average volume of water used per person is reported in our Risk and Compliance Statement available on our website. Please see Section 3.12 for details of other clean water related performance measures.

3.8 Informing our risk understanding – water use

Water use in homes built to Part G regulations and Code for Sustainable Homes water efficiency design standard

Along with several other water companies, we contributed to this collaborative survey carried out by WRc. The study analysed water use in 240 newly built homes to assess whether or not actual water use by residents matched the design requirements of the new building standards (125 litres per person per day). This is because it is recognised by the water industry that the building regulations are design standards and therefore may not reflect the actual water consumed within new homes for a number of reasons. These include the different ways in which the occupants use their domestic appliances (such as selecting different wash programmes on their washing machine or dishwasher), and the impact of product replacement over time. The study found that in general, water use was within the design parameters however the number of occupants had a significant effect, with water use per person being much higher in single occupancy homes than in multiple occupancy homes. This is likely due to economies of scale when doing washing up and laundry for one person, versus doing a larger amount of washing up or laundry for more people, but using roughly the same amount of water as a single person would use.

3.9 Actions 2010-2015

Alongside our investment in maintaining our water resource assets, we have invested £6.7 million in laying 52 km of new pipeline to connect the Scarborough and Filey area to our Yorkshire Grid. Approximately 75,000 customers have benefited as a result of this investment, which means that over 99 per cent of our customers are now connected to the grid and have a high degree of resilience and security of supply. We have also invested in a new raw water pumping station and reversible flow valves at a water treatment works near Hull, which improves the operational flexibility of the works.

In addition to investing £1.6 million in tackling leakage, we have invested around £2 million in pressure management and have delivered "Calm Networks Training" to all our network operations staff. The training is delivered using a test rig and allows network technicians to understand how closing valves on one section of the network can cause pressure transients, which can cause stress on other parts of the system.

We have installed an additional 4,500 loggers on water mains across the region which relay data automatically to our Regional Control Centre on a 30 minute basis. This gives us much greater visibility of the network and allows us to react more quickly and in a more targeted way.

We have replaced the old cast iron water mains in 17 areas with the highest frequency of bursts at a cost of £12 million. The cost of installing new domestic water meters has been £33 million, with £42 million to replace life-expired domestic meters, and £20 million on maintaining automatic meter reading equipment.

We have invested £1.5 million in water efficiency activity in the last five years.

3.10 Actions 2015-2020

Our customer outcome for this risk area is to ensure that our customers always have enough water. Over the next 25 years we plan to invest around £30 million to maintain the supply demand balance, which is over and above our investment in water treatment works or the distribution network.

In 2013/14 we produced a new WRMP and Drought Plan, as described in Section 3.1 and 3.2 above. The plans are both available in full on our website and set out how we will manage our water resources over the next 25 years. The plans are designed to meet defined levels of service which have been agreed with our customers.

Our levels of service are:
Introduction of temporary use bans: 1 in 25 years
Drought permits / orders Implementation: 1 in 80 years
Rota cuts / standpipes: 1 in >500 years

Over the next five years we will largely be focussing on demand side measures including leakage and water efficiency as these are the most cost-effective measures in the near term.

Our target is to reduce leakage from 297.1Ml/day to 287.1Ml/day by 2020. We will invest £2.4 million to achieve this. This investment will be over and above our usual leakage activity which includes resources to find and fix leaks, the continued offer of calm networks training to staff, investment in data loggers and pressure reducing valves, replacing life expired distribution zone meters, procurement of weather data and modelling.

We will continue to work with customers to reduce water demand by 1.5Ml/day from domestic customers and 0.5Ml/day from business customers, investing around £2 million in water efficiency over the next five years, through the activities described in Section 3.5 above.

We have also used the outputs from the VASTnet work set out in Section 3.4 above to identify nine schemes, costing £6.9 million to improve the resilience of our water distribution network. This is over and above our base maintenance which includes £100 million on structural mains repair and replacement.

3.11 Addressing barriers and understanding interdependencies

We have improved our understanding of uncertainties by investing in research and improving our models, as described above. Our five yearly planning process allows us to take an iterative approach to managing future water supply, taking new information into account, as we regularly review and update our plans. These activities help reduce or remove knowledge barriers, help identify knowledge gaps and ensure we invest appropriately.

We will continue to work with leading experts to model and understand how climate change and other factors will impact on water resources. For example, through the Water UK climate change network, in 2014 Yorkshire Water hosted a Met Office seminar to share the latest developments in climate science with colleagues from across the sector. Yorkshire Water also contributes to the UK Water Industry Research (UKWIR) programme. UKWIR is a water industry research forum which carries out projects on behalf of the sector. Representatives from the industry sit on steering groups for each project to ensure the outcomes are applicable to the sector. Upcoming UKWIR projects of interest include;

- Integration of behaviour change into demand forecasting and water efficiency practices
- Future estimation of unmeasured household consumption
- Assessing the impact of a distribution burst driven mains renewal programme on leakage control effort

Our first ARP report identified barriers around affordability and securing customer willingness to pay. We will need to make a strong business case for future investment, and ensure our customers and other key stakeholders are supportive of our plans. Our customer engagement programme for our current business plan was the most extensive yet, with over 35,000 customers involved. Customers told us they want us to maintain services at no extra cost, which may become increasingly challenging as our assets reach the end of their lives, or if we experience more damaging weather patterns. We will need to have a richer conversation with our customers to describe the action we, as a company are taking to reduce leakage and waste, and what action customers can take to help protect water supplies in the future.

Ensuring sufficient drinking water supplies, while also making sure enough water remains in the environment to support local ecosystems is a key interdependency which is managed through our water resource management planning. Getting this balance right requires that we work with our regulators, customers and with our neighbouring water companies to manage the impact of abstractions, reduce leakage, improve water efficiency and recognise the true value of water.

The Environment Agency's Restoring Sustainable Abstraction programme has identified operational changes at three of our reservoirs which will improve the status of water bodies downstream, but which results in a reduction in deployable output of 2.7Ml/d. This reduction is built into our WRMP and is absorbed by improving our leakage rates and by working with customers to improve their water efficiency.

We work with our neighbouring water companies to find the most economical and sustainable way of supplying our customers. We have a reasonably large scale transfer arrangement with Severn Trent Water of around 50Ml/day which helps supply Sheffield. We have also analysed the potential for water trading arrangements with Northumbrian and United Utilities, but found that these are not currently economically or environmentally desirable, however we will keep this under review.

3.12 Monitoring and reporting

We will report data about the following performance commitments on an annual basis from 2016/17 onwards on our website.

- water supply interruptions
- leakage
- per capita water use
- stability and reliability factor – water networks

You can also download our Water Resource Management Plan and Drought Plan from our website.

4. Protecting people and the environment from sewer flooding

This chapter describes how we assess and manage the risk of sewer flooding and pollution incidents caused by today's weather, including how we have identified operational thresholds for specific catchments using Hydrocast and CSO Analytics (Section 4.2). We also describe the longer term work we are doing to incorporate future rainfall in our sewer models.

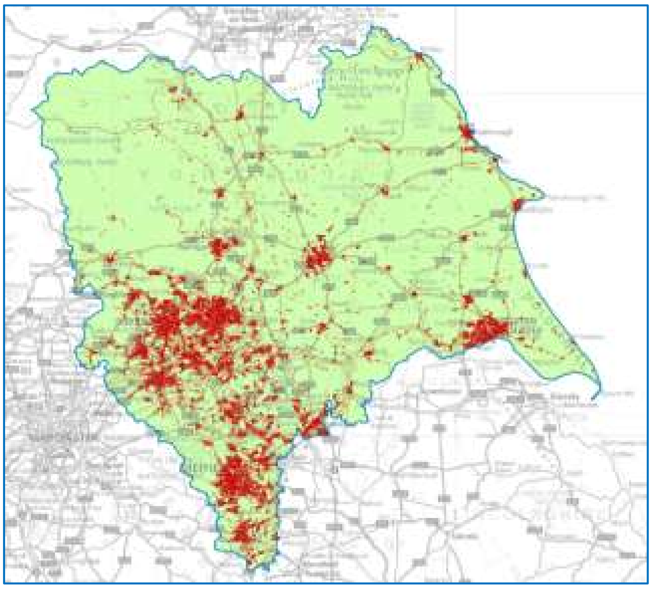
In Section 4.3 and 4.4 we discuss the action we have taken, and plan to take, often in partnership with others, to manage the risk of flooding.

In Section 4.5 we observe that barriers remain regarding the regulatory regime around sustainable drainage, and describe the opportunities and complexities we see in working with other organisations to deliver more holistic solutions to manage flood risk.

Section 4.6 sets out how we will monitor and report our performance.

We collect a billion litres of waste water every day, which is conveyed through 52,000 km of sewer pipe and pumped by 1,800 sewage pumping stations to one of our 640 waste water treatment works. Newer sewers, built since the 1960s, tend to carry only sewage. However over 80 per cent of the drainage network is made up of combined sewers. Combined sewers carry not just sewage, but also rain water and snow melt, and in many cases, also highways and land drainage, and sometimes entire water courses, which have been hidden underground and connected into the sewer network in the past. These flows can be significant, especially during storms, so outfalls called Combined Sewer Overflows (CSOs) act as emergency outlets from the network, discharging untreated storm water into rivers. This helps prevent flooding, but can sometimes result in pollution of the water body.

Figure 10. The sewer network in Yorkshire



We face a number of challenges and future uncertainties in managing the sewer network. These include uncertainty about the number, location and condition of transferred assets, uncertainty about precisely where and when new development will occur, and how climate change impacts will interact with these factors. A summary of these challenges, and our approach to meeting them are set out below.

1. A growing and ageing asset base

The UK has one of the oldest and largest sewerage networks in the world, with more than 40 per cent of it built before 1945. Changes to legislation in 2011 meant that an extra 22,000 km of sewers, which were previously privately owned, became our responsibility. Similar changes in 2016 mean we will take on an additional 720 sewage pumping stations. This will significantly increase the length of sewer and number of sewage pumping stations under our responsibility. We do not yet know the location and condition of many of these assets so there is a degree of uncertainty regarding future performance, operation and investment needs of these assets. We are currently in the midst of a public information campaign called The Big Transfer to encourage members of the public to tell us about any pumping stations they may have on their land or in their communities, so we can add them to our asset inventory and assess their future operational and investment requirements.

2. A growing population

The population of Yorkshire is expected to grow, increasing the number of customers we serve from approximately 4.9 million to 5.7 million by the year 2040. This is an additional 855,000 people, with the associated need for additional sewer and treatment capacity. We liaise closely with local planning authorities in our region so we can determine where we may need to upgrade or develop waste water treatment or drainage network capacity to meet the needs of a growing population. However, water companies are not obliged to be consulted about development plans, and all development has an automatic right to connect to the sewer network, regardless of its capacity. This presents a challenge for us in terms of our ability to proactively plan our waste water treatment and network capacity.

3. Urban creep

Data collected by the Adaptation Sub Committee shows that the area of permeable land, especially in cities, is shrinking as areas of green land such as gardens get paved over for driveways or conservatories[8]. This is known as 'urban creep' and results in less infiltration and more run-off into sewers. Research carried out by Mott MacDonald for Ofwat suggests urban creep could increase the risk of sewer flooding by around 12 per cent by the 2040s, with climate change adding another 27 per cent increase[9].

