Draft Water Resources Management Plan 2019

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NORTHUMBRIAN WATER *living water*

DOCUMENT CONTROL SHEET

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Draft	Martin Lunn John Devall	NWG Board	30 November 2017

Exclusions on the Grounds of National Security

Northumbrian Water Limited has not excluded any information from this plan on the grounds that the information would be contrary to the interests of national security.

Under Section 37B(10)(b) of the Water Industry Act 1991, as amended by the Water Act 2003 ("the Act"), the Secretary of State can direct the company to exclude any information from the published Plan on the grounds that it appears to him that its publication would be contrary to the interests of national security.

Northumbrian Water is a trading division of Northumbrian Water Limited which is a group company of Northumbrian Water Group

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Non-Technical Summary

Introduction

Water Resources Management Plan Purpose

This document is Northumbrian Water's (NW) draft Water Resources Management Plan (WRMP). It demonstrates that NW has an efficient, sustainable secure supply of water over the Company's chosen planning period. For this WRMP, the Company has prepared water demand and supply forecasts for a 40 year planning period from 1st April 2020 to 31st March 2060.

The WRMP covers the entire NW customer supply area (see Figure 1). For the purposes of the Company's demand forecasts and supply demand balance calculations, the supply area has been split into the following Water Resource Zones (WRZ):

- Kielder WRZ; and
- Berwick & Fowberry WRZ

The WRMP has been prepared following the Water Resources Management Plan (England) Direction 2017, Defra's Guiding Principles for Water Resources Planning (May 2016) and the Environment Agency's (the Agency) Water Resources Planning Guideline (WRPG) (April 2017).

The Kielder WRZ benefits from Kielder Reservoir and the Kielder Transfer Scheme. Kielder Reservoir, located in Northumberland, is the largest artificial lake in the United Kingdom by capacity holding 200 billion litres (200,000Ml) of water. The reservoir supports flow in the North Tyne to support abstractions of water further downstream. It also supports the Kielder Transfer Scheme which enables water to be transferred to the Wear, Derwent and the Tees rivers. Kielder Reservoir and transfer scheme collectively make the Kielder WRZ one of, if not the most resilient WRZs in the country.

The supply forecast Water Available for Use (WAFU) presented in this draft WRMP is based on updated reservoir control curves that NW has agreed with the Environment Agency and the existing raw water pumping station infrastructure. This WAFU provides the WRZ with a significant dry year supply surplus. However, it should be noted, that with different reservoir control curves to call on support from the Kielder Transfer Scheme, the Kielder WAFU and therefore supply surplus could be significantly higher than what NW currently report.

PR19 Supply and Demand Forecasts

In this draft WRMP, all components of the supply and demand forecasts have been reviewed using the appropriate methods recommended in the WRPG.
The chosen planning scenario remains the Dry Year Annual Average (DYAA) as no WRZ demonstrates a critical period where peak demands are driving investment within the WRZ.

Water Supply Forecasts

Future water supplies are forecast by calculating WAFU. WAFU is calculated by quantifying the Deployable Output (DO) of NW's raw water sources and treatment works within each water resource zone. Outage (e.g. when a treatment works is out of supply due to planned maintenance), process losses (e.g. the water used to back wash treatment works filters) and sustainability reductions (e.g. where NW's abstraction licence has been reduced to ensure they are sustainable) are then subtracted from DO to give WAFU.

The Kielder WRZ WAFU has reduced by around 100Ml/d (at the end of the planning horizon) due to the updated methodology for calculating DO, the Berwick and Fowberry WAFU remains similar to PR14.

Effect of Climate Change on Future Water Supplies

Climate change was assessed using the i-Think models in our PR14 WRMP, as NW have now moved over to using Aquator to carry out NW's water resource modelling an alternative method of assessing climate change for PR19 to that used for PR14 is required.
As NW only has a limited number rainfall-runoff models for the Kielder System and the Kielder WRZ is at low vulnerability to climate change, the WRPG recommends that a tier 1 analysis is carried out, that being the use of Future Flows (FF) Hydrology change factors for the 2080s.
The Kielder WRZ appears to be relatively sensitive to reductions in summer flows, this is due to the fact that under the baseline scenario, during the design drought year, some reservoir levels are already extremely low and the decrease in summer flows means that the reservoirs empty prior to the winter refill period.

For the Berwick and Fowberry WRZ, no groundwater model is available to assess the impact of climate change. In order to provide climate change predictions on groundwater levels in this area, reductions in groundwater level in response to decreasing recharge as a result of climate change (based on UK Climate Projections 2009) are used along with Long Term Average recharge spreadsheet calculations.

NW assessments conclude that after considering the effects of climate change, both WRZs remain in surplus across the whole planning horizon, with no water resource development being driven by climate change assumptions.

Environmental Improvements

Each time NW update the WRMP (every five years), NW agree with the regulators a list of schemes collectively known as the Water Industry National Environment Programme (WINEP). The WINEP is an integrated list of requirements for water resources, water quality and fisheries, biodiversity and geomorphology. It consists of investigations, options appraisals and actions to protect (prevent deterioration) and improve the water environment. Actions to protect or improve the environment include changes to NW's abstraction licences, also known as sustainability changes, and non-licence change actions, such as river restoration. The WINEP does not just consider the direct effect of abstraction. It also considers among other aspects catchment measures to improve the quality of water at abstraction intakes, Invasive non-native species risk, fish passage and discharges to the environment.

The current Periodic Review (PR14) Asset Management Plan (AMP6) National Environment Programme (NEP) (2015 to 2020) includes the following:

- Investigation into sustainable abstraction levels from the Fell Sandstone aquifer in the Berwick area;
- Investigations and trials of variable compensation releases at five impounding reservoirs in the Kielder WRZ.;
- Eight Eel Regulations Implementation Schemes, of which six were to improve intake screening and two to install or improve eel passes;
- Two fish passage installations;
- Water Quality / Drinking Water Protected Areas (DrWPA):
    - A programme of work under the DrWPA driver, implementing catchment schemes to protect raw water quality.

NW has made excellent progress in delivering all of the above schemes. All of the improvements will have been delivered by 31st March 2020.

NW has agreed a new WINEP with the regulators for AMP7 (2020 to 2025). The second iteration of the PR19 WINEP for AMP7, issued by the Agency in September 2017, contains the following schemes:

- Seven Sustainable Change investigations.
- One Eel Screen installation.
- Eight Investigations and Options Appraisals.
- Four Fish Passage Investigations.
- Five No deterioration schemes for catchment management work to protect water quality in some of the Company's surface water catchments

All of the above schemes will go forwards into NW's PR19 Business Plan.

Household Demand Forecast

The base building block for demand forecasting is the base year population served and the projected growth in population annually over the WRMP. In line with the WRPG requirement, NW has used Local Plan housing growth evidence from all local authorities and has selected the Plan-based scenario.

The population forecasts for PR19 using the plan-based scenario shows a growth in population over the planning horizon. This has resulted in a 23% increase in population over the 40 year planning horizon. The population is now forecast to be 3.15M by 2059/60. Overall occupancy in the demand forecast reduces from 2.33 to 2.27.
The average annual number of new homes is forecast at 9,271 in AMP7 for NW.

The per capita consumption (PCC) in NW is forecast to reduce annually across the planning horizon as a result of the Company's metering policy and water efficiency initiatives. Unmeasured PCC is forecast to reduce to 134.53 l/h/d by 2059/60 with measured properties reducing to 120.99 l/h/d.

The normal year forecasts have been used as the basis for dry year forecasts, and adjusted to provide figures for two climate change scenarios.

Non-household Demand Forecast

Overall non-household forecasted demand to 2060 is relatively flat, with a gradual increase over time to account for growth of non-household property numbers. This is due to the assumption built into the forecast methodology that individual customer demand will trend to a flat line over time.

Water Efficiency

NW is able to demonstrate the Company's commitment to encouraging its customers to use water wisely through a long history of delivering effective water efficiency strategies and programmes. The drivers (regulatory and other) add further emphasis to the importance of water efficiency for varying reasons. In turn, NW will commit to delivering a programme of water efficiency activities that will deliver a 2% reduction in PCC by 2024/25, equating to an annual reduction of 0.54 litres per person per day. The impact of this water efficiency, as shown in the graph below, is to reduce overall PCC for NW by 2.7 litres per person per day by 2024/25 with a further continuation of water efficiency across the planning horizon

Customer Metering

The Northumbrian Water area has a large surplus of supply over demand in its Kielder WRZ and the area is not classed as seriously water stressed. Therefore compulsory metering cannot be considered. In the much smaller Berwick & Fowberry WRZ there is a smaller surplus until the full outcome of the NEP studies in to the sustainability of NW's ground water abstractions in AMP 6 reports. However we cannot compulsorily meter this area as it is still classed as not being seriously water stressed.

The company intends to continue with its current programme of optant metering only for the AMP7 period. However we are keen to explore stimulating the number of optants, by targeted communications with customers, in areas such as Berwick, where higher metered densities would be more beneficial.

Leakage

NW's current regulatory leakage performance commitment for 2019/20 is 137Ml/d. However, a new method has been proposed by NW's regulator Ofwat to ensure all water companies report leakage consistently going forwards. Using the new leakage calculation method, we estimate that the most probable value for leakage in 2019/20 would increase from 137Ml/d to 138.5Ml/d. For AMP7 (2020 to 2025), we plan to reduce leakage by 15% by 2024/25 to 117.7Ml/d. Beyond 2025, we plan to further reduce leakage by 10% over each subsequent five year period. By 2044/45, the end of the regulatory minimum planning period, this would reduce leakage to 77.3Ml/d or 56% of current leakage.

Distribution Input Forecast

The overall effect on the forecast of DI is that in 2059/60, Kielder WRZ will have a demand of around 26 Ml/d less than today, with a population increase of 390,000 people. Berwick and Fowberry WRZ demand is also forecast to slightly decrease by 0.5Ml/d.

Target Headroom Forecast

Actual headroom is the difference between the supply and demand forecasts of the supply demand balance (i.e. the difference between WAFU and the constrained dry weather demand forecast). WAFU should be greater than the demand forecast to allow for uncertainty and ensure it can meet demand. The ‘ideal’ amount of actual headroom that a prudent water company should retain is called target headroom. Target headroom can be thought of as a security margin, or more accurately a means of assessing uncertainty in the supply demand balance. As a percentage of Distribution Input (DI) (the demand for water), target headroom is 5.3% in the Kielder WRZ and 11.3% in the Berwick and Fowberry WRZ in 2059/60

Supply Demand Balance Forecast

A supply demand balance is best illustrated as a graph showing supply WAFU and demand (known as Distribution Input plus Target Headroom). Providing the supply line is above the demand plus target headroom line, there is a supply surplus. This means there is sufficient water to meet demand during a severe drought and so there is not a need to develop new water resources.

NW has re-assessed its supply and demand forecasts for this draft WRMP. These assessments have confirmed that both of the Company’s water resource zones have a supply surplus across the full planning period to 2060. Consequently, no new water resource schemes are required in this period.

Drought Resilience

NW has tested the resilience of NW’s water supply system to a very severe drought which is calculated to occur once in every 200 years on average. NW has not observed a drought of this intensity and so has used models to simulate the effects of such a drought on DO. NW’s modelling confirms that both of NW’s WRZ are very resilient as a supply surplus would still be maintained during such an extreme drought.

CONTENTS

1.0 INTRODUCTION

1.1 Overview

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The WRPG requires the WRMP to demonstrate that NW has an efficient, sustainable secure supply of water over the Company's chosen planning period which must be a minimum of 25 years. For this WRMP, the Company has prepared water demand and supply forecasts for a 40 year planning period from 1 April 2020 to 31 March 2060.

The WRMP covers the entire NW customer supply area. For the purposes of the Company's demand forecasts and supply demand balance calculations, the supply area has been split into the following Water Resource Zones (WRZ):

- Kielder WRZ; and
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United Kingdom by capacity holding 200 billion litres (200,000Ml) of water. The reservoir supports flow in the North Tyne to support abstractions of water further downstream. It also supports the Kielder Transfer Scheme which enables water to be transferred to the Wear, Derwent and the Tees rivers. Kielder Reservoir and transfer scheme collectively make the Kielder WRZ one of, if not the most resilient WRZs in the country.

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1.2 Regulatory Framework

This WRMP has been produced as part of a statutory process, as reflected in the Water Resources Management Plan Regulations 2007 and the Water Resources Management Plan Direction 2017. Additionally, it has been produced with reference to the following guidance:

- Guiding Principles for Water Resources Planning, Defra, 2016
- Water Resources Planning Guideline, Environment Agency, 2017

Additional detailed guidance and methodologies on specific aspects of the plan are referenced in relevant sections of this document.

This draft WRMP is supported by NW's Drought Plan (www.nwl.co.uk/droughtplan), which shows how droughts will be managed, what trigger levels will be used to identify when action is required, and what measures are available to support supplies when Levels of Service (LoS) are compromised.

As both WRZs have a surplus of water across the planning horizon, no new water resource options are required, negating the need for a Strategic Environmental Assessment.

1.3 Consultation

1.3.1 Pre-draft Water Resources Management Plan Consultation

NW recognised the value of early communication with the many stakeholders potentially affected by and involved in the water resources planning process. It has:

- Communicated with neighbouring water companies seeking their views on what should be included in NW's draft WRMP.
- Held regular Agency Liaison meetings where different elements of the draft WRMP have been discussed.

- Presented to the Company's Customer Challenge Group (known as the Water Forum) on different elements of the draft WRMP including leakage, metering, water efficiency, catchment management and drought management
- Presented to Ofwat and to the Consumer Council for Water.

Outcomes of the above engagement has been taken into consideration in the development of this draft WRMP.

1.3.2 Draft Water Resources Management Plan Consultation

The following statutory consultees are invited to comment on this Plan:

- Ofwat
- Environment Agency
- Secretary of State (c/o Defra)
- Any Regional Development Agencies in the area covered by the Plan
- Any elected Regional Assembly in area of the Plan
- All local authorities in the area of the Plan
- Natural England
- The Historic Buildings and Monuments Commission for England.
- Any navigation authority in the area of the plan.
- United Utilities
- Yorkshire Water Services
- The Consumer Council for Water

NW also welcomes comments and representations from the wider community, including customers and any other interest groups.

1.3.3 Making Representation

The public consultation for NW's draft WRMP is taking place between Monday 5th March and Friday Sunday 27th May 2018. The start of the consultation will coincide with publication of the document on NW's website:

http://www.nwl.co.uk/wrmp

Any person, including statutory consultees, stakeholders and customers, may make representations to the Secretary of State during this period.

Representations by e-mail should be sent to:

water.resources@defra.gsi.gov.uk

and be titled: "Northumbrian Water Water Resources Management Plan".

Representations by post should be sent to:

Secretary of State, Department for Environment Food and Rural Affairs (Defra)
Northumbrian Water Water Resources Management Plan Consultation
Water Resources

Department for Environment Food and Rural Affairs
Area 3D
Nobel House
17 Smith Square
London, SW1P 3JR

The Secretary of State will forward all comments on to NW. We will then review the comments received and publish a Statement of Response by Friday 31st August 2018 on NW's website. This will detail any changes NW will make to the Plan as a result of the feedback we receive during the public consultation. Subject to approval by the Secretary of State, NW's final Water Resources Management Plan will then be adopted and published in 2018.

1.4 Water Resources Plan Structure

Subsequent sections of this WRMP are as follows:

Section 2 Background Information: This section provides background information including a description of each of NW's WRZs, progress made in implementing the Company's 2015 WRMP, confirmation of the base year and planning period and confirms the Company's position regarding the trading of surplus water resources.

Section 3 Water Supply: This section presents the results of the Deployable Output (DO) assessments and describes how DO has been calculated for each source and WRZ. Additionally, it describes reductions in DO, treatment works process losses and outage allowances.

Section 4 Water Demand Forecasts: This section presents the results of the demand forecast and describes in detail the method used to prepare the forecast.

Section 5 Water Efficiency: This section covers NW's full and ongoing commitment to demand management and covers water efficiency, metering and leakage.

Section 6 Effects of Climate Change: This section presents the results of the climate change assessments and describes the methodology used. The assessments consider the effect of climate change on both baseline supply and demand.

Section 7 Target Headroom: Target headroom is a buffer between supply and demand designed to cater for specified uncertainties. This section presents the results of the target headroom assessment and describes the method used to undertake the assessment.

Section 8 Baseline Supply Demand Balance: This uses the supply and demand data from the previous sections to prepare a supply demand balance graph for each WRZ. These graphs are then used to identify whether there is likely to be a supply deficit at any point across the planning horizon.

Section 9 Options Appraisal: This section would normally cover an appraisal of all supply and demand options that would be required to ensure there is a supply surplus in each WRZ over the planning horizon. However, NW's baseline supply demand balance confirms both WRZs are in surplus over the whole planning horizon and so options appraisal is not required.

Section 10 Final Water Resources Strategy: This section confirms NW's final water resources strategy.

2.0 BACKGROUND INFORMATION

2.1 Water Resource Zones

The Water Resource Zone (WRZ) is the basic building block of a Water Resource Management Plan (WRMP). Companies will have a variable number of WRZs making up their total supply area. A WRZ is the largest area of a company's supply area where supply infrastructure and demand centres are generally integrated to the extent that customers in the WRZ should experience the same risk of supply failure due to climatic conditions.

Northumbrian Water (NW) has two WRZs covering its supply area. These are the Berwick and Fowberry WRZ in the far North of the supply area and covering about 1% of the customers and the Kielder WRZ covering the remaining 99% of customers. The Berwick and Fowberry WRZ has two well fields centred around Berwick and Fowberry.

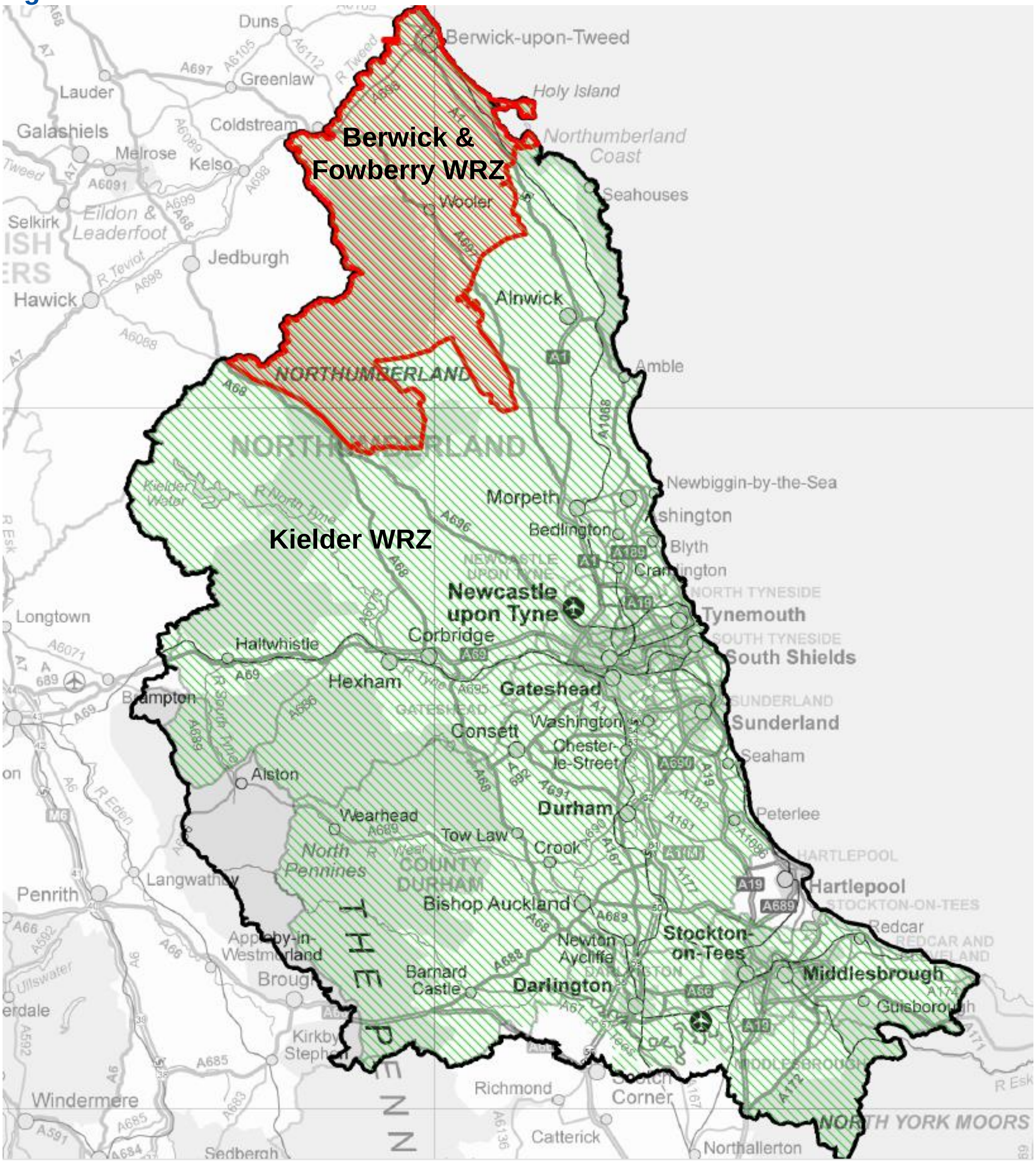
2.2 Water Resource Zone Integrity

A Kielder and Berwick and Fowberry WRZ Integrity Assessment was the subject of dialogue in NW's previous WRMP with the Environment Agency (the Agency) as they required NW to demonstrate more fully how it is a single WRZ. NW were able to demonstrate that water is integrated to such an extent over the whole WRZ, mainly by being supported by Kielder Reservoir and the Tyne-Tees Transfer (TTT), that it is a single WRZ and complies with the definition of a WRZ. There have been no major changes to this position and no area of the company has ever been subject to restrictions on their use of water due to drought conditions.

We recognise that the Kielder WRZ and Berwick and Fowberry WRZ are completely separate from each other although the company's Level of Service (LoS) to both WRZs is the same. There is a considerable surplus of supply within the Kielder WRZ that, as demonstrated in previous WRMP's can be adequately moved across all of the major customer centres.

The use of only two WRZs remains appropriate. Figure 2.1 below shows the two WRZs.

Figure 2.1 Water Resource Zones



2.2.1 The Kielder Water Resource Zone

There are three main supply zones within the Kielder WRZ, these being the "Northern", "Central", and "Southern", which incorporate the major urban conurbations of Tyneside, Wearside and Teesside respectively. They are virtually discrete in terms of treatment capacity, but they can all be supported from Kielder. As such they all have the same theoretical risk on restrictions of use and are considered as a single water resource zone.

2.2.2 The Kielder Water Supported Systems

The scheme consists of the Kielder Reservoir and Dam (associated headworks including release valves and hydropower plant), Bakethin Dam (a weir upstream of Kielder Reservoir) and a pumping station at Riding Mill on the River Tyne. The pumps deliver into a rising main from Riding Mill to Letch House. A gravity pressurised tunnel flows from Letch House into Airy Holm Reservoir, onto Frosterley discharge into the River Wear and to Eggleston discharge into the River Tees. Licenced abstractions from the tunnel allow support to Mosswood Water Treatment Works (WTW) and to Honey Hill WTW.

2.2.3 Associated Water Resources

Associated water resources include those that may be deficient in times of drought to meet demands, and may therefore be required to call upon the strategic resource provided by the Kielder Water Scheme. These resources have been grouped as follows.

- North Tyne and Northumberland Resources
- River Wear and Associated Mid Durham Resources
- Tees Resources

These groups are described as follows:

North Tyne and Northumberland Resources

The northern part of this system is supplied from Warkworth WTW, Fontburn Reservoir and treatment works and Tosson Springs and treatment works. These are linked to the Tyne system with a major potable water trunk main and full flow from Warkworth can be replaced with potable water from the Tyne WTWs.

Fontburn Reservoir is silted at its upper levels due to pine needles falling and trapping the sands and silts which do not migrate to the treatment works. Previously the amount of storage lost at Fontburn Reservoir due to siltation had been estimated to be 489 Million litres (Ml). Following a recent bathymetric survey the overall storage lost due to siltation has been re- assessed as 80Ml and confined to the area around the inlet of the reservoir.

In addition there is a linear sequence of reservoirs supplying raw water to Gunnerton, Whittle Dene and Horsley WTWs.

Catcleugh Reservoir in Redesdale feeds Hallington Reservoirs by gravity which in turn connects to the Whittle Dene group of reservoirs. Two additional reservoirs, Colt Crag and Little Swinburne contribute flow to the Hallington Reservoirs. These direct supply reservoir cannot reliably meet the raw water requirements and river abstractions are made at Barrasford on the North Tyne and Ovingham on the Tyne. The pumped abstraction at Ovingham is used to supply Horsley WTW or to support the Whittle Dene Reservoirs, whilst the abstraction from Barrasford is pumped into the Hallington Reservoirs. Kielder releases are made to regulate the River North Tyne or River Tyne when required.

Storage at other reservoirs is balanced to ensure that water is not wasted through spillage, especially at Whittle Dene, whilst higher level reservoirs are still drawn down.

Water treatment is provided at six works, three very small works, Otterburn, Rochester and Byrness, supplying the Redesdale area and Gunnerton supplying the area west of Hexham. The remaining treatment works at Whittle Dene and Horsley jointly meet the majority of Tyneside and SE Northumberland demands.

Catcleugh Reservoir Operation

The treatment works at Otterburn, Rochester and Byrness are dependent on Catcleugh Reservoir for sole supply and theoretically the needs of this demand zone should limit the rate of transfer to Hallington and Whittle Dene.

However, in practice, the capacity of the Rede pipeline restricts the rate of drawdown such that, even in extreme drought the needs of Redesdale do not act as a constraint. Transfers from Catcleugh to the Hallingtons can therefore operate continuously at full pipeline capacity. The Rede pipeline from Catcleugh to Hallington is limited (by construction) to 55 Million litres per day (Ml/d) when the reservoir is full, and therefore normally operates at full capacity.

Colt Crag, Hallington and Whittle Dene Reservoir Operation

The linear configuration of the remaining reservoirs permits them to be considered as one, with the total storage balanced between reservoirs under the company's control within the constraints imposed by the licence. The aim should be to avoid unnecessary losses by spillage, whilst maintaining throughput for treatment. Control rules for the group of reservoirs have been agreed between the Agency and the company.

2.2.4 The Tyne – Tees Transfer System

The TTT system comprises a pumping station at Riding Mill on the River Tyne, a rising main and gravity tunnel carrying water (when required) to Airy Holm Reservoir, the River Derwent, Mosswood WTW, Waskerley airshaft, the River Wear and the River Tees.

At Riding Mill pumping station six pump units, each with a nominal fixed capacity of 1.05 cumecs (90 Ml/d), are installed. However an agreed supply capacity with Central Electricity Generating Board (CEGB) limits maximum abstraction flow to three pumps, about 270 Ml/d. All six pumps remain in commission and are tested periodically.

The steel rising main from Riding Mill to Letch House is 6.2km in length and 2m in diameter and the pumping head is approximately 205 metres. The concrete lined gravity tunnel from Letch House to Eggleston on the River Tees is 34km long and 2.91m in diameter. The rising main and tunnel are designed to remain charged and have a capacity of 230,000 m^3 Airy Holm Reservoir forms a header tank on the tunnel system to correct any imbalance between rates of pumping and outlet discharge. It has a capacity of 220,000m^3 and inflow to and draw-off from the tunnel is by means of a 5m diameter shaft connected to the reservoir floor. Airy Holm will normally be maintained near to full level in order to provide a reserve for releases. However, no spillway discharge should occur as a direct result of pumping at Riding Mill.

A direct connection links the tunnel with Mosswood WTW and can provide full substitution for the Derwent Reservoir resource and thus support the water resources for mid-Durham.

Provision has been made for a licenced abstraction from Waskerley airshaft with an annual total of not more than 3,200 Ml. This water can be abstracted from the TTT into Waskerley northern catchwater.

The Tyne-Tees transfer system also supports the Rivers Wear and Tees to ensure that prescribed minimum maintained flow conditions are met and the system operation is set out in the Kielder Operating Manual.

2.2.5 River Wear and Associated mid-Durham Resources

The strategy for operating to the River Wear and mid-Durham resources is:

- To regulate the River Wear to maintain flow rates above a prescribed minimum flow rate as measured at Chester-le-Street gauging station.
- To regulate the River Wear to support abstractions, including the public water supply abstraction at Lumley.
- To provide water in emergency for flushing the Rivers Derwent and Wear, following major pollution incidents.
- To support associated water resources in mid-Durham in times of drought by making direct transfers from the Tyne-Tees tunnel to Mosswood treatment works and from Waskerley airshaft to support Honey Hill treatment works.

River Regulation for Prescribed Flow and Abstraction

The outlet from the TTT System to the River Wear is located near Frosterley. The maximum discharge capacity of the outlet valves is 2 cumecs. (173 Ml/d). Tunstall

Reservoir now acts as a regulatory reservoir following the abandonment of the treatment works at this site.

Water for public water supply is abstracted from the River Wear at Chester-le-Street to Lumley WTW the maximum licenced daily abstraction is 45.4 Ml/d.

A prescribed minimum maintained flow is set at Chester-le-Street gauging station of 2.0cumecs (173 Ml/d). Both the Agency and NW has access by telemetry to levels and flows measured at the station.

Mine water discharges to the River Wear and tributaries cause small variations in flow. However, eventually minewater pumped discharges are expected to cease.
An outlet close to Derwent Reservoir allows releases to be made from the TTT in the River Derwent. However, as there are no public water supply abstractions or prescribed flows on the River Derwent, releases are reserved for use in supporting compensation flows and alleviating pollution.

Waskerley Air Shaft allows licenced abstractions of 24 Ml/d or 3200 Ml/year to be abstracted from the TTT into Waskerley.

Mid –Durham Associated Water Resources and Support.

An operating policy for the timing and magnitude of Kielder support is agreed to provide guidance in ensuring that public water supply requirements can be met in a drought in all parts of the mid-Durham demand area.

System Assumptions

Given the complex interlinked network linking sources and demands a large number of options exist for operating the system. The control policies described later are based on the following key assumptions:

- Priority is given to meeting public water supply requirements and the needs of the rivers, as reflected by minimum maintained flows and compensation flows.
- Where either of the requirements above can be met only from a single source, sufficient water has to be retained in the relevant storage to supply these without reduction except under severe droughts, until the anticipated end of a drought.
- Other uses of water, such as for fisheries, recreation and amenity are recognised and provided for where appropriate.
- The policies provide a broad but well defined framework within which the undertaker may operate the system to meet their own needs and interests.
- The policies have been defined to minimise the operating costs for the Agency and the company within the constraints above.

Water Resources System Structure

The key mid-Durham resources are:-

The abstraction from the River Wear at Lumley, two main reservoirs Derwent and Burnhope, three smaller reservoirs Smiddy Shaw, Hisehope and Waskerley, Tunstall river regulatory reservoir, groundwater sources (mainly from the Magnesian limestone aquifer in the Sunderland area), and two small spring sources, and the TTT system as previously described.

Derwent Reservoir:-

Mosswood WTW supplies its demand centres by abstracting raw water from Derwent Reservoir or from the TTT scheme. Abstraction from the tunnel to Derwent/Mosswood is licenced to an annual total of 21900 Ml and a peak daily rate of 164 Ml/d.

Smiddy Shaw, Hisehope and Waskerley Reservoirs:-

Smiddy Shaw, Hisehope and Waskerley Reservoirs, nearby small spring sources, Waskerley air shaft and associated Honey Hill WTW are treated as a group. Water can be transferred under gravity from Waskerley, Hisehope and
Smiddy Shaw to Honey Hill WTW. The required output of Honey Hill WTW cannot be fully met from these reservoirs year round but support is available from Burnhope Reservoir. Burnhope raw water may be transferred under gravity to Waskerley, Smiddy Shaw or direct to Honey Hill at a maximum rate which depends on the level in Burnhope.
In addition water can be pumped into Waskerley Reservoir from the Waskerley airshaft (part of the TTT). A maximum of 24 Ml/d can be pumped from the airshaft while the total annual abstraction may not exceed 3200 Ml.

Burnhope Reservoir:-

Water from Burnhope can be used to supply Wear Valley WTW and the raw water pipeline to the Waskerley, Smiddy Shaw or Honey Hill WTW. Wear Valley treatment works and compensation water can only be provided from Burnhope and therefore, sufficient resources are retained at all times to provide for these two demands. Burnhope Reservoir is small for the catchment area and can be resource restricted in the summer months.

Groundwater Supply

The coastal ground water sources and shafts supplying groundwater towards Sunderland have their pump low level protection set conservatively to alleviate the problem of disturbing sediment at the lower levels. Sediment creates turbidity, which is used as a surrogate for possible cryptosporidium pollution and results in pump shut down. There is a project currently underway which involves the addition of filtration at each of the groundwater stations to control turbidity and allow groundwater to be put back into supply with shorter run-to-waste times. This investigation looks at the physical (particle size distribution) and chemical (chemical analyses of different particle size ranges) nature of particles making up turbidity. This will help identify the potential source of turbidity and the specification of filters at each groundwater station.

In addition there is also a programme of groundwater source cleaning in progress to ensure supplies can be maintained.

NW will also carry out the following investigations regarding the Sunderland Groundwater abstractions.

Saline Intrusion: There are concerns that there is not an evaluation of the impact of abstractions on possible saline intrusion into the Magnesian Limestone aquifer and therefore as part of WINEP NW will work with the Agency using the groundwater model to assess the potential for saline intrusion.

Coal Measures: Impact of rising groundwater in Coal Measures on the water quality within the Magnesian Limestone. This includes investigation with Coal Authority on the depth of the separation zone between the top of the Coal Measures and the bottom of the Magnesian Limestone which is a key mechanism to protect Magnesian Limestone aquifer and ensures the hydraulic gradient between the two aquifers is from the Magnesian Limestone to the Coal measures and sharing this information with the Agency. This also includes the proposal to develop the existing Magnesian Limestone groundwater model to include predictive modelling of the interaction between the Magnesian Limestone and Coal Measure groundwaters.

2.2.6 River Tees and Associated Tees Resources Objectives

Within the general framework of ensuring proper use of resources, objectives for the River Tees and the operation of local resources within the Tees catchment are:

- To regulate the River Tees to maintain flow rates above a prescribed minimum flow rate as measured at Broken Scar gauging station.
- To regulate the River Tees to support at Broken Scar, Blackwell and Low Worsall and hence to support associated water resources in the Tees catchment in times of drought.
- To provide water in emergency for flushing the River Tees, following major pollution incidents.

River Regulation and Prescribed Flows and Abstractions

The principal regulating reservoir on the Tees catchment is Cow Green providing the full support required for prescribed flows and abstractions under normal conditions. In conditions of dry weather or future higher abstractions, releases may be made from Balderhead Reservoir or the TTT system.

Associated Tees Water Resources and Support

The principal objective in the design of the Kielder Scheme was to augment the water resources of the Tees basin to meet the then rapidly increasing demand for water, primarily for industrial use. Although the forecast industrial demands have not materialised, recent droughts have illustrated the advantages of a strategic regional resource. Whilst the volume of transfer through the tunnel to the Tees has been limited to small amounts, the availability of support has enabled the cheaper local sources to be used more effectively, and to be drawn down further, without the necessity to place restrictions on water use.

System Assumptions

Given an inter-linked network linking sources and demands, a large number of options exist for operating the system. The control policies described below are based on the following key assumptions.

- Priority is given to meeting public water supply requirements and the needs of the river are reflected by the minimum maintained flow and compensation flows from reservoirs.
- Other uses of water such as for fisheries, recreation and amenity are recognised and provided for where appropriate.
- The policies provide a broad but well defined framework within which the company may operate the system to suit its own needs.

Cow Green Reservoir:-

Cow Green is the principal river regulating reservoir on the River Tees, and is used to support the minimum maintained flows in the River Tees to allow abstractions from the river downstream. River regulation demand can normally be met from Cow Green but can be augmented when necessary by releases from Lune and Balder Reservoirs or the Kielder transfer system.

In-river needs in the upper Tees are met by the compensation flow and by the requirement to reserve water such that at least one third of regulation releases at a given time come from Cow Green, when additional regulation releases are being made from the Lune and Balder Reservoirs, as specified in the Tees Valley and Cleveland Water Act 1967. That Act also requires that 1818 Ml be reserved in the reservoir for freshet releases for fishery purposes, at a maximum additional discharge rate of 45.45 Ml/d.

Cow Green has a flood control role during winter months with the level of the reservoir being drawn down to provide flood storage.

Lune and Balder Reservoirs:-

The Lune and Balder Reservoirs consist of Selset, Selset Weir and Grassholme on the River Lune and Balderhead, Blackton, Hury Subsidiary and Hury on the River Balder. The two cascades of reservoirs are used conjunctively by means of a tunnel connecting Selset Reservoir to Hury Reservoir.

The Lune and Balder Reservoirs directly support Lartington WTW. Water may be available for regulation releases to support the River Tees when the reservoirs are in the surplus zone. The normal minimum release to the River from these reservoirs is compensation water (44 Ml/d) and the flow to meet the requirement of Lartington WTW.

In-stream flow needs for the Lune and Balder Rivers are met by the compensation releases from Grassholme and Hury Reservoirs respectfully. There is significant recreational use of some of the reservoirs.

2.2.7 Berwick and Fowberry Water Resource Zone

The Berwick and Fowberry WRZ is a small zone in the North East of Northumberland serving the towns of Berwick-upon-Tweed and Wooler. The area has a small indigenous population of about 25,000 people but is a very popular tourist area. It is a discrete zone in terms of both water resources and treatment capacity and cannot be supported from Kielder. The resources comprise a number of groundwater sources, sunk into different layers of the Fell Sandstone Aquifers.

2.3 Progress with Implementing the 2015 Water Resources Management Plan

The 2015 Water Resources Management Plan did not contain any supply side options as a supply surplus was maintained in both WRZs across the full planning horizon.

NW's AMP6 National Environment Programme (NEP) obligations will be fully met by 31 March 2020. Progress with the delivery of the AMP6 NEP is presented in Section 3.7 while progress with NW's leakage, metering and Water Efficiency programmes are presented in Section 5.

2.4 Sharing Surplus Water Resources

WRZ supply/demand balance calculations were prepared in early 2017. These showed that there was a significant surplus of water in the Kielder WRZ that would be available for trading. However, there was considerable uncertainty as to what the surplus for the Berwick and Fowberry WRZ would be as at that point, NW's groundwater abstraction sustainability investigations had not concluded. Consequently, it was concluded that there was no surplus of water to trade from the Berwick and Fowberry WRZ.

As with previous periodic reviews, NW has held discussions with regional companies, specifically with Yorkshire Water (YWS), United Utilities (UU) and Hartlepool Water.

YWS

NW has previously met with YWS to discuss what options could be available as new water resource schemes for YWS using transfers of surplus water from NW's current licenced resources. Only two options were considered suitable for consideration of further thought.

The first was to look at a potable water supply from NW's Broken Scar WTW being piped by new pipelines into the Whitby area of YWS. A supply of 25 Ml/d would be required by YWS and Broken Scar has sufficient spare dry year DO to make this supply. NW provided YWS with its Large User Tariff rate as a likely charge it would make for the water. YWS, should they choose to look at the option in its appraisal process, would have to look at costing to lay the pipeline between the two places and estimate the pumping (energy) costs.

The second option was to look at transferring raw water into YWS area by transferring River Tees water into the existing pipeline running from the Tees almost to the River Wiske, and extending this pipeline to the River Swale. YWS asked NW to cost and model two different volumes of 50 Ml/d and 140 Ml/d, noting that the 140Ml/d would require the electrical service capacity at Riding Mill to be upgraded and an additional pump installed.

YWS has not asked to progress agreements regarding trading of water from the Kielder WRZ. Consequently, no allowances have been made in either NW's baseline or final plan supply demand balance calculations.

UU

NW has previously met with UU to explore any options that could be available for transferring surplus water from NW's Kielder WRZ into UU's area. A number of options and volumes were considered.

NW currently makes a ~1.0 Ml/d bulk potable supply from Burnhope Reservoir into UU's North Eden WRZ. UU forecast this WRZ to remain in surplus but would like to understand any potential for increasing the current volume of the bulk supply. NW estimated that there was sufficient raw water and treatment capacity (by substituting water within the Kielder WRZ) for a bulk supply of 5 – 6 Ml/d to be available. However after investigating the capacity of the current bulk supply infrastructure, NW later informed UU that the current infrastructure delivering 1.0Ml/d is at full capacity and the cost of upgrading the pipelines and intermediate pumping stages is likely to make this option unviable. UU has not ask for any further information.

Cow Green Reservoir is geographically the nearest NW resource to where UU may need water in the future. An option could be considered where a pipeline from Cow Green, crossing the Pennines, could connect into a tributary of the River Eden for the Carlisle WRZ or into Haweswater for the Integrated WRZ. UU has previously asked NW to look at the cost and availability of 25, 50, 100 and 180 Ml/d being supplied from Cow Green to UU. These costs were provided to UU in October 2012 but the following information to note was also given:-

- A supply above 100 Ml/d is unlikely to be available without a large change to NW's current operating regime
- Cow Green is a SSSI and any new abstraction from the reservoir would require a full Environmental Impact Assessment and NW would not be sure of the outcome.
- Cow Green is in a remote location without suitable roads or power supplies.

UU requested similar costings for 25, 50,100 and 180 Ml/d supplies into UU from Kielder Reservoir. Taking water from Kielder is likely to have less environmental impact on the water body but does require the water to be transferred longer distances. Transfers from Kielder into UU's Carlisle or Integrated WRZ and into its West Cumbria WRZ have been previously considered. However, the latter was discarded on cost grounds compared to other options for the WRZ.

UU has not asked to progress agreements regarding trading of water from the Kielder WRZ. Consequently, no allowances have been made in either NW's baseline or final plan supply demand balance calculations.

2.5 Regional Water Resources (Water Resources North)

A new group called Water Resources North (WRN) has been formed with initial membership comprising NW, YW, UU, Hartlepool Water and the Agency. The group anticipates opening up to other relevant stakeholders (abstractors and regulators) once water companies have gained a clear understanding of their joint long term water resources position and aspirations. It may be appropriate to have a number of levels of engagement – from those directly involved in the group, through to those who are consulted, or informed, about the group's discussions.

The purpose of WRN is to provide leadership and coordination to support the delivery of long term water resource resilience in the north of England, and to support activity aimed at ensuring national water resource resilience. The primary objectives of the group are to:

i. Contribute to securing the long-term resilience of water supplies and the water environment in the north, across all stakeholders, and
ii. Facilitate a co-ordinated approach across northern water companies to cross-boundary trading that may contribute to enhancing national water resource resilience.

The group will help to achieve these objectives by:

i. Providing a strategic forum to bring together representatives from each of the water companies in the north of England, their regulators and other relevant industries, to facilitate an effective and co-ordinated approach to water resources management;
ii. Enhancing understanding of the long-term challenges for water resource resilience, both within the north and across the whole country;
iii. Contributing to joint working on future water resource options, both to inform individual companies' WRMPs and to inform long term investment needs which may include joint investment activity;
iv. Helping the industry to articulate future challenges with a consistent voice, to assist with customer and stakeholder engagement and understanding of investment priorities; and
v. Sharing approaches and best practice in water resources planning.

NW fully supports the WRN project. Kielder Reservoir provides NW with a significant supply surplus which, with additional infrastructure, could be used to support both neighbouring water companies and also water companies further south. For example, a neighbouring water company could take a raw water supply into one of its WRZ from a Kielder Reservoir supported river. This could then allow that company to release water from another of its WRZ to one of its neighbouring water companies and so on. This theoretical transfer scheme has previously been highlighted by the Water Resources Long Term Planning Framework project and could be considered by WRN going forwards.

2.6 Planning Period

The statutory planning period for WRMPs is a minimum of 25 years from 1 April 2020 to 31 March 2045. However, the Water Resources Planning Guideline (WRPG) encourages water companies to plan over a longer planning horizon. For the purposes of this Plan, NW's planning period is for 40 years from 2020 to 2060.

The base year for supply/demand data is 2016/17, as this was the most recent year NW has out-turn data for and is also in line with the WRPG.