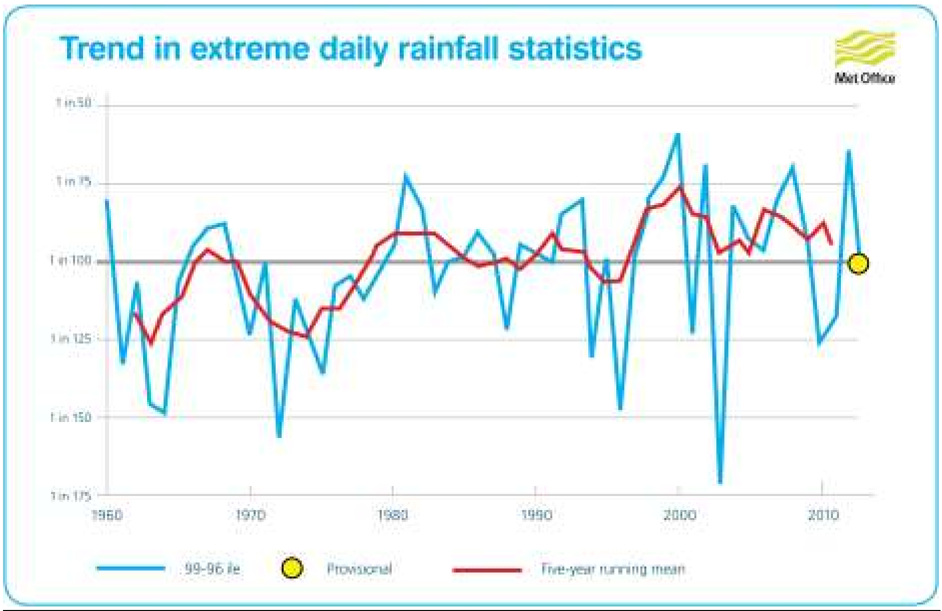
4. Climate change

Climate change is expected to add to the pressures mentioned above by increasing the number of intense rainfall events, and also by increasing the number of dry spells. Intense rainfall events can overwhelm the network and lead to flash flooding and pollution, whereas dry spells can reduce flows which means debris can accumulate and cause blockages. Over the last 50 years, and particularly over the last 30 years, there has been an increase in the intensity of rainfall events, as shown in Figure 11 below. Future climate change projections suggest there could be almost five times more events exceeding 28 mm in one hour than in the current climate[10]. These events are likely to cause increasing pressure on our drainage network, the more modern sections of which are designed to accommodate

[8] Managing the land in a changing climate, Adaptation Sub Committee progress report, 2014.
[9] Future impacts on sewer systems in England and Wales, Mott MacDonald for Ofwat, 2011
[10] Newcastle University webpage for the Convex project outputs accessed March 2015.
http://research.ncl.ac.uk/convex/newsevents/news/heaviersummerdownpourswithclimatechange.html

a 1 in 30 year[11] storm event without flooding. As the climate changes, return periods are likely to decrease. The Mott Macdonald report referred to above suggests that a 1 in 30 year storm could become more frequent in the future, occurring about 1 in every 18 years by the 2030s[12].

Figure 11. Trend in extreme daily rainfall



Source: Met Office

We use a number of tools and hydraulic models to identify and prioritise investment in our sewer network to replace and refurbish sewers, and to meet predicted increases in population growth over our five yearly regulatory investment cycles (see Section 4.2.1). We also use weather data and analytical techniques to direct our day-to-day operations to optimise the functioning of our sewer network and reduce the risk of sewer flooding (see Section 4.2.2). Our evolving approach to storm water management and investment in modelling and research is helping to inform our longer term response to development growth, urban creep and climate change (see Section 4.2.3). The number of sewer flooding incidents, and the stability and reliability of the performance of the sewer network, will be reported on our website.

4.2 Informing our risk understanding

4.2.1. Informing our investment plans

Our capital investment programme prioritises sewer replacement and repair using a risk based approach. Our Below Ground Asset Survey Predictor (BGASP) model uses asset deterioration curves, observed failure rates and asset attributes such as pipe material, to predict the probability of blockage and collapse, the consequences of failure, and when an asset will reach the end of its lifespan and need replacing.

We have recently invested £250,000 to improve BGASP by modelling how different factors (including temperature) affect different pipe materials. Our BGASP model, along with its sister application, AGASP (Above Ground Asset Survey Predictor) are part of our suite of corporate risk management and

[11] A 1 in 30 year event has an annual probability of 0.03 per cent. A 1 in 18 year event has an annual probability of 0.05 per cent.
[12] Future impacts on sewer systems in England and Wales, Mott MacDonald for Ofwat, 2011

investment planning applications, called Leading Edge Asset Decision Assessment (LEADA+). These systems allow us to produce optimised investment plans that balance risk, cost and performance. This approach aligns to the UKWIR "Capital Maintenance Planning: A Common Framework" and underpins a significant proportion of our investment plans.

4.2.2 Informing our day to day operational risk and response

We use a combination of rainfall radar data, weather forecasts, real time information from our telemetered assets, and customer contact data in our Regional Control Centre to target our operational activity. This information also informs our longer term investment planning.

HydroCast is a rainfall data analysis and visualisation tool which combines a number of rainfall data sources to provide a three hour forecast in five minute time steps at 1 km grid square resolution. The system also provides a range of forecast horizons up to ten days in advance at drainage area zone or catchment scale. We can use the tool to determine rainfall thresholds for specific areas, customers and/or assets. An alarm is issued when rainfall is predicted to exceed the threshold and we can then send out field teams or alert site operators and adjust our activity accordingly.

We also use Met Office 1 km radar rainfall data for post event analysis. This data is stored on our corporate systems and linked to a bespoke version of the Flood Estimation Handbook (FEH). Our bespoke version of the FEH was developed for Yorkshire Water by the Centre for Ecology and Hydrology and allows automatic generation of return periods for all flooding incidents. This allows us to understand in detail specific rainfall events at any location across the region.

In recent years we have worked with the University of Sheffield to develop a predictive tool called CSO Analytics. The tool uses artificial neural networks to predict the impact of weather on the drainage network and can send asset specific alerts to the control room, allowing for a targeted operational response to find and resolve developing problems. Neural networks are a type of machine learning inspired by biological systems such as the central nervous system of animals. They have a number of different nodes which interact with each other and which are tuned by a self-learning algorithm. They are a useful way to solve problems which have a large number of generally unknown inputs, and which are hard to solve using rule-based programming. In this case, how a sewer network responds to weather patterns. Our extensive telemetry archive of rainfall, sewer flow and level data, dating back some 20 years, is the main factor in successfully implementing this tool.

Alongside the above tools and data, our control centre has real time visibility of the number, nature and location of customer contacts. This enables us to see if we are getting a lot of calls from a particular location, which might suggest a problem. Using our text message alert system, Blaster, we can then automatically send text messages to groups of customers in specific areas to let them know we are aware of an issue and are tackling it.

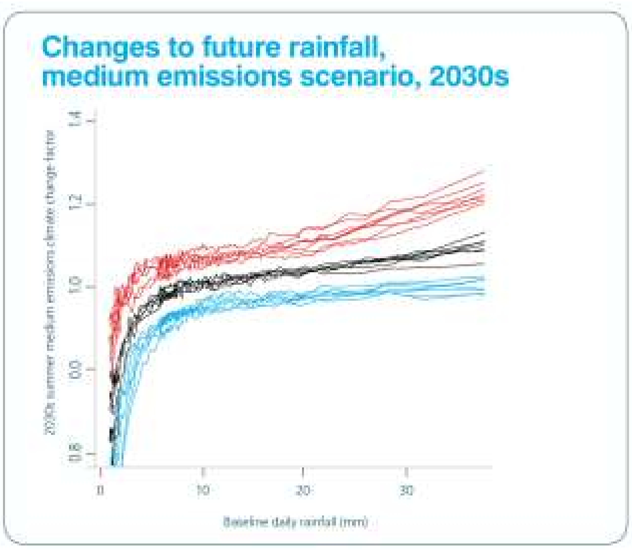
4.2.3 Informing our longer term risk understanding

In 2010, we began a 25 year programme to develop Drainage Area Plan (DAP) models for each of our 300 drainage area zones. DAPs are hydraulic models that allow us to analyse the current and future performance of the network. They make use of rainfall data, catchment characteristics and the location, size and flow patterns of our pipes. DAPs can be used to assess how a new housing development, or installation of a larger sewer will impact on the drainage network. They are also used to verify the source or cause of flooding incidents and inform what solution should be installed to address problems.

In 2012/13 we commissioned HR Wallingford to update our existing rainfall time series, and develop new ones which accommodate future climate change driven changes to rainfall. The rainfall time series were developed by perturbing historical rainfall records with climate change factors derived from UKCP09. The project made use of data from both the medium and high emissions scenarios, and provides a number of uplifts we can apply to our DAPs that account for future changes in rainfall and antecedent wetness conditions across different seasons, probabilities and time horizons.

The figure below illustrates an example output from the project showing change in summer rainfall for the 2030s. The x axis shows the baseline daily rainfall depth to which the factor would be applied, and the y axis is the climate change factor (1961-90 baseline to future). A value greater than one indicates an increase in rainfall depth. The figure shows that for all probability levels, smaller rainfall depths are generally decreasing more (or increasing less) than larger rainfall depths. This is consistent with general UKCP09 trends of rainfall extremes becoming more severe while overall summer rainfall decreases. At the 50th percentile level, there is a transition from a reduction in daily rainfall depths to an increase at daily rainfall totals around 10mm. This indicates a reduction in smaller rainfall events and an increase in the proportion of large events. There is a distinct difference between the 10th, 50th and 90th percentiles illustrating the uncertainty in the projections. Note also the curves diverging at large daily rainfall depths (towards the right hand side of the chart) indicating that uncertainty is higher for more extreme rainfall events. Outputs for the 2050s and 2080s show broadly the same changes as Figure 10 below, with a general trend of increasing scatter between locations, indicating more uncertainty into the long term future, and steeper (more extreme) curves, as climate change impacts become more severe towards the end of the century.

<u>Figure 12. Changes to future rainfall, medium emissions scenario, 2030s</u>



Source: HR Wallingford, 2013

4.3 Actions 2010-2015

The sections above have outlined recent investment in BGASP, HydroCast, CSO Analytics, and DAPs. We have also invested £179 million in sewer rehabilitation and pumping station refurbishments over the last five years, as well as £80 million in preventing sewer flooding. This investment has removed 385 properties from the regulated sewer flood risk register.

We have also invested in a number of partnership schemes to reduce the risk of surface water flooding and alleviate pressure on our network. For example, we have worked with East Riding Council on a £1.6 million scheme to reduce the risk of flooding to around 40 properties. Our original proposal was to install a very large storage tank to retain surface water and prevent it overwhelming the combined sewer system. By working with East Riding Council, a jointly funded scheme was developed with a lower overall cost. The council built a flood wall to protect the 40 properties and which held back excess surface water and stored it on an adjacent area of parkland. This flood storage area slowed the flow of water into the combined sewer system which meant we could install a much smaller tank than in the original proposal.

Photos of jointly funded flood alleviation scheme in Beverley. Photo 1 shows the 800,000 litre storage tank. Photo 2 shows some of the project team with local residents in the flood storage area with a view of the steel reinforced flood wall, faced with traditional brick, protecting the row of houses behind.

In addition to examples of capital schemes such as the project described above, we have established information sharing protocols with each of the 14 Lead Local Flood Authorities[13] (LLFA) in Yorkshire. These protocols are over and above the legal requirement to share data in that we have provided every LLFA with a copy of our public sewer records and associated assets in a format suitable for loading into a Geographic Information System. We can also re-run our models on behalf of LLFAs carrying out specific investigations. For example, we have worked closely with Calderdale Borough Council and the Environment Agency to understand flood risk in the Calder Valley, particularly in Todmorden. We have used the Environment Agency's river model alongside our own sewer network model to provide a fuller understanding of the interactions between the river and the sewer network. A similar approach has also been adopted in Goole with East Riding of Yorkshire Council and the Goole and Airmyn Drainage Board.

We have carried out feasibility studies at three sites over the last five years to test a more sustainable approach to managing drainage. The studies provided useful insights into the practicalities of implementing this approach, which we plan to develop further in the coming years. Please see Section 4.4 for more information on our evolving approach to storm water management.

[13] Lead Local Flood Authorities (LLFAs) are county councils and unitary authorities with responsibility for managing local flood risk under the Flood and Water Management Act, 2010.

4.4 Actions 2015-2020

Our customer outcome for this risk area is to take care of your waste water and protect people and the environment from sewer flooding. Over the next 25 years we plan to invest £3.6 billion to maintain current services, meeting the challenge of household growth, urban creep and climate change, while ensuring that flooding and pollution from the sewer network are managed and the resilience of our sewer network is improved.

Our capital programme includes £218 million to replace or refurbish sewers and pumps over the next five years and a further £83 million to tackle sewer flooding caused by overloaded sewers. We also plan to spend £0.6 million on upgrading and improving event duration monitoring at our CSOs.

We have allocated £25 million to continue our prioritised programme of Drainage Area Plan (DAP) modelling. By the end of 2020 we expect to have another 60 DAPs which means we will have model coverage of two thirds of the region. We have also allocated an additional £10 million to update our existing DAPs and ensure new ones will include the new rainfall time series and climate change uplifts described in Section 4.2.3 above.

Developing our storm water management strategy

Modern sections of the sewer network have been designed to carry flows from storm events up to and including a 1 in 30 year event. The challenges of urban creep, new development and climate change mean that it is not sustainable, either financially or environmentally, to build ever larger sewers and storage tanks. We recognise that a new approach is needed and later this year we will publish our Storm Water Management Strategy which will set out how we will tackle these challenges. Alongside the strategy, we have allocated £1.5 million over the next five years to carry out feasibility studies and assess different techniques for managing storm water, such as Sustainable Drainage Systems (SuDS). SuDS try to mimic natural drainage by

- storing runoff and releasing it slowly (attenuation)
- allowing water to soak into the ground (infiltration)
- slowly transporting (conveying) water on the surface
- filtering out pollutants
- allowing sediments to settle out by controlling the flow of the water

A SuDS could be any one of a portfolio of measures and could include water butts and ponds which catch and hold back water, or swales and rain gardens which are usually dry but which fill up with water when it rains.

Strategic investment planning

We play an active part in our local and regional flood risk partnerships, which bring together Lead Local Flood Authorities (LLFAs), the Environment Agency, Internal Drainage Boards and water companies to prioritise investment to reduce flood risk. The forums allow for greater shared understanding of risks, and provide a platform to discuss and agree where collaborative working could resolve flood risk in a more holistic manner. Historically these forums worked on a one year rolling programme, however the Environment Agency and LLFAs have recently published a six year forward plan of flood risk management projects known as the Medium Term Plan (MTP). This has allowed us to map our known sewer and asset flood risks against the MTP so that we can work together to identify where there may be potential for joint projects. To aid this we have established an internal Flood Steering Group, written a Partnership Working Policy and designed our Flood Partnership Process for assessing Yorkshire Water contributions to flood schemes. These have been shared with our Lead Local Flood Authorities, the Environment Agency, and others with a role in flood risk management, and we are currently working through approximately 120 possible schemes to identify any suitable partnership projects. An example of one such project is described below.

Working with others to reduce flood risk

Over the last two years, we have worked alongside the East Riding of Yorkshire Council, Hull City Council, the Environment Agency and Internal Drainage Boards to develop an integrated flood risk management plan for the River Hull. This catchment is one of the most at risk areas in the country and, without defences, approximately 5,500 ha of land and nearly 131,000 residential properties would be at risk of flooding from the sea, river, surface and ground water. We have combined our sewer network model with channel modelling and overland flow models from the other organisations involved to create an integrated catchment model. This has been used to identify a portfolio of options that reduce flood risk, including increased pumping capacity at key points in the system, river dredging and removal of sunken vessels, and alternative uses of the Environment Agency's Hull Tidal Barrier. We had already planned to upgrade a surface water pumping station to accommodate new development in the area, but by working together and making use of the outputs from the integrated model, we were able to improve our business case and include additional pumping capacity. This scheme increases the pump capacity from 5,000 litres per second up to a maximum of 20,000 litres per second. The pumping station scheme should be complete in time for winter 2015 and represents the first step in the implementation of the £16 million River Hull Catchment Strategy.

Photo of Bransholme Surface Water Pumping Station upgrade

4.5 Addressing barriers and understanding interdependencies

One of the main uncertainties (and therefore potential barriers) is related to how changes in rainfall patterns will affect performance of the sewer network. Our DAP programme and the other activity described above will help inform our plans, taking into account current and future changes in rainfall patterns. We will continue to work with the water industry research community on sector wide projects alongside our own research and development programme. Forthcoming projects of particular interest include the UKWIR projects 'Rainfall intensity for sewer design' and 'Planning for the mean or planning for the extreme'. The first of these two projects will apply the knowledge gained from the multi-agency CONVEX project. CONVEX has used new super-computers at the Met Office to combine observations of hourly rainfall with state-of-the-art climate modelling, in order to improve understanding of how summer convective rainfall events will change in the future.

Our sewer network is interlinked with assets owned and operated by a number of organisations including local authorities, the Highways Agency, and the Environment Agency. This is one of our main interdependencies and requires a holistic, catchment based approach in order to fully understand the many interactions between different systems. Additional complexity is introduced when working in partnership however, as different organisations work to different standards of protection, have different cost benefit thresholds and may make use of different climate change information. For example, the current industry design manual Sewers for Adoption v 7, does not include any uplifts for climate change or account for how levels of protection offered by drainage systems are likely to decline as rainfall patterns change.

Other barriers to the successful long term management of the drainage network relate to the regulatory regime surrounding SuDS. Following the 2007 floods across the UK, the Pitt Review recommended that water companies should be statutory consultees for all new development and that the automatic right to connect to the drainage network should be removed. This is because the water company is usually expected to take over ownership and maintenance of new sewer and surface water drainage assets once a development is complete. If water companies are consulted, they can request that the new sewers meet industry design standards. This ensures customers receive a specific level of protection from sewer flooding[14]. If water companies are not consulted about the design of these assets, they cannot be certain they will perform as expected, or that they will not cause additional pressure on the existing network. This could present additional costs and risks to the company and to customers. Although progress is being made on these matters, further clarity is required over the approval of SuDS, who should bear the costs of ownership and maintenance, and design standards. We are engaged in consultation and dialogue through national forums to clarify these and other outstanding issues, and progress the implementation of more sustainable drainage approaches.

4.6 Monitoring and reporting

We will report data about the following performance commitments on an annual basis from 2016/17 onwards on our website.

- number of internal sewer flooding incidents (flooding inside a home)
- number of external sewer flooding incidents (flooding outside e.g. to a park or garden or street)
- number of pollution incidents (all causes)
- number of solutions delivered by working with others
- stability and reliability factor – waste water networks

[14] Current industry design standards are set out in Sewers for Adoption 7th Ed. It specifies that foul-only sewers should provide a 1 in 30 year level of protection, while surface water should only connect into the existing network if there are no other alternatives, and only where there is sufficient capacity.

5. Enhancing the resilience of our critical assets and services

This chapter describes our approach to infrastructure resilience, which is ultimately about managing risk to ensure the continued delivery of services to customers and the environment.

Section 5.1 includes details of our emergency planning and response. Section 5.2 sets out how we manage our key supply chain risks and ensure a continued supply of power, chemicals and IT.

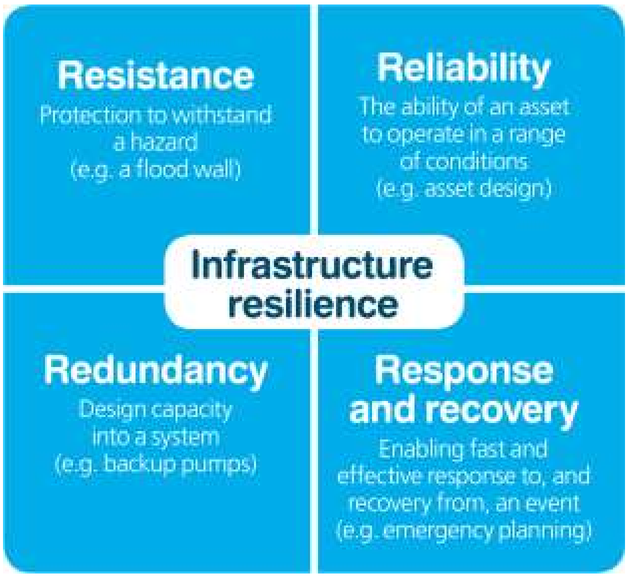
Sections 5.3 to 5.6 explain how we have assessed the risk to our assets and services from river flooding, sea flooding and coastal erosion, as well as the risk of flooding from our reservoirs. These sections also include details of the action we have taken to mitigate these risks.

Section 5.7 describes where we have identified barriers, such as securing customer support for resilience investment, and how we are addressing our interdependencies by working with other infrastructure providers, for example through both the national Infrastructure Operators Adaptation Forum and a Yorkshire equivalent. Section 5.8 sets out how we will monitor and report our performance.

We manage a substantial asset base that includes 134 reservoirs, 640 waste water treatment works, 53 drinking water treatment works and 83,000 km of pipes. We have assessed the risk to our assets from a number of climate change and extreme weather risk parameters. This section sets out how we have assessed the risk to our assets from fluvial, coastal and reservoir flooding along with coastal erosion. For details of how extreme cold impacts on our assets and services please see Chapter 3, and for details of how we manage the impact of intense rainfall on our drainage network please see Chapter 4.

Our risk assessments have enabled us to prioritise investment at our most vulnerable and most critical sites. Where we have not been able to invest in capital resistance measures, we have put in place operational contingency plans. The networked nature of our asset base and investment in the Yorkshire Grid means we are often able to re-route supplies from alternative sources and avoid the impact of individual asset unavailability on customers. We also have an Incident Management Framework for dealing with events beyond our normal operating conditions (see below). This approach is in line with the Cabinet Office guidance "Keeping the Country Running" which suggests activity is required across the four themes shown below in order to deliver effective resilience.