2.7 Planning Scenarios

NW's baseline and final plan supply forecasts for each WRZ are based on a 'dry year' which is defined by the worst historical drought NW has on record. The design drought years are described in the DO section of this report (see Section 3.1).

The WRPG also requires water companies to provide a supply and demand forecast for each water resource zone for a drought with a return period of 1 in 200 years. These are also presented in Section 3.1.

The following planning scenarios are included in this WRMP:

- Dry year annual average daily demand forecast (baseline);
- Dry year annual average daily demand forecast (final plan); and
- Normal year annual average daily demand forecast (baseline).

NW's assumptions regarding the impacts of climate change on both Water Available For Use (WAFU) and demand are described in Section 6.

Kielder WRZ has always used the Dry Year Annual Average as the planning scenario. This still remains relevant as no high peak demand is driving investment in the WRZ.

2.8 Problem Characterisation and Risk Composition.

Problem Characterisation

Problem Characterisation requires water companies to assess the vulnerability of each of their WRZs to various strategic issues, uncertainties, and risks. NW undertook a problem characterisation assessment in 2016 and submitted the resulting report to the Agency. The assessment was completed following the method outlined in the 2016 UKWIR report entitled WRMP 2019 Methods – Risk Based Planning.

The first stage of the problem characterisation assessment was an assessment of ‘strategic needs’. This entailed three simple ‘headline’ questions that explored the size of any potential supply demand deficit, and if required, the cost of any supply and demand management options. Both of NW’s WRZs had a supply surplus in all years of the planning horizon under the Baseline scenario. At the time of the assessment, it was reasonable to assume that all WRZs would continue to have a supply surplus in this draft PR19 WRMP and so no investment would be sought to fund supply and / or demand management measures.

The second stage of the problem characterisation was an assessment of the ‘complexity factors’. This stage asked whether there was concern regarding understanding of near term supply system performance, either because of:

i. recent LoS failures; or
ii. poor understanding of system reliability/resilience under different or more severe droughts than those contained in the historic record.

Given the forecast supply surplus in both of the Company’s WRZs, there were no significant concerns about understanding of near term supply system performance and NW continue to meet levels of service.

A similar question was asked regarding demand and whether the nature of current or near term demand had recently changed or was likely to change, e.g. because of large scale metering programmes or sudden changes in economics/demographics. At the time of the assessment, the nature of current and near term demand had not recently changed. Industrial demand was generally falling and domestic demand was fairly constant.

The problem characterisation assessment concluded that both of the Company’s WRZs had a “low vulnerability” score. The results of this assessment were then carried forward to the risk composition stage detailed below.

Risk Composition

Risk composition requires water companies to select and justify one of the following three approaches in developing their WRMPs:

i. Conventional;
ii. Resilience Tested; or
iii. Fully risk-based.

The WRPG provides a summary description of the approaches and techniques for each approach for developing supply and demand forecasts and is re-produced in table 2.1 below.

Table 2.1 Risk Composition Guidance

Risk Composition	What is it?	Specifics of what is Involved (supply, demand, investment)
1 – The 'Conventional' Plan	Estimates of supply capability are based on the historic record, perturbed for climate change. Any testing of droughts outside of the historic record is done using a simple 'top down' method and is only done to examine supply / demand risk under more extreme conditions (i.e. sensitivity analysis only). Uses a simple representation of dry year/normal year demand.	*Supply* – conventional 'Deployable Output' (DO) or historically based time series. *Demand* – dry year/normal year estimates. *Investment* – inputs to the Decision Making Tool (DMT) are based on analysis of the historic record and the investment programme therefore represents the 'best value' response to maintaining Levels of Service and resilience against the historic record.
2 – The 'Resilience Tested' Plan	Companies use 'Drought Events' to test the Plan and look at the implications of alternative/more severe droughts on the 'best value' investment programme. These 'Drought Events' can be derived using a variety of top down methods, but their 'plausibility' (approximate level of severity) is checked using *metrics* of rainfall, aridity or hydrology. More complex representation of demand *variability* can be tested.	*Supply* – conventional plus 'event based' DO or time series. *Demand* - conventional, or can use demand/weather models to create equivalent demands for generated events. *Investment* – Events are used to test the programme; either by comparing the resilience of similar NPV programmes, or to look at the cost implications of achieving LoS commitments and resilience to droughts outside of the historic record.
3 – The 'Fully Risk Based' Plan	Companies use modelling methods to evaluate a full range of drought risks to their supply system, supported by more sophisticated approaches to matching this with demand *variability*. This is used to generate a 'best value' WRMP at a level of resilience that is linked to Levels of Service and the Drought Plan.	*Supply* – companies use generated data sets to explore the yield response to drought severity and patterns. Inputs to system-simulation DMTs are based on probabilistic sampling of the drought response. *Demand* - demand variability to drought is incorporated, although methods/complexity can vary. *Investment* the Plan is developed to represent the 'best value' response to overall drought risk, according to the Company's stated LoS and drought resilience.

The WRPG states that the over-riding concept when choosing which approach to follow is that non-conventional methods (i.e. risk composition 2 and 3) for forecasting supply and demand should only be used where they are warranted and should be proportionate to the supply demand problem as defined in the problem characterisation stage. Methods beyond the 'conventional' baseline can be chosen, but only need to be followed where there are specific concerns with the supply/demand components that mean a risk based approach is needed to better understand the supply/demand problem that they face.

NW's early (2016) supply and demand forecasts indicated that both of the Company's WRZs would have a supply surplus across the full planning period. As such, the problem characterisation assessment concluded that the WRZs had a low vulnerability to supply deficits. Consequently, the conventional methods (i.e. Risk Composition 1) have been used to forecast future demand, water supplies and target headroom to allow for uncertainty in the forecasts.

Baseline supply and demand forecasts were re-calculated during 2016/17 and these also confirmed that a supply surplus would be maintained across the statutory minimum 25 year planning horizon. Consequently, there was no need to re-assess the forecasts using Risk Composition 2 or 3 methods.

In line with the WRPG, the Company has applied some Risk Composition 2 approaches in that each water resource zone has been tested against a theoretical drought event which could occur one year in every 200 years on average.

2.9 Company Policies including Level of Service

2.9.1 PR19 WRMP Levels of Service (LoS)

LoS are expressed in terms of expectations about the frequency of restrictions on use of water during dry years, and set out the standard of service that customers can expect to receive from their water company.

LoS are generally grouped into the following categories:

Level 1: Appeal for restraint
Level 2: Temporary Use Ban
Level 3: Drought Order Ban
Level 4: Reduced supply at customer tap

A level 1 restriction is when we ask NW's customers to use water wisely. For example, watering plants at night and not watering the lawn because grass is resilient to drought.

A level 2 restriction (Temporary Use Ban) applies mainly to the domestic use of water and stops the use of a hosepipe or sprinkler for any garden watering or cleaning. For household customers, this use to be referred to as a hosepipe ban.

A level 3 restriction (Drought Order) bans what has been applicable to the domestic customer under the Temporary Use Ban, to non-domestic or commercial customers. These bans have economic consequences for businesses and have to be used as sparingly as possible.

A level 4 restriction results in a temporary reduction or nil supply of water at the customer tap. Examples of level 4 restrictions include:

- Reduced pressure at the customer tap (and therefore reduced flow);
- Rota cuts (e.g. 12 hours normal supply, 12 hours no supply); or
- Standpipes where supplies to customer's taps are turned off leaving customers to fill containers from an in pavement standpipe tap.

NW's PR19 'planned' levels of service for NW's customers (both Kielder and Berwick and Fowberry WRZs) are as follows:

Level 1: Appeal for restraint	1 in 20 years
Level 2: Temporary Use Ban (Hosepipe Ban)	1 in 150 years
Level 3: Restriction on non-essential use	1 in 200 years
Level 4: Rota cuts	1 in 250 years

NW's latest supply and demand forecasts confirm that both WRZs have a supply surplus for the duration of the planning period under both NW's dry year (worst historical drought on record) and 1 in 200 year drought scenarios. Consequently, no new water resource schemes are needed, or planned, for at least 40 years. Therefore lowering the current LoS (i.e. introducing some form of restriction on use), does not result in the deferment of any costs.

2.10 Reconciliation of Data

NW has used the Maximum Likelihood Estimation method (MLE) to reconcile the water balance at resource zone level in order to minimise the uncertainty in base year estimates. MLE provides a good framework to reconcile the water balance to ensure the sum of the estimated components equates to distribution input. The standard method for MLE is provided in an UKWIR/NRA report (UKWIR/NRA, 1995).

2.11 Sensitivity Testing

In developing this WRMP, NW has made a number of assumptions. The Agency has highlighted the importance of including a description of the sensitivity of the WRMP to these assumptions.
The WRPG indicates that as a minimum the sensitivity analysis should consider:

i. The sensitivity of the supply demand balance to data uncertainty; and
ii. The sensitivity of the DO to leakage, climate change and sustainability reductions.

Item (i) is considered in detail within the calculation of headroom uncertainty and hence an assessment of sensitivity for each WRZ has been included in Section 7.5 within the chapter on Target Headroom.

2.12 Details of Competitors in Each Resource Zone

Since publication of NW's 2014 WRMP, there have been three new inset appointments.

The three insets are all to Wynyard Park a mixed residential and commercial development in Wolviston in the Kielder WRZ. The inset supplier is Hartlepool Water (Anglian Water) and the water is supplied by Hartlepool Water's own resources.

2.13 Links to other Plans

2.13.1 Links to Northumbrian Water Limited Business Plan

NW is part of Northumbrian Water Limited. This WRMP also informs NW's Business Plan for the 2019 Periodic Review of Price Limits (PR19). This covers the period from 1 April 2020 to 31 March 2025, otherwise known as AMP7.

Funding requirements to allow all strategies linked with this draft WRMP and regulatory programmes of work will be included in the PR19 Business Plan. This includes:

- NW's metering, leakage and water efficiency strategies that have been built into NW's baseline distribution input calculations; and
- all schemes in NW's Water Industry National Environment Programme (WINEP) – currently WINEP2.

NW's baseline supply demand balance calculations have confirmed a supply surplus for both WRZs across all years of the planning horizon. Therefore no further supply or demand management schemes are required. This position will be acknowledged in the NW PR19 business plan.

2.13.2 Links with Northumbrian Water Limited Drought Plan

NW's Drought Plan identifies how the Company intends to manage a future drought, what trigger levels can be used to identify when action is required, and what short term measures are available to support supplies when levels of service are compromised. The benefit of NW's drought actions has not been included in NW's baseline supply forecast.

Drought planning is essentially a prepared response to developing sustained dry weather (drought) conditions that have the potential to detrimentally affect public water supplies. Drought conditions are usually manifested in the form of:

- reduced raw water availability (e.g. low river flows, low reservoir storage, low groundwater levels); and/or
- increased demand (e.g. due to increased garden watering, showering etc in dry weather).

The water resources planning guideline states that WRMPs should be appropriately linked. NW's planned levels of service (see section 3.10) in this draft WRMP will be the same as those in NW's final Drought Plan when it is published in 2018. Additionally, the calculation of all elements relating to the supply demand balance are consistent in both plans.

2.13.3 Links with the Agency Drought Plan

An Agency document called "Drought response: EA's framework for England" sets out how the Agency works with government, water companies and others to manage the effects of drought on people, business and the environment. It sets out who is involved in managing drought and how the Agency and stakeholders work together and take action to manage drought. The national framework aligns with the Agency's operational area drought plans to provide a strategic overview for how it will manage a drought to minimise damage to the environment and to secure essential public water supply. Information in the framework and local Agency Drought Plans has been taken into account in the development of NW's own Drought Plan and therefore in this draft WRMP.

2.13.4 Links with River Basin Management Plans

The Agency has published a Northumbria river basin district River Basin Management Plan (RBMP) called "Water for life and livelihoods" (December 2015). The RBMP sets out the current state and pressures on the environment and sets environmental objectives and a programme of measures to improve the environment. Information in the RBMP has, where required, been used to inform the development of this WRMP, most notably in the development of NW's PR19 (WINEP) and in considering whether this WRMP increases the risk of deterioration in the status of the surface and groundwaters on which NW's abstractions could impact.

2.13.5 Links with Flood Risk Management Plans

NW has undertaken flood risk assessments to confirm whether any infrastructure including pumping stations and treatment works are at risk of flooding both now and the future. These confirm that the supply forecasts used in this WRMP are not compromised because of any current or future flood risk.

2.13.6 Links with Plans Produced by Local Authorities

Information from Local plans has been used to develop property and population forecasts which in turn have been used to develop NW's demand forecast (see Section 4).

2.14 Habitats Regulation Assessment

Both WRZs have a baseline supply surplus in each year of the planning horizon and so no new supply schemes will be developed. Consequently, a Habitats Regulation Assessment is not required.

2.15 Strategic Environmental Assessment

Directive 2001/42/EC of the European Parliament and of the Council on the Assessment of the Effects of Certain Plans and Programmes on the Environment (the Strategic Environmental Assessment Directive) was transposed into English law by the Environmental Assessment of Plans and Programmes Regulations 2004 (Statutory Instrument 2004 No.1633).

Subject to meeting defined conditions (confirmed through screening), plans and programmes require a Strategic Environmental Assessment (SEA) to be undertaken and an environmental report to be produced.

NW has undertaken an assessment to identify whether it is required to undertake an SEA of its draft WRMP using the following guidance:

- UKWIR (2007) Guidance for Water Resources Mgt Plans & Drought Plans.

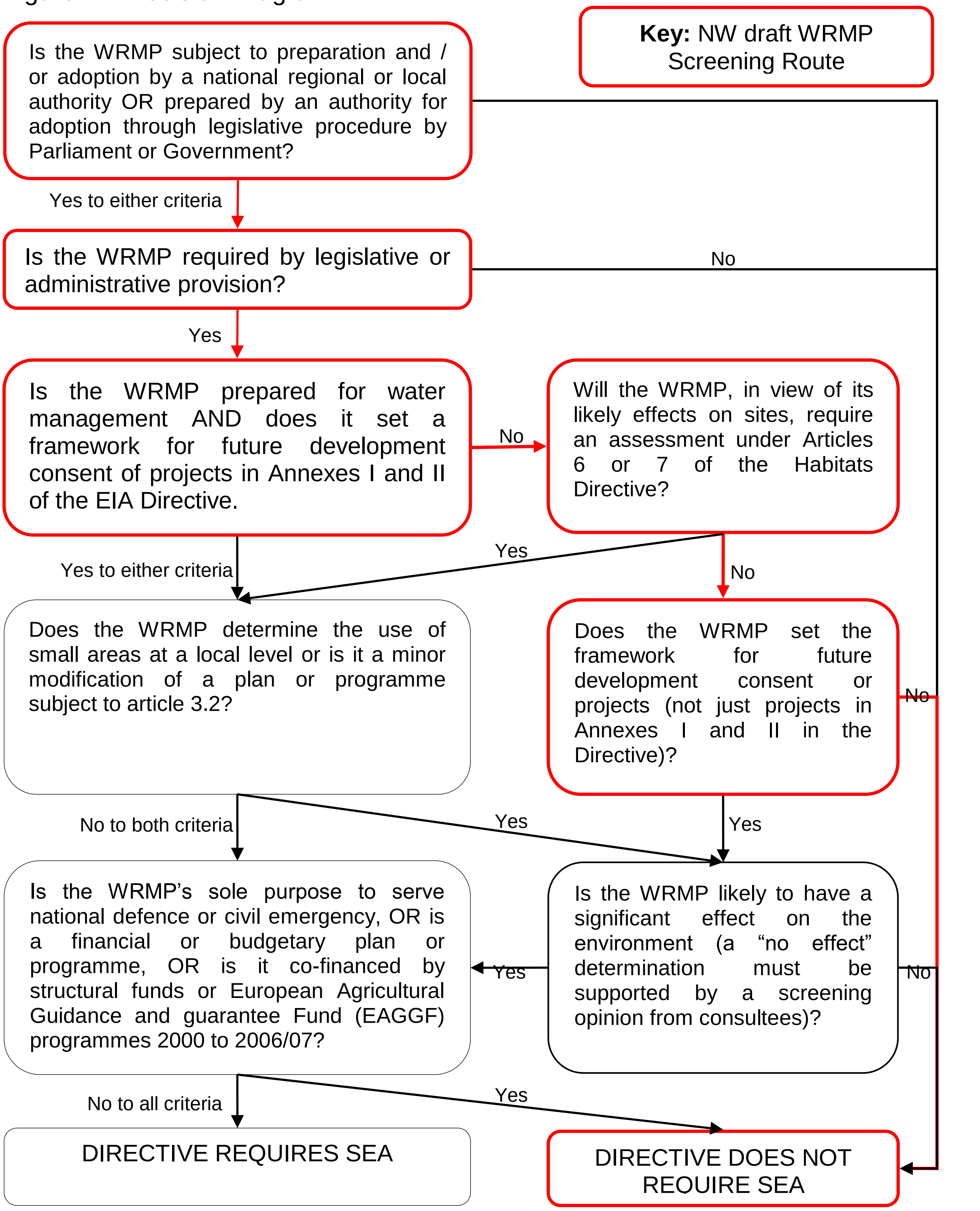
The decision diagram below illustrates the key stages and the results of NW's SEA screening exercise using the 2007 UKWIR methodology.

The results of the screening exercise are as follows:

i. The WRMP will be prepared and adopted by NW who, under the EIA Directive, is considered an "authority";
ii. The WRMP is required by legislative provision, being a statutory document under the Water Act 2003 amending the Water Industry Act 1991;
iii. The WRMP will be prepared for water management although based on the current draft supply demand balance calculations, it will not contain any supply schemes (i.e. schemes that create new deployable output);
iv. The WRMP will not be seeking permission for any schemes which will require an assessment under Article 6 or 7 of the Habitats Directive;
v. The WRMP does not set the framework for future development consent or projects (not just projects in Annexes I and II in the Directive).

Based on the above assessment, NW concludes that its draft WRMP does not fall within the remit of the SEA Directive and therefore it is not required to undertake an SEA or prepare an SEA Environmental Report.

Figure 2.2 Decision Diagram



Source: UKWIR (2007) Guidance for Water Resources Management Plans & Drought

2.16 Optimisation of Existing Operations

2.16.1 Business as Usual Optimisation

The WRPG asks water companies to describe the action that the Company has taken to lower the overall costs (financial, environmental, social and carbon) of its existing operations.

Optimising existing operations is considered by the Company to be part of "business as usual". This includes minimising process losses as back washing filters more frequently than is required incurs additional pumping which has an associated financial and carbon cost. Additionally, optimisation also reduces utilisation of annual licenced abstraction quantities. This process is controlled through the close monitoring of filter performance through the use of online water quality monitors.

2.16.2 Abstraction Incentive Mechanism (AIM)

The Abstraction Incentive Mechanism (AIM) is an Ofwat scheme. The objective of the AIM is to encourage water companies to reduce the environmental impact of abstracting water at environmentally sensitive sites during defined periods of low surface water flows (Ofwat 2017). The AIM applies once a water level or flow trigger threshold has been reached. Once flow or water level has fallen below the agreed trigger threshold, abstraction at the sensitive site should be reduced so that it is less than the agreed baseline daily quantity, and the balance is made up by increasing abstracting from an alternative, less sensitive, source. A screening exercise has been undertaken to establish whether AIM schemes should be implemented to cover any NW abstractions. However, all abstractions have been screened out and so NW is not proposing any PR19 AIM schemes in either WRZ.

3.0 WATER SUPPLY

3.1 Deployable Output

In developing Water Resource Zone (WRZ) Supply Demand Balance, water companies are required to estimate the yield of their resource zones in terms of Deployable Output (DO), a building block in determining Water Available for Use (WAFU). DO is defined as:

"The output for specified conditions and demands of a commissioned source, group of sources or water resource systems as constrained by:

- *hydrological yield;*
- *licenced quantities;*
- *environment (represented through licence constraints);*
- *pumping plant and/or well/aquifer properties;*
- *raw water mains and/or aqueducts;*
- *transfer and/or output main;*
- *treatment;*
- *water quality;*
- *levels of service."*

3.1.1 Kielder Water Resource Zone Deployable Output

Change from i-think Model to Aquator Model

For the PR14 WRMP NW used a software package called iThink to undertake water resource modelling. In the mid-1990s, in conjunction with the Agency, three iThink models were built to represent the three main areas of the Kielder Water Resource Zone (WRZ).

The main disadvantage with the iThink software for water resource modelling was that due to data limitations the Kielder WRZ zone could not be represented in a single model. This meant that DO analysis of the system as a whole could not be carried out, instead each Water Treatment Works (WTW) DO was tested against its yield independently of each other.

In 2014 working with the Agency, NW began the process of moving over to Aquator to carry out its water resource modelling and DO analysis for the Kielder WRZ.

For this draft WRMP, the DO of the Kielder WRZ is calculated using *Aquator*. *Aquator* is a windows-based water resource modelling system that utilises Microsoft Access to store information and data, and Microsoft Visual Basic for Applications (VBA) programming to explicitly define the behaviour of the components which are used to represent the hydrological entities in a water resources system.

The key features included within the Aquator model are catchment time series flows, minimum maintained flow conditions for the rivers, daily and annual licence conditions, treatment works minimum and maximum capacities, transfer main capacities, raw water pumping capacities, reservoir control curves, compensation flows and VBA coding to define the behaviour of components under certain circumstances, such as a control curve being crossed.

Model updates since PR14

In addition to moving from iThink to Aquator to carry out all water resource modelling, the following updates have also been made since publishing the PR14 WRMP:

- In partnership with the Agency, reservoir inflows have been remodelled using Catchmod, to derive inflows for the majority of the reservoirs from 1926 to 2014;
- River flow naturalisation was carried out using gauged river data and abstraction data where available. Where gauged data was not available the previously modelled river flow data (done by JBA is 1998) was adjusted to fit the parameters of the naturalised data.; and
- Given an integrated model for the Kielder WRZ is now available and updated flow data has been generated, a review and update of the current control curves has been carried out.

The English & Welsh Method DO module in Aquator has been used to determine the systems' DO. This module runs the model over the critical drought period, under a range of demands, to identify the maximum yield of the system, i.e. the maximum demand that can be continually met throughout the critical drought period.

The full details of the Kielder WRZ DO assessment are contained in a separate supporting report, *PR19 Kielder WRZ Deployable Output Report*.

Further planned updates

NW is planning to increase the number of rainfall runoff models to cover all the catchment flow time series included within the Aquator model. The catchment flows will also be brought up to date and extended back to 1920.

Deployable Output modelling assumptions

A review of all of the treatment works in the Kielder WRZ, took place to establish their minimum treatment capacities and their maximum DO capacities in 2020 and 2025 taking into account any AMP6 and AMP7 schemes that would alter the treatment works DO.

The DO values for 2020 (as seen in the table 3.1 below) were entered into Aquator as the maximum capacities of the treatment works.

Table 3.1 DO values

	Minimum TWs Output	Deployable Output on 1 April 2020 (Ml/d)
Whittle Dene	80	118
Gunnerton	6	11
Byrness/Rochester/Otterburn	0	0.45
Horsley	82	150
Fontburn	14	19
Warkworth	0	42.5
Tosson	2.04	4.56
Mosswood	90	152
Wear Valley	16	34
Honey Hill	18	45
Sunderland GWS	0	44
Lumley	10	42
Lartington	65	132
Broken Scar	60	180

Horsley WTW has a DO of 150 Ml/d, the abstraction licence for Ovingham RWPS is 136 Ml/d, and therefore for Horsley to reach its full DO water from the Great Southern reservoir is blended with River Tyne water. There is currently an ongoing AMP5 project to upgrade Horsley WTW and allow the site to treat 100% of River Tyne water regardless of the raw water quality. To allow Horsley to run at 150 Ml/d on 100% river water the abstraction licence for Ovingham was increased (in the model) to 150 Ml/d and the annual abstraction total increased to 54,900 Ml.

The River Tyne is a regulated river, the Ovingham abstraction licence specifies a minimum maintained flow (MMF) of 227 Ml/d downstream of the abstraction point. This condition is monitored at the Bywell gauging station situated upstream of Ovingham on the River Tyne, and a surrogate MMF of 364 Ml/d (227 [Ovingham MMF] + 136 [Ovingham Abstraction licence]) is applied to Bywell. To allow Horsley to run at 150 Ml/d on 100% River Tyne water the MMF at Bywell was increased to 378 Ml/d (227 [Ovingham MMF] + 150 [increased Ovingham Abstraction licence]) in the Aquator model to ensure the MMF downstream of Ovingham is adhered to.

Alterations to the way that the River Pont and Waskerley Reservoir are operated were also included in the Aquator model to reflect the variations in flows proposed under the NEP programme, these amendments are detailed below.

River Pont: A time series flow for the Pont catchment has been derived using Catchmod and inputted in to the model. The compensation flow for the Pont is either the natural catchment flow or the agreed seasonal maximums as detailed in table 3.2 below.

Table 3.2 Pont Compensation Flow

	Ml/d
Spring	19.84
Summer	9.3
Autumn	17.48
Winter	28.31

Waskerley Reservoir: In line with the NEP proposal a compensation flow of 2 Ml/d was added to the reservoir. In the original Aquator model in the design drought year the annual licenced volume of water from Waskerley Airshaft pumps is fully utilised, hence the addition of the compensation flow significantly reduces the DO of the system. To maintain the DO at the level it was prior to the addition of the compensation flow the annual abstraction licenced volume of Waskerley Airshaft pumps was increased from 3,200 Ml to 4,000 Ml in the model.

Honey Hill: At times when the Honey Hill group of reservoirs are in the drought zone the maximum demand that could be met in the area is 48 Ml/d (30 Ml/d from Honey Hill and 18 Ml/d transfer from Mosswood), to maximise the use of the available resource in the area, the restrictions on the maximum permitted flow from Honey Hill WTW was increased to 37 Ml/d and Aquator was allowed to use the water from either the Honey Hill Reservoirs or Derwent Reservoir depending which one is in the better resource state.

Results

The English & Welsh Method DO module was ran on the Kielder WRZ Aquator model set up as detailed above to determine the systems DO, with no customer restrictions applied along with 100 Ml/d of raw water demand for the Industrial water system.
The DO of the Kielder WRZ was calculated to be 836 Ml/d, the failure point under the DO model run is Derwent annual licence running out in 1953. This is not the design drought year and even though Derwent is in a healthy position as the demand is so high the licenced volume of water available from Derwent is used up before the end of the year.

3.1.2 Kielder Resource Zone Sensitivity Testing

To test the resilience of the Kielder WRZ against droughts not represented within the Aquator model, the Scottish Method DO module in Aquator was utilised. This module, unlike the English and Welsh Method, permits multiple failures to occur during the analysis period. This allows a return period to be calculated based on the number of failures and total length of the inflow data used in the model.
Once the model has been ran multiple times, each time with an incrementally increased demand, two column series are produced comprising of an increasing number of failure years paired with increasing overall demand. The return period of each of the demands can then be calculated assuming a General Extreme Value (GEV) distribution as set out in *Low Flow Studies Report, Institute of Hydrology, January 1980, Report Number 1.*

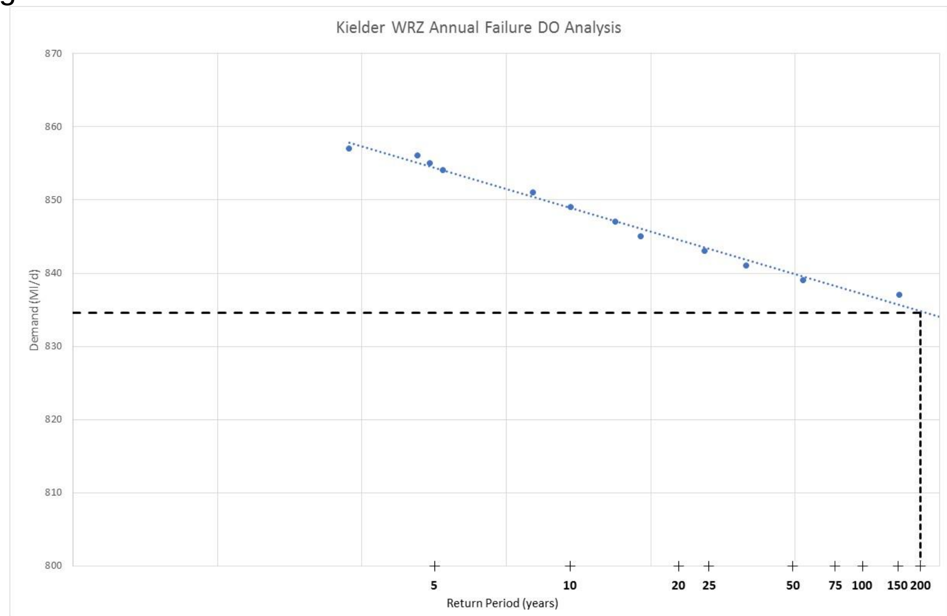
The results of this analysis for the Kielder WRZ are shown in the table 3.3 below.

Table 3.3 Kielder WRZ Return Period

Demand, Ml/d	Number of Failure Years	Return Period, Years
837	1	154
839	2	55
841	3	34
843	4	24
845	6	15
847	7	13
849	9	10
851	11	8
854	17	5
855	18	5
856	19	5
857	25	4

Interpolation of the GEV plot, figure 3.1, shown below, enables the failure demand at any intermediate return period to be estimated. Specifically the DO that could be achieved during a drought with at least an approximate 0.5% chance of annual occurrence (i.e. approximately a 1 in 200 year drought event) is 835Ml/d with no restriction on customer use. Therefore the Kielder WRZ is sufficiently resilient to withstand a 1:200 year drought event without any changes to NWs stated levels of service.

Figure 3.1 GEV Plot



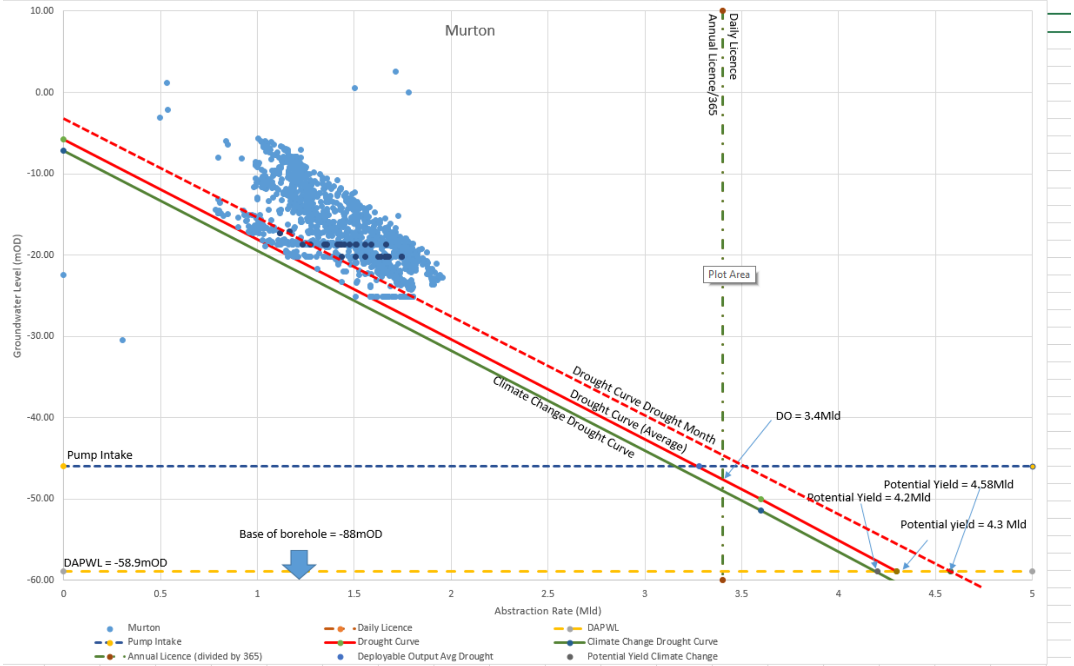
3.1.3 Groundwater Deployable Output (DO) Assessment

NW calculated the DO for the Berwick and Fowberry WRZ and Sunderland boreholes by compiling a graph of groundwater level (mAOD) against abstraction rate (m^3/hour). This produces a yield depression curve for the individual borehole which is normally either a straight or curved line plot. However, occasionally this produces a scatter plot due to poor quality data. In these cases, the time period for the data was restricted to the last 3 years as NW has independent, quality checked groundwater level monitoring data which produce meaningful yield depression curves.

A drought “curve” was plotted by drawing a line using the lowest data in the cloud of data from plotting groundwater level against abstraction rate. In effect, whilst been given the name “drought curve”, this is commonly a straight line that represents the worst-case for a calculated deployable output, usually, but not always, during a drought month. Where suitable data exist, a drought “curve” was plotted using only data for the drought month. This is the month considered to be representative of drought conditions. Either April 2017 or April 2016 was chosen as this coincides with the period of lowest recharge to the aquifer for which quality checked data exist. Normally, this would be expected to occur at the base of the data cloud created by plotting groundwater level against abstraction rate. However, frequently the lowest data lie below the drought month data. As a precautionary measure to take worst-case conditions into account, the line created using the lowest data was used.

Superimposed on these yield depression plots, annual average and daily abstraction licence levels (as m^3/hour) were plotted. Where the daily/annual licence crosses the yield depression plot produces the DO value for the borehole. In the majority of cases, the calculated DO are constrained by their daily/annual licence. Thus the average drought curve and the drought month drought curve DOs are the same. In the case of borehole sites 16 and 17, the DOs are constrained by the Deepest Advisable Pumping Water Level (DAPWL) or by the depth of the pump intake. The DAPWL is based on identifying the key depth constraint for the pumped borehole, for example the presence of adits, the depth at which water quality becomes unacceptable, or a percentage of the saturated thickness of the aquifer. If the borehole is deep enough and the pump intake could be lowered deeper into the borehole, the pump depth is not used to constrain the DO (See Fig 3.2 for Borehole 1 in the Berwick and Fowberry WRZ).

Figure 3.2 Example of yield depression plot for Borehole 1, Berwick and Fowberry WRZ



Where the DAPWL constrains the DO, it is possible that two DOs may be calculated, one for the average drought curve and one for the climate change drought curve. However, in the case of borehole sites 16 (see Figure 3.3 below) and 17 only one value is given in the table below as the Average and Climate Change drought curves produce the same DO value to within 1 decimal place.

Figure 3.3 Example of yield depression plot for Borehole 16, Sunderland

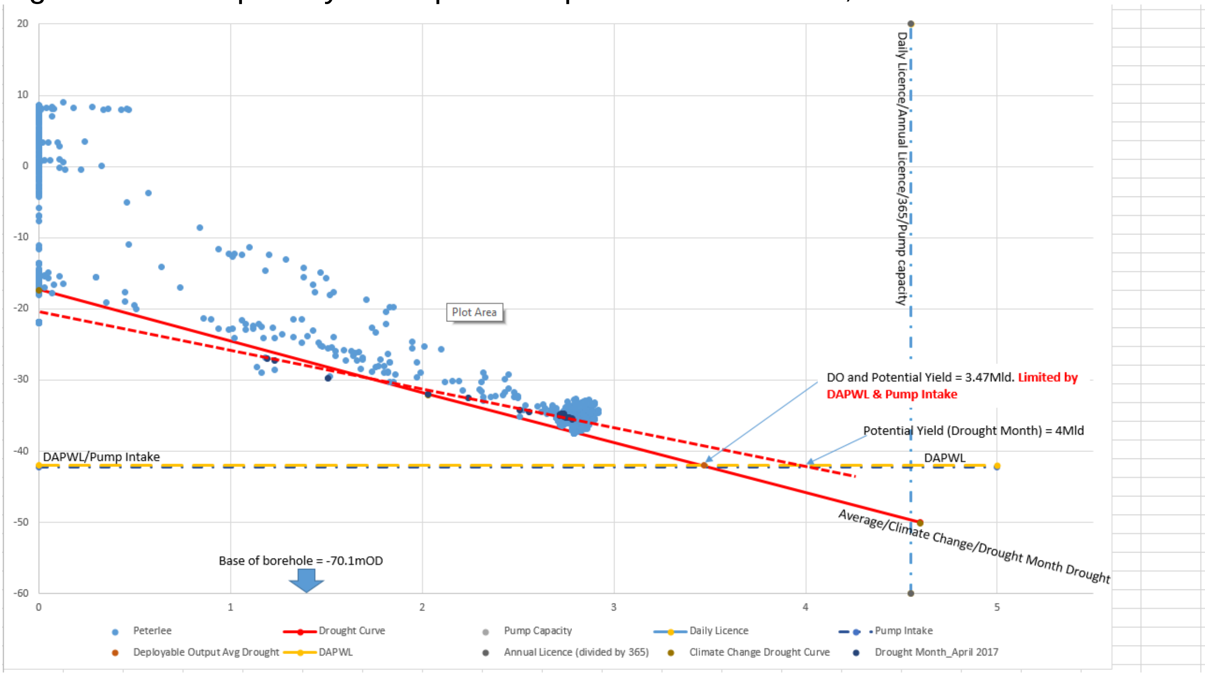


Table 3.4 below shows the calculated DO's for the Sunderland GWS using the method described above.

Table 3.4 Sunderland GWS DO

Borehole Sites	DO_2017 (Ml/d) Drought	DO_2017 (Ml/d) Climate Change	2017 Potential Yield (Ml/d) based on intersection or average drought curve with DAPWL
Borehole 10	5.13	5.13	6.55
Borehole 11	4.01	4.01	11.3
Borehole 12	4.04	4.04	7.6
Borehole 13	4.58	4.58	14.0
Borehole 14	8.31	8.31	15.7
Borehole 15	10.24	10.24	22
Borehole 16	3.47	3.47	3.47
Borehole 17	3.8	3.8	3.8
Borehole 18	9.1	9.1	9.1

Due to network restrictions downstream of the boreholes identified in the table above the maximum combined DO of the Sunderland GWS is 44 Ml/d. This DO is included in the 836 Ml/d DO calculated for the Kielder WRZ.

3.1.4 Berwick and Fowberry Water Resource Zone DO Assessment

Based on the method described above table 3.5 below shows the calculated DOs for the Berwick and Fowberry groundwater sources.

Table 3.5 Berwick and Fowberry DO

Borehole Sites	DO_2017 (Ml/d) Drought	DO_2017 (Ml/d) Climate Change	2017 Potential Yield (Ml/d) based on intersection or average drought curve with DAPWL
Borehole 7	3.4	3.4	4.6
Borehole 6	6.8	6.8	8.82
Borehole 5(2)	2.3	2.3	3.1
Borehole 5(1)	1.54	1.54	1.5
Borehole 4	2.77	2.77	5.4
Borehole 3	2.9	2.9	4.6
Borehole 2	3.18	3.18	6.4
Borehole 1	3.18	3.18	5.1

The maximum treatment capacity of Murton WTW is 8.4 Ml/d, this along with the revised dry year yield availability of Fowberry boreholes of 3.2 Ml/d gives a total DO for the Berwick and Fowberry WRZ of 11.6 Ml/d.

3.2 Industrial Water Resource Zone Deployable Output

Based on the definition of deployable output, the DO for the Industrial water system is 200 Ml/d. This is a reduction of 268.11 Ml/d from the previous WRMP DO of 438.11 Ml/d due to a reduction in the Low Worsall and Blackwell abstraction licences. The current DO of 200 Ml/d is well in excess of the current demand on the Industrial system of 100 Ml/d.

3.3 Reductions in Deployable Output

In the Kielder Zone the DO has reduced from 969.38 Ml/d to 836 Ml/d. This reduction is purely due to the methodology and change in resource modelling software. All treatment works are still capable of the DOs stated in the PR14 WRMP.

The reductions in DO for the Berwick and Fowberry WRZ is due to using the dry year yield assessments, as opposed to the peak daily figure used in the PR14 plan.

See section 4.7 below which covers assumptions regarding sustainability reductions.

3.4 Abstraction Reform

3.4.1 Allowances for Abstraction Form

NW has not planned for any changes to DO as a result of abstraction reform. This is because the Agency expects that at the time of reform, abstraction licences will be sustainable, or a plan will be in place to make them sustainable.

On transition, new permits will be issued based on current licence quantities and conditions. As no new licence controls will be imposed, this will not impact deployable output.

3.4.2 Emergency Abstraction Licenses

The WRPG states that licenced volume required for emergency purposes will only be available for those purposes and asks water companies to clearly state which sources are used for emergency purposes in their WRMPs and what the emergency purpose are. Table 3.6 below shows the emergency use abstraction licences.

Table 3.6 Emergency Abstraction Licences

Abstraction Licence Number	Emergency Use Conditions
1/23/01/002	To be used when due to failure of plant or equipment or pollution water cannot be supplied to or treated at Whittle Dene or Horsley Treatment Works.
1/25/02/103 & 1/25/02/109	To be used when due to plant or equipment failure, adverse river conditions or other circumstances it is not possible to abstract from NW's licenced sources the quantities required for supply.

3.5 Water Industry National Environment Programme

3.5.1 Background

The Water Industry National Environment Programme (WINEP) is a list of environmental requirements produced by the Agency and Natural England that water companies should include in their business plans submitted to Ofwat. It was previously called the National Environment Programme.

The WINEP is an integrated list of requirements for water resources, water quality and fisheries, biodiversity and geomorphology. It consists of investigations, options appraisals and actions to protect (prevent deterioration) and improve the water environment. Actions to protect or improve the environment include both licence changes, also known as sustainability changes, and non-licence change actions, such as river restoration.

WINEP actions generally fall into one of the following categories:

- Investigation;
- Options Appraisal; and
- Implementation

Investigations are required where the Agency suspects that an abstraction could be having an adverse effect on the environment but where the level of certainty is low. Consequently, investigations are required to raise the level of certainty so that conclusions can be drawn over the sustainability of the abstraction. Where an investigation concludes an abstraction is sustainable, the licence is re-affirmed. Where an investigation concludes an abstraction is un-sustainable, then a sustainability reduction (i.e. a reduction in the annual and or daily licenced quantities) is quantified and then implemented.

Options appraisals are required where a sustainability reduction causes a supply deficit. The appraisal considers a series of options which will:

- reduce demand to eliminate the supply deficit;
- increase supplies to eliminate the supply deficit; and
- mitigate any impact on the environment to a level whereby the sustainability reduction is no longer required.

The preferred option may comprise of either one measure or a series of supply, demand and mitigation measures.

The WINEP does not just consider the direct effect of abstraction. It also considers among other aspects, catchment measures to improve the quality of water at abstraction intakes, Invasive Non-Native Species (INNS) risk, fish passage and discharges to the environment.

The sections below describe:

- NW's progress on delivering the PR14 AMP6 National Environment Programme; and
- the PR19 AMP7 Water Industry National Environment Programme.

3.5.2 PR14 AMP 6 NEP

Investigations

Northumbrian Water abstract groundwater from the Fell Sandstone aquifer in order to provide drinking water to Berwick Upon Tweed, and the surrounding area. The Agency believe the licenced NW abstractions from the Fell Sandstone may not be sustainable, when assessed against Water Framework Directive (WFD) targets for the Fell Sandstone water body. Consequently, NW's Fell Sandstone abstraction licences were included in the Company's AMP6 National Environment Programme (NEP) for investigation. In addition, the Agency and Natural England (NE) have expressed concern that NW abstractions from its two groundwater stations near Wooler may be reducing baseflow to the River Till.

The purpose of the investigation was to evaluate the sustainability of the licenced abstraction volume from each individual abstraction, and collectively (the in-combination effect) from all of NW's abstractions from the Fell Sandstone aquifer, and to evaluate any impact from the Fowberry groundwater abstractions on the River Till. This will be achieved using the following methods:

- Identify, where possible, the size and shape of the cone of depression for each abstraction (the catchment area for each individual borehole);
- Identify, where possible, the aquifer unit(s) from which groundwater is abstracted by NW for each individual borehole;
- Drill new observation boreholes within the Fell Sandstone aquifer to
- Compile yield-depression curves and compare deployable output (DO) to potential yield (PY) for each abstraction borehole;
- Collate and review data on the groundwater level in each abstraction borehole and produce a hydrograph of groundwater level against time. If the groundwater level shows an overall year-on-year decrease in groundwater level it may be considered to be unsustainable;
- In addition, an independent MSc study has been undertaken to determine if NW's abstractions are sustainable by comparing recharge to individual aquifer units with abstractions. Where abstraction volumes exceed recharge, the groundwater abstractions may be considered to be unsustainable.