Figure 15. The Cabinet Office model for infrastructure resilience



5.1 Emergency response and recovery

Under the Civil Contingencies Act, 2009 and the Security and Emergency Measures Directive, which is part of the Water Industry Act, 1991, we have defined responsibilities to plan and prepare for emergencies and to work with other organisations in disaster situations. We are audited on these capabilities on an annual basis by Defra and were classed as "excellent" in our most recent audit. Our provisions include:

- Participation in local and regional resilience forums including joint training exercises and planning workshops
- Participation in Gold, Silver or Bronze command structures when triggered
- Mutual aid agreements with neighbouring water companies to share equipment, staff and other resources as necessary during emergencies
- Strategic stockpiles of equipment such as high capacity pumps, tankers and water treatment chemicals
- An Incident Management Framework which provides a staged response to ensure effective allocation of resources to incidents, including a requirement for post event reviews to share lessons learnt
- A regional control centre which provides a central point of co-ordination for any incident and which allows us to remotely operate our assets using real time asset performance data
- Business continuity policy and a rolling programme to test critical systems and processes.

5.2 Interdependencies

Our ability to deliver services from our asset base is dependent on a steady supply of power and treatment chemicals, as well as the ability to remotely operate our assets from our Regional Control Centre. We have taken a number of steps to improve our resilience to the loss of any of these key inputs, which are described below. We also acknowledge that we are interdependent with a wide range of other providers such as the transport network and schools. Disruption to these services and their subsequent impact on Yorkshire Water is mitigated through our business continuity policies. We are also involved in local, national and regional fora such as our Local Enterprise Partnerships, City Region Investment Boards and the national Infrastructure Operators Adaptation Forum, and are actively pursuing a more strategic approach to regional infrastructure planning and investment in order to address our interdependencies.

5.2.1 Power

Our most critical sites are dual supply with power sourced from two separate electricity sub-stations so that if one is interrupted, the site can receive power from an alternative grid source. These sites are also prioritised for reconnection by Northern Power Grid in the event of power cuts, and have on-site back-up generators and will switch power supplies automatically in the event of a power cut. The majority of our important monitoring and control equipment has Uninterruptible Power Supply (UPS) which are a series of batteries to ensure we always have visibility and control over our assets. In addition to on-site generators, we also have a standing contract with a generator hire company including the ability to deliver a ready-to-go generator to any of our sites within four hours.

We are increasing investment in our own renewable energy generation capacity which will reduce our dependence on supplies from the National Grid. Recent investment includes a Thermal Hydrolysis Plant at our waste water treatment works in Bradford and a 123 meter wind turbine at our waste water treatment works in Leeds. We aim to generate around 12 per cent of our annual electricity needs from renewable technologies installed at our works, and though energy efficiency schemes we have reduced our electricity consumption by over 8 per cent since 2010/11. For more information about how we are reducing our emissions please refer to our climate change strategy on our website.

Photo of the new wind turbine at our waste water treatment works, Leeds.

Our interdependency with the power sector is two-way. At times of high demand, electricity is two to three times more expensive than at others. We try to reduce our demand during these times to save costs. The National Grid can also ask large users such as Yorkshire Water to temporarily reduce demand in order to relieve pressure or request that we temporarily supply extra energy to the Grid from our own generators or renewable energy sources.

5.2.2 SCADA, telemetry and telecoms

The ability to operate our asset base from our Regional Control Centre depends on a system called SCADA (Supervisory Control and Data Acquisition) and associated telemetry along with our IT systems and telecoms. We work closely with the Centre for the Protection of National Infrastructure (CPNI) and the Security Services to ensure the security of our SCADA network, which is not run over the internet and is very secure. We also manage our IT system risks through ISO2701 accreditation which is a widely used IT security standard which we have held for approximately ten years.

During a civil contingency or national emergency, there are provisions in place which allow the emergency services and others involved in managing disasters to communicate with each other. These include private extranets, priority access to mobile phone networks and emergency transportable telecoms hubs.

5.2.3 Chemicals

We use a number of different chemicals in the water and waste water treatment process, and we have various mechanisms in place to ensure a continuous supply. For example, we hold strategic stockpiles of chemicals at critical sites, with telemetered reserve tanks which gives our Regional Control Centre visibility of chemical stocks, and which triggers a re-order when stocks dip below a pre-defined level. We also embed supply chain resilience into our procurement strategy and contracts. Our tendering process requires suppliers to inform us of any initiatives they have taken to ensure security of supply, details of disaster recovery and business continuity plans, and what control measures are in place to ensure products and processes meet final product specifications. These details are then embedded into the contract and are reviewed and monitored on a regular basis. Our contracts also require key suppliers to meet specified supply deadlines, hold stocks at their site which are allocated for Yorkshire Water only use in case of a global shortages, and to keep us informed of any emerging risks in their supply chain. These measures provide a margin of safety so we have time to source alternative supplies well before problems arise. In addition to these safeguards, we are exploring how we might be able to recover and re-use treatment chemicals from spent material which would normally be sent to landfill. If successful, this project has the potential to make us self-sufficient in some water treatment chemicals.

5.3 Fluvial flooding

The Yorkshire region has experienced significant flooding in recent years, most notably during the summer of 2007 when more than 30,000 homes were flooded and several people lost their lives. There was widespread disruption across the region and a state of national emergency was called. Although several of our waste water assets were completely inundated, we were able to maintain drinking water supply throughout. We carried out an extensive programme of reinstatement following this event, rebuilding seven waste water treatment works and raising critical equipment above the flood depths at a cost of more than £50 million.

5.3.1 Informing our risk understanding

After the floods in 2007, we began a multi-phase project with national experts at Halcrow (now CH2M) to quantify the resilience of our above ground assets to fluvial flooding. The first phase was carried out in 2008/09 and consisted of a simple screening exercise using Environment Agency flood maps overlaid with the location of our assets. This phase of the project was used to develop a business case for investment which is described in Section 5.3.3 below.

Phase two of the project began in 20012/13 and used a greater range of evidence and information sources including hydraulic river models developed by the Environment Agency, topographic surveys, LiDAR data, and interviews with site operators. The impact of climate change on an assets' level of resilience was assessed where data was available. Site specific reports have been produced for 150 of our most critical at risk sites which includes details of predicted flood depths, the current level of resilience at the site, and the height of critical equipment such as electrical control panels and thresholds to doorways. These reports are held on a central database so that when we are carrying our work at an asset we can use this information to improve resilience as part of our repair and maintenance activity or other capital works.

Phase two of the project was also used to inform the development of our fluvial flood risk guidance document. This sets out our aspiration to protect assets from a fluvial flood event with a 1 in 200 year (0.5 per cent annual probability) return period. Where practical, we aim to also include an allowance for climate change and freeboard. This flood resilience standard was suggested in the Pitt Review and in the Cabinet Office document “Keeping the Country Running”.

We plan to progress phase three of the project in the next few years, which will examine the risk to our above ground assets from pluvial flooding.

5.3.2 Informing our day to day operational risk and response

We monitor and manage the risk of asset inundation at our Regional Control Centre using a wide range of data and information including real time data from our telemetered assets, information from site operators and weather forecasts and alerts. This information allows us to target our operational activity to protect an asset and maintain services. When flood alerts suggest an asset is at risk of inundation we will implement the site flood plan which sets out the following:

- what levels and alarms should trigger implementation of the plan (e.g. water levels are at 1 m)
- what levels and alarms should triggers escalation of the plan (e.g. water levels are at 2 m)
- asset information e.g. what type of pumps are present, and in what sequence they should be operated
- site schematics and drawings
- whether access roads become restricted during floods
- what mitigation measures should be deployed e.g. sandbags, flood boards, back-up generators
- staffing resource required and contact details for both Yorkshire Water staff and contractors
- contact details for others who should be informed/notified such as the local authority, Environment Agency, Yorkshire Water call centre staff etc.
- triggers for de-escalating and returning to normal operations.

5.3.3 Actions 2010-2015

In addition to the risk assessment activity described above, we have also delivered three schemes during AMP5 to improve the resilience of our clean water supply for around 300,000 customers. These schemes cost £1.7 million. Where we were not able to invest in resistance measures, we have developed operational contingency plans as described in Section 5.3.2.

Site 1 – Flood wall, standby generator and telemetry provided around a clean water pumping station to provide protection against a 1 in 1000 year fluvial flood.

Site 2 – Raising flow control valves above critical flood depths and protecting electrical equipment at a clean water pumping station to provide protection against a 1 in 1000 year fluvial flood.

Site 3 – Flood proofing walls, installing flood proof doors, providing a bund around transformer and sealing cable entry ducts at a clean water pumping station to provide protection against a 1 in 1000 year fluvial flood.

5.3.4 Actions 2015-2020

We have used our improved risk understanding to develop a fluvial flood risk guidance document, as set out in Section 5.3.1. Our aspiration is to improve the resilience of all critical assets to at least a 1 in 200 year level of protection (0.5 per cent annual probability), with allowances for climate change and engineering freeboard where practical. Our historic investment and the networked nature of our asset base means the risk of asset inundation resulting in an impact on customers such as drinking water supply interruptions is low. We will look to include capital flood resilience enhancements within other projects where it is practical and cost effective to do so, and have established operational flood contingency plans for all at risk sites.

We will also continue to play an active role in our local and regional flood partnerships, including identifying opportunities to work together to mitigate flood risk from our drainage network as described in Chapter 3. In addition we have allocated £3.6 million of investment to improve our emergency response, including purchase of high capacity pumps, demountable flood defences, all-terrain vehicles and training exercises.

Over the next five years we plan to implement phase three of the flood risk assessment described above which will assess the risk of asset inundation from pluvial (surface water) flooding. Our approach to managing storm water is also in development; please see Section 3 for more information.

5.4 Reservoir flooding

The Reservoir Safety Act, 1975 and the Flood and Water Management Act, 2010 provide the legal framework that ensures the safety of reservoirs, including a requirement for regular inspection by independent civil engineers, and preparation of reservoir flood plans. Reservoir spillways are designed using a standard industry methodology and make use of guidance set out in the Flood Estimation Handbook[15]. They are model tested to accommodate a maximum probable flood with an additional safety margin of 10 per cent, which includes a climate change factor. We own and operate 134 reservoirs, 124 of which are classed as Category A or B reservoirs under the Reservoir Safety Act, which are reservoirs which would pose a risk to life if they failed.

5.4.1 Informing our risk understanding

Yorkshire Water takes its reservoir risk seriously and we believe we are the first major undertaker to carry out a full Portfolio Risk Assessment for Reservoir Safety (RARS) for every reservoir we own. The RARS methodology, developed on behalf of the Environment Agency in 2013, is the industry standard for assessing the risk of future failure of a reservoir. It takes into account construction type, monitoring regime, past work on the reservoir and possible failure modes.