NW's groundwater level data has been extensively reviewed and revised groundwater level hydrographs have been produced for these revised data. Hydrographs have also been produced for ten new observation boreholes drilled by NW in the Berwick and Fowberry areas where significant gaps in data existed and for the available Agency data for its observation boreholes. Spring discharges, principally in the Fowberry area, and surface water levels and flows principally in the Berwick area, have been monitored. Groundwater level trends have been produced for all available boreholes so that boreholes showing similar physical trends may be grouped together showing potential hydraulic connectivity to specific aquifer units by individual boreholes. Geological maps and cross-sections have been modified or produced for the Berwick and Fowberry areas which provide a different interpretation of the geological sequence from earlier studies, and support the determination of potential hydraulic connectivity to specific aquifer units from individual NW and Agency boreholes. Geochemical data indicate that relatively young/immature groundwater is Na/K-Chloride dominated. Relatively mature groundwater shows a trend from Ca- to Ca/Na/K- to Na/K-carbonate dominated groundwater.

Observations on groundwater levels in the Fowberry area adjacent to the River Till indicate there is no impact on baseflow of groundwater into the River Till associated with the groundwater abstractions by NW in the area.

An MSc undertaken at Imperial College London performed hydrological modelling in order to calculate the recharge required to support the current NW abstractions in the Berwick area. This concluded that the recharge is sufficient to meet current NW abstractions for all but the Peel Knowe aquifer.

The yield-depression curves for all the Berwick and Fowberry boreholes, with the exception of Berwick5, have a Deployable Output (DO) level that is less than the Potential Yield (PY). Based on Younger (2012) this is indicative of sustainable abstraction. Berwick5 has a DO that is equal to or < PY, and is thus considered to be borderline non-sustainable. In an earlier DO assessment by ENTEC (1997), Berwick5 had a DO < PY.

In terms of sustainability of groundwater abstractions in the Berwick and Fowberry area, taking all the current interpretations of “sustainable groundwater management” and the various methodologies used in the NEP study to evaluate the sustainability of an abstraction, the groundwater abstractions in the Berwick and Fowberry areas, with the exception of the Berwick5 abstraction, are sustainable.

Due to existing operational constraints, all the recent work on sustainability has been undertaken at current operational (recent actual) abstraction rates, and not fully licenced abstraction rates. Further work will be needed to determine if abstractions at fully licenced rates are sustainable following completion of the planned groundwater treatment works at Berwick7 and Wooler in autumn 2019. This further work will entail undertaking pumping tests on all boreholes at fully licenced abstraction rates, and an evaluation of the effect of these pumping tests on the conclusions of the sustainability report.

An Options Appraisal Report has been produced that evaluates all the possible options available to NW to make their Berwick Groundwater Abstractions sustainable. These options include: Do Nothing; Demand side measures; Changes to the existing borehole infrastructure; Warkworth Pipeline; Reallocation of Abstraction; Groundwater Augmentation scheme; Utilise groundwater abstractions by Coal Authority; and, Abstraction from the River Tweed. These options will be appraised as follows;

- Demand side management options; Increased level of metering or improvements in leakage controls
- Supply options; Identifying and developing new groundwater abstraction sources outside the Berwick5 area
- Mitigation options;
    - Identify alternative sources of drinking water including;
        - the abstraction of groundwater from the Coal Measures in the Berwick area
        - build a mains water pipeline from the Warkworth Water Treatment Works to Berwick
        - abstract surface water from the River Tweed
    - Mitigate the effects of groundwater abstraction on the Fell Sandstone
        - develop a Groundwater Augmentation Scheme whereby surface water is used to artificially recharge the Fell Sandstone aquifer to compensate for the groundwater abstracted in the Berwick5 area.

Each of these options has been subject to a high level, qualitative Stage 1 appraisal covering technical and financial feasibility issues. This removed the Do Nothing, Warkworth Pipeline, Groundwater Augmentation Scheme and Abstraction from the River Tweed options. In terms of demand side measures, only leakage reduction from the groundwater distribution network was considered to be feasible. In terms of the reallocation of groundwater abstractions, only increasing abstraction from the Berwick3 and Berwick4 boreholes was considered feasible.

Those considered feasible are appraised further in a Stage 2 appraisal, which involves an environmental appraisal based on available internal and consultants reports using expert judgement, realisation of predicted benefits, issues concerning landowner agreements, scheme operational failures, robustness of costs and/or benefits and the nature and possible outcome of legal challenges to the scheme. The Stage 2 options appraisal is currently being completed. These results of the Options Appraisal will be implemented in AMP7.

Compensation Releases

In the Kielder WRZ work for Phase 2 of the National Environment Programme has concentrated on Heavily Modified Water Bodies (HMWB) issues. At many of NW's impounding reservoirs we undertake compensation flows which are made to ensure water enters the river course below where it has been impounded.

Generally these flows have been at a constant rate and studies have suggested that this is not the best practice as naturally there should be a seasonal variation in the volumes released. The reservoirs investigated in the Kielder Zone were Burnhope, Grassholme, Hury, Derwent and Waskerley.

Fish Passage

Two fish passes are required for completion in AMP6. Design has been agreed with the Agency with one programmed for installation in 2018 and the other in 2019.

Eel Regulations

Eel screens are required to be in place before the end of AMP6 at six river abstraction points. At the time of writing one has been installed and design has been agreed at three more. All are scheduled to be completed by the due date.

Eel passage is required on two weirs, again the work has been planned for completion in AMP6.

3.5.3 WINEP AMP7

The Environment Agency's guidance entitled "Sustainable Abstraction" (June 2017), states that WRMPs should include the requirements set out in the Water Industry National Environment Programme (WINEP), which sets out measures needed to protect and improve the environment. By April 2018, there will be have been three iterations of the WINEP as follows:

- WINEP1: Issued in March 2017;
- WINEP2: Issued on 29 September 2017; and
- WINEP3: To be issued on 30 March 2018.

The Agency has applied a traffic light system to WINEP2 to indicate certainty of measures. It expects all green and amber sustainability changes, as defined in WINEP1, to be allowed for in draft WRMPs as adjustments to final plan deployable output.

WINEP 2 was issued after most water companies supply and demand forecasts had been completed. Therefore, where it is not possible to allow for new WINEP2 green and amber schemes to be included in the draft WRMP, the Agency has asked water companies to consider these schemes and their associated sustainability reductions as a supply demand balance scenario rather than as a reduction in deployable output in the final plan supply demand balance calculation.

The second iteration of the PR19 WINEP for AMP7, issued by the Agency in September 2017, contains the following schemes:

- Seven Sustainable Change Investigations.
- One Eel Screen installation.
- Eight Investigations and Options Appraisals.
- Four Fish Passage Investigations.
- Five No deterioration schemes for catchment management work to protect water quality in some of the Company's surface water catchments

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Sustainability Reductions

Kielder WRZ – six of the seven Sustainability Change investigations involve alterations to compensation flows building on the work completed in the AMP6 NEP. It is not yet clear what values will be given to these changes and therefore they have not been included in NW's supply demand balance calculations. Once confirmed, NW will incorporate them into the baseline DO assessments.

Berwick and Fowberry WRZ – the other Sustainability Investigation involves groundwater abstractions in Berwick (see AMP6 Investigations above). In previous discussions with the Agency a value of 9.5 Ml/d has been seen as the likely abstraction limit from the Berwick area boreholes and this figure has been used in NW's supply/demand calculations.

Invasive Non-Native Species

In addition to the above, NW will undertake investigations and options appraisals, covering all the Company's raw water transfer systems, and other pathways of potential INNS transfer are required which will involve undertaking risk assessments of the risk of spreading INNS, and then an options appraisal of the available measures to reduce any identified risks.

Protection of Drinking Water Protected Areas

Two surface drinking water protected areas (DrWPA), the Warkworth and Whittle Dene abstractions, are deemed to be 'at risk' for metaldehyde, a widely used molluscicide for the control of slugs. This is as a result of agricultural activities in the catchments and in order to protect the DrWPA from further deterioration the areas of land where management practices and other activities may impact on the abstraction have been designated as Safeguard Zones (SGZ). SGZ action plans detail measures designed to protect the water quality in the DrWPAs and national and local initiatives are in place to raise awareness and to work with pesticide users to try and reduce the impacts of pesticide use on the DrWPAs. Some of these initiatives are targeted specifically at controlling pesticide use, others are more generic and aim to encourage good agricultural practise. Details of all actions are shown in the action plans.

Links to SGZ action plans:

- Whittle Dene SGZ - https://Agency.sharefile.com/app/#/share/view/s0c1e95c74cd4131a
- Warkworth SGZ - https://Agency.sharefile.com/d-s8b5008dd8ea4e188

The Berwick Fell Sandstone Aquifer has recently been designated as a groundwater SGZ, as the aquifer is deemed to be 'at risk' for nitrates. NW are undertaking research, in collaboration with the Agency and Newcastle University, to understand the impact of the application of nitrate fertiliser on groundwater quality in the Berwick area. Current nitrate levels are well below the drinking water standard, but timely action through engagement with local farmers is aimed at preventing, or even reversing, any derogation of water quality in the area due to the application of nitrate fertiliser. A formal action plan is currently being drawn up.

In order to help protect NW's raw water sources, NW has employed two catchment advisors to work across NW's operating area in the catchments from which we abstract water, with particular focus on the SGZs. Their purpose is to engage with all stakeholders such as farmers, landowners and agronomists with the aim of reducing nutrient, sediment and pesticide runoff from land to the rivers. It is expected that this work will contribute to an improvement in river water quality and therefore reduce the risk of outage due to pollution from land practices and help protect supplies against long-term pollution risks e.g. rising nitrate in groundwater.

In AMP6 much of NW's catchment work has been focussed through the 'Pesti-wise' programme. Pesti-wise is the name of NWG's catchment investment programme for 2015-2020 which launched in April 2015 in five small catchments, two in NW - Tyelaw Burn on the River Coquet and the Whittle Dene Reservoir complex. Pesti-wise aims to work with farmers and their agronomists to deliver practical guidance and on-farm solutions that helps minimise pesticide run-off and supports sustainable agriculture.

Key objectives are to:

i) Prove the concept that voluntary action can reduce raw water concentrations of key pesticides in catchment waterbodies; and
ii) Determine the level of engagement, adoption of best practice, and scale of investment, required to achieve the observed pesticide reductions.

The desired outcome is to reduce average and peak pesticide concentrations at the sub-catchment outlets, compared to a control catchment and the pre-intervention dataset.

Some form of engagement; a 1:1 visit, conversation at a meeting or a telephone call has been delivered to farmers covering 77% of the land area in the Pesti-wise catchments. Around 13% of the land holding that has not been engaged is not arable land or not even farmland leaving only 10% of potentially relevant land that has had zero engagement. Three grants have been given to farmers in the catchments to improve their slug pellet applicators. Attempts to engage will continue over the remainder of the AMP.

In addition to Pestiwise, NW also committed to invest in peat land restoration in partnership with the North Pennines Area of Outstanding Natural Beauty (AONB). The money was to provide match funding for a wider EU Life Bid, 'Pennine PeatLIFE, a £6 million peatland restoration project led by the North Pennines AONB Partnership in collaboration with Yorkshire Wildlife Trust and Forest of Bowland AONB. The project aims to restore 1,300 hectares of internationally important blanket bog habitat in northern England. Eroding peat bodies are massive sources of sediment and carbon and there is a clear link between eroding peatlands and increased sediment loading into rivers either as DOC or POC. Restoring these landscapes should help protect NW's water resources for the future.

Although a good level of engagement has been achieved in AMP6 through NW's Pestiwise approach there is still work to be done in terms of improvements to water quality. It has become clear that 'one size' does not fit all and we need to ensure that NW's approach for AMP7 recognises the differences across the catchments and looks at how we can work better with external partners to help deliver a wider range of benefits. For AMP7 we plan to implement a grant scheme that will replace Pestiwise. The aim is to consider a wider range of diffuse pollutants and measures and to develop a grant delivery system which will allow other stakeholders to bring in money that will fund other ecosystem service improvements.

In addition we plan to undertake work in the new Berwick groundwater SGZ to help address the rising nitrate trend to safeguard this important resource. This will involve working with farmers to help reduce nitrate losses from agriculture. We will also continue with NW's investment in peatland restoration to protect NW's upland water resources.

An allowance in NW's PR19 Business Plan has been made to fund all of the above work in AMP7.

3.6 Raw Water Losses

Similarly to previous WRMPs a default value for trunk main losses of 200l/Km/day/year of age of main, taken from “Managing Leakage”, has been used. Lengths of raw water mains and their average age have been taken from NW’s GIS for the Kielder, Berwick and Fowberry zones and also the Industrial system.

This analysis showed that in Kielder WRZ there are 292 Km of raw water mains with an average age of 73 years at the start of the planning period giving an estimated loss of 4.26 Ml/day in 2020/21 rising to 6.54 Ml/day in 2059/60.

Berwick has 35 Km of raw water mains with an average age of 43 years giving losses of 0.30 Ml/day rising to 0.57 Ml/day in 2059/60.

The Industrial system has 192 Km of mains with an average age of 43 years giving losses of 1.65 Ml/day rising to 3.15Ml/day in 2044/45.

There is only limited operational use on the raw water system within the Kielder water resource zone. On an annual basis the pipeline from Catcleugh Reservoir is cleaned and releases are made at Frosterley and Eggleston to maintain water quality in the Tyne-Tees tunnel. These operations were estimated to use the equivalent of 0.56 Ml/day during 2016/17.

An analysis of water onto and out of some treatment works sites has shown that on average the losses across works is around 7%. This figure has been applied to the water abstracted value to give overall treatment works losses within the Kielder WRZ.

In the Berwick & Fowberry area the treatment process involves re-circulation of the water and therefore there is perceived to be no losses across the treatment works.

Raw water losses in the form of leakage, operational use and treatment works losses, have been determined to allow the calculation of the amount of raw water abstracted in the planning tables. They have not been included in the DO calculation as the licenced abstraction volumes are in excess of the treatment works capacities and therefore there is an excess of raw water available to support these losses without impacting on the DO calculation.

3.7 Outage

3.7.1 Approach

Since the last Water Resource Management Plan, NW has improved its system of recording daily outages at each treatment works. This has allowed the outage to be developed using the principles set out within the ‘Outage Allowance for Water Resource Planning (UKWIR 1995)’ document using data covering the previous 5 years.

The outage figure would only be varied over the planning horizon if the company had some very specific changes that it was highly confident would result in a change to the calculated outage figure. NW do not has nothing of this nature occurring over the life of the Plan that would cause a varied outage figure to be used.

Outage is defined in the UKWIR report Outage Allowances for Water Resource Planning (1995) as:

"A temporary loss of deployable output"

Outage events can be divided into planned outage and unplanned outage. The UKWIR report defines planned outage as:

"A foreseen and pre-planned outage resulting from a requirement to maintain sourceworks asset serviceability"

Unplanned outage is defined as:

"An outage caused by an unforeseen or unavoidable legitimate outage event affecting any part of the sourceworks and which occurs with sufficient regularity that the probability of occurrence and severity of effect may be predicted from previous events or perceived risk"

The report also provides a definitive list of what is to be considered as legitimate unplanned outage. The categories include:

1. Pollution of Source
2. Turbidity
3. Nitrate
4. Algae
5. Power Failure
6. System Failure

Under the assessment carried out for the NW WRZs both planned and unplanned outage events were considered.

The methodology used by NW to determined outage allowance comprises of the following:

3.7.2 Data Gathering and Interpretation

Daily Distribution Input (DI) data along with the Production Plan (PP) is used as the basis to calculate outage magnitude and duration.

Planned Outage: the PP is analysed and if a treatment works is not due to be running at its treatment capacity further investigation is undertaken. If the treatment works is running below its treatment capacity for optimisation purposes (for example minimising an expensive treatment works) then it is not a planned outage. If the PP for a treatment works, that would normally be optimised, is below its treatment capacity then this categorised as a planned outage.

Note if the PP for a treatment works, that would normally be optimised, is below its treatment capacity for a forecasted resource restriction or predicted low demand then this is not a planned outage.

Unplanned Outage: daily DI data provided by the Network Performance Team is used to compare the actual daily works output, to the planned PP output for each treatment works. If the DI data is below the PP value for the day then further investigation is carried out.
The daily Water Production reports and the WAFU report are used to determine the reason that a treatment works DI is below the PP value. If the treatment works DI is below PP due to resource restriction, or because another cheaper WTW is out performing its PP flows then this is not classified as an outage. If however the treatment works DI is below its PP flows due to a failure or issue on site then the PP value minus the treatment works DI is recorded as an outage and assigned to a category (either pollution, turbidity, nitrate, algae, power or system failure).

Outage events excluded: There was a planned outage at Warkworth WTW where the site was totally offline for 2 months to allow the strategic mains in the area to be cleaned. This outage event has been removed from the calculation as a mains cleaning programme of this magnitude will not take place again in the planning horizon.

3.7.3 Development of Probability Distributions and Monte Carlo Analysis

For each treatment works, the mean and standard deviation of the outages is calculated. These are then used to derive 5,000 random outages for each site based on a normal distribution. For each iteration the random outages at the treatment works are summed together for each water resource zone. The unplanned outage allowance is then calculated as the 90th percentile of the 5,000 WRZ unplanned outages, and the planned outage allowance is taken to be the 50th percentile of the 5,000 WRZ planned outages.

The tables below summarise the daily averages of the actual planned and unplanned outage events experienced from 2012 to 2016.

Table3.7 Planned Outage

2012 -2016	Planned Outage, Ml/d
BERWICK	0.00
FOWBERRY	0.00042
WHITTLE DENE	1.41
GUNNERTON	0.41
HORSLEY	0.00
FONTBURN	0.41
WARKWORTH	4.51
HONEY HILL	3.20
WEAR VALLEY	0.38
MOSSWOOD	6.7
SUNDERLAND GWS	1.48
LUMLEY	0.0
LARTINGTON	6.3
BROKEN SCAR	0

In the Kielder WRZ, Warkworth and Honey Hill WTW were the main contributors to planned outage due to a yearlong programme of capital maintenance of filters at Warkworth and clarifier repair work at Honey Hill.

Table 3.8 Unplanned Outage

	Pollution	Turbidity	Nitrate	Algae	Power	System Failure	Other	Total, Mld
BERWICK	0.00	0.00	0.00	0.00	0.0032	0.00	0.00	0.0032
FOWBERRY	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.017
Total, Ml/d	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.021
WHITTLE DENE	0.00	0.00	0.00	0.00	0.00	0.04	0.28	0.323
GUNNERTON	0.00	0.01	0.00	0.00	0.00	0.27	0.00	0.284
HORSLEY	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.009
FONTBURN	0.00	0.00	0.00	0.00	0.00	0.10	0.04	0.139
WARKWORTH	0.00	0.00	0.00	0.00	0.00	3.18	0.00	3.177
TOSSON	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000
HONEY HILL	0.00	0.00	0.00	0.00	0.00	0.30	0.47	0.767
WEAR VALLEY	0.00	0.01	0.00	0.00	0.02	0.40	0.49	0.916
MOSSWOOD	0.00	0.00	0.00	0.00	0.00	0.54	0.16	0.704
SUNDERLAND GWS	0.00	0.00	0.00	0.00	0.00	0.37	0.00	0.370
LUMLEY	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.041
LARTINGTON	0.00	0.00	0.00	0.00	0.00	0.93	2.61	3.542
BROKEN SCAR	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.025
Total, Ml/d	0.00	0.02	0.00	0.00	0.02	6.15	4.11	10.30
Total, Ml/d	0.00	0.02	0.00	0.00	0.03	6.15	4.14	**10.339**

As can be seen the table 3.8 above the majority (99.7%) of the unplanned outages were a result of system failure or ‘other’ which includes outages due to filters / clarifiers requiring cleaning that wasn’t planned in.

The results of the Monte Carlo analysis are presented figure 3.4 and 3.5 below.

For the Kielder WRZ the 50^{th} percentile (the 50^{th} percentile was chosen as due to the fact the outages are planned NW did not feel they would alter greatly from the previous 5 year average over the planning horizon) of the planned outages is 31.3Ml/d, and the 90^{th} percentile of the unplanned outages is 26.3Ml/d, giving a total outage for the Kielder WRZ of 57.6Ml/d. An increase on the 2012 WRMP figure (of 38.99Ml/d), this is due to the increased planned outages due to large capital maintenance schemes experienced during the past five years.

Figure 3.4 Monte Carlo Planned Outage

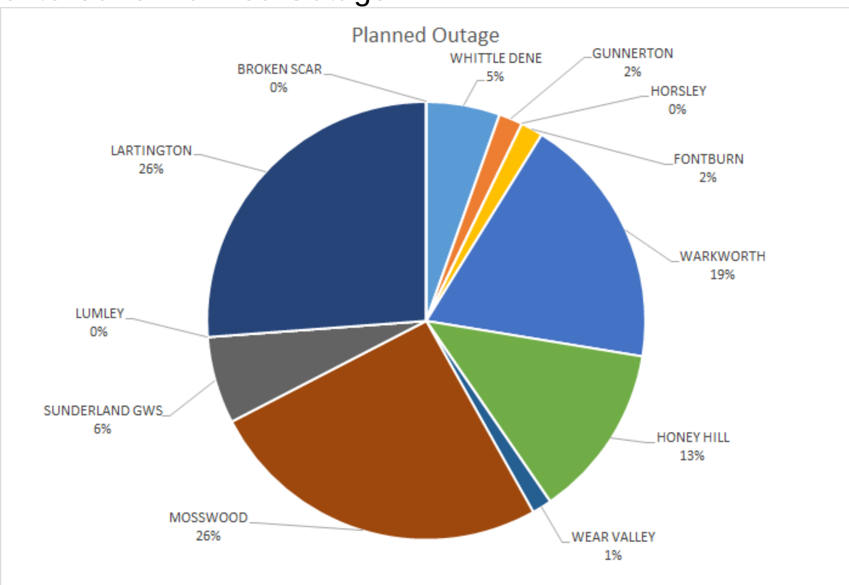
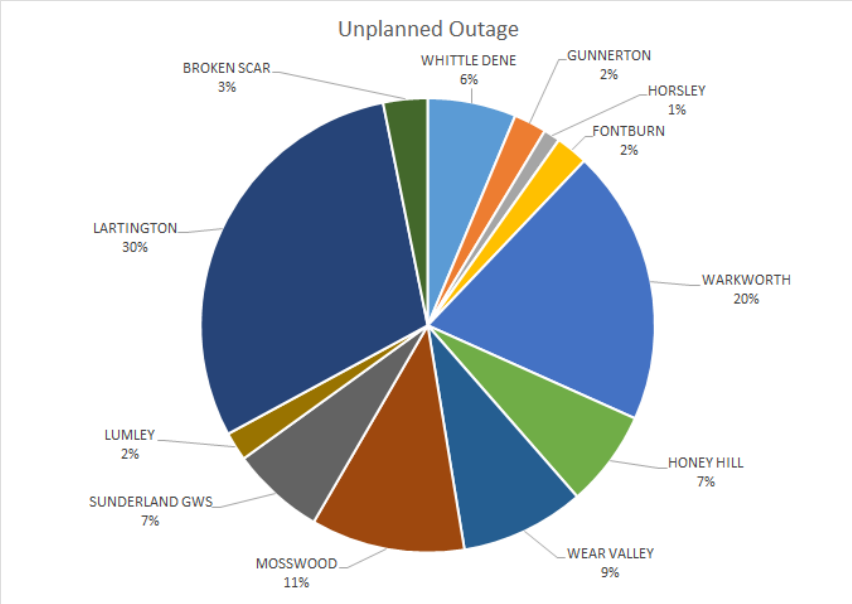


Figure 3.5 Monte Carlo Unplanned Outage



For the Berwick and Fowberry WRZ the results of the Monte Carlo analysis was an outage of 0.28Ml/d.

3.7.4 Opportunities to reduce outage

The WRPG (April 2017) states that, where appropriate, water companies should identify potential options for reducing outage allowance for inclusion in options appraisal to solve a supply demand deficit. NW's draft dry year annual average supply demand balance calculations indicate that both of the WRZs will have a surplus across the full planning horizon. Consequently, no investment will be driven by a resource deficit and therefore it is unnecessary for NW to conduct an options appraisal.

However, as part of routine investment and operations, some of the factors that result in outage will continue to be managed. For example, NW has an ongoing programme of asset maintenance to refurbish abstraction and treatment works infrastructure, such as pumping stations. This should reduce the occurrence of unplanned system failures but will likely require planned outage to allow for works to be carried out.

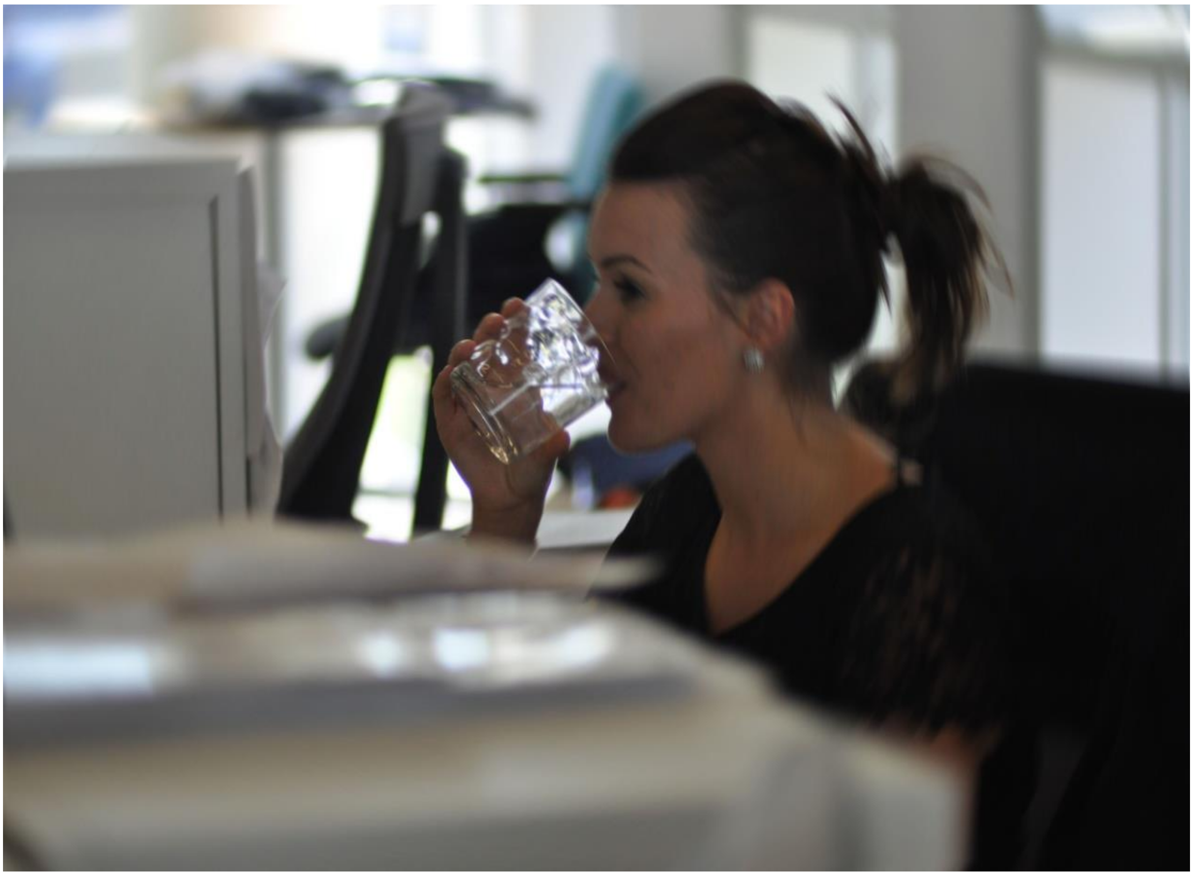
Pollution of NW's groundwater sources is minimised through both the design of NW's wells and boreholes and through an ongoing inspection programme. As a minimum, all of NW's groundwater sources have a full inspection every five years. This includes a CCTV inspection as well as geophysical logging to identify the condition and any emerging issues with the well or borehole. Once an emerging issue has been identified mitigation action is taken either in the form of refurbishment of the existing borehole (e.g. re-lining) or by constructing a replacement borehole.

NW employs catchment advisors to work in each of the catchments NW abstracts from. Their purpose is to engage with all stakeholders such as farmers, landowners and agronomists with the aim of reducing nutrient, sediment and pesticide runoff from land to the rivers. It is expected that this work will contribute to an improvement in river water quality and therefore reduce outage as a result of nitrate, turbidity and pesticides, as agricultural activity intensifies over the planning horizon. Further information on NW's catchment management work can be found on NW's website www.nwl.co.uk/catchmentmanagement.

3.8 Raw and Potable Water Transfers and Bulk Supplies

Currently there are only very small transfers of potable water between NW and United Utilities. The transfer to United Utilities from Wear Valley TW averages 0.65 Ml/day and would be maintained in all scenarios. The transfer of potable water from United Utilities at Reaygarth of 3 m^3/day is also seen as secure in all circumstances.

4.0 WATER DEMAND FORECAST



4.1 Introduction

The methodologies used to prepare the demand forecasts have followed published best practice as defined in WRMP19 Methods – Household Demand Forecasting (UKWIR, 2016), WRMP19 methods – Risk based planning (UKWIR, 2016), Methods of Estimating Population and Household Projections and Customer Behaviour and Water Use 12/CU/02/11 (UKWIR, 1995)(UKWIR/EA, 1997).

Forecasts have been prepared for the Northumbrian supply area. The forecast has then been apportioned into the water resource zones (WRZs), Kielder and Berwick. Normal year forecasts have been made against a 2016/17 normalised base year which has been amended from the published Annual Regulatory report figures. They incorporate the rebasing process for properties as well as normalising the 2016/17 per capita consumptions (PCC). This ensures a smooth projection from the base year into the forecast.

The normal year forecasts have been used as the basis for dry year and weighted average year forecasts.

4.2 Base Year

As outlined in section 4.10, 2016/17 is classed as a 'normal year' as it exhibited normal rainfall totals and temperatures through the year. Therefore, no weather related adjustments have been made to base year demands for the forecast. The PCC's have been normalised based upon the water balance being re-based.

In order to forecast from a normal year, the PCCs for both measured and unmeasured customers have been 'normalised' against trend.

Normalised PCCs Unmeasured

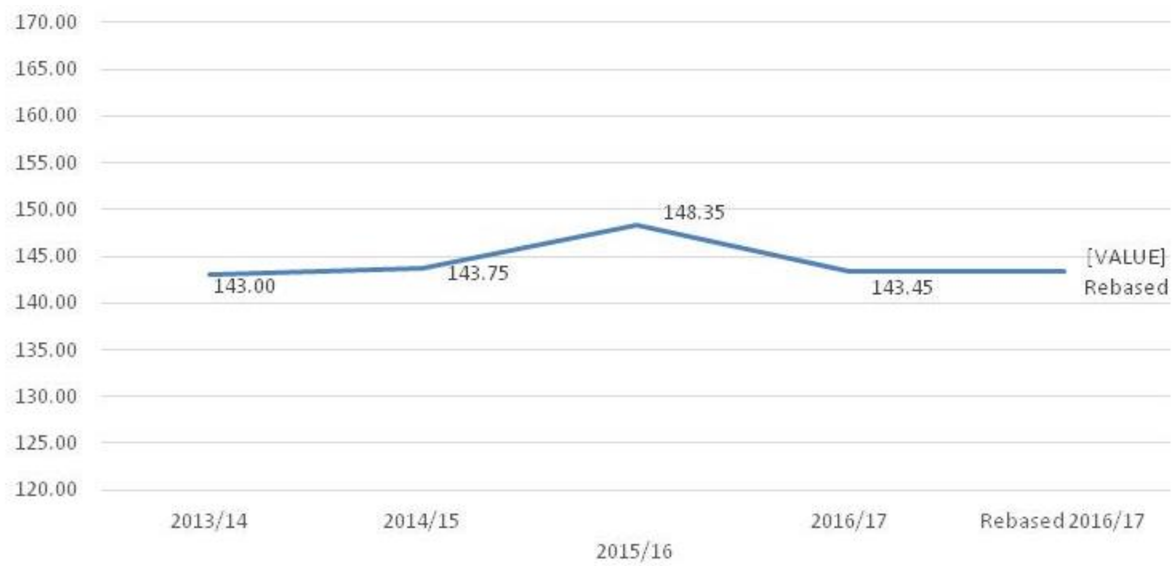
The unmeasured normalised PCC for 2016/17 is calculated from the re-basing of the water balance.

Kielder - Unmeasured PCC

2016/17: 143.45
2016/17: 143.40 (rebased)
PCC adjustment: -0.05

To ensure the trend for micro-components is consistent with the Water Resource Management Plan (WRMP), total PCC has been adjusted by +0.04 across the forecast.

Figure 4.1: Kielder Unmeasured Household l/h/d



Berwick - Unmeasured PCC

2016/17: 143.72
2016/17: 147.24 (Rebased)
PCC adjustment: +3.53

Figure 4.2: Berwick Unmeasured Household l/h/d

To ensure the trend for micro-components is consistent with the WRMP, total PCC has been adjusted by +3.53 across the forecast.

Normalise PCC's Measured

The measured PCC has been rebased by using the 2016/17 reported PCC and adjusting the volume by the water efficiency target for that year

Kielder - Measured PCC

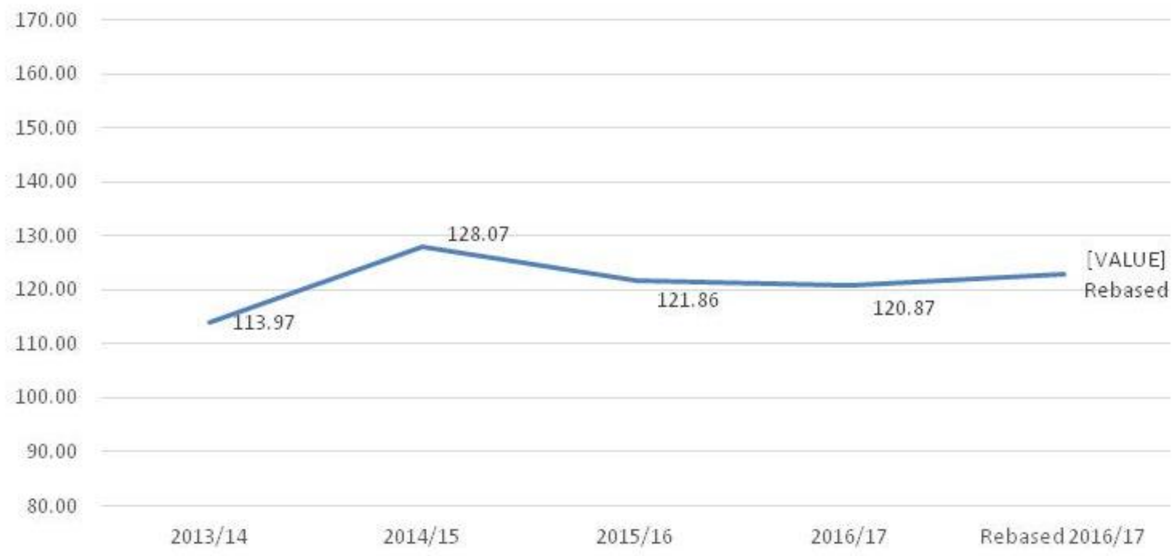
2016/17: 127.99
2016/17: 130.01 (Rebased)
PCC adjustment: +2.02

Figure 4.3: Kielder Measured Household l/h/d

Berwick - Measured PCC

2016/17: 120.87
2016/17: 123.02 (rebased)
PCC adjustment: +2.16

Figure 4.4: Berwick Measured Household l/h/d



To ensure the trend for micro-components is consistent with the WRMP, total PCC has been adjusted across the forecast by the values stated above.

In addition, at the end of each Asset Management Plan (AMP) period NW believes the best approach is to group all the metered households, metered by the base year, into a single group, which NW calls “Existing Metered”, for forecasting forward. This is because households which became metered through customers opting for a meter, will in time have new occupiers and no longer exhibit characteristics of a new optant household. Also from AMP to AMP NW's metering policy changes, which impacts upon the type of households metered, and over time the balance of low occupier/low consumption and high occupier/high consumption households varies between the unmeasured and metered categories.

4.2.1 Per Capita Consumption

The PCC is provided by NW's Cul-de-Sac monitor with 3135 properties split into three socio-economic groupings based on Rateable Value. This monitor has remained very stable with the same amount of close management that it has received over the last 15 years. NW operates the PCC calculation using Netbase and ensures it remains in accordance with the UKWIR best practice for small area monitors.

NW is proactive in NW's Assessed Fixed Charge Scheme (AFCS) which is offered to customers where necessary, in order to ensure less than 10% measured households. NW's overall figure for meter penetration is maintained at less than 5%. Most of the measured household consumption within the monitor is calculated by monthly meter reading. However, a small number of internally installed meters have proved difficult to read on a regular basis. Their consumption is estimated throughout the year based on the previous year's meter readings.

The reported PCC figure is not influenced by any form of Meter Under Registration (MUR) as the meters within the PCC area (20 No.) are very high specification Electromagnetic (EM) meters which are verified every 2 years. NW mechanisms for the management of the void properties within the monitored areas is based on regular surveys, the results of which are input to the billing system ICIS.

NW continues to check occupancy rates within the monitor in line with UKWIR best practice. A number of quality procedures are regularly completed to ensure accurate robust data is used in the calculation of this figure. These include the programme of "door knock" surveys for area occupancy rates and proactive leakage checks of all areas, based on close monitoring of nightlines and boundary valve operations.

NW has clear mechanisms for the management of the void properties within the monitor, based on regular surveys which are input to ICIS and then supplied monthly to an income generation project team that uses the Land Registry website to investigate and validate void properties.

Each PCC monitor area is monitored closely with NW's own District Meter Area (DMA) operability which maintains an average above 90%. Any areas that are not operable are not used for their period of inoperability.

Total customer night use (CNU), including plumbing losses, continues to be assessed on a monthly basis from area flows using Smart software from WRc. Like Smart, the 15-minute flow data are adjusted by one hour between April and October for the calculation of DI and rolling minimum nightline. This is required due to loggers remaining set at GMT throughout the year.

4.2.2 Water Delivered Measured Households

The average water consumption for measured households for 2016/17 has been rebased by using the normalised measured PCC's. This is then increased to allow for meter under-registration. An estimate of supply pipe leakage for internally metered households is added to this to provide the water delivered figure.

The volume of water delivered to measured households continues to increase, due to the effects of the metering.

4.2.3 Water Delivered Unmeasured Non-household

NW's estimate of consumption for unmeasured non-household consumption has been based on the research reported eight years ago, in which unmeasured customers were compared with metered properties of the same type (e.g. shops, warehouses) and also compared the rateable values of metered and unmetered properties. It has been assumed that an unmeasured customer consumes 50% of a similar metered property, based upon the relationship between rateable value and consumption and the average rateable value of unmeasured properties being 50% of that of equivalent measured properties.

There are currently only 8,266 unmeasured non household properties in NW. It should be noted that because of the very small number of properties involved, this group only accounts for 3.5% Northumbrian non household demand.

4.2.4 Supply Pipe Leakage

NW previously calculated the supply pipe leakage for the purposes of the overall leakage calculation as 35% of total losses within the distribution system. However the methodology has now been aligned to Essex & Suffolk Water's (ESW) procedure for quantifying supply pipe leakage to improve accuracy.

The same methodology for quantifying supply pipe leakage has been used since 2006 in ESW, when a project was undertaken to improve estimates. Regular review of current practices has taken place in this time although no methodology has improved the accuracy of quantification of supply pipe leakage. For this project, unmeasured leakage flows were collected from the SWU (Study of Water Use; ESW's unmeasured household monitor) and measured leaks were gathered from the customer billing database, which stores information collected on leakage allowance forms. Two databases (measured and unmeasured) were compiled, through which the average volume, duration and frequency of leaks could be calculated. It was recognised that the measured database had limitations because generally only larger leaks are recorded because they have been detected through meter readings. Similarly, the SWU leaks have not been left to run as long as undetected leaks on unmeasured households could run for and also it is based on southern data rather than local northern area data.

It was established early on that every leak would start with similar characteristics irrelevant of the property meter status. It was also suggested that every leak has a hypothetical flow rate, at which the leaks become 'noticeable'. The average leakage volume of the 'noticeable' stage could be taken from the respective databases. The importance of determining the average duration, frequency and flow rate of leaks before they reach the hypothetical 'noticeable' stage was recognised.

The SWU leakage records provided daily flow rates. Analysing these in detail allowed a 'natural rate of rise in leakage' curve to be constructed. From this, it was possible to assume that the average leak will run for a period at a flow rate of 0.0073 l/sec (regarded as so small that it cannot be noticed). Once noticeable, the duration, frequency and volume of leaks depend upon the meter status of the property. The frequency of occurrence of leaks was 0.014 for unmeasured properties and 0.004 for measured properties. The frequencies were calculated using population and leakage figures specific to each year.

Calculations revealed average daily leakage volumes of 27.12 litres per property per day for unmeasured properties and 17.37 litres per property per day for measured properties. Supply pipe losses are then allocated to the various categories of properties, on the assumption that losses from the typical externally metered household property will be lower than those of unmeasured or internally metered properties. This assumes that externally metered household customers will notice any unexpected increase in their consumption and will inform us sooner than the other categories of customer. Final Supply Pipe Leakage (SPL) values as shown in Table 4.1 below.

Table 4.1: Supply pipe leakage values

	NW (l/p/d)
Unmeasured Hsehld SPL	32.00
Measured Hsehld/Measured Non-Hsehld SPL (Ext)	17.00
Measured Hsehld SPL (Int)	32.00
Unmeasured Non-Hsehld SPL	32.00
Empty Property SPL	32.00

4.2.5 Meter Under-Registration

The allowance for household and non-household meter under-registration is consistent with the results found in the Review of Meter Under-Registration (WRc, 2009).
The results were as follows:

- Under-registration figures for household meters have been calculated based on the data supplied to WRc, as: Northern region: 3.79%
- Under-registration figures for non-household meters have been calculated based on the data supplied to WRc, as: Northern region: 3.83%

4.3 Void Properties

Base year property figures are taken from the Company billing database this includes the total number of void properties each year. The forecasted voids are a consistent percentage of the total properties.

Table 4.2: NW Forecast Voids

	NW Forecast Voids
Unmeasured Households	4.6%
Measured Households	4.3%
Unmeasured Non-Households	26%
Measured Non-Households	14%

4.3.1 Operational Use and Water Taken Unbilled

Operational use continues to be assessed using similar methods in both Northern and Southern Operating Areas. The original methodologies were supported by a consultancy report (Ewan Associates, 2002), these have been used and new data input where it has become available. In addition, individual components have been reviewed and clear methodologies have been developed for determining all aspects of operational use and water taken unbilled and included site measurements for certain parameters. Some improvements have been made generally in data reporting systems and also the standpipes we hire are now metered.

The reported figure for Operational Use includes volumes used for treatment works' use, service reservoir and tower cleaning, third party bursts, flushing, new mains and rehabilitation.

Operational use, water taken legally unbilled and water taken illegally unbilled include the following components show in tables 4.3 – 4.5.

Table 4.3: Distribution System Operational Use

1.1	Sample Taps (Continuous & Non-Continuous)
1.1.1	Continuous
1.1.2	Non-Continuous
1.2	Service Reservoirs & Tower Cleaning
1.3	Tanker Filling/Bowsers
1.4	Bleeds
1.5	Sewer Flushing & Jetting
1.6	Third Party Events
1.6.1	Bursts
1.6.2	*Tyne Only* - STM Charging + GTAS Mains Cleaning + TMC Contract 4
1.7	Flushing

1.7.1	Routine
1.7.2	Planned / Reactive / Water Quality
1.8	New Mains, Diversions, IM and S19
1.8.1	New Mains
1.8.2	Non-Strategic Mains Diversions
1.8.3	Infrastructure Maintenance

Table 4.4: Water Taken Legally, Unbilled

2.1	Supply Pipe Leakage Voids
2.2	Unbilled Supplies
2.2.1	Treatment Works + Offices
2.3	Standpipes
2.4	Water Donations
2.5	Council Usage
2.6	Metered Allowances
2.6.1	Vulnerable Customers
2.6.2	New Properties
2.7	Waste Water Notices
2.8	Fire Fighting
2.8.1	Fire Brigade
2.8.2	UGSPL On Fire Mains

Table 4.5: Water Taken Illegally, Unbilled

3.1	Occupied Voids
3.1.1	Measured
3.1.2	Unmeasured
3.2	Illegal Connections
3.3	Hydrant Vandalism
3.4	Illegal Hydrant Use
3.5	Transient Population Usage

4.3.2 Bulk Supplies

NW water accounting records make use of MIPS Enterprise, a bespoke NW internal system, channelling the data with the highest level of accuracy for collation.

NW calculate the daily average distribution input, taking account of major service reservoir stock changes and any imports to or exports from the distribution network.

In both Northern and Southern Operating Areas Distribution Input meter verifications are no longer carried out. The verification program which previously existed, attempted to prove the accuracy of NW's meter stock and quantify the level of accuracy of both NW's permanent meters and the temporary meter at each site. The accuracy of permanent full-bore electromagnetic meters exceeds that of the temporary meters used for verification. 96% of NW's DI meter stock is full-bore electromagnetic meters and the remaining type are monitored closely.

4.3.3 Distribution Losses and Service Reservoir and Trunk Main Leakage

No change has been made from last year in the methodology used for determining distribution losses. Service Reservoir losses are based on drop test results routinely carried out as part of the reservoir cleaning programme.

The Netbase leakage analysis process provides a calculation of total leakage across the entire mains network for the whole of the Northern Operating Area. In order to achieve this, it must provide calculated values or estimates of leakage for all operable and non-operable DMAs and also for the dummy DMAs. The dummy DMAs are areas which contain mains but which are outside the DMAs. Trunk mains are generally upstream of the district meters and are therefore not included in DMAs. Consequently, most of the trunk mains are in dummy DMAs and, as a result, a significant proportion of the leakage attributed to the dummies is trunk main leakage. For each DMA or dummy DMA which contains trunk mains, an estimate has been made of the leakage that can be attributed to the trunk mains. This indicates a total trunk main leakage in the Northern Operating Area. This leakage is already included in the overall bottom-up leakage analysis in Netbase.

As of April 2020 we will be fully compliant with the leakage consistent reporting methodology as defined by Water UK and Ofwat.

4.4 Re-basing the 2016/17 Figures

For NW the normalised PCCs have been used to calculate measured consumption. PCCs have been calculated from the population and occupancy figures from the new forecast described below.

NW's work planning database has been analysed to provide figures for the number of households internally and externally metered and for the sub-division into optants, selectives, new and pre-existing metered groups.

For the final submission of the NW Business Plan in 2004, it was decided that the best way to forecast metered household consumption, was to create a category of customers NW calls "existing metered". To forecast metered consumption, base year consumptions had been derived from the billing database (ICIS) for recent new houses and for recent optants. In theory, the base year customer base could be divided into these broad categories but past metering policy had not been this simplistic.

For this reason, the base year consumptions for recently metered new and optant customers, if applied to the whole metered household base in 2002/3, did not give a total metered consumption matching that of the June Return reported total household metered consumption. It was therefore decided that all households metered up until the base year would be placed into a single category of known consumption – the existing metered, with the total base year metered household consumption. For these customers their consumption is known with confidence and so it makes sense to use this certainty in the forecast.

The existing metered customer base will not increase over time within the forecast, in that new customers will not be added until a new forecast is created every five years, but the number of households may be expected to change slightly due to voids, disconnections or demolitions. The customers metered by the 2016/17 base year have been moved into the existing metered base. Customers metered from 2017/18 onwards will join one of the following categories: new, options, selective.

NW believes it is reasonable to regroup the customers every five years because changes in occupiers mean that a household metered through one particular metering process cannot be expected to keep those characteristics for all time – low occupier optants will be replaced by "average" occupiers, those whose behaviour may have changed through publicity surrounding a compulsory metering process may be replaced by occupiers who are ambivalent to the property being metered etc. Any attempt to forecast these uncertain changes could not be completed with reasonable accuracy and therefore such a process would not improve the accuracy of the demand forecast. A compromise position is therefore to re-base every five years.

To create the base year figures for the WRMP, the following processes took place:

1. The households in the 2016/17 Regulatory Report new, optant and selective groups were added to the existing metered group. This means for the WRMP, figures for 2016/17 have zero households in the new, optant and selective categories, but from 2017/18 households are added to these groups in line with the metering forecast.

2. For 2016/17 onwards the latest population forecast has been applied. This is the Edge Analytics forecast based on the plan based scenario. The overall occupancy forecast for 2016/17 onwards is derived from this population forecast and household forecast.

3. 135.38 Ml/d total leakage figure has been applied to 2016/17.

4. As a result of the changes in the base year a water balance has been produced to provide the post rebased MLE figures.

4.5 Populations

4.5.1 Overview

The base building block for demand forecasting is the base year population served and the projected growth in population annually over the WRMP. This is a highly specialised area of the demand forecast, along with property growth numbers, and NW employs specialist consultants to prepare the forecasts of population and property by each WRZ. Population for the base year and forecasted years has been commissioned from Edge Analytics.

In line with the WRPG requirement, NW has used Local Plan housing growth evidence from all local authorities and has selected the Plan-based scenario. The detailed methodology used to determine household growth is provided in Population, Household and Property forecast technical report (2017). [1] A comparison between Trend and Plan-based scenario's is shown in the following figures.

Figure 4.5: Kielder WRZ Total Population

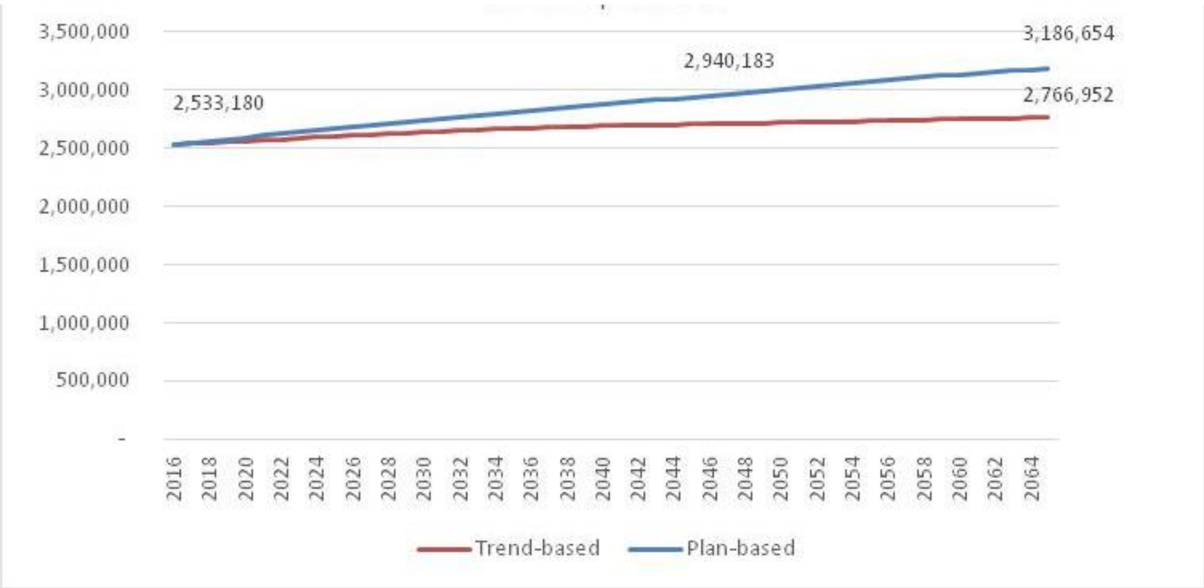
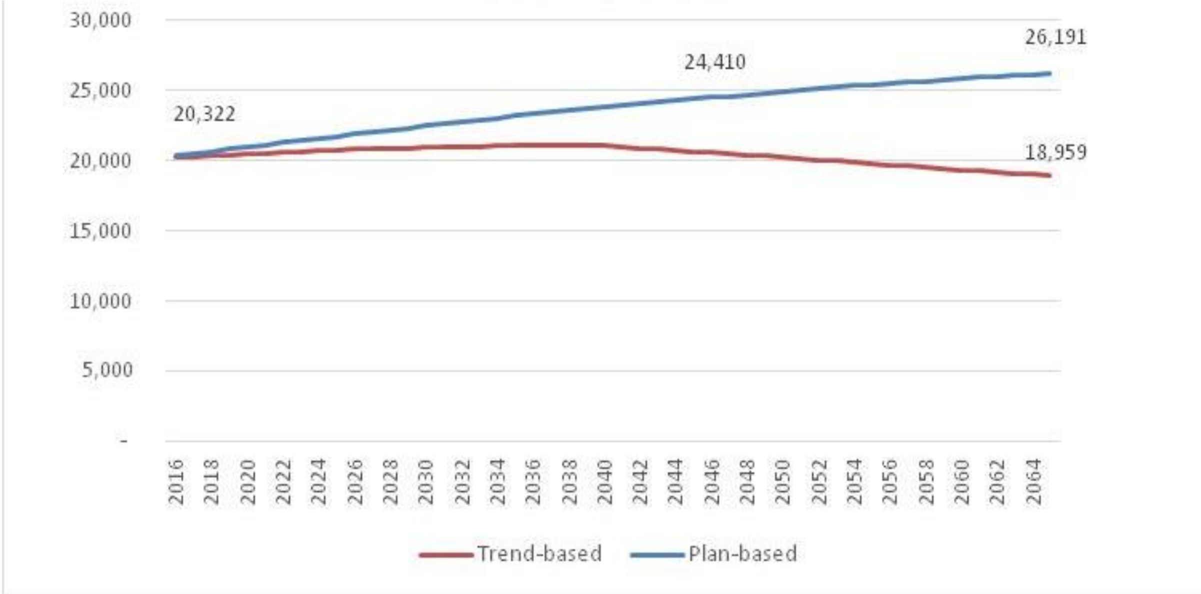


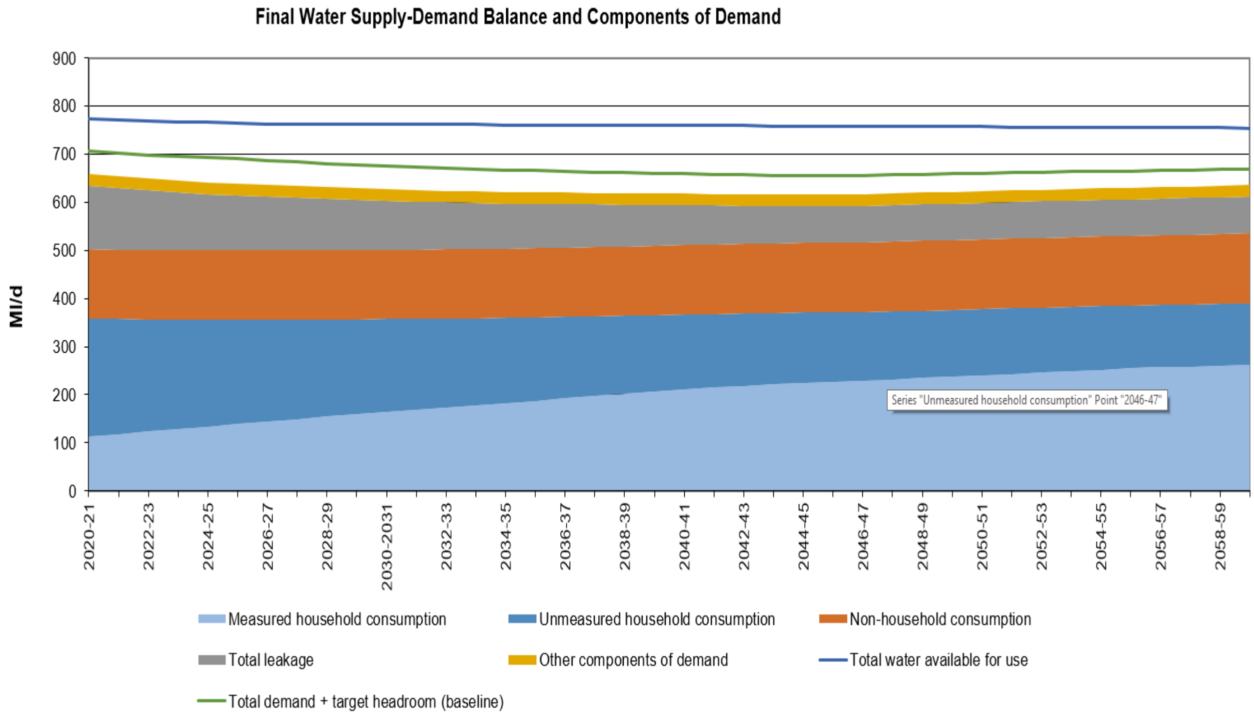
Figure 4.6: Berwick and Fowberry WRZ Total Population



[1] Edge Analytics (2017) Population, Household and Property forecast, Demographic evidence for Water Resource Management Plans, Edge Analytics.

Edge Analytics used best practice methodology which follows the requirements of the WRPG. Below in **Error! Reference source not found.** is the supply demand balance for the Local Plan growth projections for population and property.

Figure 4.7: Supply-demand balance for the Local Authority Plan growth projections



4.5.2 Edge analytics methodology summary

Edge Analytics was contracted to produce an update to the population and household forecasts by DMAs in NW areas. In line with the WRPG requirement, Edge Analytics has collected Local Plan housing growth evidence from all local authorities that are either wholly or partially included within the NWG operational boundary (Northumbrian Water and Essex & Suffolk Water).

Each of the 38 local authorities (plus 5 National Park Authorities) is at a different stage of Local Plan development. All have collated a variety of demographic and economic evidence to inform the plan-making process. Some plans have been adopted; others remain under development or open for consultation.

The information in table 4.6 provides a summary of the current status of each Local Plan with an indication of the likely housing growth target over a designated plan period. These data are subject to change but provide a point-in-time perspective on likely housing growth outcomes that can be compared directly to existing 'trend' outcomes (on which the majority of the Local Plan evidence will have been based).

Table 4.6: Local Plan status, January 2017 NWG area (Source: Local Planning Inspectorate, Local Plans)

Area	Latest Local Plan Status[1]	Local Plan Period	Housing Target
Barking & Dagenham	Consultation	2015-2030	28,492
Basildon	Draft	2014–2034	15,260
Braintree	Draft	2016–2033	14,365
Brentwood	Draft	2013-2033	7,240
Carlisle	Adopted	2015-2030	9,606
Castle Point	Adopted	2011-2031	2,140
Chelmsford	Consultation	2021–2036	11,625
Colchester	Emerging	2017-2032	18,400
County Durham UA	Consultation	2014-2033	29,127 - 32,623
Darlington UA	Emerging	2016-2036	10,000
Eden	Examination	2014-2032	3,600
Epping Forest	Consultation	2011-2033	11,400
Gateshead	Adopted	2010-2030	11,000
Great Yarmouth	Emerging	2020-2036	7,140
Hambleton	Consultation	2014-2035	5,400
Hartlepool UA	Consultation	2016-2031	6,135
Havering	Consultation	2017-2032	17,550
Lake District National Park	Adopted	2010-2025	900
Maldon	Examination	2014–2029	4,410
Mid Suffolk	Emerging	-	11,100 (2011-2031)
Middlesbrough UA	Consultation	-	6,970
Newcastle upon Tyne	Adopted	2010-2030	30,000 (Newcastle upon Tyne & Gateshead)
Newham	Emerging	-	-
North Tyneside	Examination	2011-2032	17,388
North York Moors	Consultation	2017-2035	522
Northumberland National Park	Emerging	-	-
Northumberland UA	Consultation	2011-2031	24,320
Redbridge	Draft	2015-2030	16,845
Redcar & Cleveland UA	Draft	2051-2032	3,978
Richmondshire	Adopted	2012-2028	2,880
Rochford	Emerging	-	4,800 (2011-2031)
Scarborough	Examination	2011-2032	9,450
South Norfolk	Emerging	Until 2036	15,516
South Tyneside	Consultation	2011-2036	-
Southend-on-Sea UA	Emerging	-	6500 (2011-2031)
Stockton-on-Tees UA	Consultation	2014-2032	11,061
Suffolk Coastal	Emerging	2010-2027	7,900
Sunderland	Consultation	Until 2033	-
The Broads Authority	Consultation	2012-2036	320
Thurrock UA	Emerging	2014-2037	19,044
Uttlesford	Consultation	2011-2033	12,496
Waveney	Emerging	2011-2036	7,700 - 9,525
Yorkshire Dales National Park	Submission	2015-2030	825

Where available, the annual allocation of the overall housing target was taken from the information provided by each council. In cases where this information was not available, the overall housing target was distributed equally over the Local Plan period with adjustments made to take account of historical completions if available. These annual housing growth trajectories form the key input to the Plan-based forecast.

The methodology report has detailed the development of two key scenarios: a Trend-based scenario which replicates the 2014-based sub-national projection from Office for National Statistics (ONS); and a Plan-based scenario which is driven by Local Plan housing growth statistics. NW's billing data has provided the basis for alignment of property numbers in the base year of the forecast period. A sensitivity analysis has been presented, to explore the uncertainty associated with forecast development.

Household and property forecasts at Census Output Area (OA) level

- Household forecasts at OA level have been calculated by applying household representative rates from the DCLG (Department for Communities and Local Government) household projection model at LADUA (Local Authority District & Unitary Authority) level to the OA level population, excluding population not in households.
- For the forecast years, OA level households have been reconciled to the trend in the LADUA level household totals derived at Step 3.
- The DCLG provides data for a forecast period that is shorter than the NW forecast horizon. After the last year for which the DCLG data are available (2039), the household representative rates have been kept fixed for the remainder of the NW forecast period.
- An OA-level vacancy rate has been calculated using statistics on households (occupied household spaces) and dwellings (shared and unshared) from the 2011 Census. This vacancy rate has been applied to the OA level households for each of the forecast years to create OA-level property figures.
- Property data from NW's billing database has been used to provide an alternative property forecast that is more closely aligned to the number of NW properties in 2016.

Sensitivity analysis -

- All demographic forecasts are subject to an element of uncertainty. Consideration of this uncertainty is an important element of the WRMP demographic evidence. The Edge Analytics approach includes a 'sensitivity' analysis, which considers the uncertainty associated with its forecasts in three ways: through the use of error distribution statistics recommended in the UKWIR guidance; through the development of both trend and plan-based scenarios; and through the application of variant assumptions to its scenarios.

- The Trend-based and Plan-based scenarios provide a range of growth outcomes, the first based on a continuation of historical trends, the second based on an expected trajectory of housing growth.
- In addition, the UKWIR guidance provides error distribution tables which have been applied to NW growth forecasts, identifying broad upper and lower confidence percentiles for each year of the plan period. Furthermore, with international migration being a key area of uncertainty, the aggregate Trend-based scenario is presented alongside ONS high and low migration variants.
- Finally, the aggregate Plan-based forecasts have been derived using variant household growth assumptions, applying faster and slower rates of household formation from the DCLG's 2008-based (HH-08) and 2014-based (HH-14) models respectively. These alternatives consider variations in the rate at which household occupancy is expected to decline over the plan period.

Chosen population growth scenario

In the case of NW supply areas, the population forecasts for PR19 shows a growth in population over the planning horizon. For NW this has resulted in a 15% increase over 25 years as shown in table 4.7.

In the demand forecast overall occupancy reduces from 2.33 to 2.27.

The detailed methodology used to determine population growth is provided in detail in the Population, Household and Property forecast technical report (2017).

Table 4.7: Population Growth

	2016/17	2044/45	Increase	% Increase
Northumbrian	2554.25	2952.13	384.57	15%

Figure 4.8: Kielder WRZ Total Population

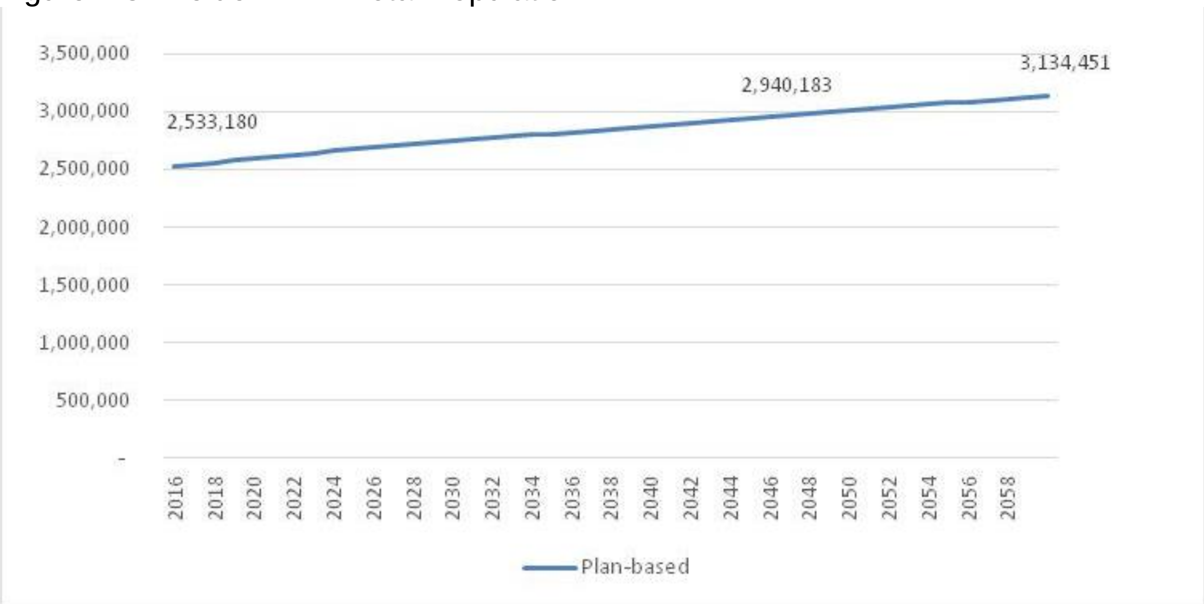
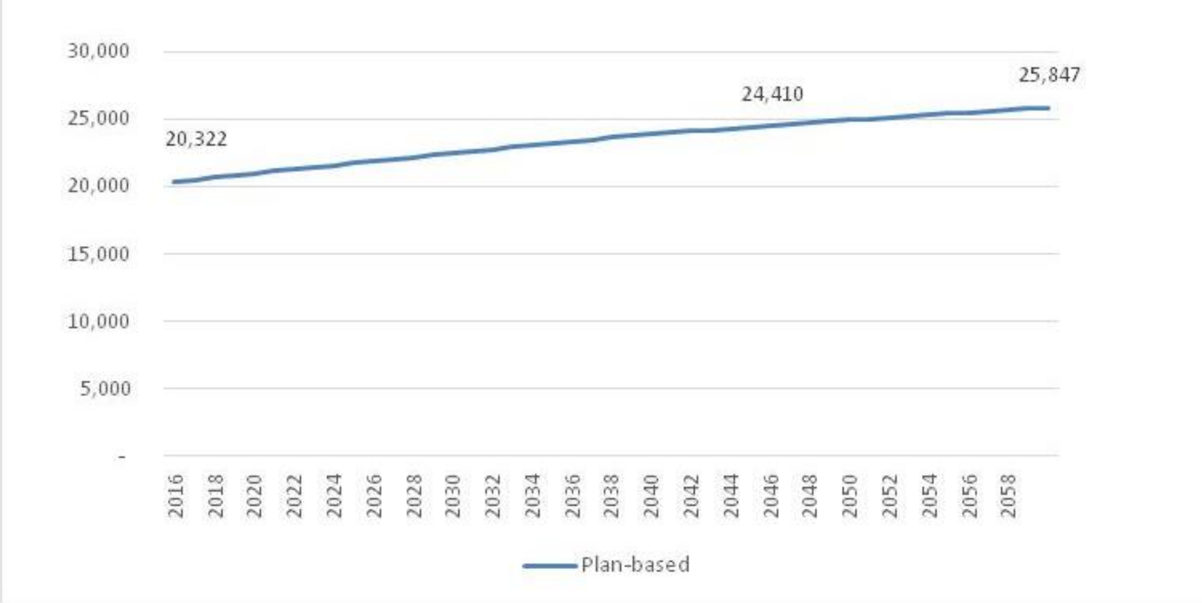


Figure 4.9: Berwick and Fowberry WRZ Total Population



4.6 Occupancy

The overall occupancy comes from the Edge Analytics domestic population figure plus the short term migrant / illegal immigrant population from Demographic Decisions. This total population is divided by the total number of billed households for the year to give an overall occupancy rate. However, whilst a total population figure is essential in NW's demand forecasts, an overall occupancy figure is at too high a level to be useful in the demand forecast directly. This is because the different housing categories of NW's customers have different average occupancies. For example unmeasured customers have a higher occupancy than that of the optant meter customers. This is due to low occupied properties where the customer gains financially by paying a measured charge whereas a high occupied property, if electing for a meter, would pay more for their water and sewage than if they remained unmeasured. It is therefore necessary to have a specific occupancy for different classes of customer.

The occupancies are set by various sources of information available to NW, ranging from specific occupancy surveys sent to a random selection of customers, occupancy taken from meter optant applications, and professional judgement based on past occupancy and future forecasts of changes in the customer base.

The most recent survey data has come from the Micro-component Survey used to determine the ownership and frequency of use of water using appliances in the home. These surveys were carried out in January-March 2017 to populate the model for looking at future changes in PCC. For NW, a total of 5,028 responses were received. In the survey customers were asked to indicate the total number of people in the households and the breakdown of occupants for six different age groups as recommended in the UKWIR 'Integration of behavioural change into demand forecasting and water efficiency practices' report (UKWIR, 2016). More information on these surveys is available in section 4.6.3.

Some customers left the 'total' box blank and entered the number of occupants within each age group. Where this was the case, the numbers were totalled to give an overall occupancy. On the contrary, several customers did the opposite, stating the total number of occupants but not stating the breakdown. In these cases, the breakdown could not be established and were therefore left blank.

New homes

The occupancy for new homes have been lowered to 2.15 to reflect the overall lower occupancy, the results from the micro-component survey and the fact that in the recent few years there has been a significant increase in the number of single bedroom apartments being built. The occupancy is forecast to increase gradually through to the end of the planning horizon in line with an increase in overall occupancy.

Table 4.8: New Homes Occupancy Rates

Year	2016/17	2020/21	2030/31	2040/41	2050/51	2059/60
Occupancy	2.15	2.20	2.25	2.30	2.35	2.39

New Optants

The optant occupancy has been slightly lowered to 1.60 from the previously forecast 1.64. NW forecasts a modest increase in optant occupancy through to 2059/60 as there will always be changes to family occupancy that will result in the remaining occupier opting for a meter.

Table 4.9: Optant Occupancy

Year	2016/17	2020/21	2030/31	2040/41	2050/51	2059/60
Occupancy	1.60	1.69	1.79	1.89	1.99	2.08

Existing metered

The base year for what becomes the existing measured is all the measured groups used in the reported outturn year, rebased to take account of changes in overall population and information from occupancy surveys. The figure of 1.83 has been used in the rebased numbers to account for the overall drop in total population. This figure then increases steadily over the whole of the planning horizon to 2.11 in 2059/60. In reality this occupancy is reset every five years when the new WRMP is produced.

Measured properties

The occupancy of the measured property group is calculated from all of the different metered components using their assigned occupancy and weighted by their forecast property numbers. Changes in this occupancy in the forecasts are influenced by the occupancy of the groups that dominate in future years e.g. new homes, optants or change of occupier selectives.

Table 4.10: Occupancy of Measured Property

Year	2016/17	2020/21	2030/31	2040/41	2050/51	2059/60
Occupancy	1.84	1.86	1.93	2.02	2.13	2.19

Unmeasured properties

The unmeasured occupancy is calculated by subtracting the population assigned to all of the measured groups from the total household population and dividing this by the remaining number of billed unmeasured properties. This would be expected to be the highest occupancy class but over time the overall measured occupancy and unmeasured occupancy will tend to converge towards each other.

Table 4.11: Occupancy of Unmeasured Property

Year	2016/17	2020/21	2030/31	2040/41	2050/51	2059/60
Occupancy	2.59	2.63	2.75	2.76	2.59	2.48

4.7 Properties

Base year property figures are taken from the Company's billing database. The growth property figures for each of the forecasted years are provided by Edge Analytics. In line with the WRPG requirement, NW is using Local Plan housing growth evidence from all local authorities that are either wholly or partially included within the NW operational boundary.

4.8 Baseline Household Demand Forecasts

The household demand forecast has been developed by considering the population in groups as follows:

1. Unmeasured customers
2. Meter Optants

3. New Homes
4. Existing Metered

These groups have been chosen because NW believes their consumption characteristics are noticeably different. However, households already metered cannot sensibly be assigned to the separate metered groups, as the consumption of this group is known, so it makes sense to regroup the metered customer base into a single category, which NW calls "Existing Metered" every five years.

For the unmeasured, new homes and existing metered groups NW has forecast PCCs using a new improved micro-component model, which has been populated for the base year using data collected from an appliance survey.

4.8.1 Meter Optants

For the meter optant groups NW has determined their future PCCs as a percentage reduction relative to the unmeasured PCC, maintaining the previously accepted and agreed assumptions.

Savings from the water efficiency target have been included in the baseline and final PCC forecasts. It has been assumed that the savings will be met equally by measured and unmeasured customers. Further details of these savings are provided in section 5 of the WRMP.

4.8.2 New Homes PCC

All new homes across the forecasted years have a PCC of 118 l/h/d. As a result of the introduction of water efficiency standards into Part G of the Building Regulations which came into force in April 2010, it is a requirement that all new homes are built to deliver consumption not exceeding 125 l/h/d. In 2017, ESW completed analysis of consumption in new homes built after 2012, the results showing that the PCC was lower than the 125 l/h/d standard.

4.8.3 Water Use Survey

To insure the latest source of information about NW's customers is included in the formation of a robust demand forecast a water use survey was created to collect occupancy, household appliance and water use information from NW customers. An overview of the method is given below with detailed information available in the Micro-components Technical Report (2017).[2]

Following the best practise for customer water use surveys in the UKWIR (2016)[3] report, a stratified sampling method was selected where the customer base is split

[2] Northumbrian Water (2017) Micro-components Technical Report

3 UKWIR (2016) Integration of behavioural change into demand forecasting and water efficiency practises, Appendix 7.

into sub-groups which are presumed to have distinctly different water consumption characteristics. Customers were split into the sub-groups of measured and unmeasured properties as shown in table 4.13. The measured group was divided by meter status (e.g. optant, selective) and then all these groups were further divided into ACORN[4] categories. (Please refer to the Micro-components Technical Report for more detailed information on the sampling method).

Table 4.12: Sub-group definitions

Sub-Group	Description
Unmeasured	Customers paying for their water by the rateable value of the property.
Measured	Customers paying for their water by water meter.
Existing	All properties that were metered before 2012.
Optant	Properties whose occupier opted to have a meter fitted after 2012.
New	New-build properties built since 2012.
Acorn Cat 1	Wealthy Achievers
Acorn Cat 2	Urban Prosperity
Acorn Cat 3	Comfortably Off
Acorn Cat 4	Moderate Means
Acorn Cat 5	Hard-pressed

A postal and online survey method was employed to collect responses from customers. The survey design is based upon the ‘long survey form’ in the UKWIR (2016) report to follow a consistent approach to water use surveying with other water companies which in the future can develop nationally consistent datasets for comparison and pooling of data.

The survey consisted of 31 detailed questions which began with household type, age and occupancy questions, followed by household water using appliance ownership, frequency and duration of use questions, and finishing with questions on outdoor water use.

Previous surveys of this nature have generated a 20% response rate in NW and so based upon this expectation a total of 23,684 NW customers were mailed in January 2017 with the water use survey. 3,288 of these customers also received an email version as they had already supplied NW an email address.

4 ACORN is a consumer classification that segments the UK population created by CACI. By analysing demographic data, social factors, population and consumer behaviour, it provides precise information and an understanding of different types of people.

A sum of 4,700 surveys was returned from this initial mailing. Although this is a 20% uptake a few sub-groups did not reach their specified quota and therefore a subsequent mailing was necessary. A totally different set of customers was randomly selected for the second mailing following the same sampling techniques as the first. 2,315 customers were sent the second mailing in February 2017 with 317 of these also receiving the email version. In total 5,027 surveys were returned. Survey answers were then split into different micro-components for analysis.

4.8.4 Integration of behavioural change

Water companies are increasingly interested in the way customers use water and the effect their behaviour and habits have on the total demand for water and how to forecast changes in behaviour. The UKWIR (2016)[5] project developed a framework for water companies to integrate behavioural change into demand forecasting.

The report looked at customer survey and consumption data and from this discovered it was possible to explain about 50% of the variation in household demand by a particular property type or garden size and dishwasher ownership (hence why these questions are included in the water use survey). Therefore, the remaining 50% of the variation might be attributable to additional 'human factors' but frequency of use information is able to explain a further 30% of the variation.

Following the framework of the UKWIR (2016) report a medium level of planning concern approach was followed for all WRZs. The framework recommends following the approach of the previous study's report UKWIR (2014)[6] with the inclusion of scenario analysis allowing the sensitivity of the central demand forecasts to be tested.

Therefore the framework from UKWIR (2014) uses the standard micro-component approach inferring consumption from self-reported survey data using micro-component assumptions. This is detailed in the following section on the Micro-component Model. A lowest tier has been selected for the level of detail for analysis where segmentation of customers is by unmeasured / measured status and a further split by metered status (optant, selective). Segmentation by acorn data has been collected for future analysis but has not been utilised in the micro-component model. This segmentation allows for sensitivity to external factors to be identified for each customer segment and included in the model to integrate behavioural change.

The information collected in the customer water use surveys helps understand the current behaviours and attitudes to water use of NW customers and this is then reported and forecast through the micro-component model. For more information on the integration of behavioural change please refer to the Micro-component Technical report.

[5] UKWIR (2016) Integration of behavioural change into demand forecasting and water efficiency practices.
[6] UKWIR (2014) Understanding customer behaviour for water demand forecasting

4.9 Micro-component Model

A micro-component model has been selected for estimating future household water consumption. This well-established model offers a more detailed logical approach as it quantifies the water used for specific activities (e.g. showering and toilet flushing) by combining values of ownership, volume per use and frequency of use to give a per capita consumption (PCC) figure (UKWIR, 2015) [7]. In the UKWIR (2012) report alternative approaches to household consumption forecasting were reviewed and this approach of using a micro-component model was recommended based upon the work of Paul Herrington (1996)[8]. From this report the highest tier for forecasting PCC has been selected for improved accuracy which forecasts trend using micro-components.

The model data sources are customer water-use surveys (please see section 4.8.3) and Defra MTP reports[9].

The model used for PR14 has been updated and the base year is now 2016/17 which projects forward annually to the end of the demand planning horizon. The micro-components are split into the following sections as recommended by the Agency et al (2012):

- Toilet flushing
- Personal washing
- Clothes washing
- Dishwashing
- Outdoor use
- General use

These sections are subsequently split into sub-components to analyse ownership, frequency and duration of use in detail. Wherever possible NW specific data has been utilised and then reviewed alongside previous surveys and other available data sources to ensure that spurious results from small samples are identified and treated with caution.

For all micro-components the start position and rate of change is defined and applied to the duration of the planning horizon. For those components involving white goods, a range of models and their associated average volumes per use have been identified. Along with this are stated the assumed model lifespan and the dates when lower-volume technologies are expected to be introduced. The model has been split between the two WRZ's, Kielder and Berwick to account for the different occupancy in both zones, however both areas use the same customer survey base data to ensure a large enough sample.

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[7] UKWIR (2015) WRMP19 Methods- Household consumption forecasting- Supporting guidance
[8] Paul Herrington, Climate change and the demand for water, HMSO, (1996).
[9] DEFRA (2012) MTP reports

In the tables the values for micro-components are the values detailed in this section (normal year values) with dry year uplift and meter under-registration added on. The values also do not include any water efficiency savings. Metered values refer to metered existing properties only.

An overview of each of the micro-components is given below but for more detailed information please refer to the Micro-components Technical Report (NW, 2017).

4.9.1 Toilet flushing

Toilet flushing was split into five separate groups to reflect the varying flush volumes. These include:

Dual flush pre 2001	9.25 litres
Full flush pre 2001	8.25 litres
Full flush post 2001	6 litres
Dual flush post 2001	4.7 litres

All households have at least one toilet therefore the ownership for all four types of WCs was portioned to equal 100%. Please refer to Table 4.13 for a summary of the toilet flushing base year and forecasting results.

Ownership of the different groups of toilets is based upon the results of the water use survey. Due to a toilet lifespan of 15 years[10] and an increase in the ownership of toilets which increases the replacement rate[11], ownership is forecast to decrease for pre 2001 installed toilets. Ownership of post 2001 installed toilets is forecast to grow by 30% (full flush) and 70% (dual flush) of the decreasing rate of the pre 2001 two types of toilet combined for the planning horizon.

The frequency of toilet flushing is taken from the answers in the water use survey and is calculated by averaging the number of flushes per person per day across the toilets owned for each household. Based on the extrapolation of Herrington (1996), frequency is set to increase at a rate of 0.0504 flushes per week per year.

The respective volume for each of the toilet types is forecast to remain constant over the planning horizon.

Table 4.13: Summary of toilet flushing base year and forecasting

	Ownership %		Frequency (/h/day)		Volume (l)
	Base Year	Replacement Rate	Base Year	Growth Rate	
Dual flush pre 2001					
Kielder Unmeasured	8.58	minus 1% p.a.	4.94	0.0504/7 p.a.	9.25

[10] DEFRA (March 2011) MTP BNWAT01 WCs: market projections and product details version 1, pp7
[11] DEFRA (March 2011) MTP BNWAT01 WCs: market projections and product details version 1, pp7

	Ownership %		Frequency (/h/day)		Volume (l)
	Base Year	Replacement Rate	Base Year	Growth Rate	
Dual flush pre 2001					
Kielder Existing	12.80		4.30		
Berwick Unmeasured	8.58		4.94		
Berwick Existing	12.80	minus 0.5% p.a.	4.30		
Full flush pre 2001					
Kielder Unmeasured	29.47	minus 1% p.a.	5.85	0.0504/7 p.a.	8.25
Kielder Existing	31.87		4.64		
Berwick Unmeasured	29.47		5.85		
Berwick Existing	31.87	minus 0.5% p.a.	4.64		
Full flush post 2001					
Kielder Unmeasured	25.23	+30% of the decreasing rate of dual flush pre 2001 and +30% of decreasing rate of full flush pre 2001	6.33	0.0504/7 p.a.	6.00
Kielder Existing	16.27		4.96		
Berwick Unmeasured	25.23		6.33		
Berwick Existing	16.27		4.96		
Dual flush post 2001					
Kielder Unmeasured	36.72	+70% of the decreasing rate of the dual flush pre 2001 and +70% of the decreasing rate of full flush pre 2001	6.21	0.0504/7 p.a.	4.7
Kielder Existing	39.06		4.87		
Berwick Unmeasured	36.72		6.21		
Berwick Existing	36.72		4.87		

4.9.2 Personal Washing

The personal washing micro-component has been split into bathing, showering, hand washing / teeth cleaning and bidet use.

Bath

Ownership levels and frequency of use have been taken from the water use survey with ownership forecast to decrease by -0.73 per annum in measured properties to account for the increase in showers replacing baths particularly in smaller households[12]. In unmeasured categories it decreases at around half this rate. The frequency of baths is forecast to decrease until 2030 where it becomes level. Decreasing frequency of baths is primarily due to the shift from bathing to showering[13].

The volume of baths has been based upon the Waterwise average volume figure of 80 litres[14] and evidence from the Market Transformation Programme (MTP)[15]. Measured volumes use half this value for the proportion of baths that are shared. The respective volumes for all property groups can be seen in Table 4.14. These remain constant for the forecasting horizon.

Table 4.14: Summary of bath base year and forecasting

<table>
<tr><th rowspan="2">Bath</th><th colspan="2">Ownership %</th><th colspan="2">Frequency (/h/day)</th><th rowspan="2">Volume (l)</th></tr>
<tr><th>Base Year</th><th>Replacement Rate</th><th>Base Year</th><th>Growth Rate</th></tr>
<tr><td>Kielder Unmeasured</td><td rowspan="2">72.94</td><td rowspan="2">-0.38 p.a. until 2040</td><td>0.4704</td><td rowspan="2">-0.5% p.a. until 2030</td><td>75.500</td></tr>
<tr><td>Berwick Unmeasured</td><td>0.4763</td><td>77.500</td></tr>
<tr><td>Kielder Existing</td><td rowspan="2">68.27</td><td rowspan="2">-0.73 p.a. until 2040</td><td>0.6019</td><td rowspan="2">-0.8% p.a. until 2030</td><td>59.041</td></tr>
<tr><td>Berwick Existing</td><td>0.6152</td><td>60.343</td></tr>
</table>

Showers

Showers are split into three types; mixer, electric and power shower to account for the variance in flow rates. Ownership is taken from the water use survey with ownership of showers forecast to increase over the planning horizon with unmeasured properties increasing at a faster rate than measured. This is because it is assumed showers will have a higher take-up rate in unmeasured properties than measured. See Table 4.16 below for details.

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12 DEFRA (March 2011) MTP BNWAT08 Modelling projections of water using products, pp11.
13 DEFRA (March 2011) MTP BNWAT08 Modelling projections of water using products, pp11.
14 Waterwise (November 2011) Showers vs Baths: facts, figures and misconceptions "average bath's 80 litres" *http://www.waterwise.org.uk/news.php/11/showers-vs.-baths-facts-figures-and-misconceptions*
15 DEFRA (March 2011) MTP BNWAT03 Baths -reference scenario average pp 9 and highest % of sales in 2010 were for medium sized baths (80-90 litres) pp10.

The frequency of use was assumed to be the same for all types of showers and is taken from the water use survey. Shower frequencies are forecast to increase until 2030 as it is uncertain beyond this whether people would increase their shower use further.

To determine the respective volumes for each shower type results from the UK Water Industry Collaborative Fund project with Unilever R&D (2014) were used[16]. An average of the various durations found in this research for different meter status and shower type were multiplied by the flow rate per shower type taken from this research as well. Shorter shower durations have been assumed for measured properties with power showers having the larger volumes per use. Shower duration is predicted to decrease across the planning horizon with a limit of five minutes as the minimum shower time. Results are shown in Table 4.15.

Table 4.15: Summary of showers base year and forecasting

	Ownership %		Frequency (/h/day)		Volume (l)
	Base Year	Replacement Rate	Base Year	Growth Rate	Base Year
Mixer Shower					
Kielder Unmeasured	35.36	+0.2% p.a.	0.72	+0.6% p.a. until 2040	36.648
Berwick Unmeasured			0.73		
Kielder Existing	42.46	+0.1% p.a. until 2040	0.92	+0.005 p.a. until 2030	
Berwick Existing			0.94		
Electric Shower					
Kielder Unmeasured	38.84	+0.2% p.a.	0.79	+0.6% p.a. until 2040	29.425
Berwick Unmeasured			0.80		
Kielder Existing	42.46	+0.1% p.a. until 2040	0.92	+0.005 p.a. until 2040	
Berwick Existing			0.94		
Power Shower (>10l/min)					
Kielder	7.99	+0.2% p.a.	0.67	+0.6% until	57.78

[16] Hendrickx et al (2014) Showering behaviour in the UK and a behavioural intervention to reduce water use in the shower, UK Water Industry Collaborative Fund and Unilever R&D.

	Ownership %		Frequency (/h/day)		Volume (l)
	Base Year	Replacement Rate	Base Year	Growth Rate	Base Year
Mixer Shower					
Unmeasured				2040	
Berwick Unmeasured			0.68		
Kielder Existing	10.20	+0.1% p.a.	0.74	+0.005 until 2040	
Berwick Existing			0.75		

Hand Washing / Teeth Cleaning

The ownership is set at 100% and remains constant. Frequency is set at seven times a day (five times after toilet use and two times brushing teeth). Frequency decreases over the planning horizon to account for assumed lower tap flow rates. The average tap flow rate of 6 l/min[17] is the bases for the volume of hand washing and teeth cleaning which has been multiplied by the estimated length of time each activity takes. The volume remains constant over the forecasting period. Results are shown in table 4.17.

Table 4.16: Summary of hand washing / teeth cleaning base year and forecasting.