As well as the above risk assessment work, we have a number of different flood risk maps which show the potential impact of reservoir failure. Detailed inundation maps show the geographical extent of the possible flood area, along with flood depths and water velocity. These are shared with the Environment Agency who publish less detailed version of these maps, showing the flood extent only, on their website. We also have "on-site" plans for each of our 134 reservoirs which are for internal use. These identify what the procedure is for dealing with an incident on site relating to dam failure,

[15] The *Flood Estimation Handbook* and related software offer guidance on rainfall and river flood frequency estimation in the UK. Flood frequency estimates are required for the planning and assessment of flood defences, and the design of other structures such as bridges, culverts, and reservoir spillways. http://www.ceh.ac.uk/feh2/fehintro.html

and also identify which other Yorkshire Water assets would be affected downstream should a reservoir breach. These plans are stored on our corporate risk system and are reviewed and updated annually by an independent Supervising Engineer.

We also work with the emergency services to develop and test contingency plans for in the event of a reservoir failure. These have included hosting a study day for Local Resilience Forums in 2012, training exercises with Kirklees Council in 2013, Calderdale Council in 2013, and with South Yorkshire emergency services in 2014.

5.4.2 Actions 2010-15

In AMP5 we began a ten year programme of activity to enhance the resilience and safety of our reservoirs. The first phase involved £45 million of investment. This work has included spillway modifications and improvements, valve refurbishment, improvements to embankment stability and draw down capacity. As described above, we have also worked with the emergency services and other regional organisations to carry out joint training and contingency planning exercises.

5.4.3 Actions 2015-20

We will continue our programme of investment in the next five years by investing a further £60 million. This will be used to maintain reservoir structural integrity and enhance their spillways to ensure excess water can bypass a reservoir without harm. We will also continue our programme of reservoir safety inspections and further develop our flood risk plans for all our A and B category reservoirs. We will also continue our programme of on-site exercises and training with our own operatives and staff as well as joint training exercises with the emergency services and other key stakeholders such as the Environment Agency.

5.5 Coastal flooding

Storm surges are caused by a combination of low pressure weather systems offshore and strong winds coinciding with a high tide. These factors can combine to push a surge of sea water inland and result in coastal flooding. The shape of the North Sea and the Humber Estuary contribute to our storm surge vulnerability as surges tend to "bounce" around the North Sea and get channelled up the funnel shaped Humber Estuary. Current evidence from UKCIP suggests that the risk of storm surges will mainly be affected by sea level rise, causing extreme sea levels to be higher and increasing the likelihood of defences being overwhelmed[16]. The Yorkshire region has recently experienced a storm surge which is described in the section below.

5.5.1 Informing our risk understanding

In 2012/13 we worked with JBA consulting to undertake a provisional assessment of our risk from storm surges. The project used the 1 in 200 year (0.5 per cent annual probability) coastal flooding outlines from the Environment Agency flood maps and combined these with sea level rise data from UKCP09. The assessment is a worst case scenario as it assumes no defences are present, when in actual fact sea defences are present along almost all of the Humber Estuary, as shown in the figure below. The assessment provided a useful list of at risk assets during the storm surge event in December 2013, described below.

[16] Jenkins, G.J., Murphy, J.M., Sexton, D.S., Lowe, J.A., Jones, P., Kilsby, C. G. (2009) UK Climate Projections: Briefing Report. Met Office Hadley centre, Exeter UK.

Figure 16. Potential coastal flood extent (black) assuming no flood defences (pink)

Source: Humber Flood Risk Management Strategy, Environment Agency, 2011

In December 2013 the Yorkshire region experienced a storm surge with an estimated return period of as much as 1 in 568 years at Whitby (0.0012 per cent annual probability)[17]. An emergency was declared and command and control arrangements were triggered, attended by Yorkshire Water and other emergency responders. We deployed our high capacity pumps to assist the Fire Service in pumping excess water from around the sea front in Whitby, and also ran our emergency storm pumps in Hull which evacuated 35,000 tonnes of water, preventing flooding in the city. Several of our coastal sewage pumping stations were flooded and two coastal outfalls were damaged, which we estimate cost around £200,000 to repair. Deployment of the Hull Tidal Barrier combined with a fortunate change in wind direction at high tide, meant that although several hundred homes and businesses were flooded, the extent and depth of flooding was much less than predicted. Advance warning of the storm surge and well-practiced preparations by local authorities, emergency services and others ensured a robust and effective response. Formal post event debriefs were held and were generally very positive with Category 1 and 2 partners commenting that there was excellent multi agency working, mutual aid and co-operation throughout the response to the emergency[18].

5.5.2 Actions 2010-2015

As part of our investment to improve bathing water quality along the east coast we have refurbished two of our coastal sewage pumping stations and ensured they are resilient to a 1 in 200 year (0.5 per cent annual probability) storm surge event. We have also invested in operational response plans for our most at risk assets, see section 5.3.2 above.

[17] Return period analysis available on the Surgewatch website www.surgewatch.org developed by the University of Southampton, the National Oceanography Centre and the British Oceanography Data Centre.
[18] Humber Local Resilience Forum Tidal Surge Flooding Event – 5 December 2013 – Response and Recovery Initial Debrief Report.

We have taken part in multi-agency workshops to develop and understand the risk of an east coast flood event in 2012 and 2013, and carried out a flood plan exercise with the Humberside Local Resilience Forum in 2014.

5.5.3 Actions 2015-2020

Our risk assessment and cost benefit analysis has not identified any Yorkshire Water assets at sufficient risk from coastal flooding to invest. However we are working with Scarborough Borough Council to enable delivery of a coastal defence scheme which will repair and improve existing sea defences for the village of Runswick Bay in North Yorkshire.

We will continue to play an active part in our local and regional flood risk partnerships. These partnerships bring together Lead Local Flood Authorities (LLFAs), the Environment Agency, Internal Drainage Boards and water companies in order to prioritise flood risk management investment. We have mapped our asset flood risks against flood risk schemes prepared by local authorities and the Environment Agency and this work may identify future collaborative projects.

We will also continue our involvement in our Local Resilience Forums including joint training and exercises. We have allocated £3.6 million of investment to improve our emergency response, including purchase of high capacity pumps, demountable flood defences, all-terrain vehicles and training exercises.

5.6 Coastal erosion

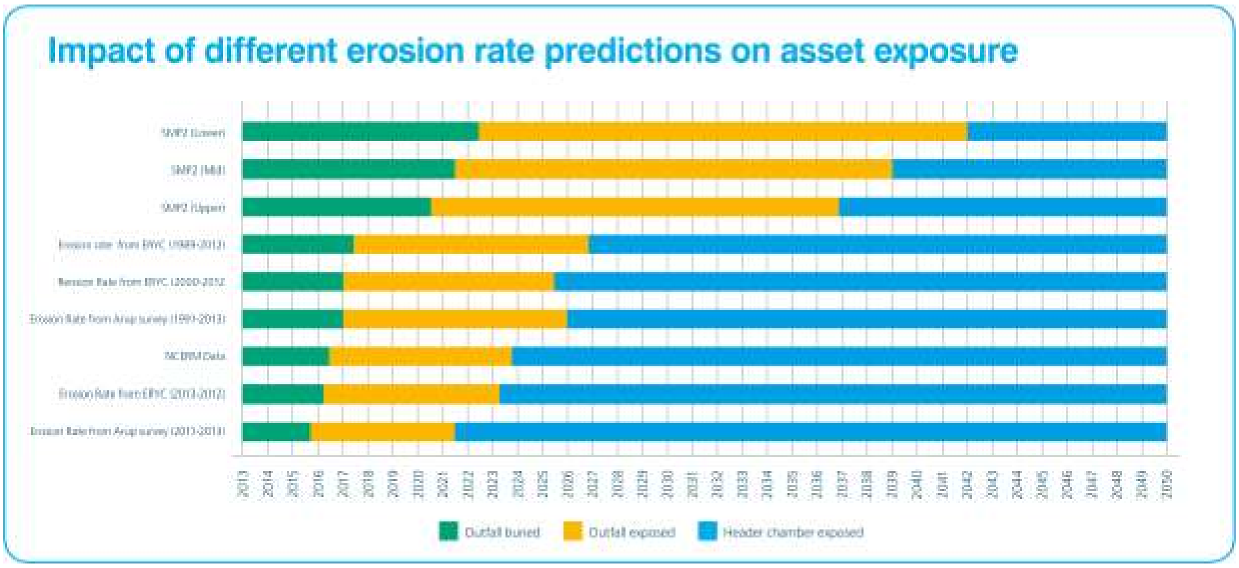
Yorkshire has one of the fastest eroding coastlines in Europe and observations show that the rate of erosion has increased in recent years[19]. Climate change is expected to increase this risk as erosion rates are exacerbated by rising sea levels and increasing storminess, placing our coastal assets at risk.

5.6.1 Informing our risk understanding

We have worked with Arup to assess the risk to our coastal assets from erosion, including the impacts of climate change. The project used the full range of available evidence including observed data collected from coastal monitoring points by local authorities, historical maps and the National Coastal and Erosion Risk Maps (NCERM) dataset. The NCERM dataset includes the impacts of climate change. The uncertainty in predicting coastal erosion rates is demonstrated by the chart below which shows the different predictions for when our waste water treatment works at Withernsea may become compromised. More detail about the methodology for this project is available in Appendix Three of our Climate Change Strategy available on our website.

[19] Quinn J, Philip L, and Murphy W,. (2009) Understanding the recession of the Holderness coast, East Yorkshire, UK: a new presentation of temporal and spatial pattersn. Quarterly Journal of Engineering Geology and hydrogeology, 42, 165-178.

Figure 17. Impact of different coastal erosion rate predictions on asset exposure.



5.6.2 Actions 2010-2015

Our investment during the last five years has been focussed on our risk assessment described in the section above. This was used to inform our investment plans for the next five years, which are set out below. We have also carried out reactive repairs to coastal assets such as our sewage pumping stations along the coast.

5.6.3 Actions 2015-2020

Our risk assessment project identified a number of assets that are at risk in the near future including our waste water treatment works at Withernsea, three sewage pumping stations and a section of water main. We have allocated £29 million to relocate these assets further inland over the next five years. We have already begun detailed design work to relocate one of our at-risk sewage pumping stations at Flamborough Head, which we expect to cost around £400,000. This pumping station is located on top of a cliff next to a lighthouse, and both the lighthouse and pumping station are served by an electricity sub-station owned by Northern Power Grid. Through discussions with the Lighthouse Authority and Northern Power Grid we have highlighted the need to relocate all three of these assets in the near term, and hope to work in partnership to reduce costs and align delivery.

5.7 Addressing barriers and understanding interdependencies

Climate change projections suggest that extreme events are likely to happen more often, with greater severity, and in locations that may not have experienced these events before. Our emergency planning and response capabilities are well established and provide an essential backstop for these types of event, however several such events in succession or in multiple parts of the region or country at the same time would prove challenging to manage, stretching resources and capacity. We therefore support the Adaptation Sub-Committee's recommendations to improve information sharing between infrastructure operators and to quantitatively assess local capabilities to respond to extreme weather events. The first recommendation could make use of Resilience Direct, a secure government web portal for information sharing during emergencies, to which Yorkshire Water already has access.