Hand washing / teeth cleaning	Ownership %		Frequency (/h/day)		Volume (l)
	Base Year	Replacement Rate	Base Year	Growth Rate	
Kielder Unmeasured	100	Remains constant	7	((2060 freq – base year freq) / 44) + previous yr freq	2.573
Berwick Unmeasured					
Kielder Existing					1.785
Berwick Existing					

[17] Waterwise ‘6 litres / min’ and DEFRA (March 2011) MTP BNWAT04 ‘washbasin tap flow rates range between 3.54-1.68’, pp7.

Bidet

Household ownership of a bidet has been taken from the water use survey results. In most cases, bidet use is considered too small to be included, therefore, in the forecast, frequency is assumed to remain at one use per day for the forecasting period. Volume per use also remains constant over the forecasting period at 1 litre in unmeasured properties and 1.2 litres in measured properties[18].

4.9.3 Clothes Washing

The sections within the clothes washing micro-component are washing machine, washer-drier (drying part only) and washing clothes by hand.

Washing Machine

All washing machines have been split into four model groups with each model assigned an average volume use per load based upon the models currently available to customers.

It is assumed customers will buy from the most water efficient model on the market. Replacement rates of these models are applied to the forecast and fluctuate around double the assumed mean of 12.59 years[19]. As the ownership of washing machines increases and old models are replaced by new more water efficient models, the percentage ownership of model one decreases and models two, three and four are proportionally increased.

From the water use survey the total percentage ownership of all washing machines is calculated. The growth rate of washing machines is 0.25 per annum with total ownership capped at 99%. This allows for the total number of washing machines to be calculated based upon the total number of properties in the forecasting year.

The frequency of use for washing machines is taken from the survey. Baseline washing machine volume is the average of 30 models available on the market at the moment with the higher tertile used for unmeasured properties and the lower tertile for measured with an assumption that measured properties will purchase more efficient models. The volume for each forecasted year is based upon the percentage of each model owned multiplied by the total litres per use. Results are shown in Table 4.17.

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[18] Scientific American (2017) *https://www.scientificamerican.com/article/earth-talks-bidets/* "1/8 gallon per use" (= 0.6litres per use, which has been increased to 1 for uncertainty).

[19] DEFRA (March 2011) MTP BNWO01 Combined Laundry 'washing machines and washer drier lifespan is assumed to be 12.59 years', pp13. Waterwise report prepared for DEFRA (September 2008) Water and energy consumptions of Dishwashers and Washing Machines, 'on average a clothes washing machine is replaced once every 12 years', pp 9.

Table 4.17: Summary of washing machine base year ownership and frequency

		Frequency		
	Base Year Ownership	Base Year (property / week)	Growth Rate	Base Year Volume (litres)
Kielder Unmeasured Berwick Unmeasured	95.21	3.539	+0.02 p.a. until 2040	51.777
Kielder Existing Berwick Existing	92.88	3.178	remains constant	43.970

Washer Driers (drying part only)

Washer driers use similar amounts of water in the washing phase as washing machines; however the drying phase also uses significant amounts of water as most operate by a process of condensation that removes humidity but consumes water[20].

The ownership of washer driers for each customer group is taken from water use survey results. Ownership is forecast to increase by 1% of the base year ownership. Penetration of washer-driers is thought to increase as single-occupancy households and confined living spaces make washer driers more practical than separate washers and driers[21].

Base year frequency of use is the same as washing machines and increases by around 1% per annum over the planning horizon with the assumption that they will be used more frequently. Similar to washing machines, the baseline washer dryer volume is the average volume (drying part only) of 30 models available on the market at the moment, with the higher tertile used for unmeasured properties and the lower tertile for measured with an assumption that measured properties will purchase more efficient models. Results are shown in table 4.19.

[20] Waterwise report prepared for DEFRA (September 2008) Water and energy consumptions of Dishwashers and Washing Machines, pp 21.
[21] Waterwise report prepared for DEFRA (September 2008) Water and energy consumptions of Dishwashers and Washing Machines, pp 21.

Table 4.18: Summary of washer drier base year ownership and frequency

Washer Dryer (drying part only)	Ownership %		Frequency (/h/day)		Volume (l)
	Base Year	Replacement Rate	Base Year	Growth Rate	
Kielder Unmeasured	7.081	+0.8% p.a.	3.539	+0.02 p.a.	81.500
Berwick Unmeasured					
Kielder Existing	9.32	+1% p.a.	3.178	remains constant	64.450
Berwick Existing					

Washing clothes by hand

The ownership values determined for washing clothes and frequency of use are taken from the water use survey. Unmeasured household ownership remains constant throughout the forecasting horizon, whereas measured households decrease by 0.2% per annum over the horizon.

Volume per use is based upon the average washing up bowl volume of ten litres with the assumption measured households wash by hand 3-4 times per week and measured 1-2 times a week. The volume is assumed to decrease over the forecast to account for the increase in water efficient behaviours.

4.9.4 Dishwashers

The dishwashing micro-component has been split into four sections; dishwasher, washing up, waste disposal and recycling.

Dishwashers

The forecast model for dishwashers is based on the same approach as that used for washing machines. All dishwashers have been split into three models with each of these models assigned an average volume per load based upon the models currently available to customers[22]. It is assumed customers will buy from the most water efficient model on the market. Replacement rates of these models applied in

[22] Waterwise report prepared for DEFRA (September 2008) Water and energy consumptions of Dishwashers and Washing Machines, pp 10.
Which? (September 2012) *http://www.which.co.uk/energy/creating-an-energy-saving-home/reviews-ns/water-saving-products/water-efficient-dishwashers/*.

the forecast vary around the assumed mean of 14.5 years[23]. As the percentage ownership of model one decreases, models two and three proportionally increased.

The baseline ownership of dishwashers is taken from results of the water use survey. Ownership is forecast to increase for all households, with total ownership capped at 99%. This allows the total number of dishwashers to be calculated based on the total number of properties. The frequency value assigned to dishwashers has been taken from the water use survey. The forecast of frequency of use is related to the number of people living in a property, so as the average occupancy increases over the forecast the dishwasher frequency increases at the same rate.

Similar to washing machine, baseline dishwasher volumes are the average of the 30 models available on the market at the moment with the higher tertile used for unmeasured properties and the lower tertile for measured with an assumption that measured properties will purchase more efficient models. The volume for each forecasted year is based upon the percentage of each model owned multiplied by the total litres per use. Results are shown in table 4.20.

Table 4.19: Summary of dishwasher base year ownership and frequency and volume

		Frequency		
Dishwasher	**Base Year Ownership**	**Base Year (property / week)**	**Growth Rate**	**Base Year Volume (litres)**
Kielder Unmeasured	34.30	3.98	base year freq multiplied by 1.5 x change in occupancy	10.35
Berwick Unmeasured				
Kielder Existing	34.49	3.68		9.24
Berwick Existing				

Washing Up

It is assumed that all homes that do not own a dishwasher will wash up. It is also assumed that 60% of households with a dishwasher will also do some washing up as

23 DEFRA (March 2011) MTP BNDW01,'13 years', pp11. Waterwise report prepared for DEFRA (September 2008) Water and energy consumptions of Dishwashers and Washing Machines, '16 years' pp 10. Mean of both these values is 14.5 years lifespan.

well. Therefore the total percentage of customers who wash up is dependent upon the growth rate of dishwashers.

The frequency consists of a two part calculation based upon people without a dishwasher wash up more times than people with a dishwasher. It is presumed that properties without a dishwasher wash up 18 times a week and those with a dishwasher are assumed to wash up at the same frequency as dishwashers. The forecasted frequency is therefore also dependant on the growth rate of dishwashers. Volume per use is based on the average washing up bowl size of ten litres. Results are shown in Table 4.20.

Table 4.20: Summary of washing up base year ownership and frequency.

Washing up	Ownership %	Frequency (/h/day)	Base year volume (l)
	Base Year	Base Year	
Kielder Unmeasured	86.28	14.66	12.00
Berwick Unmeasured			
Kielder Existing	86.20	14.56	6.00
Berwick Existing			

Waste Disposal Units

The ownership and frequency of use for waste disposal units is taken from the water use survey and remains constant over the forecast. From Waterwise's components of demand figures (Sep 2008)[24] the volume of nine litres per use has been assumed for unmeasured properties and six litres per use for measured properties. Volume of use also remains constant over the planning horizon.

Recycling

Ownership and frequency for recycling is based on the water use survey. Volume per use is calculated by using the average tap flow rate of six litres per minute with the assumption each item is rinsed for 10-15 seconds. Results are shown in Table 4.21.

[24] Waterwise (Sep 2008) Water consumption of components of domestic demand 'waste disposal unit (used with running water) 9 litres per min, can range between 6-25 litres / min'.

Table 4.21: Recycling ownership, frequency and consumption.

Recycling	Ownership %	Frequency (/h/day)	Total consumption (l/h/d)
	Base Year	Base Year	
Kielder Unmeasured Berwick Unmeasured	39.20	7.56	1.25
Kielder Existing Berwick Existing	36.89	6.93	0.70

4.9.5 Outdoor Use

The micro-component section outdoor use has been split into the following sections:

- pressure washer
- lawn sprinkling
- hose for watering garden
- watering can
- bucket for car wash and rinse
- hose for car rinse
- paddling pool
- large paddling pool (12-15ft +/or temp swimming pool)
- pond filling
- and swimming pool filling

Pressure washer

The ownership and frequency of use for pressure washer (power washers) is taken from the survey results. Ownership is expected to continue to increase over the next few years before stabilising with measured properties increasing at a slower rate than unmeasured properties.

A typical pressure washer volume ranges between 350-500 litres per hour with Waterwise stating the average is 400 litres / hour[25]. Base year volume is calculated from the average of the 30 models available on the market at the moment with the higher tertile used for unmeasured properties and the lower tertile for measured with an assumption that measured properties will purchase more efficient models. Results are shown in table 4.23.

[25] Argos products available (September 2012) range from between 350-500 litres per hour, Waterwise estimate average is 400 litres / hour.

Table 4.22: Summary of pressure washer base year and forecast

Pressure Washer	Ownership %		Frequency (/h/day)		Volume (l)
	Base Year	Replacement Rate	Base Year	Growth Rate	Base Year
Kielder Unmeasured	21.72	+0.25 p.a. until 2040	0.05	Remains constant	210.30
Berwick Unmeasured					
Kielder Existing	19.89	+0.025 p.a.			189.45
Berwick Existing					

Lawn sprinkling

The ownership and frequency of lawn sprinkling has been determined from the survey as well. Across all the property areas the average time sprinklers were used during the summer six months was between 17-19 hours. Similar to pressure washers, the frequencies are set to remain constant in measured properties.

The Defra MTP report states that 'sprinklers typically use 540-1000 litres per hour (9-16 litres per minute)'. [26] Customers were asked in the water use survey to indicate the size of their garden. Large gardens were assigned a higher volume of 1000 l/hr and small gardens were assigned the lower volume of 770 l/hr for unmeasured and 540 l/hr for measured. Medium gardens were given the midpoint volume of between the higher and lower assigned volumes. Volumes were then weighted based upon the proportion of garden size of customers. Volumes remain constant until 2040 and then decrease for the remainder of the forecast. See Table 4.24 below.

[26] DEFRA (March 2011) MTP BNWAT06 Domestic water use in new and existing buildings, 'Sprinklers typically use 540-1000 litres per hour (9-16 litres per minute)', pp 9.

Table 4.23: Summary of base year and forecast for lawn sprinkling

Lawn Sprinkling	Ownership %		Frequency (/h/day)		Volume (l)
	Base Year	Replacement Rate	Base Year	Growth Rate	Base Year
Kielder Unmeasured	4.00	Remains constant until 2040 then -0.5% then remains constant	19.59	Remains constant until 2040 then -5% p.a.	674.82
Berwick Unmeasured					
Kielder Existing	2.80	-0.01 p.a. until 2040	17.02	Remains constant	471.33
Berwick Existing		-0.02 p.a.			

Garden Watering using hose or watering can

The percentage of people who water their garden using a hose or watering can is taken from the water use survey answers along with the frequency of use. For unmeasured properties hose watering is assumed to increase over the forecasting period and existing properties are assumed to decrease over the forecasting period due to expected difference in water efficient behaviours.

The volume for watering cans used is based upon the Defra MTP report[27] of an average of ten litres per fill along with 4 fills per use. Volumes per use for hoses are estimated by Waterwise of between 600-1000 l/hr. It has been assumed for this model that that the volume of a hose used to water the garden will be 770 l/hr and if a trigger hose gun is attached 540 l/hr. From the water use survey the percentage of customers who did or did not own a trigger hose gun were used to calculate the average volume per use for each group. Results are shown in table 4.25 and 4.26.

[27] DEFRA (March 2011) MTP BNWAT06 Domestic water use in existing buildings, 'Watering cans come in a variety of volumes typically between 7-13 litres', pp 9.

Table 4.24: Summary of base year and forecast for hose used for garden watering.

<table>
<tr><th rowspan="2">Hose used for watering garden</th><th colspan="2">Ownership %</th><th colspan="2">Freq. (/h/day)</th><th>Volume (l)</th></tr>
<tr><th>Base Year</th><th>Replacement Rate</th><th>Base Year</th><th>Growth Rate</th><th>Base Year</th></tr>
<tr><td>Kielder Unmeasured</td><td rowspan="2">27.93</td><td rowspan="2">+0.5% p.a.</td><td rowspan="2">23.37</td><td rowspan="4">Remain constant</td><td rowspan="2">680.66</td></tr>
<tr><td>Berwick Unmeasured</td></tr>
<tr><td>Kielder Existing</td><td rowspan="2">20.53</td><td rowspan="2">-0.1% p.a.</td><td rowspan="2">10.99</td><td rowspan="2">347.22</td></tr>
<tr><td>Berwick Existing</td></tr>
</table>

Table 4.25: Summary of base year and forecast for watering cans

<table>
<tr><th rowspan="2">Watering can</th><th colspan="2">Ownership %</th><th colspan="2">Frequency (/h/day)</th><th>Volume (l)</th></tr>
<tr><th>Base Year</th><th>Replacement Rate</th><th>Base Year</th><th>Growth Rate</th><th>Base Year</th></tr>
<tr><td>Kielder Unmeasured</td><td rowspan="2">29.98</td><td rowspan="4">Remain constant</td><td rowspan="2">18.32</td><td rowspan="4">Remain constant</td><td rowspan="4">40.00</td></tr>
<tr><td>Berwick Unmeasured</td></tr>
<tr><td>Kielder Existing</td><td rowspan="2">28.53</td><td rowspan="2">9.83</td></tr>
<tr><td>Berwick Existing</td></tr>
</table>

Car Washing

Car washing has been split into three activities:

- using a bucket for both washing and rinsing
- using a bucket for washing
- using a hose for rinsing only

The ownership and frequency of all three of these activities comes from the water use survey and these remain constant through-out the planning period. The volume for a bucket used for car washing is based on an assumption of two buckets per wash and six buckets per rinse, with the volume of one bucket as an average of seven litres[28]. The volume per use of 90 litres is used for a hose for rinsing[29]. These remain constant over the forecasting horizon. Results are shown in table 4.27.

Table 4.26: Summary of base year and frequency for car washing

<table>
<tr><th rowspan="3">Car Wash</th><th colspan="3" rowspan="3">Bucket for both washing and rinsing</th><th colspan="3">Bucket just for washing</th><th colspan="3">Hose for rinsing only</th></tr>
<tr><th colspan="3">litres</th><th colspan="3">litres</th></tr>
<tr><th colspan="3"></th><th colspan="3"></th></tr>
<tr><th></th><th>Vol (l)</th><th>Owner-ship (%)</th><th>Freq. (H/wk)</th><th>Vol (l)</th><th>Owner-ship (%)</th><th>Freq. (H/wk)</th><th>Vol (l)</th><th>Owner-ship (%)</th><th>Freq. (H/wk)</th></tr>
<tr><td>Kielder Un-measured</td><td rowspan="4">50.00</td><td rowspan="2">18.67</td><td rowspan="2">14.49</td><td rowspan="2">28.00</td><td rowspan="2">11.47</td><td rowspan="2">22.92</td><td rowspan="4">90.00</td><td rowspan="2">15.03</td><td rowspan="2">23.37</td></tr>
<tr><td>Berwick Unmeasured</td></tr>
<tr><td>Kielder Existing</td><td rowspan="2">17.97</td><td rowspan="2">15.66</td><td rowspan="2">14.00</td><td rowspan="2">9.20</td><td rowspan="2">23.90</td><td rowspan="2">12.69</td><td rowspan="2">12.69</td></tr>
<tr><td>Berwick Existing</td></tr>
</table>

Paddling Pool, Large paddling pool (12-15ft), Pond and Swimming Pools

Ownership of a paddling pools, large paddling pools / temporary swimming pools, ponds and swimming pools is taken from the water use survey. Households are assumed to use or refill these 10-15 times a year which converts to 0.02-0.04 times per household per day. Measured properties frequency has been lowered to reflect the water conserving awareness of these customers. A range of 30 advertised products currently available provides the basis for the volumes with the higher tertile used for unmeasured properties and the lower tertile for measured with an assumption that measured properties will purchase more efficient models. The daily water use of swimming pool filling has been taken from the Market Transformation Programme report evidence as 271 litres for all households[30]. Ownership, frequency

[28] Most buckets on sale in B&Q (Sep 2017) average at 10 litres, assumed not to be filled to full capacity so a volume of 7 litres has been assigned.
[29] DEFRA (March 2011) MTP BNWAT06 Domestic water use in existing buildings, 'Hoses can use upwards of 540 litres of water per hour depending on the pressure and hose size', pp9. Therefore assuming 540 litres / hour which is gives 9 litres / min flow rate for 10 minutes to give 90 litres per use.
[30] DEFRA (March 2011) MTP BNWAT06 Domestic water use in new and existing buildings pp9-10. BSPF response to DEFRA's consultation on proposed changes to powers to restrict non-essential uses of water.

and volume remain constant over the forecasting period. Results are shown in table 4.28-4.31.

Table 4.27: Summary of base year and forecast for paddling pools

Paddling Pool	Ownership %		Frequency (/h/day)		Volume (l)
	Base Year	Replacement Rate	Base Year	Growth Rate	Base Year
Kielder Unmeasured	4.63	Remain Constant	0.02	Remain Constant	383.10
Berwick Unmeasured					
Kielder Existing	3.36		0.01		196.40
Berwick Existing					

Table 4.28: Summary of base year and forecast for large paddling pools

Large Paddling Pool	Ownership %		Frequency (/h/day)		Volume (l)
	Base Year	Replacement Rate	Base Year	Growth Rate	Base Year
Kielder Unmeasured	2.18	Remain Constant	0.01	Remain Constant	4268.20
Berwick Unmeasured					
Kielder Existing	2.24				3408.90
Berwick Existing					

Table 4.29: Summary of base year and forecast for pond filling

Pond filling	Ownership %		Frequency (/h/day)		Volume (l)
	Base Year	Replacement Rate	Base Year	Growth Rate	Base Year
Kielder Unmeasured	3.44	Remain Constant	0.01	Remain Constant	800.00
Berwick Unmeasured					
Kielder Existing	2.40				381.67

Berwick Existing					

Table 4.30: Summary of base year and forecast for swimming pool filling

Swimming Pool filling	Ownership %		Frequency (/h/day)		Volume (l)
	Base Year	Replacement Rate	Base Year	Growth Rate	Base Year
Kielder Unmeasured	2.18	Remain Constant	0.01	Remain Constant	271
Berwick Unmeasured					
Kielder Existing	2.24				
Berwick Existing					

4.9.6 General Use

The general use category takes into account all other areas of water use within the home and garden. For each household group a constant figure has been used over the planning horizon. General use has been split into the following areas of water use:

- Plumbing losses
- Other internal use (DIY, children's play, steam irons, house plants, washing paint brushes etc)
- Animals (Water used for drinking, washing and cleaning cages etc)
- Cleaning
- Drinking (Including filling kettles)
- Food prep / cooking
- Running tap (Running tap till hot/cold)
- Hot tubs and water softeners

For each component the assumptions have been built up from ownership, frequency of use and volume assumptions. The resulting figures are shown in table 4.32 below.

In determining these figures the normalised base year total PCCs to achieve a balance was taken into account. No additional allowance has been made for new appliances or for activities not mentioned above. It is assumed that these are accommodated within the uncertainty of the above assumptions.

Table 4.31: Summary of base year and forecast for general use

General Use	Kielder Unmeasured l/hd/d	Berwick Unmeasured l/hd/d	Kielder Existing l/hd/d	Berwick Existing l/hd/d
Plumbing losses	1.06	1.08	1.81	1.84
Other internal use	1.75	2.00	1.00	1.00
Animals	0.36	0.36	0.32	0.33
Cleaning	2.32	2.35	1.87	1.67
Drinking	2.00	2.00	2.00	2.00
Food preparation and cooking	1.55	1.56	2.19	2.22
Running taps	1.62	1.60	0.47	0.47
Water Softeners	0.39	0.39	0.06	0.06
Hot Tubs	0.09	0.09	0.11	0.11
Total	11.12	11.39	9.77	8.67

4.9.7 Overall Household Demand

The resulting PCC forecasts show an overall household PCC, for the normal year, reducing steadily over the planning horizon from 141.12 l/h/d in 2016/17 to 125.35 l/h/d in 2059/60.

4.10 Non-Household Demand Forecasts

This section sets out NW's non-household demand forecasts for 2017/18 to 2059/60. These forecasts show actual volumes up to 2016/17 and use NW's non-household demand forecast methodology for 2017/18 and beyond. We set out the methodology NW has used for forecasting its non-household demand and then discuss the forecast results.

Non-potable demand is forecast using the same methodology as potable demand, and we also discuss the forecast demand for this type of water use.

In April 2017 there was a major change to the water industry with the creation of a new non-household water market. This saw the separation of retail activities and the creation of wholesale companies and retail companies.

This means that going forward for the non-household water market the primary 'customers' of Northumbrian Water are the retail companies, who then in turn bill the end user or non-household customer. For simplicity, through this report the term 'customer' will still refer to the end user rather than retail companies.

While these changes to the industry will not affect the demand of water from non-households it does mean that, as a wholesaler, Northumbrian Water will not have responsibility for the primary direct contact with end customers in the same way that it did in the past and that the only information held by Northumbrian Water about end users will be the data that is available within the Central Market Operating System (CMOS).

4.10.1 Methodology

NW has developed its own methodology forecast for non-household demand for the 2020 Water Resource Management Plan and for use in Ofwat's PR19 price control process. This methodology uses trend data based on past actual use by customers to predict a profile of future demand.

4.10.2 Approach

NW's demand forecast methodology is based on a number of assumptions and a formula built on three elements.

NW has split its customer base into two groups by:

- Identified customers who use more than 10,000 cubic metres of water per year and for whom an individual forecast has been generated for each customer; and
- Non-identified customers who use less than 10,000 cubic metres per year for whom an average volume per property is forecast, and their total demand is calculated by multiplying this average by the forecast number of properties.

The key assumptions that NW has made are:

- No new identified customers will open during the forecast period, and no closures will be forecast, unless robust, public domain information is available. Any new customers will fall into the non-identified group of customers;
- In general demand for individual customers remains relatively stable unless there is an expansion or reduction on the customers site, or if they fundamentally change how they use water. These events cannot be predicted and so we cannot make assumptions that these events will happen unless they are already in progress;

- Demand will trend to a flat line over time if there are no changes to water use on site. Recent past data may show a decreasing trend due, for example to water efficiency measures. However forecasting that reduction to continue at the same rate for 40 years is unrealistic. Therefore NW has use a forecast calculation that trends demand to a flat line over time;
- It is extremely difficult to robustly forecast the economic climate 25 years in advance. Therefore NW has not modified NW's forecast for the behaviour of the economy;

Taking into account these key assumptions NW has developed a formula that uses a logarithmic trend to forecast demand. This forecast is based on three sections:

- Trend data
- Step change adjustment
- Economic adjustment

Demand components used in the calculation of household demand are all weighted average demand.

4.10.3 Trend forecast

The past 10 years of actual demand is used to develop a profile of demand based on a logarithmic trend. Using trend data provides a more average look at demand over time, and should provide a central forecast of demand out to the future. Any abnormal demand, such as a single year of high demand caused by leakage, or abnormally low demand as caused by a partial closure, will be smoothed out and will not overly influence the forecasts.

4.10.4 Step change adjustment

Over the past 10 years, some customers may have made a step change in their demand, which means that demand in recent years should have more influence over demand than the demand from 10 years ago. A pure trend analysis will not take full account of this step change, and therefore NW has included a calculation that looks at the difference between demand early in the series of data and demand in the most recent years. The forecast based on the trend is adjusted by this difference, which NW has called the "step change adjustment", to bring the forecast into line with actual demand experienced in the recent past.

4.10.5 Economic adjustment

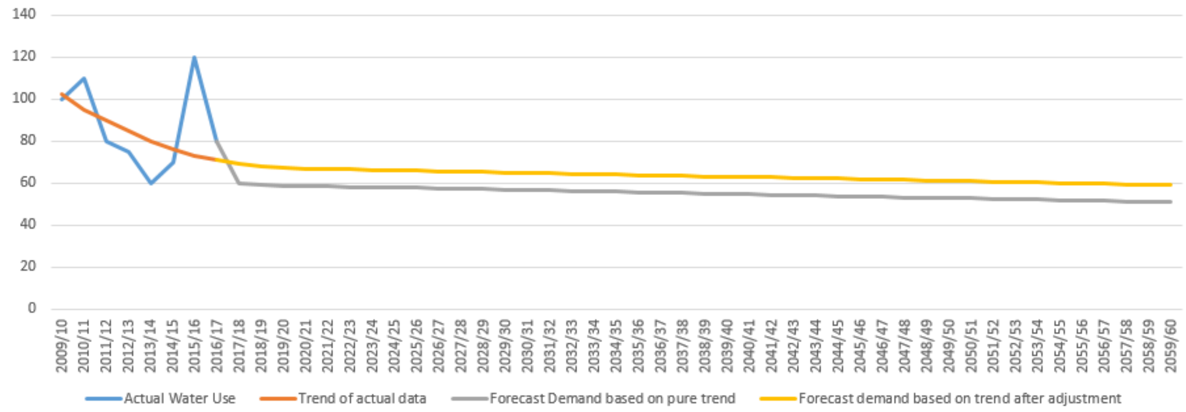
This is a percentage multiplier to be factored in to the trend forecast, which is an assumption that allows us to say whether future demand will be more or less positive than experienced in the past.

NW has currently not applied an adjustment to this element of the formula because we do not believe there is sufficiently robust data available to forecast the economy out into the future. At the most it may be possible to indicate that the next few years may show lower demand than past trend data may indicate, however it is difficult to say by how much. In addition the various forecasts of the economy, for example from HM Treasury, change on a regular basis. We also believe that it is difficult to tie demand for water use to the strength of the economy. Implementation of water efficiency measures can offset any growth, and the opening or closure of one large customer can throw any forecast out of line with expectations. Therefore we prefer to make no adjustment on this basis at this time. We may review NW's position on this adjustment.

Example

Figure 4.10 below illustrates how this demand methodology would predict demand for a customer.

Figure 4.10: Example of demand forecast (yellow line would be used in NW's forecast).



This customer clearly had some abnormal demand in 2015/16. This influences the trend and so purely using the trend forecast would over forecast (for this particular customer). The most recent demand has been lower than the trend would indicate, and so the step change adjustment modifies the forecast downwards for this example customer, although not to the lowest ever demand, but to a position in line with recent demand. The "step change adjustment" would adjust upwards, should recent demand be higher than the trend data indicates.

4.10.6 Application of the methodology

NW's demand forecast applied an individual trend line for each of NW's identified customers. For all of the remaining non-identified customers NW has derived an average demand per property and have applied the same trend approach to the average demand per property. The forecast average per property is then multiplied by the forecast number of non-identified properties to generate a total forecast demand for the non-identified customers.

4.10.7 Non-Household Forecasting

Uncertainty

NW can never predict with certainty what will happen in the future, as has been demonstrated with the change to the economic climate over the past five years. Customers can close at a moment's notice, and as there are no contracts with water customers, they can increase or decrease demand at any time.

While good contact with customers can keep track of general changes, frequently significant changes are commercially sensitive, and are not communicated in advance within NW in question, let alone with external suppliers, such as water companies.

The methodology NW has chosen to use for NW's non-household demand forecast uses the real data NW has available, and combines this with an overall view to result in a reasonable looking forecast. If NW has experienced decreasing demand in recent years, and the economic climate seems to remain generally pessimistic, it seems reasonable to forecast decreasing demand in the next few years. It is unlikely that demand may suddenly surge, unless there is major growth in industry, but it is possible that a slight increase could occur, should the economy recover. On the other hand demand could collapse should current trends continue into the long term. Using a flat trend gives a forecast that arrives somewhere between these two scenarios. In reality, some customers will increase their demand and other will decrease, which in many cases will offset one another.

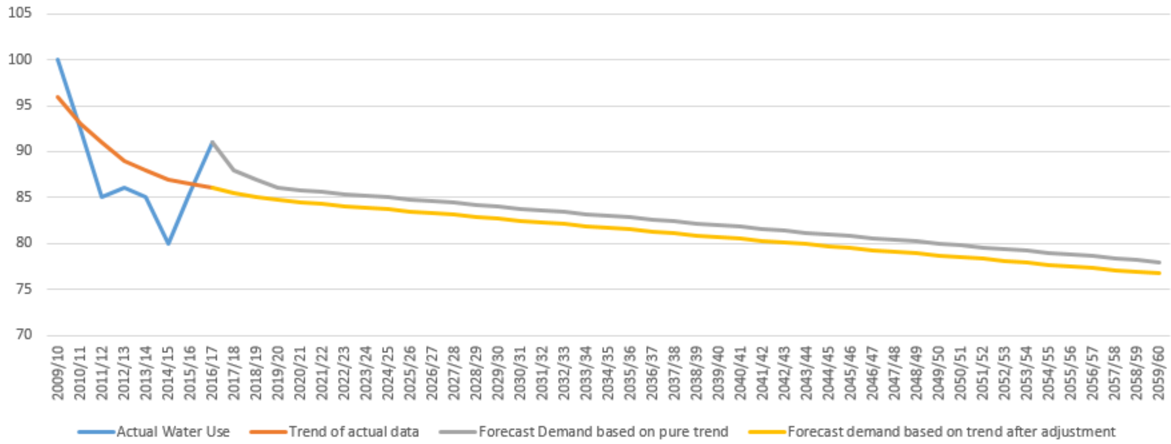
Sensitivity

Different ways of forecasting will produce different forecast volumes. We tested NW's demand forecast based on individual trend forecasts for individual customers against what the forecast would look like in trends based on sector or size were used instead.

These forecasts do not pick up step changes in single customer behaviour, they tend to be smooth. They also incorporate data for properties that have closed, therefore a sector or size trend tends to be lower than one based on individual trends. Such a trend could be viewed as valid, however it is counter to NW's starting assumption that all existing identified non-household customers will remain open, unless otherwise publicised.

NW's overall demand forecast is most sensitive to assumptions in demand of the largest contributors to demand. These are the assumptions applied to the group of non-identified customers, and the demand profiles of NW's largest customers. The forecasts for NW's largest non-household customers have been reviewed individually to ensure that they take account of the latest information NW has about them, and that their forecast consumption is based on a centrally reasonable estimate. Figure 4.9 below shows how demand for a large customer can be volatile year on year. Using NW's trend based approach ensures that the forecast demand is not based on the peak or lowest demand. In this case NW's recent demand is slightly higher than the trend would indicate so the forecast used is adjusted slightly upwards to by the “step change adjustment” as previously described.

Figure 4.11: Example demand forecast for variable demand at anonymous larger customer.



NW’s forecast would be sensitive to demand for this customer if we used either the 2016/17 peak demand or the lower demand of 2014/15. The trend gives us a clear way to make a decision on where to pitch demand and which can be consistently applied across all customers.

Should we hear that this particular customer is making a step change to their demand, for example by a partial closure in the next year, or maybe that they intend increasing their production line which will increase their demand, we can then build this information into NW’s forecast, by either reducing demand in the year stated for the partial closure, or by increasing demand by overwriting the “step change adjustment” to reflect the expected increase.

Having tested NW’s forecast methodology in several ways, we feel confident that it provides a reasonable forecast that is based on sensible assumptions.

4.10.8 Non-Household Potable Water Demand by Sector

At this stage NW has not analysed demand by Standard Industrial Classification (SIC). This is because NW’s methodology of looking at smaller customers as a group means we do not need to look at different types of smaller customers. Small customer demand is discussed in more detail below.

Each of NW’s larger customers have been allocated to one of ten broad sectors, which have been aimed at grouping their demand into a small set of groups for which drivers of demand should be fairly similar.

Figure 4.12: Non-Household Potable Water Demand by Sector.

	Title	Description	Examples
Small customers	Non-Identified Customers	All customers who use less than 10,000 cubic meters of water per year.	
Large customers	Heavy Industry		Mining, oil refinery, car manufacturers
	General Manufacturing	All industry that produces something physical	
	Food & Drink	Food and drink manufacturers	
	Utility	All utilities.	Power stations, water services, water and sewerage companies.
	Public Sector	Organisations which are mostly funded by government and will be affected by the public finances.	Hospitals, schools, councils, prisons, police, fire services etc.
	Retail	Anything that sells to the general public.	Shopping centres and supermarkets.
	Leisure	All customers who are part of providing leisure and holiday activities to the general public.	Hotels, holiday parks, sports clubs.
	Agriculture		Farms, Dairies, etc
	Services	General service industries	Finance, insurance etc.
	Teesside	A small group of large industrial customers on Teesside.	

4.10.9 Defined industrial sectors

Figure 4.13 below illustrate the proportion of demand in each region from each of the sectors defined above. Small customers who use less than 10,000 cubic meters per year make up approximately 45% of all demand.

Figure 4.13: Make up of non-household demand in the North East in 2016/17

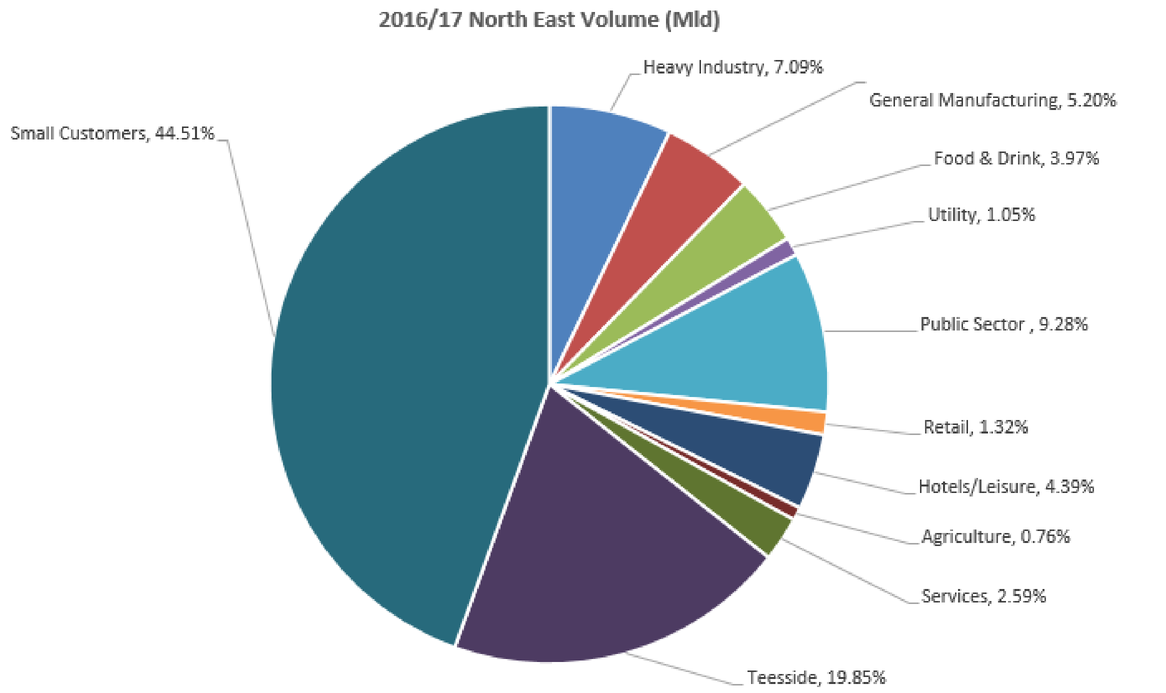
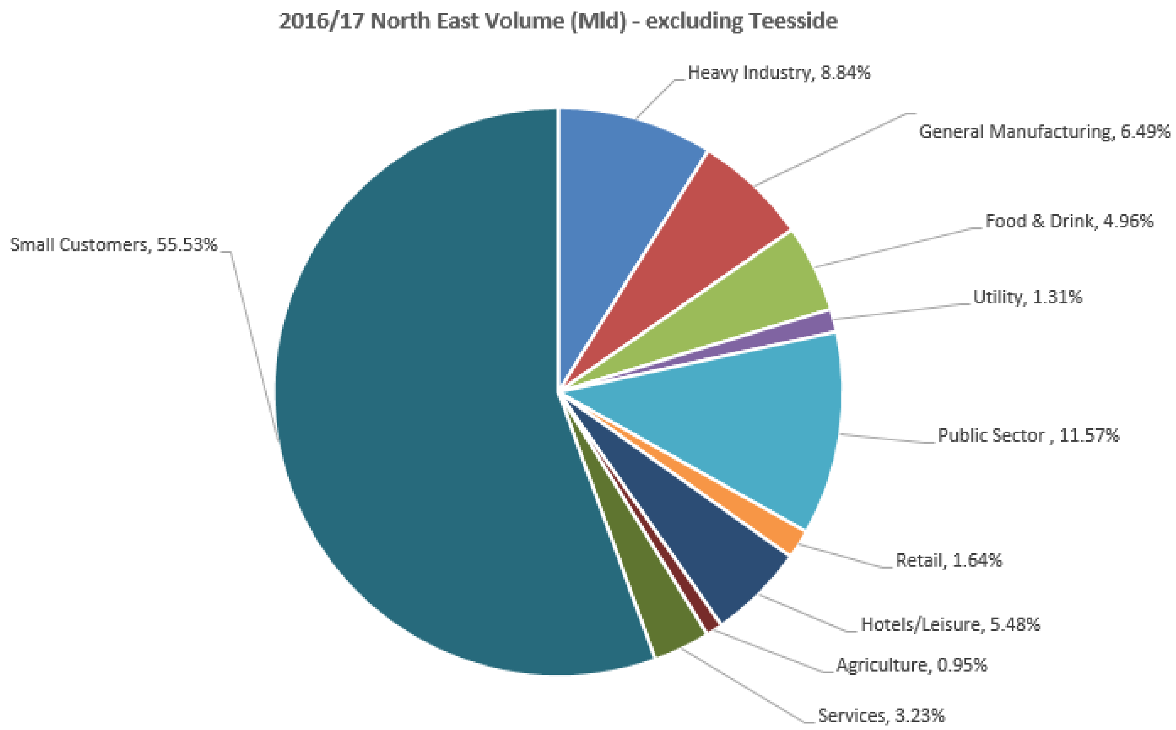


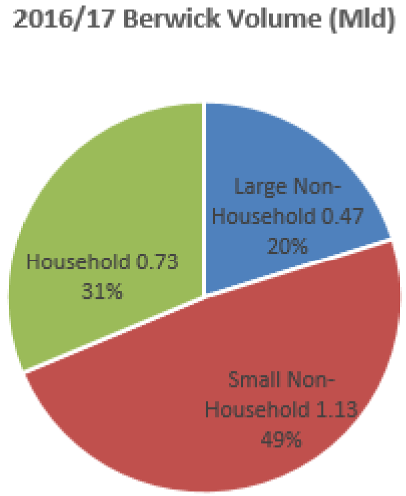
Figure 4.14: Make up of non-household demand in the North East in 2016/17, excluding Teesside.

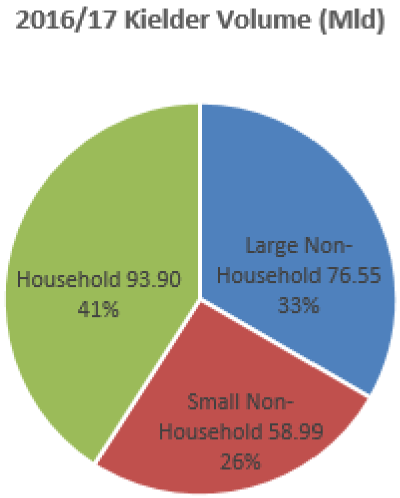


In the North East NW has identified a sector of customers as “Teesside” as show in figure 4.11 above. This is a group of very large industrial customers based in a small area of Teesside, some of whom are dependent on one another to survive, and who have a significant impact on the overall demand in the North East, at about 20%.

4.10.10 Demand by Water Resource Zone (WRZ)

Figure 4.15: Breakdown of measured demand in North East Water Resource Zones for 2016/17.



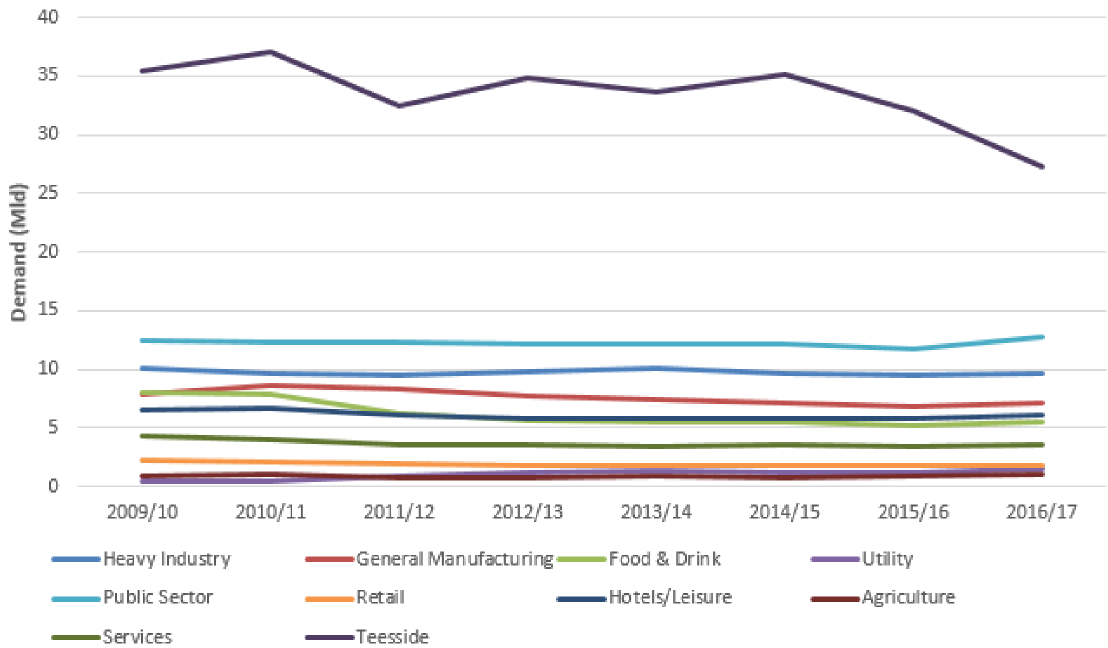


Comparing the two WRZ as in Figure 4.15 above shows that small non-household demand is a large proportion of the Berwick zone demand, whereas in the Kielder zone, household demand makes up the largest proportion of measured demand.

4.10.11 Large Customer Historical Demand

Historically non-household demand has been quite stable, other than for closures of properties as illustrated in Figure 4.16 below. Only demand from Heavy industry has been reducing, which is due to a mixture of customer closures and reducing usage.