In our first ARP report, we identified the challenge of securing customer support for resilience investment and called for a national debate regarding who should pay and when. Customers have told us that they want us to maintain services at no additional cost over the next five years; however the cost of delivering these services is likely to increase in the longer term as climate impacts take hold. Investing now could be cheaper than waiting, and could be more equitable, spreading costs across current and future customers. The challenge for Yorkshire Water is to assess and communicate these cost increases and secure customer support in order to maintain levels of resilience against an increasing risk profile.

Managing the risks described in this chapter often requires a partnership approach. We will continue to develop our approach to partnership working, which is described in Chapter 3. Partnership working is not without its own challenges however. The differing requirements of partner organisations, such the need to meet different cost benefit thresholds for funding approval, or different organisations working to different standards of protection, using different climate change information and so on creates additional complexity. Sector wide or national standards for critical national infrastructure would help ensure a consistent approach.

We are committed to exploring opportunities to work collaboratively to address our shared risks, and have recently hosted a Yorkshire Infrastructure Operators Forum. This forum was similar in its aims to the national Infrastructure Operators Adaptation Forum, which is attended by Yorkshire Water on behalf of Water UK. The Yorkshire event bought together infrastructure operators alongside organisations with a role in infrastructure investment. Since this event, we have held several meetings to discuss a more collaborative approach to infrastructure investment in Yorkshire.

5.8 Monitoring and reporting

We will report data about the following performance commitments on an annual basis from 2016/17 onwards on our website. These indicators will not directly track the number of times our assets are flooded or otherwise affected by extreme weather, but will record any resultant impact on services to customers, or on the environment.

- Water supply interruptions
- Bathing water quality
- Pollution incidents
- Number of solutions delivered by working with others

6. Maintaining excellent drinking water quality

This chapter describes how we assess and manage risks to our raw water sources so we can ensure customers always have water that is clean and safe to drink.

Section 6.1 describes how we assess, monitor and manage the quality of drinking water from source to tap.

Section 6.2 summarises the extensive body of research we have carried out to understand how upland peat habitat management affects raw water quality, an issue of particular importance in Yorkshire as we source almost half our drinking water supplies from these internationally protected habitats.

Section 6.3 and 6.4 describes the action we have taken to mitigate the risk of declining raw water quality, which includes both working with land owners and managers to improve and restore land, as well as targeted investment in water treatment works.

Section 6.5 sets out some of the barriers and interdependencies we are working to overcome including how to accommodate the differing needs of the many stakeholders whose activities influence raw water quality. Section 6.6 describes how we will monitor and report our performance.

Raw water is the untreated water that we take from reservoirs, rivers and groundwater before it is filtered, cleaned and treated at one of our water treatment works. The quality of raw water, and therefore the cost of treating it to reach drinking water quality standards, can vary enormously depending on factors such as the weather and how the land is managed. For example there is more sediment in raw water following heavy rainfall, which can also wash farm chemicals like fertiliser from fields into rivers.

We own around 30,000 hectares of land across the region, largely around our reservoirs and operational sites. However in many areas, particularly in the uplands, we own the land but not the agricultural or sporting rights, which means a third party may have control over grazing, heather cutting and burning or other land management practices.

Changing weather patterns combined with changes to agricultural practices, policy and subsidies are likely to have complex effects on how land is used and managed, with subsequent impacts on both the natural environment and the quality of raw water taken from it. We have spent a decade or more carrying out research and development in this area to improve our risk understanding and identify the most effective risk control measures.

6.1 Informing our risk understanding

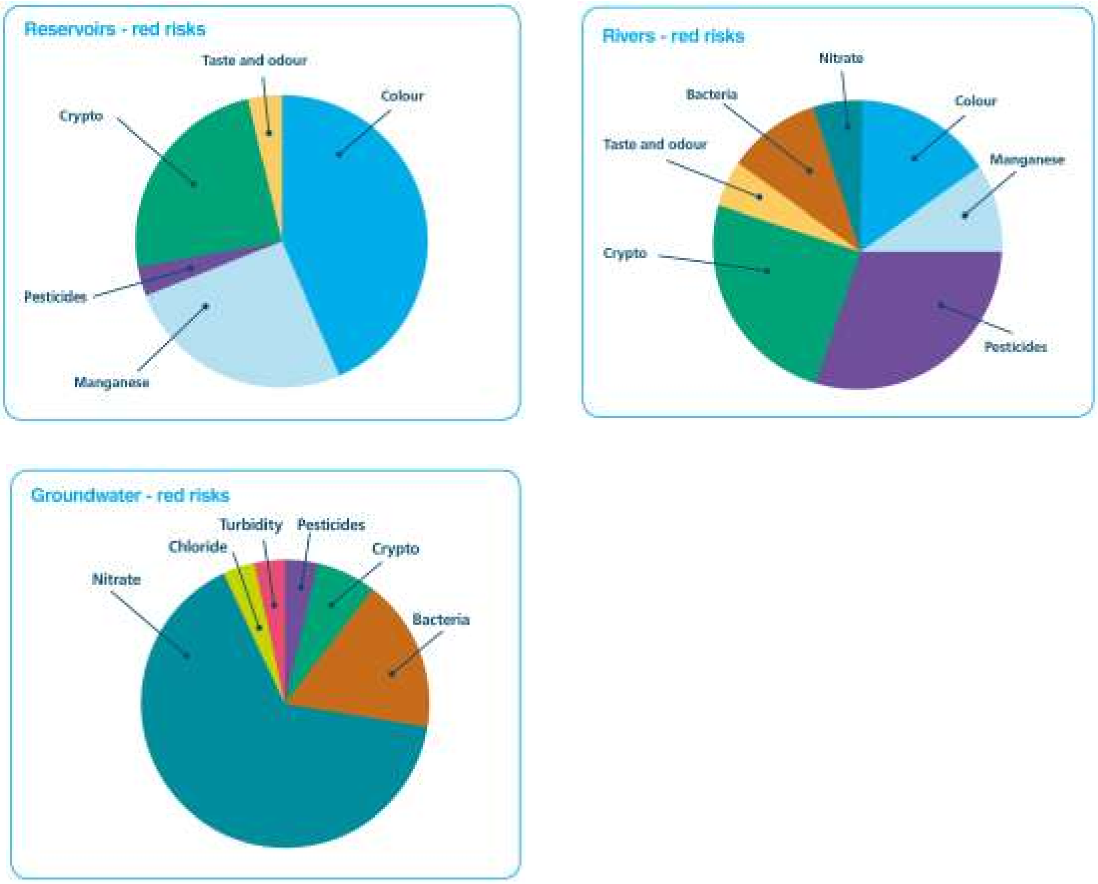
We monitor the quality of drinking water from source to tap and have regular samples taken at all stages of the water cycle including at the inlet to works, the distribution network, customers taps, rivers and coastal waters. Samples are sent to independent laboratories for analysis and the results are shared with the Drinking Water Inspectorate. This analysis informs our Drinking Water Safety

Plans and helps us work with the Environment Agency to identify Drinking Water Protected Areas and Safeguard Zones. Safeguard Zones are areas where action is required to reduce pollution, avoid deteriorating water quality and increases in treatment costs. Safeguard Zone Action Plans have been produced in conjunction with the Environment Agency and cover a range of specific water quality parameters including colour, pesticides, nitrates and saline intrusion on reservoir, river and borehole sources.

We have also developed a number of raw water quality risk maps which take into account crop cover, soil type, slope, and distance to watercourse in order to inform our decision making. We used this mapping work to demonstrate a recent increase in winter oil seed rape production, which has increased the levels of certain pesticides in raw water, thus requiring additional investment at our water treatment works. We also use this data to target hotspots of high pesticide run off within a catchment so we can target educational campaigns in specific areas, for example by encouraging famers to plant buffer strips to protect water courses from farm run-off.

We currently have just over 7000 risks on our drinking water risk database. Only two per cent of the risks are classed as red. These red risks are shown in Figure 18, below, which illustrates the different risks in different raw water sources. Raw water drawn from reservoirs is largely affected by the health of the peat habitats it drains from, whereas raw water drawn from rivers is affected more by the pesticides used by farmers, and groundwater tends to be affected more by fertilisers. All raw water sources are intimately affected by weather patterns combining with impacts of human activity in the catchment.

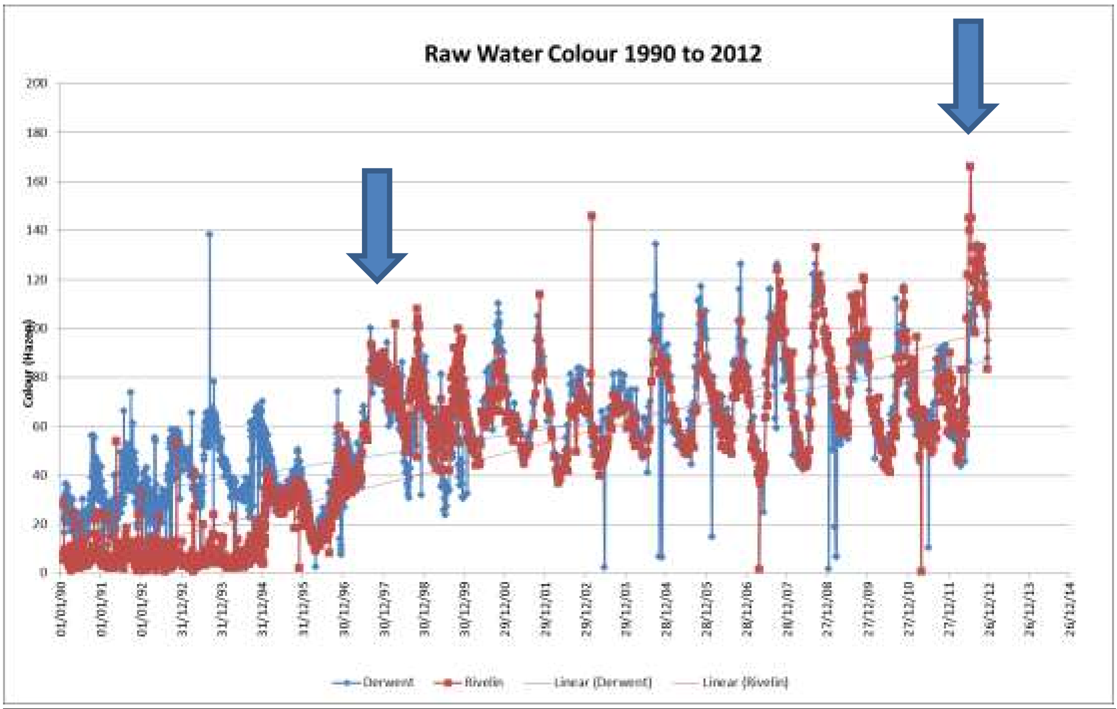
<u>Figure 18. Drinking water quality risks by source</u>



6.2 The importance of peat habitats

We have carried out a substantial amount of research with the University of Leeds, and with Durham University, to assess the impact of different land management techniques on raw water quality. Much of this research has been focussed on how land management affects upland peat bog habitat. We have a considerable amount of this rare and unique habitat in Yorkshire[20], which is internationally important for its biodiversity and also acts as a carbon sink, storing huge amounts of carbon. We source almost half of Yorkshire's raw water from these habitats, which have been substantially altered by human activity. They have been drained using artificial channels to allow sheep farming, and burnt to encourage heather which is a food source for game birds called grouse, which are shot for sport. Environmental regulation of industrial emissions has also had a dramatic effect on the water chemistry of peat habitats. Levels of sulphuric acid in the atmosphere have reduced, which is beneficial for human health and the health of forests and other types of habitat. However, the effect of reducing acid deposition on peat bog habitats is enhanced mobilisation and release of stored carbon as dissolved organic carbon (DOC, also known as colour). This colour is expensive to remove and is one of the main costs of treating upland water sources. We have seen an increased trend in colour levels in raw water from our upland catchments, shown in Figure 19 below. Peaks (shown by the blue arrows) are evident following the drought in 1995/96 and again following the dry spell followed by intense rainfall in 2012.

<u>Figure 19. Trend in raw water DOC</u>



Areas of the Yorkshire Pennines have peat over six meters deep, equivalent to more than 6000 years of peat formation. Cores taken from Keighley Moor (see photo below) show that peat began forming

[20] Yorkshire has about a quarter of the UK's peat habitats with the rest mainly located in Scotland and Wales, with some also found in Dartmoor and Exmoor.

around 700 BC and has continued ever since, occurring over a range of climatic conditions, including dry periods[21].

Figure 20. Peat core analysis from Keighley Moor.

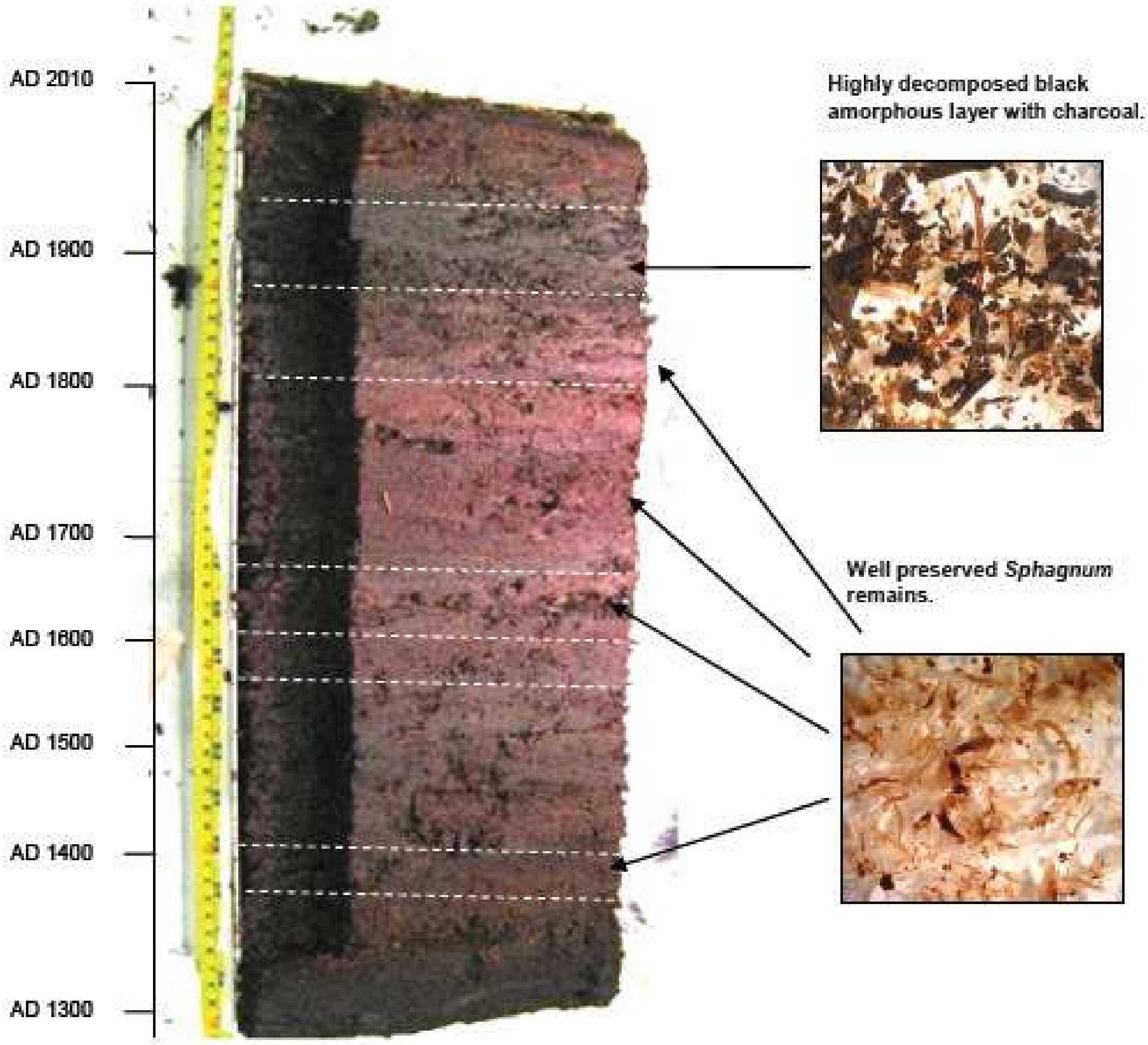


Figure 26. Changes in macrofossils and levels of humification visible in the top 50 cm of peat.

Source: Blundell et al, 2012

The cores also show that peat formation has been inhibited by recent land management practices such as draining and burning, which began in the 1900s. Nonetheless the core evidence is encouraging as it suggests that peat formation can continue even under the drier conditions we can expect in the future as the climate changes. This is important because other research by the University of Leeds suggests that climate change will reduce the area of land that is suitable for peat habitats. This research found that peat habitat within the region will not be in a suitable climate by

[21] Blundell, A., Holden, J. and Kay, P. (2012) *Investigating the vegetation history of Keighley Moor to support contemporary land management decisions.* Yorkshire Water Services Innovation Delivery Report B4635 10010.

2050 under the high emissions scenario and by 2080 under low emissions scenarios[22]. That does not mean, however, that the peat habitats in the region will disappear. It emphasises that the peat lands may become more unstable, releasing more DOC into surface waters. This is why land management interventions are critical for Yorkshire Water's supplies in the long term. If nothing is done then the peat resource of the Pennines and Dales has the potential to cause large water quality problems in the future. Management interventions that rewet the peat, hold back sediment and encourage *Sphagnum*-rich surfaces will, in the long term, add resilience to the peat system reducing and delaying problems caused by climate change. It is also highly likely that wet, *Sphagnum*-rich peat lands will be much more resilient to wildfire than peats dominated by shrubby vegetation and deeper water tables.

Before and after photos showing the impact of peat habitat restoration activity.

Fortunately, a healthy peat habitat is not incompatible with other land uses such as sheep farming, and grouse hunting. A recent stakeholder event called 'Bog-a-thon' bought together representatives from the Moorland Association, RSPB, Heather Trust, Yorkshire Water, National Trust and a range of landowners and their representatives. The event was a real success and heralded a genuine breakthrough, bringing together stakeholders who have been in disagreement for many years and reaching a new found consensus on peat land management. The group agreed that improving the health and functionality of deep peat will deliver carbon storage, improved raw water quality, enhanced biodiversity, and importantly, still enable grouse and sheep production. A number of actions were agreed in order to achieve these aims, which now form the basis for the Government's strategy for blanket bog restoration.

6.3 Actions 2010-2015

We take a twin track approach to managing water quality by investing in catchment management to tackle pollution at its source, alongside investment at our water treatment works to improve the efficiency and effectiveness of treatment processes and technologies. Catchment management

[22] Holden, J., Blundell, A., Grayson, R., Chapman, P.J., Palmer, S.M., Kay, P. and Irvine, B. (2012) An evaluation of upland catchment management schemes for raw water improvement. Final report to Yorkshire Water Services, Project S2832, University of Leeds, Leeds.

includes a wide range of activities such as blocking drainage channels, fencing and wall repairs, erosion control, re-planting areas of degraded habitats, and installing slurry covers or other farm infrastructure to protect raw water quality from pollution risks.

Informed by our research and monitoring activity, we began our catchment management work in around 2010, carrying out over £7 million worth of ecological restoration activity to address raw water quality risks. This work included blocking up drainage channels, and re-seeding degraded areas of peat with sphagnum moss plants. This work has led to the improvement of over 11,000 ha of protected habitat.

6.4 Actions 2015-2020

Our customer outcome for this area is to ensure our customers always have water that is safe and clean to drink. We plan to invest £2.7 billion over the next 25 years to ensure clean, safe drinking water. This investment will be used to upgrade and improve our water treatment works, pipes and other infrastructure, as well as delivering catchment management solutions to protect long term water quality.

We have a targeted programme of work to improve raw water quality over the next five years. This includes £2 million investment to enhance and protect upland habitats, £0.45 million for education campaigns, as well as the appointment of two catchment officers, a Geographical Information Systems Specialist and a hydrogeologist. Most of this work will be carried out in partnership with Natural England, the Yorkshire Peat Partnership, Moors for the Future and other ecological restoration specialists.

We will also carry out a number of studies to inform our future approach including three projects to map where there are high concentrations of nitrate in groundwater, identify their source, and identify what action can be taken to reduce nitrate pollution. We will continue to improve our risk understanding though our research and monitoring activity to ensure our decisions are evidence based. As well as the investigations into nitrates outlined above, we will continue to monitor the effectiveness of our catchment interventions, sharing learning with others through forums such as the Catchment Sensitive Farming groups.

In addition we are investing £15 million at several of our upland water treatment works to improve the stability and reliability of the treatment processes.

6.5 Addressing barriers and understanding interdependencies

The quality of raw water is determined by a wide range of interconnected factors which can be difficult to disentangle from each other, especially in large complex catchments. The weather, market conditions, changing policy and subsidy regimes all interrelate with each other to produce a complex set of drivers for how land is used, and the quality of raw water from that land. These interdependencies require an evidence based, partnership approach in order to identify the best way to meet everyone's needs without damaging the natural environment.

Our research and development programme has provided us with a growing body of evidence about how land management practices affect raw water quality. We have been able to use this to inform both our investment needs, and to inform our education and influencing work with land managers and other stakeholders. We will continue to investigate, share and debate the best scientific knowledge to restore and enhance peatland catchments, to inform the debate on how the uplands can be managed sustainably for multiple benefits.

We have also provided feedback for the new National Environmental Land Management Scheme (NELMS) which will replace various stewardship schemes under the Common Agricultural Policy. We would like to see water quality included as a key focus for agri-environment schemes which could be a mechanism for aligning habitat restoration with water source protection. We would also welcome further clarity over how habitat condition assessments will evolve to include consideration of climate resilience, in order to identify appropriate remedial action for land owners and managers.

Finally we are supportive of the Adaptation Sub Committee's recommendations in their 2013 report to i) set an explicit goal to increase the area under restoration, ii) review the enforcement of current regulations and iii) improve incentives for landowners to invest in restoration. We also support their further recommendations in their 2015 report to ensure 15 per cent of degraded ecosystems important for climate change adaptation are being restored, and encouraging Natural England to review consents for burning on protected sites and assess the extent to which agri-environment schemes are being used to fund damaging practices on peatland habitats.