Figure 4.16: Large Non-Household demand 2009/10 - 2016/17 - changes in volumes

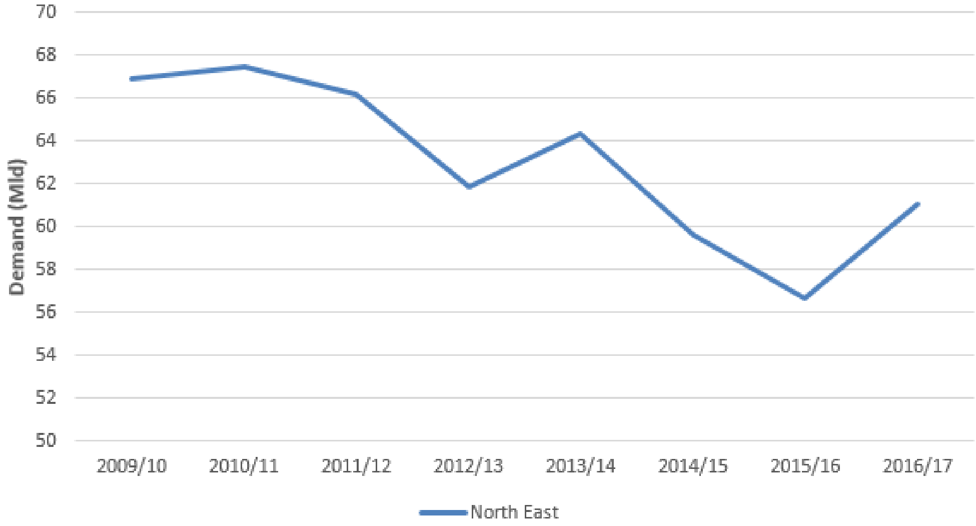


Demand in all sectors is now lower than it was in 2009/10, other than utility and public sector. The significant growth in the utility sector is due to a single large customer who has opened in 2010/11 and proportionately uses most of the water in the utility sector. The largest proportional reduction in demand can be seen in Teesside, which is largely due to one large customer closure.

4.10.12 Small customer historic demand

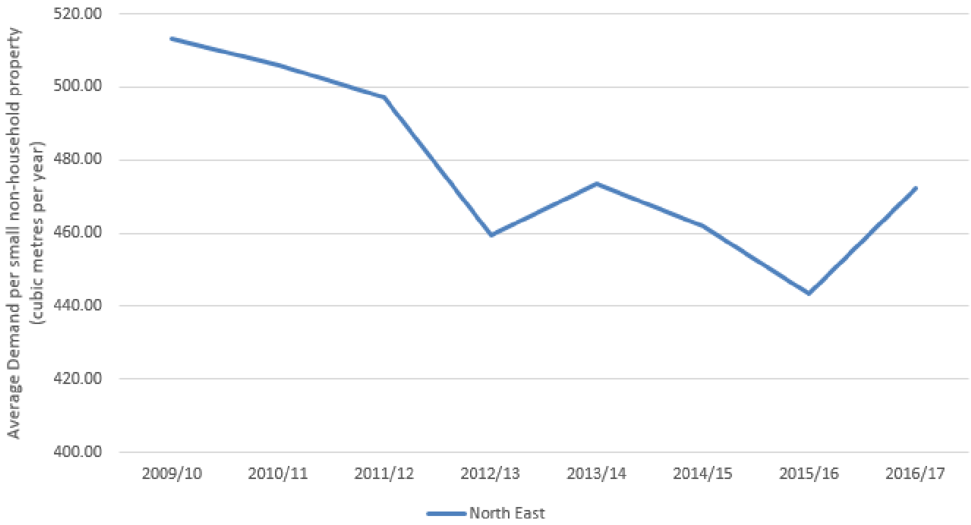
Since 2009/10 there has been a clear reduction in demand from smaller non-household customers, as shown in Figure 4.17 below, which we believe will be permanent.

Figure 4.17: Historic small non-household demand.



This reduction in demand is also reflected in the average demand per property, which is illustrated in Figure 4.18 below. The most significant change can be seen between 203/14 and 2015/16, where demand fell, however demand then increased in 2016/17.

Figure 4.18: Historic small non-household demand.



It is not possible to exactly determine the cause of the change from stable demand to reducing demand and then back to an increased demand, however given that it has occurred a couple of years after the economic climate changed in 2008 and after the harsh winter of 2010, we would suggest that this reduction is a combination of customers finding and repairing leaks, and more attention being paid to water usage.

As such we would expect the lower demand average demand per property to continue into the future.

While the reduction in average demand per property seems relatively small, accumulated over all small non-household properties this can add up to a significant change in total demand.

4.10.13 Forecast Demand

Overall measured non-household forecast demand to 2060 is relatively flat. This is due to the assumption built into NW's forecast that individual customer demand will trend to a flat line over time. In the short term the forecast shows reducing demand compared to recent years, and there is some question about when this is likely to flatten out. Given the current views of government and HM Treasury, that the UK economy is likely to continue as it is for the next 3 to 5 years, the flattening of demand within this timescale seems reasonable. See Figure 4.19 below.

We do not believe that demand is likely to suddenly begin increasing again, unless new large water users open. NW's forecasts do not assume that this will happen because assuming new demand is uncertain until the new site actually starts operation.

Figure 4.19: Forecast demand in the North East by sector - volumes are cumulative, so the gap between each line is the size of each sector.

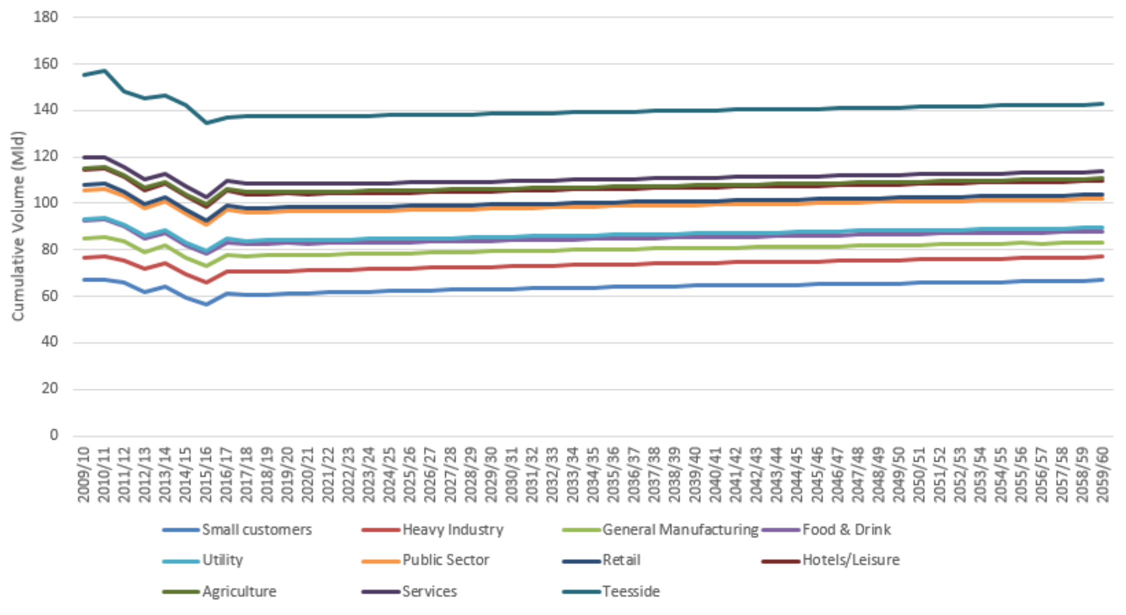
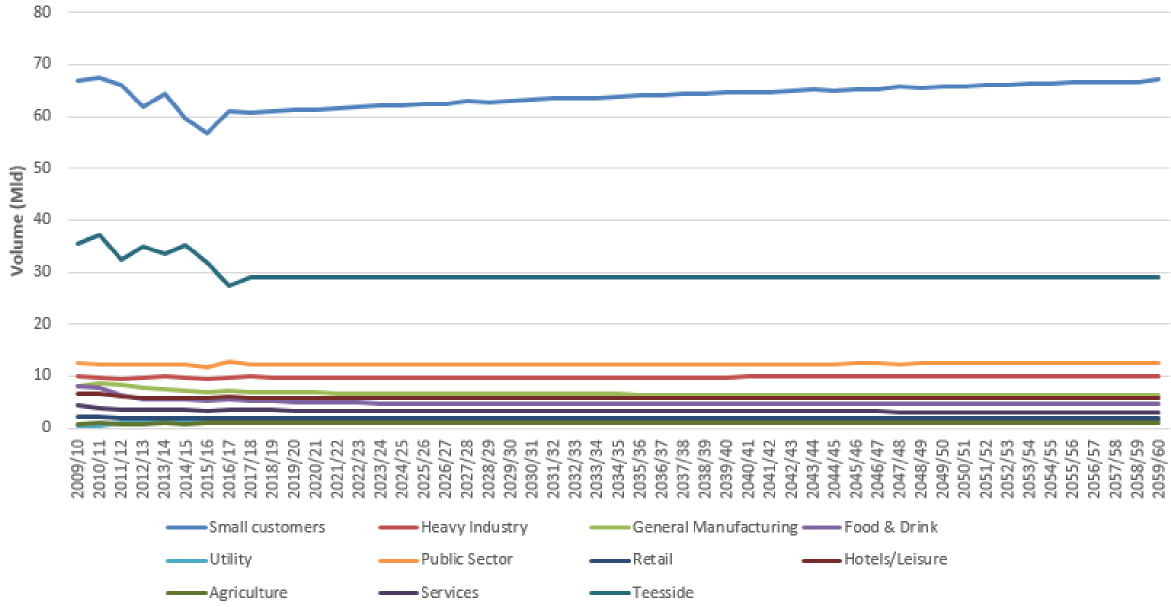


Table 4.32: Change in measured non-household demand by sector between 2016/17 and 2059/60.

Sector	Demand (Ml/d)		Change (Ml/d)	% Change	Notes
	2016/17	2059/60			
Small Customers	61.0	67.0	6.0	9.8%	
Heavy Industry	9.7	10.0	0.3	3.1%	
General Manufacturing	7.1	6.3	-0.8	-11.3%	
Food and Drink	5.5	4.7	-0.8	-14.5%	
Utility	1.4	1.7	0.3	21.4%	Increase is due to 2 large customers with increasing consumption
Public Sector	12.7	12.4	-0.3	-2.4%	
Retail	1.8	1.7	-0.1	-5.6%	
Hotels/Leisure	6.0	5.9	-0.1	-1.7%	
Agriculture	1.0	1.0	0	0%	
Services	3.6	3.1	-0.5	-13.9%	
Teesside	27.2	28.9	1.7	6.3%	
Total	137.0	142.7	5.7	4.2%	

The largest areas of change in forecast demand are due to expected growth of smaller non-households as shown in Table 4.32 above and Figure 4.20 below. Other changes in the forecast demand is a result of the trends of each individual customer, and where the sector trend is decreasing this will be because more individual customer demands have decreasing trends than increasing, and vice versa.

Figure 4.20: Forecast demand in the North East by sector.



4.10.14 Non-potable demand

In the north east we supply a significant volume of non-potable water to a small group of customers on Teesside. To forecast demand for this non-potable water NW has applied exactly the same methodology as applied for the potable water. A trend, based on non-potable demand, has been generated for each of these customers, and used to forecast demand into the future. As each of these customers are large, changes from any one customer can significantly affect the forecast. Nevertheless NW has used the same principles as the potable forecast, and have only forecast a change to a customer's demand where it is based on robust, public domain information.

4.11 Total Normal Year Baseline Demand Forecasts

The total baseline demand forecast is comprised of the elements described in the preceding sections and the demand management described in section five.

4.12 Defining Dry Year Factors

The historic record of weather versus demand has been examined to identify conditions of a dry year and the weighted average number of dry years expected has been calculated for Northumbrian Water.

4.12.1 Background Information

A dry year definition is required when a company decision is to be made for the June Return submission to Ofwat stating that the weather experienced during the period of the return has been a dry year or not. Simple criteria will be selected based on average maximum temperature and total rainfall for the return year. The supply and demand should be forecast under a dry year scenario reassuring people and organisations that the actions they will take under a dry year scenario will meet their expected level of service.

Guidelines from the Agency, Ofwat and NERA state that a dry year should be the basis of the demand planning process, however there appears to be no distinct, precise definition of the characteristics of a dry year. This definition is problematic to apply as the introduction of demand restrictions is more commonly linked to water resource availability resulting from weather conditions over a prolonged period, usually a previous year.

A weighted average demand forecast is required as the basis of the company's revenue forecast[31]. In the planning horizon not all years will turn out to be 'dry'. Typically the demand a company is most likely to be faced with will be a combination of demand from 'normal' years, 'dry' years or 'wet' years[31]. The frequency of each type of year in the planning horizon and the demand associated with these types of years will be reflected in the weighted average forecast.

4.12.2 Objectives

- To review the dry year definitions available.
- To examine the relationship between weather and demand and identify years of specific interest due to unusual weather and demand patterns with the peak summer period (June-September) being examined in greater detail.
- To compare rainfall with the 10 and 30 year long-term averages and maximum temperature compared to the 10 year and 30 year long-term means for the identified years of specific interest.
- To identify the dry years that have occurred in the Northumbrian Water supply regions in the past 25 years as determined by the annual number of days greater than 25^{o}C and yearly cumulative rainfall.
- To determine the weighted average number of dry years which may occur in a 10 year period for Northumbrian Water.

4.12.3 Dry Year Definitions

Agency

The Agency state the definition of a dry year (household) is, "a period of low rainfall and unconstrained demand" (the Agency, 2007a). In the Agency report "a scenario approach to demand forecasting' (the Agency, 2001), 1995 is assumed to represent a dry year.

[31] Water Resource Planning Guideline, (2012), the Agency, Ofwat, Defra, Welsh government.

The WRPG (the Agency, Ofwat, Defra, Welsh Government, 2012) states a water company should analyse historical supply and climate data to set out the dry year demand as a continuous profile over a year at monthly or weekly intervals. The term 'dry year' is defined as a period of unconstrained demand and low rainfall.

Ofwat

Ofwat stated in their Business Plan Guidelines (Ofwat, 1998) that "Companies should describe in the commentary of their Business Plan the relationship between expected demand in a year with normal weather and expected demand in a dry year.

Where a company has provided the Agency with a demand and supply forecast based on its critical period (assumed to be peak week unless otherwise stated), they should focus on key milestone planning years e.g. 2002-2003 and 2007-2008." (Part D, D8, Business Plan Guidelines).

NERA

NERA (UKWIR/the Agency, 2002) state, "there is no universally accepted standard specifying the increase and decreases in demand associated with dry and wet conditions. In the absence of a standard, forecasts of weather related variations in demand should have an empirical justification, for example, they might be based on an historical analysis of demand and relevant weather variables, or demand given weather conditions that occur '1 in x' years."

Guidelines state, "the characterisation of supply e.g. during a wet/dry/normal year, is a simplification of reality. The distribution of supply is not necessarily such that a dry year implies the lowest deployable output. Instead, there could be effects that carry over from one year to a next, so that deployable output in a normal year could be low as a result of the preceding year being dry, or it could be reduced in an extremely wet year due to turbidity disabling sources."

NERA (UKWIR/the Agency, 2002) also state, "any given year could be categorised as wet, normal or dry, although there is an infinite number of possibilities ranging from the very wettest to the very driest years possible. For any given 'type' of year, say a dry year, there is a distribution of possible yields around the expected value. Thus, it would be possible to say that dry year yield is 120Ml/d with 95% confidence, but only 110Ml/d with 98% confidence, for example. Furthermore, for each 'type' of year, normal, wet or dry, there is a distribution of possible demand outcomes around the expected value, with this distribution driven by stochastic processes. In addition, over a number of years climate change will also influence demand."

Stage 1 of the NERA guidelines suggests that, "planners collect supply and demand detail for a range of weather conditions and for a number of critical periods. Critical periods are when there is the greatest stress on the ability of the water supply system to meet demands. Critical periods may be driven by peaks in demand, by troughs in deployable output, or by a combination of the two."

4.12.4 Methodology and limitations

Weather data for NW was acquired from the Met Office weather stations, mainly Durham. NW operates over a large area and as such the use of a mixed source of data would be the main limitation for this information as this may not deliver a correct and sufficient level of detail. However it must be assumed that these measurements are representative of the region as a whole although there will be small regional differences. Demand information, in the form of daily distribution input for NW was obtained and imported into spreadsheets for analysis.

The period of analysis chosen was 1995-2016. This period would be affected by changes in conditions that have occurred over the last 10 years, such as increases in metering and improved leakage controls. Key years of interest that comprise of dry year conditions were identified from analysis of weather data. The summaries of weather data for these years of specific interest were collated and a number of graphs were prepared as a basis for identifying patterns in demand and weather.

Specific Years of Interest

The weather and demand data for the period 1995-2016 was carefully studied and a number of years identified for further comparisons. The weather summaries for these years are shown below as taken from the Met Office yearly summaries.

Weather Summaries

1990: A very warm and dry year. Rainfall totals from the period since early March being one third of the average. The first four days in August saw a degree of high temperatures that exceeded any other hot spell in the 20th century with 3rd seeing the hottest temperatures on record.

1995: The hottest summer since 1976, one of the warmest years on record and one of the driest years since 1976.

1996: The driest year on record since records began in 1943.

2003: Very warm year with a mean maximum air temperature was 12.53^{o}C, 0.43^{o}C above the 1995-2012 average.

2005: Warm and very dry year. This year was at the midpoint of the dry-year spell of 2004-06 where from November 2004 to July 2006.

2006: A warm and dry year with July 2006 as the warmest month on record and 10% less rainfall than the 30 year mean and an exceptionally sunny year in the North East of England as well.

2010: The driest year since 2003. The period between January and June was particularly dry generally the driest period since 1953. However rainfall deficits were reduced by a very wet July and August in the North.

2011: A very warm April and October with record temperatures widely exceeding 25ºC during the heat wave in October.

Figure 4.21: Comparison of Demand, Temperature and Rainfall

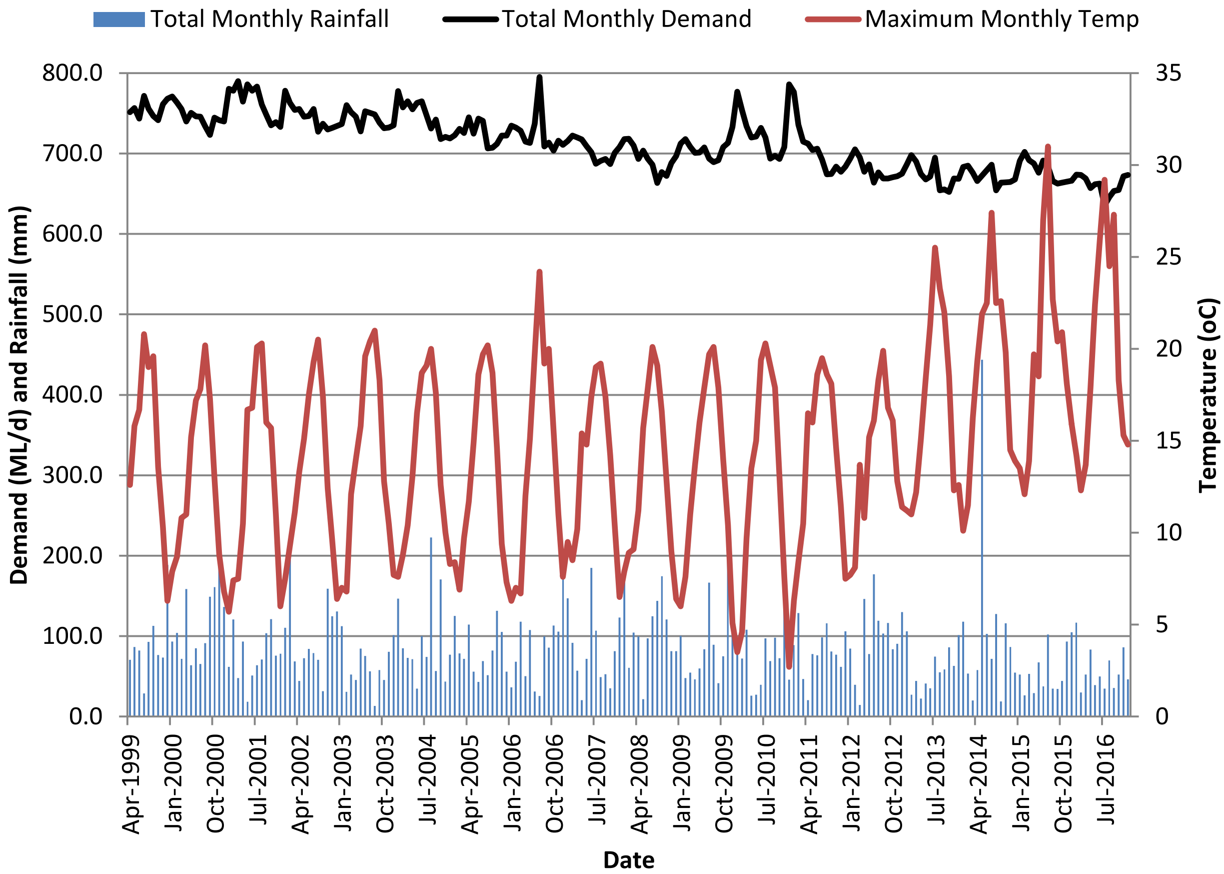
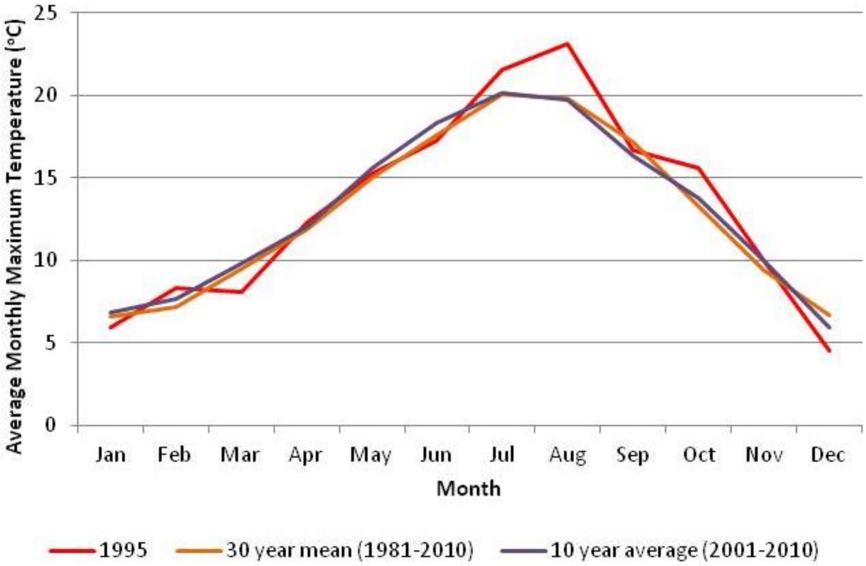


Figure 4.21 shows a comparison of monthly total demand (black), monthly maximum temperature (red) and monthly total rainfall (blue) from 1995 until 2016 for the Northumbrian supply area. Identified periods of interest as determined by a high total demand and maximum temperature combined with a low total rainfall.

Figures 4.22 – 4.31 below summarise the relationships between demand and weather for three of the key specific years of interest; 1995, 2003 and 2006.

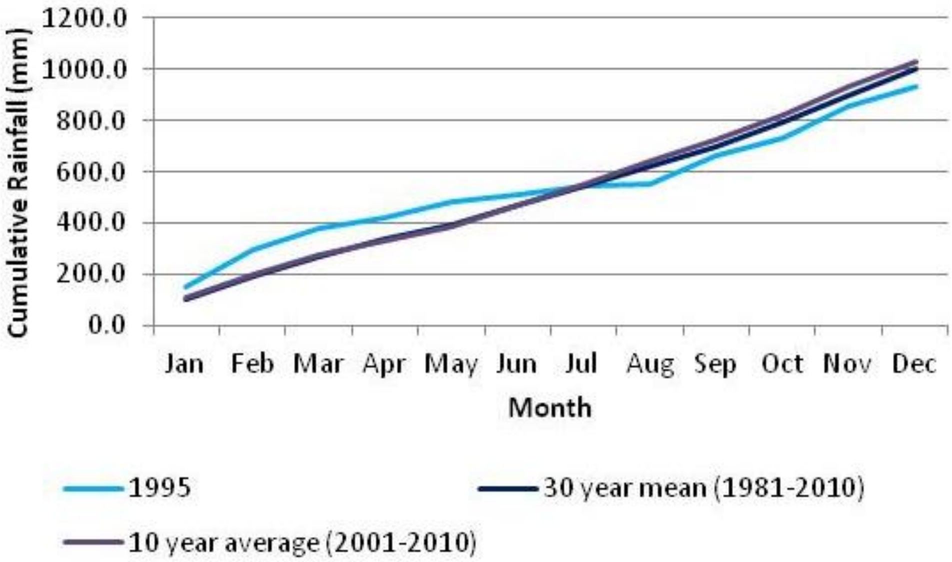
1995:

Figure 4.22: Average Monthly Maximum Temperature



The average monthly temperature for 1995 compared to the 30 year and 10 year means. It shows 1995 temperatures where higher than average for the summer peak period.

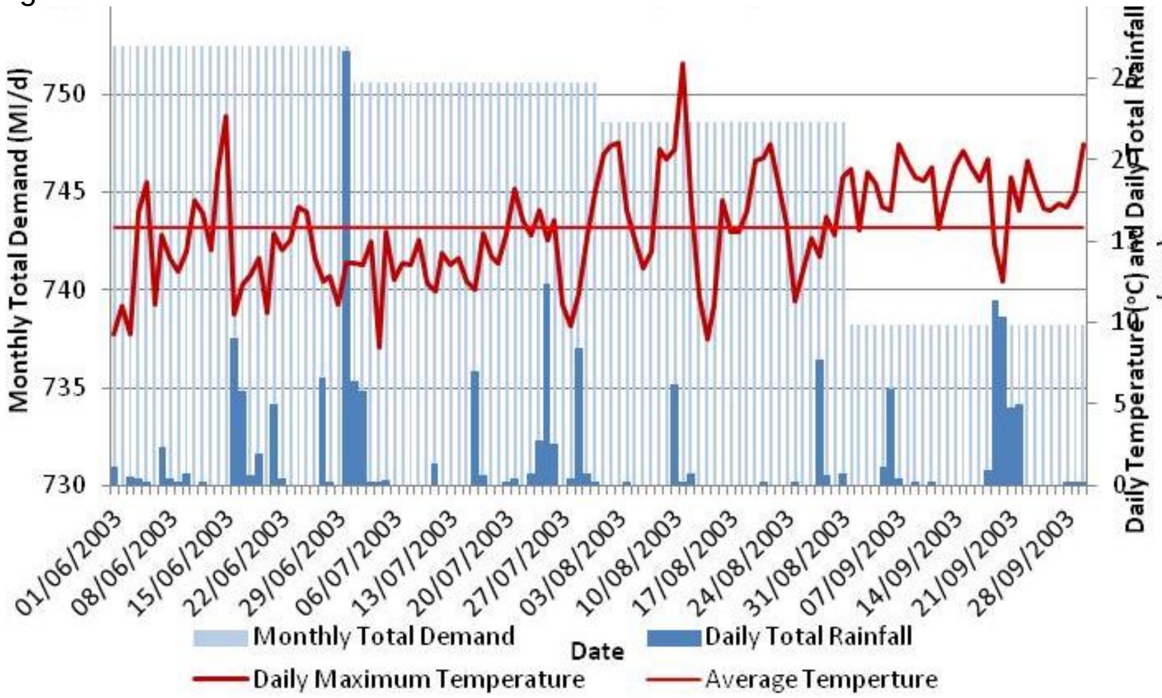
Figure 4.23: Cumulative Monthly Rainfall



The cumulative monthly rainfall for 1995 compared to the 30 year and 10 year means. The graph demonstrates that the rainfall for 1995 is greater than the mean at the beginning of the year and close to the average monthly rainfall for the remainder of the year.

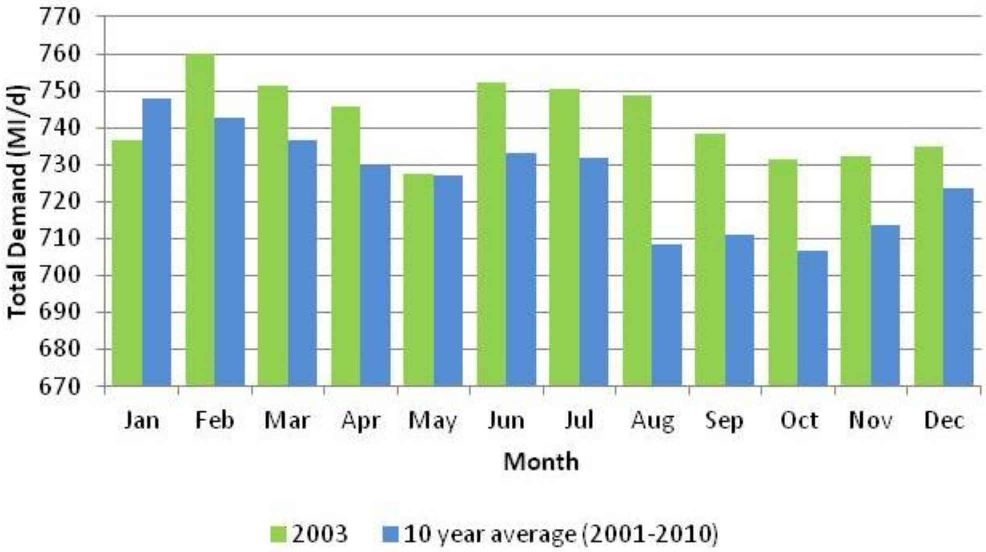
2003:

Figure 4.24: Peak Demand



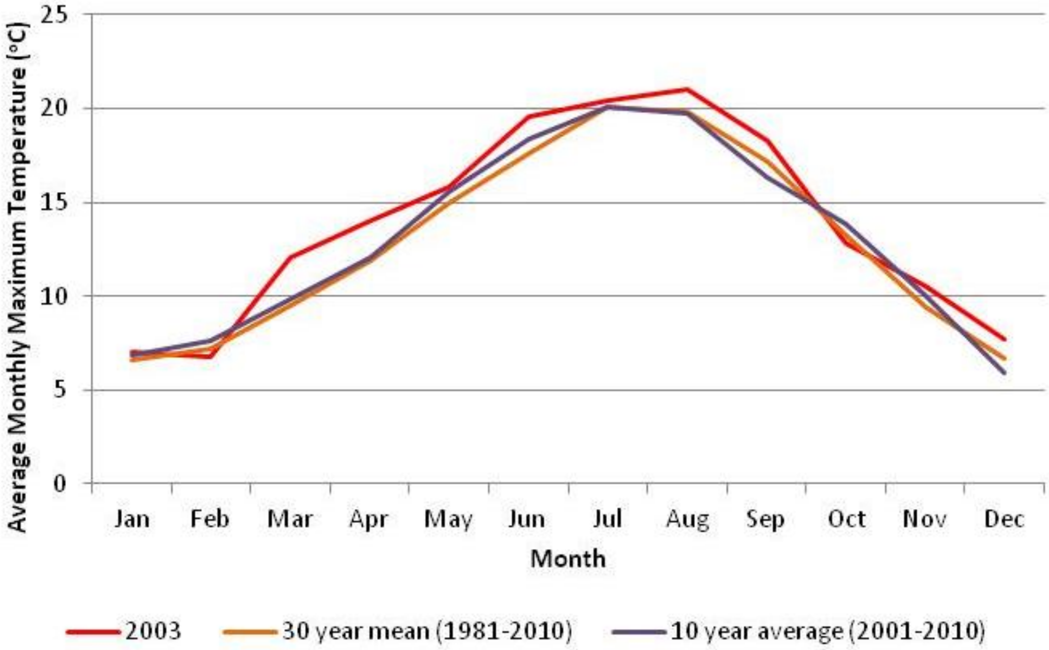
Peak period demand compared to maximum daily temperature and total daily rainfall for 2003.

Figure 4.25: Average Monthly DI



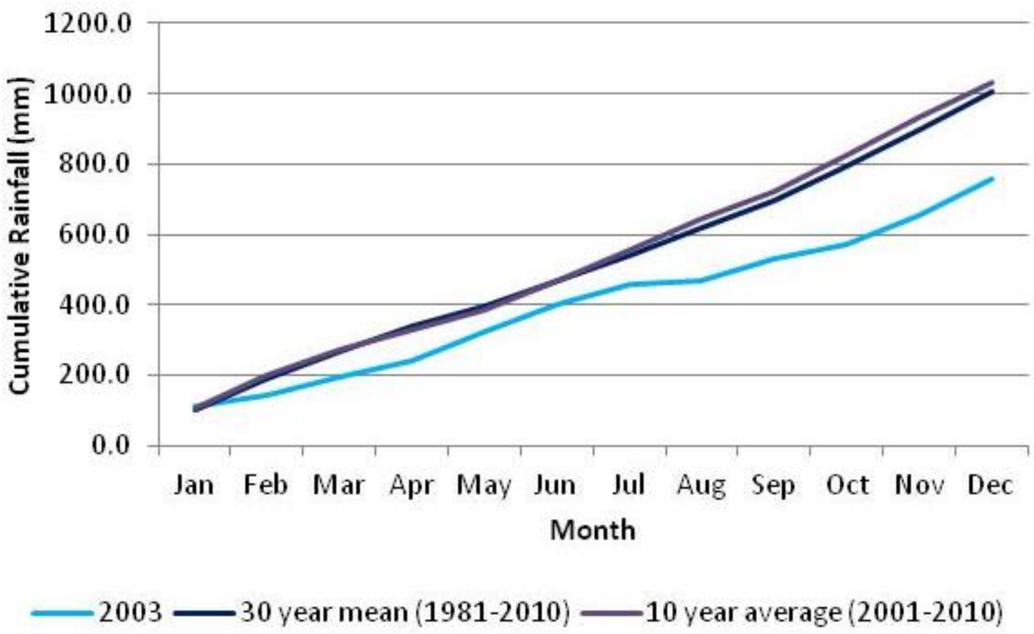
2003 total demand compared to the 10 year average. For 10 months of the year the 2003 demand is higher than the 10 year average.

Figure 4.26: Average Monthly Maximum Temperature



The average monthly temperature for 2003 compared to the 30 year and 10 year means. It shows 2003 temperatures where higher than the 30 year and 10 year means over the peak summer period.

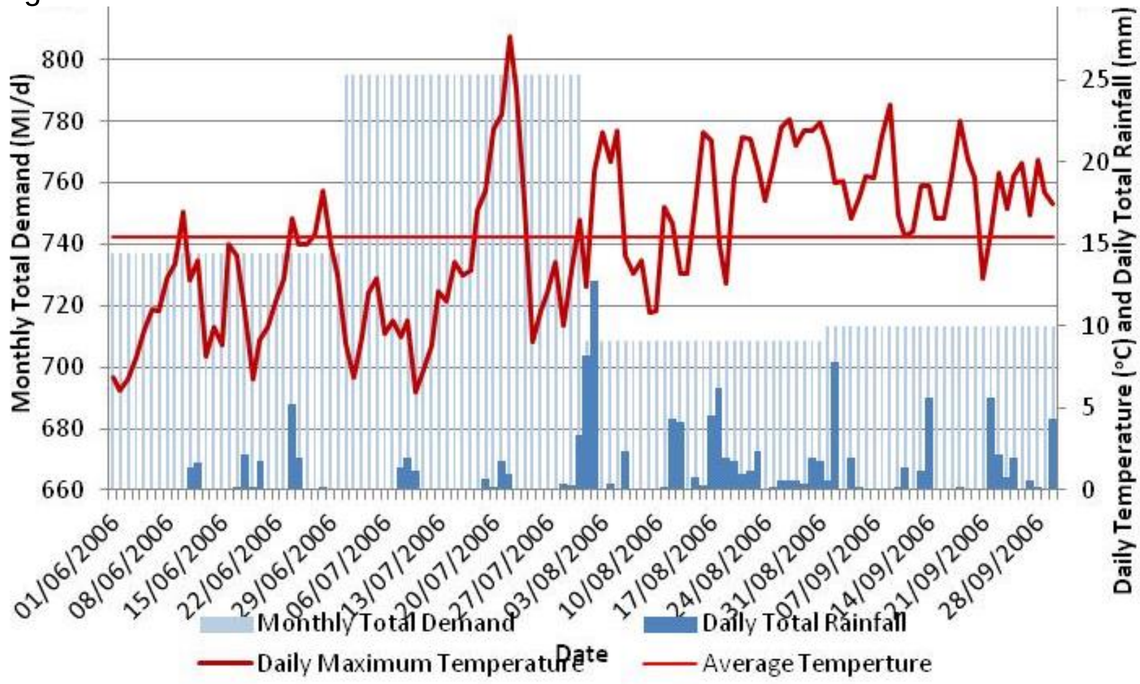
Figure 4.27: Cumulative Monthly Rainfall



The cumulative monthly rainfall for 2003 compared to the 30 year and 10 year means. The graph shows clearly that rainfall for this year was much lower than the average.

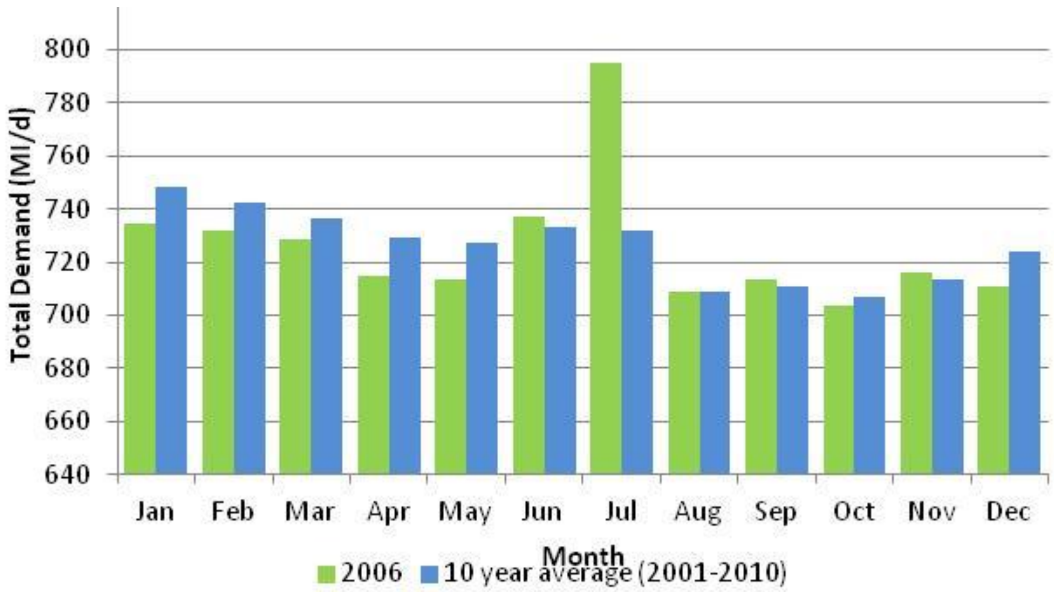
2006:

Figure 4.28: Peak Demand



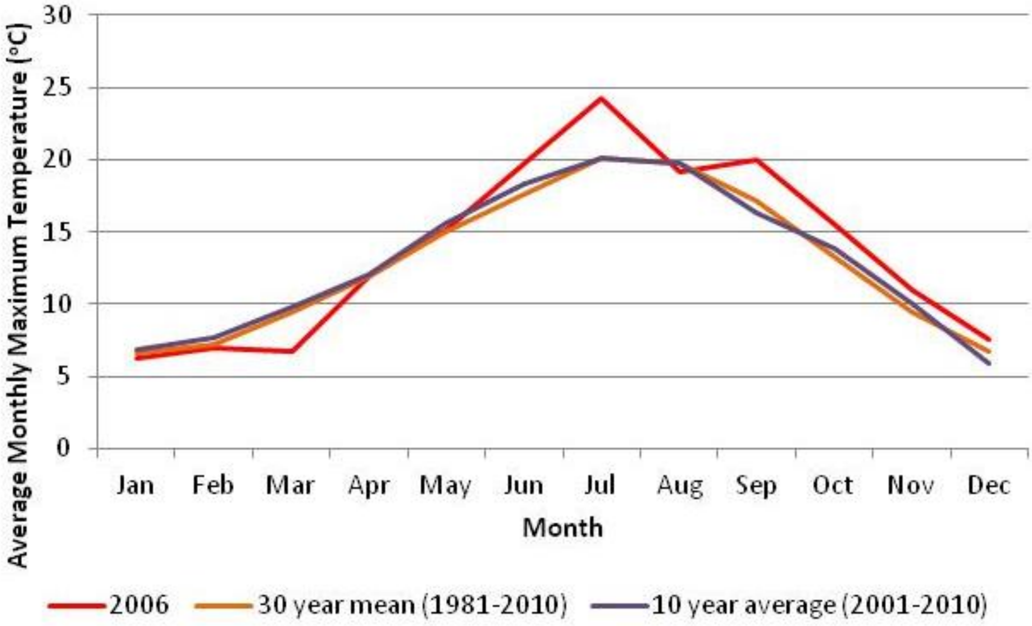
Peak period demand compared to maximum daily temperature and total daily rainfall for 2006.

Figure 4.29: Average Monthly DI



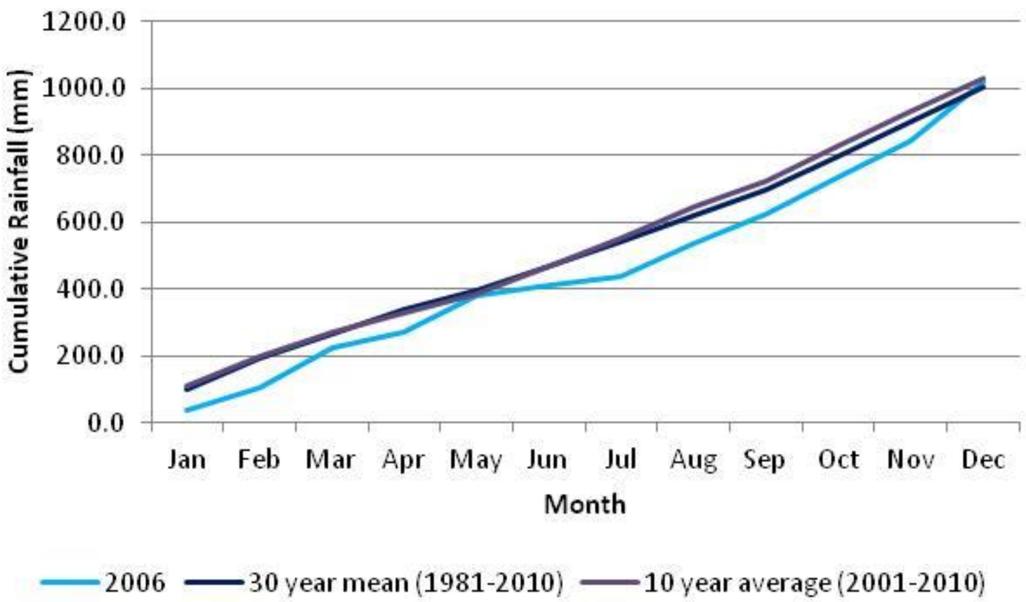
2006 total demand compared to the 10 year average whereby 2006 demand tends to be slightly lower than the 10 year average demand apart from the month of July where demand is much higher.

Figure 4.30: Average Monthly Maximum Temperature



The average monthly temperature for 2006 compared to the 30 year and 10 year means. Average monthly temperature increases considerably in the months of June and July and stays above the 30 year mean for the rest of the year.

Figure 4.31: Cumulative Monthly Rainfall



The cumulative monthly rainfall for 2006 compared to the 30 year and 10 year means. For eight months of the year cumulative rainfall stays below both 30 year and 10 year means.

4.12.5 Data Results

By undertaking analysis of the patterns in weather and demand data for the specific years of interest in NW, the following summary of the results for each these years are given.

1995: Across the country 1995 was classed as one of the warmest and driest years since 1976. Low rainfall and high temperatures occurred over the summer peak period. Summer temperatures were on average 1.03oC higher than the 10 year mean (2001-2010) and cumulative rainfall for 1995 was 96mm less than the 10 year cumulative average.

1996: Cumulative rainfall was 153mm lower than the 30 year cumulative mean (1981-2010). Out of the eight specific years of interest, 1996 is classed as the second driest. Temperatures for this year were close to the 10 and 30 year means.

2003: The annual cumulative rainfall is the lowest recorded from the specific years of interest at 755.6mm, 73% of the 10 year average (2001-2010). Temperatures were seen to be above average for most of the year. The highest temperature of 30oC was experienced on the 16th September. For ten months of the year the average monthly total demand is higher than the 10 year average.

2005: This year was at the mid-point of the dry-year spell of 2004-06 where from November 2004 to July 2006. Total demand is variable for 2005 with the months April, June and July showing the highest demand. Both temperature and rainfall matched closely to the 10 and 30 year averages.

2006: July 2006 was the warmest month on record with the average maximum temperature reaching 24.2oC for the month, 4.1oC higher than the 30 year mean (1981-2010). Average total demand peaked this month for the year and was 8% higher than the 10 year average (2001-2010). However the rest of the peak demand period saw an average total demand that was less than the 10 year average. Cumulative monthly rainfall was below the 10 and 30 year averages for the year.

2010: For most of the year rainfall was less than the 10 year and 30 year average however rainfall deficits were reduced by a very wet August. Temperatures remained closed to the 10 and 30 year averages with small peaks in April and June. Total demand was found to be below average to most months, except the winter months of January, February and December where demand was significantly higher than the 10 year average.

2011: Temperatures in 2011 were above the mean in the spring and autumn with the average maximum temperature in April 39% higher than the 30 year mean. 2011 total demand was below average for most of the year with the exception of January which was 3.9% higher than the 10 year average for that month. Rainfall for the year matched very closely to the 10 and 30 year means.

4.12.6 Data Analysis

In developing a dry year definition it is important that the approach should combine the summer demands with the all year round weather conditions. A simple approach was decided upon where the number of days in a year where the temperature rose above 25oC was compared to the cumulative rainfall for that year.

Table 4.33 below indicates the number of days where the maximum daily temperature exceeds 25oC and the annual cumulative rainfall for the years 1987-2016 in Northumbrian Water.

The axes of the quadrant are drawn to include the dry years experienced in the 25 year historic record. Once constructed to account for the dry years, the days of temperature above 25oC and rainfall allow the other year's to fall into the appropriate section of the quadrant. Whilst the choice of number of days over 25oC and rainfall below 1025mm is pragmatically selected, use of these criteria does then aid in making the selection of dry, wet or normal years far more objective than the previous subjective judgements that were made.

The number of days greater than 25^{o}C and the annual cumulative rainfall for the years 1987-2016 in NW supply area. Highlighted values in red show those rainfall and temperature values that are above the thresholds for dry year (>19 days above 25oC and <1025mm rainfall). Dry years are highlighted in yellow.

Table 4.33: Number of days where the maximum daily temperature exceeds 25^{o}C and annual cumulative rainfall

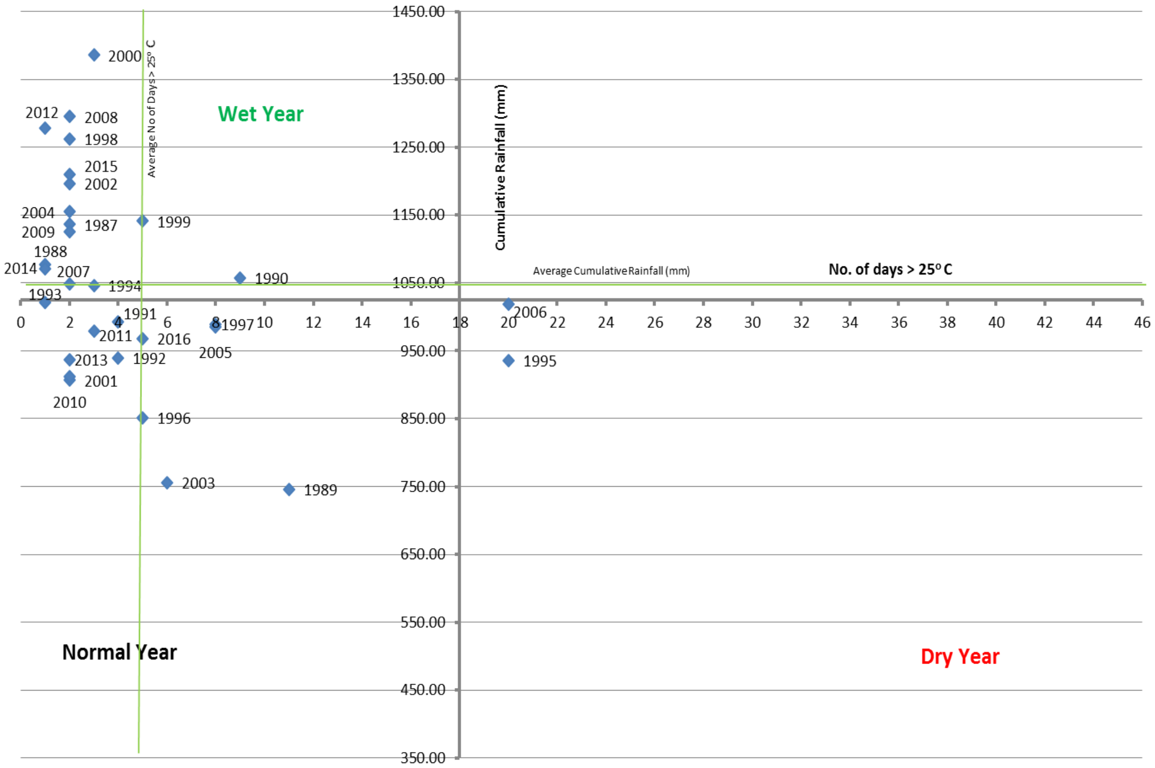
Year	No. of days > 25oC	Total Rainfall Jan-Dec (mm)
1987	2	1136.26
1988	1	1077.23
1989	11	745.79
1990	9	1057.59
1991	4	992.18
1992	4	939.39
1993	1	1071.07
1994	3	1046.26
1995	20	935.91
1996	5	851.16
1997	8	989.40
1998	2	1261.89
1999	5	1141.09
2000	3	1385.90
2001	2	906.68
2002	2	1196.59
2003	6	755.57
2004	2	1154.75
2005	8	985.07

Year	No. of days > 25oC	Total Rainfall Jan-Dec (mm)
2006	20	1018.75
2007	1	1021.17
2008	2	1295.08
2009	2	1125.71
2010	2	912.21
2011	3	978.68
2012	1	1278.30
2013	2	936.90
2014	2	1048.80
2015	2	1209.60
2016	5	967.90

Graphic representation of this data shows that the position of the year in a specific quadrant defines the year as either a wet, normal or dry year as shown in the figure below. The quadrants for the graph were drawn where the number of days greater than 25^{o}C equalled 19 as this is regarded as a significantly higher than average number of warm days, and secondly that cumulative rainfall equalled 1025mm, as rainfall less than 1025mm would be considered as on the dry side of the average year in the Northumbrian Water supply region. Thus the ‘dry’ quadrant would be where the number of days greater than 25^{o}C exceeded 19 and the cumulative rainfall was below 1025mm and years placed within this quadrant would be defined as ‘dry years’.

The results from this graphic representation approach show that the two years defined as dry years are 1995 and 2006 in NW region.

Figure 4.32: Days greater than 25ºC against cumulative rainfall.



The annual number of days greater than 25ºC and the annual cumulative rainfall for the years 1987-2016 in the Northumbrian region. The green lines indicate the average temperature and cumulative rainfall for the period 1987-2016. The axes indicate the split in quadrants which are named either 'wet', 'normal' or 'dry' according to the likely conditions experienced. The graph shows that the years 1995 and 2006 are classed as dry years under this approach.

4.12.7 Summary

Various statistical analyses are available to apply to weather data to clearly define the weather conditions for a particular year or seasons of that year but there seems to be no universally accepted method to employ.

The decision to take into account the two variables of cumulative rainfall and number of days with maximum temperatures greater than 25ºC offers a very simplistic but effective approach.

4.13 Dry Year Baseline Forecasts

The increases (from Normal Year to Dry Year) assumed for a Dry Year were applied to unmeasured and measured per capita consumptions, plus an increase for non-household consumption and leakage. These increases were reviewed in 2008 and it is now considered that only household demand is likely to increase in a Dry Year, The household increases were based on analysis of the demands in 1995/96 and were modified for PR09 to take account of the changes to the base demands arising from metering.

The previous additional PCC has been applied to the 2006/7 populations to provide an estimate of the 1995/96 based Dry Year forecast for 2006/7. It is expected that as metering has increased, the current and future Dry Year impact on unmeasured households will have increased and the impact on measured households will have decreased.
This is because the measured households are increasingly composed on meter optants, who are low users of water and selectively metered customers who will be seeking to restrain their bills. The remaining unmeasured households will have a strong element of customers who have deliberately chosen not to opt for a meter, and are high users.

The increases have been calculated as follows:

Previous increase in measured PCC x 2006/7 measured population = 95/96 based additional Dry Year Measured Consumption for 2006/7

Previous increase in unmeasured PCC x 2006/7 unmeasured population = 95/96 based additional Dry Year Unmeasured Consumption for 2006/7

Sum the above to give Total 95/96 based additional Dry Year Consumption for 2006/7.

Unmeasured Population x Revised PCC increase = 2006/7 rebased Dry Year Unmeasured Consumption

2006/7 rebased Dry Year Unmeasured Consumption - Total 95/96 based additional Dry Year Consumption for 2006/7, divided by Measured population gives 2006/7 rebased Dry Year Measured Consumption. Results are shown in table 4.36.

Table 4.34: Increases in PCC

	Unmeas PCC l/hd/d	Meas PCC l/hd/d
NW	3.1	1.24

5. BASELINE WATER EFFICIENCY, METERING & LEAKAGE CONTROL

5.1 Water Efficiency

5.1.1 Overview

Water efficiency has remained a key strand of NW's demand management undertakings throughout AMP6. Having initiated the first water efficiency retrofit programme in 1997, NW is able to demonstrate the successful delivery of industry-leading projects, schemes and initiatives spanning over twenty years. These activities have resulted in quantifiable water savings, unrivalled customer experiences and a significant contribution to the water efficiency evidence base.

The strategy has, and continues to be, designed to create water efficiency programmes that make genuine savings in water as cost effectively as possible. A critical part of the programme is the monitoring of results to find out what the actual savings in water are and how sustainable they are, and customer surveys to gauge the effectiveness of the approach. Whilst this benefits NW's water efficiency planning and ultimately the high levels of demonstrable water savings achieved, it has and will continue to contribute significantly to the Industry's water efficiency evidence base, in turn aiding others in developing demand management and water efficiency strategies.

Particular achievements have been the increase in effectiveness of NW's water efficiency retrofit projects, the strong emphasis on the measurement of water savings (at a more detailed level than household meter readings which can easily mislead), interest in the sustainability of savings, a determined focus on the delivery of sustained behaviour change and proactive attempts to share and disseminate the results, experience and learning. NW has also received recognition for its innovative and creative approach to delivering its wide range of initiatives via a whole-town approach. Every Drop Counts is NW's largest ever water saving programme taking a wide-reaching and community-focused approach. It was awarded Water Resources Initiative of the Year in the 2017 Water Industry Achievement Awards and a The Green Apple Award for Environmental Best Practice in 2017.

5.1.2 Progress in AMP6 and Current Strategy

Following Ofwat's water efficiency targets in AMP5, NW designed its water efficiency strategy in AMP6 based on the direction set out in Defra's Water for Life (precursor to the Water White Paper) and its Statement of Obligations for PR14, which emphasised the Government's expectation that water companies will deliver overall demand reductions via demand management measures, including water efficiency. Defra also clearly stated that it expected companies to show in their Water Resource Management Plan how they will reduce per capita consumption.

The Agency and Defra accepted NW's water efficiency proposals to annually reduce PCC by 0.12 l/head/day (equating to 0.33 Ml/day) by delivering water efficiency activities in AMP6; a target that it is on track to meet. Water savings have been achieved primarily through the delivery of household water efficiency activity, applied equally to unmeasured and measured customers. Water efficiency programmes were delivered to non-households prior to retail separation in April 2017, following which it has been deemed the responsibility of retailers.

The following section will highlight the key water efficiency activities that have been undertaken in order to deliver the water efficiency strategy in AMP6, in turn giving a background to some of the activities that will form the strategy in AMP7.

5.1.3 Every drop Counts

Every Drop Counts is NW's largest ever water saving campaign, taking a truly innovative and wide-reaching approach by offering customers the chance to participate in a range of initiatives that are usually delivered at different times and places throughout the year.

EVERY DROP COUNTS

It uses a combination of targeted advertising and community-based marketing to maximise participation in the wide range of water efficiency projects to help communities not only save water, but energy and money too. Since the initial trial of the whole-town approach in 2014, NW has completed 5,856 home retrofit audits and 58 business audits in four towns. The culmination of refining and improving the process annually has seen success in terms of customer participation increase each year.

Every Drop Counts offers water savings schemes, initiatives and solutions to households and schools within the targeted town. A key component of the campaign is the offer to householders of a free plumber-led home retrofit visit worth over £130. The water and energy saving visit includes the installation of a wide range of retrofit products alongside effective engagement with the householder to enact long-term behaviour change. The water efficiency retrofit project has formed a key component to NW’s water efficiency strategy since 1997. A retrofit audit involves a plumber attending an appointment at a customer’s property with a view to fitting and/or delivering a wide range of water saving products to ensure the household is water efficient. The customer is engaged in conversation and encouraged to spend time with the plumber whilst fitting the devices, to ensure that behaviour change messages are conveyed effectively.

Participating customers that have received an Every Drop Counts water efficiency retrofit visit are each saving on average 21.3 litres per day. This equates to an annual saving of 7,775 litres which in turn results in monetary savings of approximately £21 on each participating customer’s water and sewerage bills. Each participating customer received a comprehensive plumber-led home water audit including water and energy saving products such as aerated or regulated showerheads, tap inserts, leaking toilet repairs, dripping tap repairs, water butts and dual-flush retrofit devices. The project to date is now saving 124,733 litres of water per day.

On an annual basis, NW delivers the Every Drop Counts whole-town approach in a specific town selected for varying reasons. Each annual campaign is launched with a stakeholder engagement event in May, following which the home retrofits and school educational programmes are delivered throughout the summer. Activity concludes in October, following which the autumn sees a period of customer research and data analysis, and throughout the winter the identification of recommendations and planning for the subsequent year.

A key component of Every Drop Counts is an overarching innovative marketing campaign. The campaign aims to generate a buzz around the community using bill boards, electronic panels, stunt marketing and newspaper/radio advertisements to raise awareness. NW also worked with the environmental charity Groundwork to deliver a series of customer engagement events that were tailored to provide opportunities for NW's customers to sign-up for a water saving retrofit in the local high street, at supermarkets, shows and festivals. By working in partnership with the community and environmental charities, NW is also able to engage community champions to deliver a series of customer engagement stands, utilising their understanding of the community to encourage wider participation.


5.1.4 Behaviour Change and Education

NW fully understands the importance of engaging with customers to influence water using behaviour. The distribution and fitting of water saving products forms only part of the story. Influencing customer behaviour, through informing customers of how much water they use, how they use water and challenging the habitual nature in which they use water, in turn delivers quantifiable and sustainable water savings. The Company has understood this for many years and therefore behaviour change underpins all projects and initiatives.

Through each of NW's home retrofit projects, whether delivered internally, using contractors or trusted third-parties, the customer is fully engaged about their consumption, the links to energy and monetary savings and how the devices installed work. In 2015, NW delivered a piece of research that aimed to establish the proportion of water savings achieved through the installation of products compared to those achieved through effective behaviour change engagement. The research was conducted in conjunction with a phase of home retrofits audits undertaken during the summer of 2015 in which 1,495 properties participated. The properties were randomly assigned to two groups; one receiving the full audit (product installation and customer engagement) and the other receiving a product-only audit (product installation but no engagement). Customers that received a full audit saved on average 24.9 l/prop/day. Customers that received a product-only audit saved on average 18 l/prop/day, suggesting that behaviour change accounts for between a quarter and a third of water savings achieved through home retrofit projects.

NW also recognise the importance of educating the younger generations, and in turn has implemented two highly energetic, engaging and creative programmes delivered to primary and secondary schools respectively:

- Super Splash Heroes

  Between 2010 and 2015, NW delivered an educational play and workshop named Little Green Riding Hood. Working with a local theatre company, the programme was delivered to 106,535 pupils through 580 performances in 503 schools. It was a successful project that resulted in sustained behaviour change in primary school aged children.

  In 2016 Water Saving Week, NW launched a refreshed programme named Super Splash Heroes. Based on the concept that the pupils themselves could become Super Splash Heroes, an educational play and workshop was created in collaboration with a national theatre company. An engaging, fast-paced and drama-based play is delivered to all pupils at participating primary schools. This is then followed by an educational workshop, led by the actors, with the aim of reinforcing the messages the pupils learnt during the play.

  Super Splash Heroes visit 100 schools in the NW supply area on an annual basis, engaging approximately 200 pupils at each play/workshop. The offering takes an entire morning or afternoon and leaves the pupils fully engaged about water conservation and why water is important. A full day workshop with additional activities is offered to schools within the Every Drop Counts target towns.

  Alongside the primary school play and workshop, which forms the core of Super Splash Heroes, NW created a picture book, smartphone/tablet based app game, trump cards, a children’s kit and a social media marketing toolkit, all of which support the programme and are used at events throughout the year.

- #WATERSAVINGSELFIE

  The #WATERSAVINGSELFIE project is a result of collaborative working with teenagers to identify a problem, create an innovative solution and then make it a reality. The project is a ‘first of its kind’, blending water efficiency with social media. Using the platforms of Twitter, Facebook and Instagram, 1,690 students at The Gable Hall School in Corringham encouraged to wear a t-shirt provided by NW, take a creative selfie and post their picture along with a water saving hint, tip or pledge on their preferred social media site.

On 4th September 2015, the project was launched at The Gable Hall School. A tube, containing the t-shirt and a series of leaflets, was distributed to each student at an assembly and a subsequent stall held over lunchtime. With immediate effect students, adorned in their t-shirts, were posting selfies on social media, sharing water saving tips, messages, hits and pledges with their friends and family. The project will be delivered again in 2018 and then annually thereafter.

NW also recognise the importance of providing advice and information to customers to ensure water is used wisely in the garden during the summer months. The Save a Bucket Load campaign was initiated in 2014 and aims to encourage customers to keep their gardens looking their best whilst using water wisely. The programme, which has evolved and adapted each year, aims to promote sustainable water use in the garden and generate long-term behaviour change. The BBC's One Show horticulturist Christine Walkden was engaged to be the 'face' of the campaign. In 2016, three routes were employed to spread the message of 'using water wisely' in the garden. Firstly, Christine Walkden did four informative talks across NW's supply area to gardeners and allotment holders on the top ways to save water. The talks were located in Brentwood in Essex, Lowestoft in Suffolk, Wingrove in Newcastle and also at Howard Nurseries Ltd in Wortham near Diss in Norfolk. Howard Nurseries Ltd won the Waterwise 2016 UK Water Efficiency Awards where they received both the Farming and Horticulture Award and the Agency Chairman's award for their self-sufficient water management system. It was therefore a fantastic opportunity to be able to partner with Howard Nurseries Ltd and celebrate their achievement as a water efficient business. The talk at Howard Nurseries attracted over 100 attendees who alongside hearing great information on gardening from Christine also got to go on a tour of the nurseries. As a wholesale nursery, Howard Nurseries are almost unique in United Kingdom in offering an extensive range of field and container grown perennials, growing two million plants annually in over 1,500 varieties.

5.1.5 Water Saving Kits and Products

In 2009, ESW (the southern operating arm of NWG) became the first water company to develop a water saving kit, aimed at providing customers with a variety of 'easy-to-install' products and information about saving water in and around the home. The kit proved effective in providing customers with the tools to make their home more water efficient and also provided details about how the customers could purchase further water saving products for elsewhere within the home. The water saving kit includes a five-minute shower timer, Save-a-Flush, in-line shower regulator, twin-pack of tap inserts, universal plug and an information leaflet/questionnaire.

To date, 67,686 water saving kits have been distributed to customers, upon request, following introduction in 2010. Water Saving Kits are promoted on the NW website, at events and by Customer Advisors in the NW Call Centre.

NW also offers customers the opportunity to request a selection of products for their home and garden in the form of a bespoke kit. When requesting water saving products from the NW website, customers have the option of requesting a ‘standard’ water saving kit or a ‘bespoke’ kit consisting of products selected from those mentioned previously and including a range of other products. The distribution of water saving kits to customers upon request has ensured that customers have enjoyed easy access to water saving products at no cost. It is believed that making such products available has made water efficiency applicable and available to a large proportion of customers.

5.1.6 Affordability and Vulnerability

Water efficiency can play an essential role in assisting vulnerable customers and those that struggle to pay their bills. NW recognises this and has hence both incorporated vulnerability/affordability messages into the water efficiency retrofit visits and initiated a retrofit programme specifically targeted at customers that will benefit the most. AMP6 has seen closer ties develop between the Water Efficiency team and the Affordability and Vulnerability teams to ensure that the messaging, literature and programmes delivered by NW focus on both aspects in parallel. Also, as described in the ‘Collaborating with Trusted Third Parties’ section below, NW has and will continue to collaborate with organisations such as National Energy Action to tackle energy efficiency, water efficiency and fuel poverty more generally.

5.1.7 Research

NW fully understands the importance of undertaking research in order to appreciate better the effectiveness of the projects carried out by the Company and to help shape future strategies. NW collects a vast amount of data whilst carrying out water efficiency projects. This data can be used to better understand a range of interests. To name a few, it is important that the Company better understands why customers do or do not participate in projects, the effectiveness of water saving products installed and/or delivered, the longevity of the water saving achieved, what influences the water savings achieved and how the initiatives have influenced customer behaviour. The following research projects were carried out in order to help NW better understand some of the points of interest noted above. The results of all are made available to the wider industry.

- Behavioural economics

  In 2014, NW worked with leading professors in the field of behavioural economics to undertake research to understand how and whether financial incentives would encourage participation. Using NW’s home retrofit programme as a platform, NW’s collaboration with Oxford University and the University of Chicago was split into two years. In the first year, the 15,000 customers invited to participate in Phase 9 of H_2eco were split into seven groups, each offered different financial incentives. One group acted as a control, and the remaining six groups were offered different financial values, ranging from £5 - £15 for taking part, some of which were also tasked with recruiting a friend or neighbour to receive the incentive. The second stage of the research, delivered as part of Phase 11 of H_2eco, was based on the programme's Recommend-a-Friend scheme. For many years, NW has offered customers a £5 supermarket voucher for each friend or neighbour they recommend that then participates in the project. The research tested whether differing financial incentives, ranging from £10 for participating and recommending one friend, to £50 split by £10 per recommendee to a maximum of five. Again, the customer mailing list was split into groups, one as a control and the rest testing different financial incentives. The research provided some useful findings that have been applied to subsequent programmes. The collaboration with the two universities will also continue into AMP7.

- Home retrofit analysis

  NW commissioned Artesia Consulting Ltd to perform an in-depth statistical analysis of the datasets for Phases 1-9 of NW's H_2eco retrofit project. The work involved compiling the raw data from the individual project databases into one large database in order to explore the complete dataset to determine how the water savings vary between phases and what factors explain the difference in water savings. A key objective of the research project was to apply a range of statistical analysis techniques to the device data (point of use measurements such as pre and post flow measurements and cistern measurements) along with the meter read data to quantify the impact each key device has on the volume saved. Among other factors, the research also explored the long term sustainability of water savings, the characteristics of a property able to have an ecoBETA fitted and the socio-demographics of participating properties against water savings. The outcomes and findings have contributed significantly to the development of NW's water efficiency programmes and also formed a key component to the Environment Agency's 'Water Efficiency Evidence Base; Review and Enhancement (2012) and the UKWIR: The Links and Benefits of Water and Energy Efficiency Joint Working project (2012).

- Seasonal effects on measured water savings

  NW has routinely carried out water efficiency projects since 1997. As part of these projects, NW has installed thousands of water efficiency devices and encouraged customers to embrace water saving habits through behavioural change campaigns. These initiatives are monitored through the collection of three separate meter reads; these are used to calculate overall study savings. Through this process NW has produced a measurable decrease in their customers' consumption. However, there is an understanding that the measured water saving resulting in a water efficiency project is subject, or at least influenced, by a variety of external factors. It was suspected that seasonal variations have an impact on the water savings calculated following the undertaking of a project. In order to explore whether any further value can be extracted by re-analysing the results, Artesia Consulting Ltd were employed in 2012 to analyse and report on the extent to which external factors influence demand during periods when water efficiency studies are undertaken. If external influences were found to be statistically significant a method of correctly adjusting for them was to be developed and reported upon in order that the analytical methods could be used for future studies. This study showed that, due to the nature of the project and the fact that audits are carried out over a number of months, the seasonal effect on the measured water savings was negligible.

5.1.8 Collaborating with Trusted Third Parties

NW recognises the importance of delivering water efficiency in collaboration with trusted third parties. NW has developed programmes that, even working alone, result in some of the highest levels of participation and engagement seen across the industry. That said, there are significant advantages to working in collaboration, whether it be to increase participation or deliver combined messaging and benefits to customers.

NW is currently working with three organisations (Cenergist, AgilityEco and National Energy Action) on separate programmes that aim to deliver water saving advice and product installation in conjunction with energy saving initiatives already underway. NW also has a long history of collaborating with housing associations to deliver water efficiency projects for their tenants. Based on a successful pilot with Flagship in 2011, NW has since worked with Swan Housing to undertake water saving retrofits in their housing stock both through their refurbishment programme and as a distinct targeted project.

5.1.9 Customer-side Leakage

NW has contributed to two industry-wide pieces of research which concluded that approximately 5% of toilets in the UK leak, each wasting on average 215 litres per day. NW’s evidence of measured savings to date indicates that the volume of wastage suggested in the industry-wide research is conservative. That aside, for NW specifically this equates to approximately 57,000 properties with leaking toilets potentially wasting 12.29 Ml/d. In response to this finding, NW has proactively focused on the identification and repair of leaking toilets through its water efficiency retrofit programmes and in response to high consumption queries.

NW delivers approximately 5,000 water and energy saving retrofits per year. At each of these visits, the plumber or technician will use leak dye capsules in each toilet within the home to identify any leakage from the cistern. Upon identification, a repair will be made whilst at the home if possible or at a remedial visit if specific materials are required to make a satisfactory repair. Going forwards, NW has identified a number of additional routes by which it will identify and repair leaking toilets.

5.1.10 Industry Sharing, Involvement and Recognition

In May 2007 NW distributed the first edition of Water Efficiency News. Since then, the Company has produced a further nine issues. The purpose of this newsletter is to keep stakeholders and other interested organisations up to date with the Company's work. Many projects are in progress at any one time and there is now too much material to be able to rely on others to spread the word for us. The latest issue was produced in 2017 and focused on the key water efficiency and demand forecasting projects being undertaken by NW. It is hoped that Water Efficiency News will be able to be used to disseminate results and also to draw attention to key issues or aspects that have not received sufficient attention and to provoke discussion and new research ideas.

NW remains actively involved in the water efficiency arena taking a lead wherever possible. The Company remains active contributors to the WaterUK Water Efficiency Network having Chaired the network since 2005, providing the opportunity for companies to exchange ideas and experiences and to jointly meet with suppliers, regulators and others. NW also actively supports Waterwise (a not for profit organisation), continues to sit on and contribute to the Water Efficiency Strategy Steering Group and is also influential in scoping and seeing to fruition the development of the Collaborative Fund. Lastly, NW's Customer Director sits on the newly formed Leadership Group for Water Efficiency and Customer Engagement.

NW has received industry recognition through receipt of numerous awards. Below is a list of awards that NW has received since 2015.

- Winner of Water Resources Initiative of the Year at the 2017 Water Industry Achievement Awards for the Every Drop Counts campaign.

- Winner of Business and Industry Award at the 2016 Waterwise UK Water Efficiency Awards for the Bourne Leisure Holiday Home Retrofits programme.
- Winner of the Research & Evaluation Award at the 2016 Waterwise UK Water Efficiency Awards for the H_2eco Research and Analysis.
- Winner of the Innovation Award at the 2016 Waterwise UK Water Efficiency Awards for the #watersavingselfie project.
- Gold in the Utility category at the 2017 Green Apple Awards, demonstrating environmental best practice through the Every Drop Counts programme.
- Bronze in the Built Environment and Architectural Heritage category at the 2015 Green Apple Awards for the Swan Housing retrofit programme.
- Winner of a SWIG (Sustainable Water Industry Group) award in 2015 for Every Drop Counts.

5.1.11 Water Efficiency Strategy for the Remainder of AMP6

NW will continue to deliver projects and initiatives similar to those documented in the preceding sections for the remainder of AMP6. The Every Drop Counts whole-town approach will form the core activity in 2018 and 2019, within which water efficiency programmes will be delivered on an annual basis at a similar scale to that detailed above. This community-focused approach will ensure that NW is able to maximise its effectiveness in terms of participation and water savings in target areas. The home retrofit programme will continue to be offered to a minimum of 5,000 domestic properties per year, acting as a cornerstone to the strategy as a means of ensuring the existing housing stock is as water efficient as possible whilst delivering behaviour change. The Super Splash Heroes programme forms an effective means by which NW is able to engage with future generations and will be delivered to a minimum of 100 schools per year. NW will continue to focus on housing associations, develop stronger links with its affordability strategy and focus on identifying and repairing internal plumbing losses. The majority of the aforementioned initiatives will be underpinned by a new digital engagement platform and an enhanced marketing strategy. This will enable NW to offer its water saving initiatives, including water saving products, in a more personalised and bespoke way.

The strategy will continue to be designed to create water efficiency programmes that make genuine savings in water as cost effectively as possible. The programme will continue the detailed monitoring of results to find out what the actual savings in water are and how sustainable they are, and customer surveys to gauge the effectiveness of the approach.

NW will continue to actively contribute to the industry's efforts to improve the water efficiency evidence base, through chairing the WaterUK Water Efficiency Network, sitting on numerous industry-wide steering and working groups and making the results of projects and initiatives available to the industry.

5.1.12 Water Efficiency Strategy for AMP7

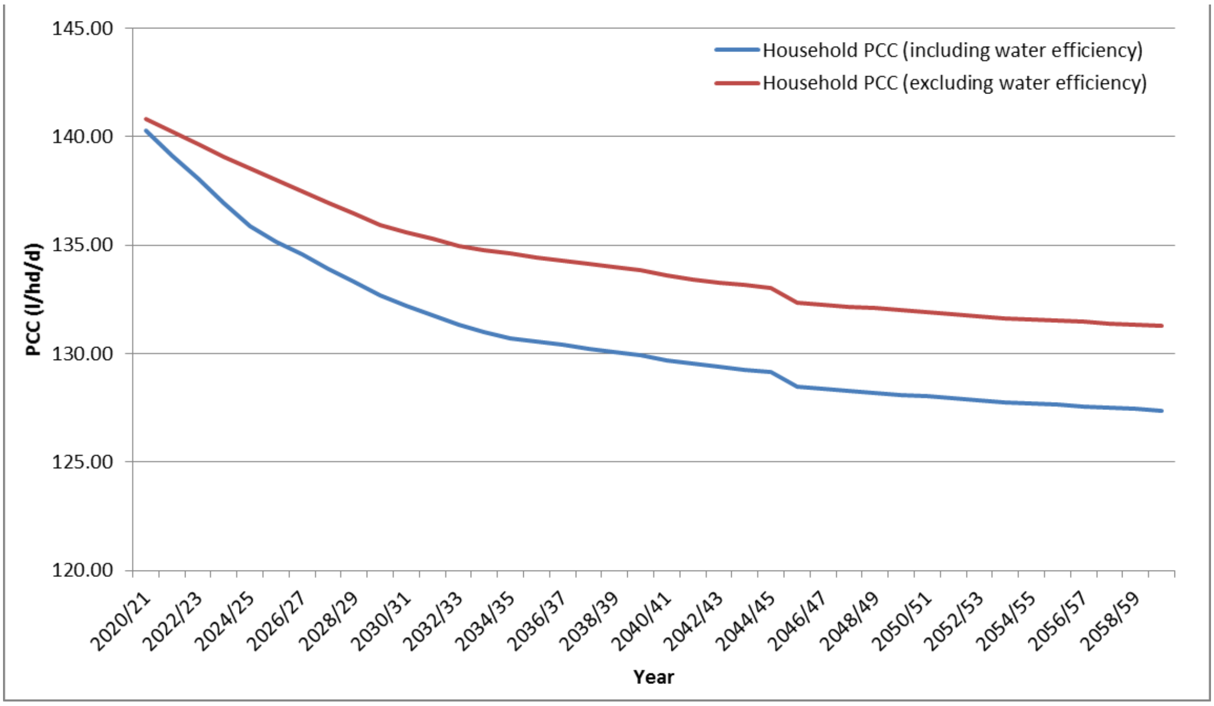
In AMP7, water efficiency will be more important than ever. In addition to recognising the underlying and founding principle that water efficiency is a key tool for managing demand and therefore supporting the supply/demand balance, NW has considered the numerous and varying drivers for water efficiency that now exist. In response, NW will deliver a water efficiency programme between 2020/21 and 2024/25 that is even greater in scale and ambition than delivered previously. With more than twenty years' experience in the delivery of water efficiency programmes, NW is best placed within the industry to develop a strategy that will deliver quantifiable water savings and sustained behaviour change. This section will detail the drivers that NW deem important in developing the water efficiency programme for AMP7, highlighting the projects that NW will deliver and the anticipated water savings resulting from such activities.

In Ofwat's draft PR19 methodology (Delivering Water 2020: Consulting on NW's methodology for the 2019 price review, July 2017), four key themes are emphasised that will focus on benefitting customers; namely great customer service, resilience, affordable bills and innovation. It is arguable that water efficiency plays a key role in the delivery of all four outcomes. Delivering an effective, engaging and ambitious water efficiency strategy has the ability to provide unrivalled customer service, manage demand such that NW is more resilient in the future, provide support to vulnerable customers who are struggling to pay and demonstrate innovation through the use of new technologies and approaches. Further to this, Ofwat has proposed a new common performance commitment based on per capita consumption. Alongside an effective metering strategy, this common performance commitment emphasises the importance of demand management in general, and more specifically water efficiency.

WaterUK's 'Water Resources Long-Term Planning Framework (2015-2065)' suggests that more action is needed to protect against the growing risk of drought. The report emphasises the role that water efficiency at a greater scale can play in mitigating some of the risks. The Blueprint for Water's Blueprint for PR19 also emphasises the importance of using water wisely by reiterating Ofwat's suggestion that companies need to go much further on metering and leakage reduction, as well as working with customers to help them reduce consumption. Waterwise has also published a national water efficiency strategy that calls for greater ambition and collaboration in water efficiency.

NW is able to demonstrate the Company's commitment to encouraging its customers to use water wisely through a long history of delivering effective water efficiency strategies and programmes. The drivers (regulatory and other) detailed above add further emphasis to the importance of water efficiency for varying reasons. In turn, NW will commit to delivering a programme of water efficiency activities that will deliver a 2% reduction in PCC by 2024/25, equating to an annual reduction of 0.54 litres per person per day. The impact of this water efficiency, as shown in the graph below, is to reduce overall PCC for NW by 2.7 litres per person per day by 2024/25 with a further continuation of water efficiency across the planning horizon. The demand reductions highlighted here and in Figure 5.1 below denote those from water efficiency activity alone and do not include the efficiencies related to the metering activities detailed in section 5.2.

Figure 5.1: Effect of Water Efficiency on Baseline Overall PCC



NW will achieve the ambitious demand reductions stated above through a continuation of the range of activities currently delivered although at a far greater scale. Central to the water efficiency strategy in AMP7 will be the Every Drop Counts programme, taking a community-focused and wide-reaching approach to saving water through the delivery of all of NW's activities in one town at one time. The whole-town approach ensures that NW is able to maximise its effectiveness in terms of participation and water savings in target areas. Home water efficiency retrofits will remain a cornerstone to the strategy as a means of ensuring the existing housing stock is as water efficient as possible whilst delivering behaviour change. The Super Splash Heroes programme forms an effective means by which NW is able to engage with future generations. NW will continue to focus on housing associations, develop stronger links with its affordability strategy and focus on identifying and repairing internal plumbing losses. Each of the activities discussed previously will be delivered in AMP7 at a greater scale.

It is however important to highlight that the water efficiency scene is changing, which in turn will influence the strategy as time progresses through AMP7. There will be three key priorities for water efficiency in the coming decade. Firstly, there will be a transition whereby the importance of behaviour change grows exponentially. Secondly, the delivery of home retrofits will need to become more targeted towards only those homes that will truly benefit from the programme. NW's research and statistical analysis tells a story suggesting a limited lifespan of the home retrofit project as the stock of existing inefficient water using appliances is replaced with those that are more efficient. NW is able to demonstrate that product installation rates associated with the home retrofit programmes are declining on an annual basis, in turn diminishing the cost-effectiveness of the projects. And thirdly, the use of smart metering/technologies will be deemed beneficial to water companies and an expectation of customers. In response, NW will implement an innovative digital engagement platform that will underpin and assist in the delivery of these priorities whilst further supporting its drive to deliver unrivalled customer service. Linked to the digital engagement platform will be two additional themes. An innovative incentive scheme, building on the behavioural economics research undertaken by NW in conjunction with Oxford University and the University of Chicago, will be implemented to intelligently incentivise customers. NW will also deploy a series of smart technologies allowing more frequent and circular customer conversations around water efficiency.

5.2 Metering

5.2.1 Background

The NW area has a large surplus of supply over demand in its Kielder WRZ and the area is not classed as seriously water stressed. Therefore compulsory metering cannot be considered. In the much smaller Berwick and Fowberry WRZ there is a smaller surplus until the full outcome of the NEP studies in to the sustainability of NW's ground water abstractions in AMP 6 reports. However NW cannot compulsorily meter this area as it is still classed as not being seriously water stressed.

NW intends to continue with its current programme of optant metering only for the AMP7 period. However NW are keen to explore stimulating the number of optants, by targeted communications with customers, in areas such as Berwick, where higher metered densities would be more beneficial.

NW started the year 2000 with a very low level of meter penetration. Up until this time, when the Water Act required a water company to provide a meter free of charge to any domestic customer who requested one (and it was not unduly expensive for the company to meter the property), a customer wanting a meter had to pay the full installation cost. Only new properties built since 1989 were metered. However, once free optant meters became available there was a pent up demand for meters with high numbers of requests through to 2010. By the start of 2010 (AMP5) over 20% of domestic properties had measured supplies

For the AMP5 period NW had forecast new optant meter installations of 14,000 per annum and achieved an outturn for the AMP close to 70,000 total. This raised the level of metered customers to 30.6% by the end of 2014/15.

For AMP6 NW again forecast an average 14,000 optants per annum for each year as even towards the end of AMP5 it was still seeing this level of optant meters being installed. So far in AMP6 NW are seeing this level of optant meters being installed, partially inflated by one of the Local Authorities removing the water rate from the overall rent on their social housing. This means for the first time these customers now receive a water bill and a number realise that being measured would reduce their water charges. NW believe that another of NW's LA's intends to follow suit next year meaning the AMP6 total is likely to be met, if not exceeded. The forecast meter penetration by April 2020 is 39.61%.

5.2.2 Customer opinion on metering

Customer attitudes towards metering appear to be mixed to favourable. Quantitative research conducted in 2011 gives an inconclusive picture with 53% of NW customers stating they felt positive towards metering as a means of charging. A more positive attitude is apparent across three programs of qualitative research conducted for PR09 and PR14. Favourability towards metering primarily seems to be concerned with three factors. On a personal level some respondents believe that the installation of a water meter would bring their water bill down; *"I want to get a meter because I think my bill is too much"* (NW, 2012). Secondly, on a societal level respondents have suggested that metering is the fairest method of charging for water consumption across customers. A third factor cited in support of metering is that metered systems make customers more aware of how much water they use, and so encourage water saving behaviour. This is supported by qualitative evidence that metered customers seem more aware of their bill amount than non-metered customers.

Despite this positivity towards metering there is evidence that customers are against enforced metering. Quantitative work conducted in 2011 showed that 82% of NW customers were against enforced metering. Qualitative research conducted in 2012 indicates why this is the case, these respondents were against enforced metering on two grounds; firstly that it restricts consumer choice, which is considered to be unacceptable. Secondly concerns were expressed that bills would increase following the installation of a meter either instantaneously or as a result of unanticipated increases to the household size; *"They would cost more money when you have children" (NW, 2011).* This is supported by two programs of recent qualitative research (May 2012 and December 2012) which suggest a customer requirement for education around metering and potential bill savings.

Further customer research in to their attitudes towards metering were carried out in 2017 to inform this WRMP.

NW undertook qualitative research about metering, supply and demand with customers from a variety of backgrounds at two locations in North East England in April 2017. NW ran deliberative workshops at Stockton-on-Tees and Gosforth in Newcastle, using an independent agency to facilitate and analyse the results. Senior members of NW's water team were present to engage directly with customers and customers were segmented by metered status.

Customers were asked about the same topics as those in ESW, but the information presented to them was tailored to North East England, e.g. leakage was at 20%, the network of pipes was twice the length, NW spend 50% more per year on metering in the north, and average estimated consumption is slightly different. Although compulsory metering would not be permitted in the north due it not being water stressed, NW wanted to ask customers about the extent to which they wanted NW to impose metering on them in the same way as NW had done in the south, so that the results would be comparable. On a qualitative level, no significant differences were found between the opinions of ESW and NW customers about any of the topic areas.

Some quotes that show some customer views in the north include:

"In this part of the country we aren't short of water... It should be a lot cheaper. We've got that much that now they've put pipelines from here down …south. You shouldn't have to worry about how much water you use. You're never gonna run short. We're the North East of England. We're part of the country we shouldn't have to worry about what we do with our water. We've got some of the biggest reservoirs."
Some customers who have inherited meters when they moved, would like the opportunity to revert to unmeasured tariffs.
There can also be high levels of worry caused by being on metered tariffs among lower income customers*: "I am using it, probably not like I did in my old house, washing my bins out every fortnight, I'm doing them monthly. I am cutting back, because I'm conscious of the water and I don't want to be like that. I don't want to be shouting at the kids and saying you've ran the bath and it's full up, like that. It's habits of a life time probably. But I have seen the cost rise. I had a sleepless night, as daft as it sounds, because I had a leaking tap. Until I got it sorted. Just the fright of the bills."*

Given the water supply situation in the North East and NW's customer research findings that choice is what they value, NW intend to retain NW's current optant metering strategy.

5.2.3 Proposed metering strategy going forward

Given the current rate of meter installation from the AMP6 optant programme, and the views of customers, optant only metering will continue for AMP7 and AMP8 at the current rate of 14,000 properties per annum. Achieving these numbers will see NW reaching a meter penetration of 48% by the end of AMP7 and 55% at the end of AMP8. Achieving an average of 14,000 optant meters per annum in AMP8 may require a more targeted promotion of meters to customers. Experience in Essex & Suffolk by using personalised communications and the use of pre-metering (installing meters at properties that remain unmeasured but providing them with the equivalent bill they would receive if measured) makes NW confident it can maintain 70,000 optant meters over AMP8.

The more active promotion of meters to potential optants, by either personalised communications or pre-metering already installed but empty meter chambers, may be trialled during AMP7 in the Berwick and Fowberry WRZ to further increase the level of metering in this ground water fed WRZ.

Table 5.1: Meter Optant Rates

	AMP7	AMP8	AMP9	AMP10	AMP11
Optant	70,000	70,000	50,000	50,000	30,000
Total	70,000	70,000	50,000	50,000	30,000
End of AMP Metered %	48	55	61	66	69

5.3 Leakage Forecast

5.3.1 Background

Water companies have been working together, co-ordinated by Water UK, to improve the consistency of reporting of definitions of key measures of performance, so that performance can be compared between companies more easily. This work is supported by Ofwat, the Agency, Natural Resources Wales and the Consumer Council for Water.

Companies need to make changes to their current reporting to align with the new, more consistent, reporting definitions, and for some of these changes it will take some time to have robust data. One of the measures of performance this applies to is leakage. Each company's draft WRMP explains how the company is implementing the new reporting definition for leakage and the extent to which it might impact on their future plans for balancing supply and demand for water. The change in reporting of leakage is purely a change in reporting; it does not affect the actual amount of water lost through leakage.

Each company will be making different changes to their current reporting to come into line with the more consistent definition, and so the impact will be different for each company. For NW, the changes and their potential impact are explored below.