6.6 Monitoring and reporting

We will report data about the following performance commitments on an annual basis from 2016/17 onwards on our website.

- Drinking water quality compliance
- Drinking water quality contacts
- Land conserved and enhanced

7. Improving the water environment

This chapter describes how we manage the risk of our activity causing an adverse impact on the water environment as we recognise that a healthy, well-functioning environment is more resilient to the pressures of climate change.

Section 7.1 describes how we assess the risks to the water environment, and Section 7.2 and 7.3 set out the action we have taken and plan to take to enhance and improve our regions' rivers and seas.

In Section 7.4 we observe how barriers may be overcome to deliver more innovative and sustainable ways to achieve compliance with environmental regulations, such as river restoration schemes.

Section 7.5 describes how we will monitor and report our performance.

The previous chapter described how we assess and manage the risk to raw water quality, though our twin track approach of working to restore land as well as investing at our water treatment works. We also recognise that our operational activity can impact on the water environment, for example through the treated effluent we discharge into rivers. Our impact is regulated through a wide range of legislative measures, many of which are bought together under the EU Water Framework Directive (WFD). The aim of the WFD is to get all surface water bodies into Good Ecological Status. We are also subject to a number of other environmental protection regulations such as the Bathing Waters Directive which requires all bathing beach waters to meet a defined water quality standard, in order to protect public health. The Infrastructure Bill, which legislates against the spread of invasive plant and animal species, and the Natural Environment and Rural Communities Act, 2006 which seeks to protect and enhance wildlife, are also all applicable to our activities.

7.1 Informing our risk understanding

We use a number of different models to assess the impact of our activity on the natural environment and determine where we need to take action.

Urban Pollution Management (UPM) models investigate environmental water quality problems associated with our sewerage network. The outputs of these studies are shared with the Environment Agency and inform the investment needed to reach Good Ecological Status, as required by the WFD. UPMs are built up of several different elements. A rainfall-driven Drainage Area Plan (DAP) is used to model the performance of the sewerage network. The impact is then assessed using a pair of river models, one of which is a rainfall driven flow model and the other is a water quality model.

We use another model called SIMCAT to assess the impact of our waste water treatment works on river water quality. These models use river flow and data about the effluent from our works to assess where our works may be affecting river water quality, and therefore inform where further investment may be required.

A further suite of models are used to determine the impact of our discharges on coastal waters. Our marine impact model, which incorporates hydrodynamics and water quality, is used in conjunction with models of sewer flow, river flow and river quality to support an "Integrated Catchment Management" approach. The outputs from the individual models are combined using a unit impact tool, so that the statistical impact on bathing water quality can be assessed. As a pre-cursor to setting the marine impact models up, source apportionment studies have been carried out to determine potential sources of faecal indicator organisms. The outputs of the marine impact model have informed where capital investment should be undertaken in order to reduce the impact of Yorkshire Water assets on designated Bathing Beaches.

As well as our modelling work, we have also increased our knowledge and understanding of where invasive species are on our land or affecting our assets, such as Himalayan Balsam or zebra mussels. This work has been used to identify a number of sites for action.

Our activity to improve the protected habitats we own is informed by condition surveys carried out by Natural England. These assessments are carried out every three years to determine priority areas for restoration activity. Details of this investment is included in Section 6 above as these habitats are largely areas in the peat uplands.

7.2 Actions 2010-2015

We have invested at many of our waste water treatment works and other assets to ensure compliance with existing regulations and meet the demands of population growth over this period.

We have also further developed our capacity to model and understand the impact of our assets on the natural environment, in order to inform our investment needs. We have built eight UPM studies covering nine water bodies, which have been used to inform our investment programme for the coming years.

During AMP5 we invested in a river flow and water quality monitoring and sampling programme across the region to investigate the impact of our assets on the rivers of Yorkshire. The aim was to upgrade the existing SIMCAT models to contain additional sanitary and nutrient data. A total of six models across the region were updated and used to analyse the impact of our assets upon the receiving water body in line with WFD targets. The results were used to show where investment would be required to improve WFD classification to meet Good Ecological Status during AMP6 and beyond.

We have taken a multi-agency approach to improving the quality of coastal waters in order to protect public health, establishing the Yorkshire Bathing Water Partnership in 2010. We have invested £110 million over the last five years to help achieve Excellent status under the revised Bathing Water Directive. This investment included a new underground storm water tunnel, storage tanks and pumping stations in Bridlington, Scarborough and Filey. As part of this investment we have installed monitoring at all overflows that could impact on bathing water quality, and developed a prediction system to help beach managers inform the public of bathing water quality. We plan to extend this monitoring and prediction system to all of Yorkshire's bathing beaches. This will integrate with the work the Environment Agency are doing to develop a unified prediction system across the UK.

As described in our first ARP report, we have piloted an innovative catchment management system called rtRIVERi during AMP5. This project seeks to integrate all our abstraction and discharge consents using a dynamic, optimally controlled system. The continued investment in and development of rtRIVERi will help to:

- Ensure water needs are met, now and in the future
- Protect against sewer flooding
- Enable partnership working to protect the water environment
- Understand our impact on the environment and act on this
- Provide low cost solutions
- Build understanding of what is needed to meet consents with associated cost/resources implications
- Aid understanding of reasons for failure, and what environmental objectives are achievable against the Water Framework Directive.

We have carried out two innovative river restoration schemes in the last five years. The first scheme was on the River Aire in Leeds where a Victorian weir was blocking the passage of migratory fish, preventing them from moving upstream to breed. We were unable to remove the weir as we only owned half of it and were unable to get consent from the owner of the other half to remove it. Instead we have installed a by-pass channel that allows fish to navigate around the weir through a series of pools. The second scheme was on a small stream that runs through a former coal mining area which has been restored and is now a country park well used by runners, dog walkers and families near Barnsley. The stream had poor water quality and instead of installing a capital solution we wanted to see if a more natural approach could be taken, so we have re-engineered a section of the stream, adjusting the course by putting more meanders and riffles in. It is hoped that this will improve the ecological functioning of the stream, and provide a wider variety of habitat niches for wildlife.

Photo of Rodley fish by-pass channel

7.3 Actions 2015-2020

Our customer outcome for this area is to protect and enhance the environment and is the single largest area for investment in our 25 year plans, with over £6.8 billion of planned investment. This will mainly be targeted at improving and upgrading our waste water treatment works to meet the needs of the Environment Agency's National Environment Programme (NEP). The NEP is developed jointly between water companies and the Environment Agency to help meet the requirements of the Water Framework Directive and other legislative requirements.

The outputs from our water quality models have been shared with the Environment Agency and together we have defined a programme of environmental investment and investigation needs, totalling over £300 million between 2015-2020. This represents Yorkshire Water's contribution to the National Environment Programme (NEP) for the next five years.

The bulk of this investment will be targeted at enhancing our waste water treatment capabilities where we have confirmed biological and/or chemical issues that need to be resolved in order to meet legislative standards. We will develop another 13 UPM models to inform our investment for 2020 onwards, as well as new water quality models for the Humber estuary and Holderness region.

Around £3.8 million of the NEP investment package will be used to remove barriers to fish passage such as weirs and other structures in rivers. Around £2 million will be used to help tackle and eradicate invasive species. We plan to work in partnership with other riparian owners on an invasive species eradication strategy for the River Aire, and to trail approaches to removing Crassula on the Gouthwaithe reservoir. We have also allocated a biodiversity enhancement fund of £1 million to enhance areas of habitat that are not protected by legislation such as pockets of woodland or other natural habitats around our assets.

Having piloted our innovative real time river management system at a waste water treatment works in Leeds, we are planning to extend this system, called rtRIVERi, to cover a whole catchment in the next five years.

7.4 Addressing barriers and understanding interdependencies

We welcome the more holistic approach to measuring environmental health which is implicit in the Water Framework Directive's requirement for all water bodies to meet Good Ecological Status. Our investment in modelling how the natural environment responds to changes in flows, temperature and water quality allows us to identify which of our activities are having an impact and target investment accordingly. However it is not yet clear how the Water Framework Directive regulations and their enforcement will account for changes in the natural environment which may be driven (partly or wholly) by climate change.

We also observe that a catchment based approach, working with multiple stakeholders, is often the most sustainable and effective way to improve the water environment, however this approach is not without its challenges as described in various places within this report. Our own efforts to restore rivers have been hampered by difficulties in identifying owners of riparian infrastructure, the effort and resources required to set up and manage multi-stakeholder projects and also by the relatively innovative nature of ecological restoration projects and the degree of uncertainty regarding their effectiveness when compared to a more traditional technology-driven solution. We will continue to engage with our regulators and other organisations in order to overcome these barriers and identify opportunities to work in partnership to improve the water environment in the most sustainable way.

7.5 Monitoring and reporting

We will report data about the following performance commitments on an annual basis from 2016/17 onwards on our website.

- Pollution incidents
- Length of river improved
- Bathing water quality
- Land conserved and enhanced

10. References

1. Yorkshire Water, 2012. Climate change and weather resilience – a position paper.
2. Yorkshire Water, 2013. Climate change strategy.
3. Yorkshire Water, 2014. Water resources management plan.
4. Yorkshire Water, 2014. Drought plan.
5. Met Office, 2011. Analysis of weather conditions during November and December in the Yorkshire Water region.
6. Mott MacDonald, 2012. Climate change trends and evidence analysis for Yorkshire Water.
7. Fowler, H., J. and Wilby, R., L. (2010) Detecting changes in seasonal precipitation extremes using regional climate model projections: Implications for managing fluvial flood risk. Water Resources Research, Vol. 46.
8. HR Wallingford, 2010. Using UKCP09 in water resources planning.
9. WrC, 2012. Duration modelling; impact of multi-year drought events on resources and assets.
10. WrC, 2013. Water use in homes built to Part G building regulations and Code for Sustainable Homes water efficiency design standards.
11. ASC, 2013. Managing the land in a changing climate.
12. Mott MacDonald, 2011. Future impacts on sewer systems in England and Wales.
13. UKWIR, 2002. Capital maintenance planning: A common framework.
14. HR Wallingford, 2013. Using UKCP09 in sewer network modelling.
15. The Cabinet Office, 2011. Keeping the country running.
16. Quinn J, Philip L, and Murphy W,. (2009) Understanding the recession of the Holderness coast, East Yorkshire, UK: a new presentation of temporal and spatial patterns. Quarterly Journal of Engineering Geology and Hydrogeology, 42, 165-178.
17. Blundell, A., Holden, J. and Kay, P. (2012) Investigating the vegetation history of Keighley Moor to support contemporary land management decisions. Yorkshire Water Services Innovation Delivery Report B4635 10010.
18. Holden, J., Blundell, A., Grayson, R., Chapman, P.J., Palmer, S.M., Kay, P. and Irvine, B. (2012) An evaluation of upland catchment management schemes for raw water improvement. Final report to Yorkshire Water Services, Project S2832, University of Leeds, Leeds.
19. ASC, 2015. Progress in preparing for climate change.