5.3.2 Summary of Approach

In the course of preparing NW's WRMP, NW has considered the outputs of the report on Consistency of Reporting Performance Measures (UKWIR, 2017). Some of the elements have been readily implemented but others require detailed studies or significant investments which are likely to take two to three years to complete. The impact of each of these elements has been assessed and an overall range of outputs derived.

The SELL model used for PR14 has been updated with new company-specific input data. The minimum achieved leakage levels (MAL) within DMAs have been referenced to the range of industry "Frontier" values.

The 2016/17 base year has been derived and a number of scenarios forecast to reflect the potential range of impacts from the consistency projects. For each of these starting values, future profiles of leakage levels have been projected forward to 2045.

5.3.3 Adoption of Consistency of Reporting Measures

The 2017 UKWIR report contains a compliance checklist containing sixteen components. The checklist requires each element to be assessed using a Red / Amber / Green scale and any reasons for non-compliance to be documented.

The Company has further divided this checklist into sub-criteria and assessed each element individually. The output of this work identifies a number of enhancements to the current reporting methods which are categorised into two main areas:

a) Changes to the calculation method
b) Improvements to the data quality.

Work is underway to ensure NW is fully compliant with all aspects by commencement of the AMP7 period.

Changes in Calculation Method

The calculation changes have been incorporated within the corporate leakage analysis software (Netbase). A second database has been constructed adopting these changes to enable the effects to be monitored alongside the existing reported values.

The key changes are:

a) Weekly leakage values calculated from a seven-day mean rather than median value.
b) The minimum night flow period is calculated from a fixed hour rather than a minimum rolling one hour period.
c) Individual daily leakage values are allowed to be lower than zero rather than fixed at zero.

The effect of these improvements is, therefore, fully accounted for in the company "bottom-up" pre-MLE value of leakage.

Improvements in Data Quality

The improvements in data quality require significant investment in terms of time and money and it is not possible to predict the effect of these accurately.

The key requirements are:

a) Non-Household Night Use Study – A company specific night use model is required derived from a minimum of 1000 logged customer results, each over 14 days.
b) Large Metered Customer Logging – All customers with a daily consumption of a minimum of 24 – 48 m^3/hour will be continuously logged using telemetry loggers.
c) Study of Plumbing Losses – A company specific study will be undertaken to understand the magnitude of customer plumbing losses. These company values will replace the generic industry values currently used.
d) District Metered Area (DMA) Coverage – Additional DMA's will be created to ensure that a minimum of 95% of properties are within reporting areas.
e) Extension of Small Area Monitor (SAM) – The SAM will be extended to ensure that it is representative of the demographic characteristics.

f) Night Flow Interpolation of Missing Data – The report identifies a requirement to treat missing and corrupted data differently. This requires a change to the analysis routines within Netbase and will be incorporated in the next software release.

These data improvements will be delivered within a three year period and, as each individual element is delivered, the effect on leakage will be incorporated into the second Netbase database. This will ensure that the effects of all changes are fully understood and incorporated prior to the AMP7 reporting period.

5.3.4 SELL Review

In 2007, NW introduced a new SELL model to replace the earlier LIMES model. The model is based on the natural rates of rise of leakage, with the economics of active leakage control being optimised at DMA level. It was conceived and designed in 2007 by in-house experts but has been completely rebuilt for the PR19 submission. It is fully compliant with the recommendations of the Tripartite Report of 2003, and therefore conforms to best practice.

NW has also complied with most of the recommendations of the 2012 Strategic Management Consultants (SMC) report "Review of the calculation of sustainable economic level of leakage and its integration with water resource management planning" commissioned by Environment Agency, Ofwat and Defra. Specific actions NW has taken include:

- NW has considered all operational leakage options to reduce leakage. NW has also included a stand-alone optimisation of pressure management. However NW has not considered other capital options such as mains renewal as NW has not constructed a least cost plan for any of NW's resource zones, as none are expected to be in deficit within the planning period.
- NW has included the environmental, social and carbon costs of leakage and leakage management, using company or catchment-specific values where appropriate.
- The study on Factors Affecting Minimum Achieved Leakage Levels (UKWIR, 2016) found that it is not currently possible to forecast minimum achievable leakage levels. However NW has used the methods presented in this report to calibrate NW's minimum achieved levels against those of other UK companies to demonstrate that they are appropriate for a company with relatively low leakage.
- NW has not considered the economics of operating slightly above or below the SELL, as NW's proposed performance commitments for leakage are substantially below the SELL.
- In the derivation of NW's leakage cost curves, NW has assumed that we will achieve substantial future improvements in the efficiency of NW's active leakage control processes.
- NW are actively investigating and trialling opportunities to reduce leakage by the use of innovative techniques.

- Since 2010 NW has routinely carried out leakage assessments at sub-DMA level prior to implementing leakage-driven mains renewal schemes, and as a result have achieved efficiencies in NW's renewal programme by renewing parts of DMAs where appropriate.

The SELLs are calculated at DMA level, and these are then simply summed to give the overall Economic Level of Leakage (ELL) at company level. The model is applicable to a system in steady state.
A water undertaker has a choice of two operational options in response to increasing levels of leakage:

(i). Increase the volume of water put into supply
(ii). Increase the level of effort on active leakage control (ALC).

Figure 5.2 below illustrates the trade-off between the two options. Increasing the volume of water put into supply results in increased production costs (i.e. cost of water), which follows a linear relationship. The cost of increasing effort on active leakage control (ALC) is non-linear and shows diminishing returns. The total cost curve is the sum of the marginal supply cost curve (the cost of water lost) and the manpower cost curve (the manpower costs incurred in undertaking ALC). It is at a minimum when the gradients of the two component curves are equal and opposite.

Figure 5.2: Trade off between increasing volume of water and level of ALC

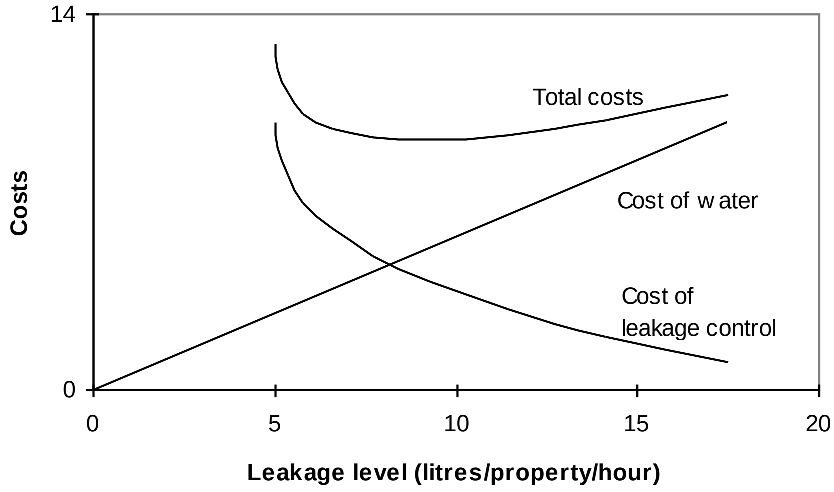


Figure 5.3: represents the hypothetical behaviour of leakage in a DMA

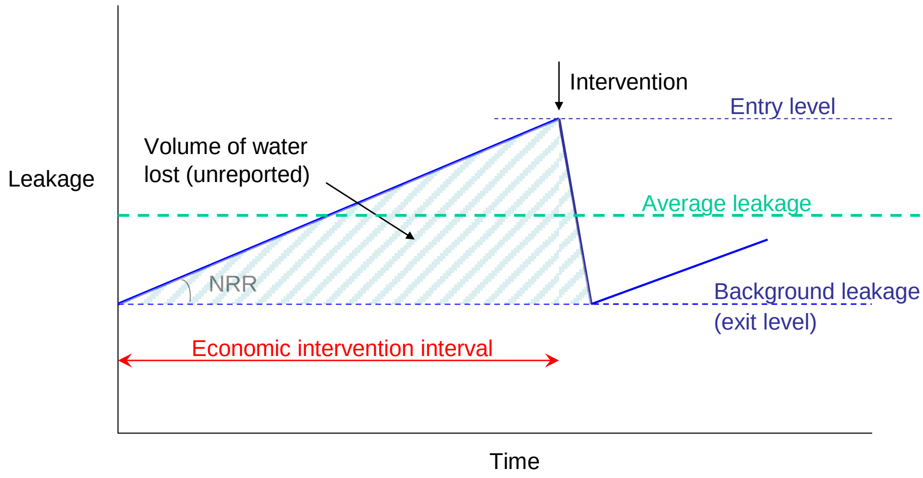


Figure 5.3 above represents the hypothetical behaviour of leakage in a DMA. At time zero an intensive leak detection and repair campaign has just been completed, and leakage has been reduced to the background level. Thereafter leakage rises at a gradient equal to the natural rate of rise. Eventually another leakage reduction campaign is undertaken, and leakage is again brought down to the background level. The shaded triangle represents the volume of water lost above the background level between interventions, i.e. water lost due to unreported burst leakage. It can be shown that the total cost to the company is a minimum when the value of the water lost between interventions is equal to the cost of the intervention. The intervention frequency will then be the economically optimum intervention frequency.

The average leakage level in the medium or long term is at half the height of the triangle as shown, and this is the economic level of leakage for the DMA. The ELL for the company is then calculated by summing the ELLs for the DMAs.

The output of this calculation process is the short-run SELL, which represents the optimum balance between the manpower costs of active leakage control and the marginal operational costs of water (power and chemicals). For zones which are in supply-demand deficit at some time within the planning horizon, additional leakage control options must be considered, along with other demand management options and possible new resource schemes. However none of the resource zones in NW are expected to be in deficit within the planning horizon.

In keeping with the 2012 SMC report, a separate economic optimisation of pressure management is carried out as a stand-alone option even in zones without resource deficits. In NW a programme has commenced to maximise the coverage of pressure management schemes during the AMP6 and AMP7 periods. These schemes will be constructed typically at sub-DMA level, often where there is significant variance in ground levels.

Previous submissions and current positions

The most recent submissions on the SELL analyses and leakage targets were made as part of the Strategic Business Plans and WRMP for AMP5 and AMP6. It was demonstrated that the SELL for AMP5 was 141.2Ml/d and for AMP6 was 137.74Ml/d. The leakage targets since 2015/16 have been below the SELL value.

The following leakage targets through the AMP5 and AMP6 periods were agreed with OFWAT.

Table 5.2: Leakage targets for AMP5 and AMP6.

Annual Reporting Period	Leakage Target (Ml/d)
2010/11	150.0
2011/12	147.0
2012/13	144.0
2013/14	141.0
2014/15	141.0
2015/16	139.0
2016/17	137.0
2017/18	137.0
2018/19	137.0
2019/20	137.0

Background leakage levels and Natural Rate of Rise values have been updated with new data values representing the five years since the PR14 submission. These elements were completed within separately commissioned studies.

All other elements of data for the model were collated and updated in-house, incorporating Netbase data outputs, Active Leakage Control (ALC) team records and marginal cost of water values.

External costs of leakage have also been updated, the most notable being the carbon cost of leakage. This utilises an emission factor of 0.44 kg of CO_2 per KWh and a non-traded cost of carbon of £14 per ton of CO_2. The resulting cost was £0.71/Ml.

Background leakage Frontier levels

For each of the DMAs with observed MAL values, the MAL values and other DMA characteristics data were used to calibrate the “MAL explanatory factors relationships” developed by RPS as part of the 2016 UKWIR study on “Factors Affecting Minimum Achieved Leakage Levels” (Report No. 16-WM-08-58)

An equation was calibrated for each of the 4 mains material cohorts. The equation is of the form:

$$MAL\ (l/hr) = (L/N)^{a}.AZNP^{b}.R1^{c}.D1^{d}.R2^{e}.D2^{f}.kJ^{g}.Age^{h}$$

Where:
L/N = Network Density (m/prop)
AZNP = Average Zonal Night Pressure (m)
kJ = size (joints in thousands)
R1 = Reported customer-side repairs (CSP) per year per 100 properties
R2 = Reported company-side repairs (mains, communications pipe and ancillary leaks) per year per kJ
D1 = Detected customer-side repairs (CSP) per year per 100 properties
D2 = Detected company-side repairs (mains, communications pipe and ancillary leaks) per year per kJ
Age = Average DMA age based on mains pipe age weighted by length (years).

a to h are exponents determined through regression performed on the MAL_{50} values.

These relationships were then utilised to derive additional frontier level values in the range MAL_{15} to MAL_{50}. The background levels derived were then compared to these reference values as shown in Table 5.3.

Table 5.3: Comparison between background and reference values.

MAL (m^3/d)	MAL_{50} (m^3/d)	MAL_{45} (m^3/d)	MAL_{40} (m^3/d)	MAL_{35} (m^3/d)	MAL_{25} (m^3/d)	MAL_{15} (m^3/d)
70.90	74.86	67.08	59.51	52.44	39.67	26.42

This work shows that the Background level of leakage calculated of 70.90 m3/day is equivalent to an industry value of approximately MAL_{47}. In other words, the overall level of minimum achieved leakage levels in NW North is equivalent to the 47th percentile of values achieved at UK national level. This is appropriate for a company with leakage levels which are slightly below the UK national average.

Results of ALC modelling

The resulting leakage-cost curves for active leakage control are shown in Figure 5.4 below.

Figure 5.4: ALC cost curve for the North East.

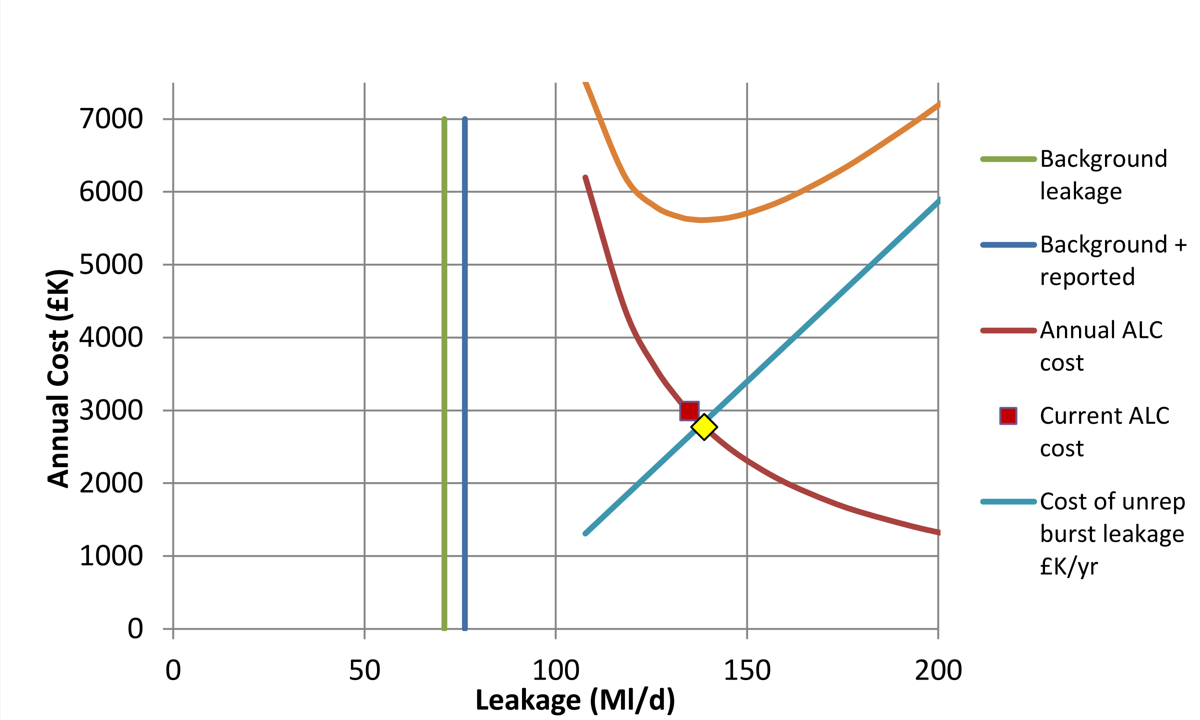


Figure 5.4 shows that the current SELL is 138.8 Ml/d. This SELL is a short-run economic level, and is marginally higher than both the current leakage level and the current target.

Figure 5.4 shows that the point representing the current position, i.e. the current leakage level and the current annual expenditure, lies on the ALC curve. For this purpose, the calculation of current expenditure is consistent with the unit rates used for the derivation of the ALC cost curve itself, i.e. it includes all marginal costs relating to the active leakage control process. The current leakage level is the reported value for 2016/17, as for a given level of expenditure the actual leakage level will vary with weather conditions

5.3.5 Future Profiles of Annual Leakage

Scenario Approach

The ongoing consistency programme creates a new problem for this WRMP submission. Whilst the reported value of leakage for 2016/17 has been calculated, audited and submitted, this value will change as the individual projects are completed and the effects incorporated into the calculation. A further complication is that the changes will be made to the value of bottom-up leakage, hence all of the outputs from the MLE water balance process will also change.

At this stage NW has taken the reported 2016/17 values to be equivalent to the base year. In parallel, a further number of scenarios have been calculated which will represent a range of leakage outputs including one value which is considered to be the most probable outcome. All of these scenarios are based on the incorporation of calculation method changes which are fully understood. Each of the bottom-up scenarios will be separately input into the MLE water balance process to output each of the other associated parameters.

Leakage Reductions during AMP7

Leakage reductions have been proposed for AMP7 and are calculated as a percentage reduction below the existing 2019/20 performance commitment value. The absolute values for leakage performance commitments within AMP7 will, therefore, be calculated as:

2019/20 Perf. Commitment ± Consistency Adjustment – AMP7 Reductions %

With the current leakage calculation method, the Performance Commitment for 2019/20 is 137 Ml/d. Following the changes to be made for compliance with the Leakage Consistency report, we estimate that the most probable value of this Performance Commitment will be 138.5 Ml/d. However NW's scenario analysis shows that the actual value of this PC could range from 130.8 to 142.4 Ml/d.
For AMP7, the planned percentage reduction over five years is 15.0%. Therefore the range of Performance Commitments through the five-year period for the three scenarios is as shown in Table 5.4.

Table 5.4: Performance Commitments through AMP7

AMP	Year	Leakage Performance Commitments (Ml/day)		
		Most Probable	Upper Scenario	Lower Scenario
AMP6	2019/20	138.5	142.4	130.8
AMP7	2020/21	134.4	138.1	126.9
	2021/22	130.2	133.8	123.0
	2022/23	126.1	129.6	119.1
	2023/24	121.9	125.3	115.1
	2024/25	117.7	121.0	111.2

These leakage reductions will be achieved by a combination of the following measures:

- Maintaining the right level of committed resources for leak detection and repair
- Maximisation of pressure management coverage, typically at sub-DMA level
- Optimisation of all existing pressure management installations
- Increased efficiency in the active leakage control process, especially through the use of noise loggers. NW already makes use of temporary noise logger deployments, but from 2020 onwards NW intends to invest heavily in the latest generation of noise loggers for permanent or semi-permanent installation.
- Other innovations (see Section 5.3.6 below)

This plan will maximise the most cost effective solutions available to achieve the target reduction by 2024/25.

Leakage Reductions beyond AMP7

For each of the four periods of five years, NW proposes a further 10% reduction on the performance commitment for the final year of the preceding AMP period. Over the 20 year period 2025 to 2045 this will equate to a further 34% reduction on the PC for 2019/20. The proposed PCs for the final year of each of the four AMPs, for the three scenarios, are listed in Table 5.5.

Table 5.5: Performance Commitments beyond AMP7

AMP	Final Year	Leakage Performance Commitments (Ml/day)		
		Most Probable	Upper Scenario	Lower Scenario
AMP6	2019/20	138.5	142.4	130.8
AMP7	2024/25	117.7	121.0	111.2
AMP8	2029/30	106.0	108.9	100.1
AMP9	2034/35	95.4	98.0	90.1
AMP10	2039/40	85.8	88.2	81.1
AMP11	2044/45	77.3	79.4	73.0

These leakage reductions will be achieved by a combination of the following measures:

- Maximise resource levels for leak detection based on the SELL ALC curve.
- Increased efficiency in the active leakage control process.
- Other innovations (see Section 5.3.6 below)
- Increased levels of mains replacement

Most of the cost effective solutions will be exhausted during AMP7 and at the moment the only remaining option to reduce leakage further will be through increased mains replacement. This is much more expensive per Ml/d reduced so the forecast costs for AMP8 to AMP11 increase significantly.

5.3.6 Innovations for Leakage Management

In addition to the measures listed above, NW will invest in the following innovative initiatives for leakage management during the latter part of AMP6 and into AMP7.

- Sophisticated data analytics to seek new insights into leakage and leakage management. This will be a direct follow-up to the very successful NW Festival of Innovation held in Newcastle in 2017.
- Detailed review of operational leakage survey strategy
- Investigations into the impact of pressure transients

- Trials of new leak detection equipment

NW will also continue to take the lead role in UKWIR’s “Zero Leakage by 2050” research programme

6.0 CLIMATE CHANGE

6.1 Introduction

This chapter outlines how NW has assessed the risk and possible impact of climate change on the deployable output of current sources of water and on customer demand. NW's assessment has been undertaken following guidance set out in the Water Resource Planning Guidelines (WRPG) and is presented in the following sections:

- Vulnerability to climate change;
- Method selection;
- Presentation of climate change assessment results (scenarios);
- Scaling method used to factor in any climate change that has already happened; and
- Allowance for climate change in the headroom assessment.

6.2 Vulnerability to Climate Change & Method Selection

The WRPG states that a climate change vulnerability assessment should be undertaken to understand how vulnerable each Water Resource Zone (WRZ) is to changes in deployable output as a result of climate change.

This information can then be used to decide which method should be used to assess the effect of climate change on WRZ deployable output. NW's PR14 climate change assessment modelled the effect of the mid-climate change scenario on deployable output but not the effect of the wet and dry scenarios. Consequently, it is not possible to use the magnitude versus sensitivity plot to assess vulnerability.

The guidance states that the methods a water Company uses to assess the effect of climate change on Deployable Output (DO) should be proportionate to the risks presented by climate change to each water resource zone. Early draft PR19 supply demand balance calculations indicated that both WRZs will have a supply demand balance surplus across the full planning period. Consequently, climate change poses a lower risk to security of supply than otherwise would have been the case. Additionally, NW's surface and groundwater sources have historically performed well during drought.

For groundwater, lowest pumped water levels in all sources have always remained significantly above deepest advisable pumped water levels. NW therefore believes that given the points summarised above, that a low vulnerability classification is likely to be appropriate for the NW WRZs. Consequently, it is acceptable to use the Future Flow method for the Kielder WRZ.

6.3 PR19 Climate Change Assessment

6.3.1 Approach

NW only has rainfall-runoff models for 11 of 22 of the catchment flows in the Kielder System, this constrains the range of potential options available for climate change modelling.

For WRZs at low vulnerability to climate change and there are no rainfall runoff models, the WRPG recommends that a tier 1 analysis is carried out, that being the use of Future Flows (FF) Hydrology change factors for the 2080s.

The approach set out in the guidance is detailed below:

- For surface water the Agency has generated monthly change factors for each future flows station representing change against the 1961 to 1990 climate baseline.
- Select the change factors for the station nearest the source but still within the same catchment and with similar BFI where possible.
- Perturb baseline flow sequences using these factors.
- Complete this analysis for all 11 scenarios of FF

The monthly change factors from each of the 11 FF scenarios were applied to all the catchment time series flows in Aquator, the English and Welsh DO analysis module was then ran. Using this approach, the impact of climate change on DO can be estimated.

6.3.2 Selecting FF catchments

Table 6.1 NW catchments requiring climate change factors.

Catchment Model Reference	Catchment Name	Assigned time series
CM1	Fontburn Catchment	Fontburn Catchment
CM2	R Coquet Catchment	R Coquet Catchment
CM3	Kielder Catchment	Kielder Catchment
CM4	Catcleugh Catchment	Catcleugh Catchment
CM5	South Tyne Catchment	South Tyne Catchment
CM6	Colt Crag/Little Swinburn Catchment	Colt Crag/Little Swinburn Catchment
CM7	Hallington Catchments	Hallington Catchments
CM8	Whittle Dene Catchment	Whittle Dene Catchment
CM9	Derwent Catchment	Derwent Catchment
CM10	Hisehope Catchment	Hisehope Catchment
CM11	Smiddy Shaw Catchment	Smiddy Shaw Catchment
CM12	Waskerley Catchment	Waskerley Catchment
CM13	Tunstall Catchment	Tunstall Catchment
CM14	Upper Wear Catchments	Upper Wear Catchments
CM15	Burnhope Catchment	Burnhope Catchment
CM16	Lower Wear Catchment	Lower Wear Catchment
CM17	Cow Green Catchment	Cow Green Catchment
CM18	Upper Tees Catchment	Upper Tees Catchment
CM19	Selset Catchment	Lune & Balder
CM20	Grassholme Catchment	Lune & Balder
CM21	Balderhead Catchment	Lune & Balder
CM22	Blackton Catchment	Lune & Balder
CM23	Hury Catchment	Lune & Balder
CM24	Middle Tees Catchment	Middle Tees Catchment
CM26	North Tyne Catchment	North Tyne Catchment
CM27	Mid Tyne Catchment	Mid Tyne Catchment
CM28	Burnhope Burn	Burnhope Burn
CM30	Rede Catchment	Rede Catchment
CM31	Lower Tees Catchment	Lower Tees Catchment
CM32	Pont Catchment	Pont Catchment

Of the FF sites in the North East region only 4 can be directly applied to catchment time series in Aquator as shown in table 6.2.

Table 6.2 Catchments containing FF sites.

FF Station No.	FF River	FF Station	Aquator Time Series
23004	South Tyne	Haydon Bridge	South Tyne Catchment
23011	Kielder Burn	Kielder Burn	Kielder Catchment
22001	Coquet	Morwick	R Coquet Catchment
24009	Wear	Chester Le Street	Lower Wear Catchment

For the other catchment time series in Aquator the FF database was then interrogated to determine the geographically closest FF site to each of the catchments. Where there wasn't a FF site either on the same river or in close geographical proximity a site on a similar longitude was chosen as shown in table 6.3 below.

Table 6.3 Catchments using surrogate FF sites

Catchment Name	FF Station No.	FF Station
Burnhope Catchment	24009	Wear @ Chester Le Street
Catcleugh Catchment	23011	Kielder Burn @ Kielder
Colt Crag Catchment	22009	Coquet @ Rothbury
Cow Green Catchment	23011	Kielder Burn @ Kielder
Derwent Catchment	24005	Browney @ Burn Hall
Derwent Indirect Catchment	24005	Browney @ Burn Hall
Fontburn Catchment	22009	Coquet @ Rothbury
Hallington Catchment	22009	Coquet @ Rothbury
Honey Hill Catchment	24009	Wear @ Chester Le Street
Kielder Catchment	23011	Kielder Burn @ Kielder
Lower Tees Catchment	25007	Clow Beck @ Croft
Lune/Balder Catchment	23004	Sth Tyne @ Haydon Bridge
Mid Tees Catchments	23004	Sth Tyne @ Haydon Bridge
Mid Tyne Catchment	23011	Kielder Burn @ Kielder
North Tyne Catchment	23011	Kielder Burn @ Kielder
Pont Catchment	22009	Coquet @ Rothbury
Rede Catchment	23011	Kielder Burn @ Kielder
Tunstall Catchment	24009	Wear @ Chester Le Street
Upper Tees Catchment	23011	Kielder Burn @ Kielder
Upper Wear	24009	Wear @ Chester Le Street

6.3.3 NWs Final Water Resources Plan Approach

NW recognises that an improved approach is required to assessing the impact of climate change on its surface water resources. Therefore, a full suite of rainfall-runoff models are being developed, for all catchments that are included in the Kielder WRZ Aquator model, these will cover the period from 1920 to date.

The rainfall runoff models will be ready to re-assess climate change impacts for the final WRMP. A Tier 2 analysis will then be carried out, which will use the UKCP09 climate change factors to perturb historic climate data in order to derive new river flow time series. It is felt this approach is more rigorous than that adopted for the draft plan, although it should be noted that no approach is perfect, and the drawback of using UKCP09 climate change factors is that it does not reflect the change in rainfall patterns over time, only the magnitude of change.

6.3.4 Kielder Resource Zone Results

The monthly change factors were applied to the four river flow time series in the Kielder Aquator model. Generally, the climate change scenarios are showing a predicted change in rainfall patterns with drier summers and wetter winters.

In total, 220 climate change perturbed time series were imported into the model, 11 for each of the catchment flow time series. The DO under each of the 11 FF climate change scenarios are shown in table 6.4 below with the associated change in DO relative to the baseline.

Table 6.4 Kielder WRZ Climate Change DO.

			Deployable Output (Ml/d)	Change from Baseline (Ml/d)	
Baseline (no climate change)			836		
Future Flows Climate Change Scenarios	1	FF-HadRM3-Q0_afgcx	835	-1	-0.1%
	2	FF-HadRM3-Q3_afixa	832	-4	-0.5%
	3	FF-HadRM3-Q4_afixc	830	-6	-0.7%
	4	FF-HadRM3-Q6_afixh	835	-1	-0.1%
	5	FF-HadRM3-Q9_afixi	840	4	+0.5%
	6	FF-HadRM3-Q8_afixj	792	-44	-5.3%
	7	FF-HadRM3-Q10_afixk	724	-112	-13.4%
	8	FF-HadRM3-Q14_afixl	771	-65	-7.8%
	9	FF-HadRM3-Q11_afixm	839	3	+0.4%
	10	FF-HadRM3-Q13_afixo	724	-112	-7.8%
	11	FF-HadRM3-Q16_afixq	840	4	+0.4%
Minimum climate change scenario DO			724	-112	-13.4%
Average climate change scenario DO			806	-30	-3.6%
Maximum climate change scenario DO			840	4	+0.4%

Climate Change Deployable Output

The Kielder WRZ appears to be relatively sensitive to reductions in summer flows, this is due to the fact that under the baseline scenario, during the design drought year, some reservoir levels are already extremely low and the decrease in summer flows means that the reservoirs empty prior to the winter refill period. High level assessment of the two worst case FF scenarios (FF-HadRM3-Q10_afixk & FF-HadRM3-Q13_afixo), suggest that a higher DO would be achievable with some minor alterations to the rules that govern the transfer of water between different zones in the model.

The impact of climate change on the DO of the Kielder WRZ is included in the supply demand planning tables. The minimum, average and maximum DO figures calculated from the 11 climate change scenarios will be used.

The uncertainty of climate change impact on DO of the Kielder System is included in headroom. The required triangular distribution for the headroom calculation will use the minimum, average and maximum loss to DO from the figures derived.

6.3.5 Groundwater Climate Change Assessment

The impact of climate change on groundwater levels, and thus on the DO, was input into the DO calculations using the data from (AMEC, 2013). This report identifies the decrease in groundwater level in the Sunderland and Berwick areas in response to decreasing recharge as a result of climate change based on UK Climate Projections 2009 (taken from the UKWIR 2009 Rapid Assessment Report) which provides projections appropriate up to the 2030’s.
For the Sunderland Groundwater Stations, the Sunderland Groundwater Model, developed on behalf of NW and the Agency by AMEC, identifies specific groundwater level reductions for each borehole. Where data are not available for a specific groundwater station, the value for the next nearest station has been used. Table 6.5 below shows the calculated reduction in water level.

Table 6.5 Reduction in water level in Sunderland GWS.

Sunderland Groundwater Station	Reduction in Groundwater Level (m)
Borehole 10	0.789
Borehole 11	0.789
Borehole 12	0.556
Borehole 13	0.835
Borehole 14	0.930
Borehole 15	0.940
Borehole 16	0.162
Borehole 17	0.162
Borehole 18	0.162

These new water levels were then used in the method to calculate DO as described in Section 3.1.3 above and produced no reduction in the DO of the boreholes as a result of the water level changes.

Berwick & Fowberry WRZ

For the Berwick and Fowberry WRZ, no groundwater model is available to undertake predictive calculations of the impact of climate change. In order to provide climate change predictions on groundwater levels in this area, a reduction of 1.4 m in the

Berwick area and 1.0m for the Wooler area were estimated using Long Term Average recharge spreadsheet calculations.

Table 6.6. Reduction in water level in Berwick and Fowberry GWS

Berwick& Fowberry Groundwater Station	Reduction in Groundwater Level (m)
Borehole 1	1.0
Borehole 2	1.0
Borehole 3	1.4
Borehole 4	1.4
Borehole 5	1.4
Borehole 6	1.4
Borehole 7	1.4

Again these new levels were used to calculate DO and resulted in no reduction in output as a result of the changes.

6.4 Effect of Climate Change on Demand

Background:

The impact of climate change on demand has been considered in terms of:

(1) The explicit effect on distribution input. This has been defined for two scenarios; the most-likely and least likely (maximum) scenarios. The most-likely scenario has been chosen as the central scenario to be included within the DO in the supply demand balance.

(2) The uncertainty on the effect on distribution input as described in target headroom (using triangular distributions defined by zero, best estimate and maximum scenarios)

The above assessment can also enable definition of an envelope of climate change. Such an envelope can be defined for each weather scenario considered in demand forecasts (principally dry and normal).

The above information has been used to illustrate the effect of climate change on demand in each resource zone both in tabular and graphical format. The following sections give a brief synopsis as to how climate change has been considered followed by this summary information of the results.

6.4.1 Methodology

The UKWIR Impact of climate change on demand project (UKWIR, 2013) results have been used to calculate forecasts of climate change impacts on household water demand for this WRMP. The report associated with this project has been used as an updated reference source that quantifies the impact of climate change on demand.

In summary, this UKWIR project used statistical analysis on five case studies looking at household and micro-component water consumption and non-household water consumption. The weather- demand relationships developed from the case studies have been used in combinations with UKCP09 climate projections to derive algorithms for calculating estimates of the impact of climate change of household water demand for each UK region in the format of look-up tables (UKWIR, 2013). These look-up tables present the estimated future impacts of climate change on household demand for any river basin between the years 2012-2040 and for a range of percentiles to reflect the uncertainty of the UKCP09 climate projections (UKWIR, 2013). Please refer to the report for a complete description on the methodology in creating the look-up tables' used (UKWIR, 2013).

A look-up table is provided for each UKCP09 river basin areas and the associated area. Within each area look-up table demand factors, describing the percentage change in household demand, are for two case study relationships (Thames Water and Severn Trent Water) and three demand criteria (annual average, minimum DO and critical period). The changes in household demand are provided for the 10th, 25th, 50th, 75th and 90th percentile to reflect the uncertainty in UKCP09 climate projections.

Due to the planning scenario selected for the Company the annual average demand criterion is the only one that applies to NW, therefore this is the only set of rows that have been employed.
Table 6.7 below shows the river basin area and case study relationship chosen for each area.

Table 6.7 River basin area and case study relationship

Area	River Basin look-up table selected	Case Study relationship selected
North	Northumbria	Severn Trent

The Severn Trent case study relationship was selected for the North as the Severn Trent area is more rural than Thames and provides a better representation of the North.

Different percentiles have been selected to give the most-likely and least likely (maximum) effects of climate change on demand across the planning horizon. For the most-likely effects of climate change the 50th percentile has been chosen (a one in two chance of occurrence). To determine the least likely (maximum) effect of climate change of demand the 90th percentile was selected (a one in ten chance of occurrence). This approach allows the different probabilities of climate change occurring to be examined over the next 25 years.

The look-up table values give the percentage change in demand between 2012-2040. As these look-up tables were not updated for PR19 the projections were extended along the same trajectory until 2060 to cover the demand forecasting horizon. This has been applied to the total micro-component consumption to give the most-likely and least likely (maximum) forecasts of climate change impact. The report has advised that the same percentage change in demand can be assumed for both measured and unmeasured properties (UKWIR, 2013). Therefore within the micro-component model the total Per Capita Consumption (PCC)s have been adjusted by the overall percentage change in demand as found in the look-up tables. It has been assumed that household demand is the only component of demand affected by climate change. Non-household demand is not expected to be effected by climate change. The report also stated that where necessary to allocate the effects of climate change across components of household demand, it would be reasonable to assume that all additional water consumption in hotter or drier weather is for external water uses (UKWIR, 2013).

6.4.2 Impact on Supply Demand Balance

After taking account of climate change on deployable output, both WRZs have a supply surplus across the planning period. Consequently, climate change is not driving any investment.

6.5 Carbon emissions from water operations

We report annually on the volume of greenhouse gas for which the company is responsible and has done so since 2008. The trend in these emissions is a falling one though there is some year on year variation in this, mainly due to the impacts of weather and NW's response to it.

This fall reflects a structured approach to emissions reduction through the implementation of a carbon management plan, initiated in 2009. This plan has the ambition to reduce emissions by 35% by 2020 against a 2008 baseline. If the emissions linked to grid electricity were to fall as projected by government at that time this should result in a total reduction of 50% in NW's Company-wide operational emissions by 2020.

The plan is based on a combination of actions to improve NW's efficiency in the use of energy, and the displacement of grid electricity by the development of renewable energy, in particular the use of biogas from sewage sludge and hydroelectric power generation.

The latest estimate of Greenhouse Gas (GHG) emissions for operational carbon as a result of providing drinking water to customers in NWG's Northumbrian operating area is 46,902 tonnes CO2e. The Northumbrian region benefits from being able to use gravity in the provision of water services. Combined with effective energy management, the result is that the emissions intensity of the provision of water to customers is one of the lowest in the country at 191 kg CO2e/Ml. Only Thames Water of the larger companies has a lower emissions intensity, due to the way it accounts for the low carbon energy it sources from third party suppliers.

We expect emissions to continue to fall, partly as a result of NW's own efforts, and partly as a result of falling emissions linked to grid electricity. Most of the Company's emissions result from NW's use of grid derived power. The proposed closure of the

UK's coal powered generation plant by 2023, combined with a growing capacity of renewable energy, means that grid emission factors are likely to fall by half by 2025, then halve again by 2045. The future emissions projections reflect this as shown in table 6.8.

NW has no projects for the further development of water resources in NW's plan, and no consideration of options or the carbon emissions resulting from them has been necessary.

Table 6.8 Drinking Water Emissions Table

	2008	2017	2025	2045
Tonnes CO2e	52,370	46,902	22,600	12,900

7.0 TARGET HEADROOM

7.1 Background

Actual headroom is the difference between the supply and demand forecasts of the supply demand balance (i.e. the difference between Water Available for Use (WAFU) and the constrained dry weather demand forecast). A water company would ideally like WAFU to be greater than the demand forecast to allow for uncertainty and ensure it can meet demand.

The 'ideal' amount of actual headroom that a prudent water Company should retain is called target headroom. Target headroom can be thought of as a security margin, or more accurately a means of assessing uncertainty in the supply demand balance.

For the PR14 WRMP NW followed the 1998 UKWIR document 'A Practical Method for Converting Uncertainty into Headroom'. The methodology is based upon the identification of the principal uncertainties in the supply/demand balance assessment and assigning scores to each of these categories of uncertainty. The total score for the Resource Zone is then converted into a Target Headroom value.

A probabilistic approach to determining target headroom in both of NWs resource zones has been adopted for this periodic review, utilising the latest industry standard methodology produced in 2002 (UKWIR, 2002).

A description of the methodology, the results produced and their interpretation has been summarised below.

7.2 Methodology

The 2002 headroom methodology (UKWIR, 2002) introduces the concept of 'headroom uncertainty', which is defined as:

"a probability distribution that represents a likely range of values for headroom for selected years within the planning period".

Inherent in the definition is the need to make choices from the probability distribution on the level of risk (or degree of uncertainty), that a water Company is prepared to accept in relation to headroom. This is necessary in order to define a value for target headroom for each resource zone for each year across the planning horizon, suitable for incorporation in the supply demand balance. The calculation of headroom uncertainty is required over the planning horizon from 2020/2021 to 2059/2060. However, as headroom uncertainty is forward-looking, the calculation of headroom uncertainty has commenced in 2018/2019.

The basis of the 2002 methodology (UKWIR, 2002) is to apportion target headroom into two main areas; supply side and demand side, subdivided into respective supply or demand side components indicated as follows:

Supply Side Headroom Components

S5 Gradual pollution of sources causing a reduction in abstraction
S6 Accuracy of supply side data
S8 Uncertainty of impact of climate change on deployable output

Demand Side Headroom Components

D1 Accuracy of sub-component demand data
D2 Demand forecast variation
D3 Uncertainty of impact of climate change on demand
D4 Uncertainty of demand management measures

Three additional supply side components known as S1 (vulnerable surface water licences), S2 (vulnerable groundwater licences) and S3 (uncertainty of renewal of time-limited licences) have not been included. This is because the Agency has stated that no allowance for the risk of sustainability reductions should be made in target headroom. In addition, the Agency has been instructed by ministers to ensure that there is not a risk of security of supply due to time-limited licences. S4 (Bulk imports) has not been included as there are no imports into either of NW's WRZs and S9 (Uncertainty of new sources) was not included as no new sources are required over the planning horizon.

Supply side components generally require the identification of individual groundwater or surface water sources, which are likely to be impacted. Demand side components are considered on a holistic basis for each resource zone.

To formally document all the sources identified under each supply side component and all demand side components, the methodology makes use of 'Headroom Issues Proforma' spreadsheets, which contain details of each identified headroom component for a particular resource zone. The proformas allow each component to be uniquely identified and relationships between components to be defined.

Where a component is not independent, the UKWIR methodology (UKWIR, 2002) and Crystal Ball® allows for overlapping, correlated and dependent relationships to be included in the headroom calculation. These relationships are determined as follows:

- Overlapping or mutually exclusive relationships ensure that it is only possible for the DO of a source to be lost once. Each component is assessed independently before taking the largest value selected from two or more overlapping components.

- Correlating data allows a variety of relationships to be defined between two or more components. For example groundwater sources at different locations may abstract from the same aquifer and therefore face similar sustainability issues or risks from pollution. A correlation coefficient is applied to describe the relationship between the different sources.

- A dependent relationship occurs when a source's headroom uncertainty is dependent on the uncertainty at another source. No dependent relationships occur between any headroom components associated with NW and consequently dependent relationships were not used in any of the headroom uncertainty calculations.

A summary of the assumptions used to assess the uncertainty for each supply side and demand side headroom component is provided below.

<u>Supply Side Components</u>

S5 All NW groundwater sources were included as being at risk from pollution, with the headroom uncertainty for each source separated into point and diffuse pollution. Catchment risk assessment work was undertaken to determine the uncertainty of point and diffuse pollution at all of NW's groundwater sources. The calculation of the uncertainty of point pollution additionally made use of the number of petrol and diesel storage sites currently within the total groundwater protection zone of each groundwater source.

The uncertainty of dead storage in reservoirs was also considered for inclusion within S5, but was not carried forward to the final analysis as the estimated levels of sedimentation in 2060 were not at a level that would restrict the use of any of NW's reservoirs.

S6 All NW groundwater and surface water sources are constrained by either:

- licence constrained sources, using the accuracy of abstraction meters;
- infrastructure constrained sources, subdivided into pump capacity and Water Treatment Works accuracy, using accuracy of pumps and Water Treatment Works output meters, respectively.

S8 The DO for all NW groundwater and surface water sources was assessed for the impact of climate change. All sources determined as being potentially impacted were included in the uncertainty of impact of climate change on DO.

Demand Side Components

D1 The accuracy of distribution meters was used to determine the accuracy of sub-component demand data for each NW resource zone, on a holistic basis.

D2 DI was subjected to a statistical technique known as the MLE, which took into account the difference between recorded DI and the sum of all its components, with the aim to make these figures reconcile as closely as possible. The uncertainty surrounding the dry year distribution input for each of the four resource zones was used to determine the demand forecast variation.

D3 The 'Impact of Climate Change on Demand' project results and report (UKWIR, 2013) were used to calculate forecasts of climate change impacts on household water demand and to quantify the impact of climate change on demand. The uncertainty of impact of climate change on demand was defined using 50^{th} and 90^{th} percentile to determine the best estimate and maximum values, and the minimum uncertainty assigned as zero. Further information on climate change can be found in Chapter 6 of this report.

D4 The uncertainty of demand management measures for each NW water resource zone was determined for each of the following:

- delivering the meter strategy, using the number of meters forecast to be installed;
- leakage, using historical data to determine the expectancy of meeting the leakage targets;
- water efficiency, using the likelihood of NW's current water efficiency targets.

Further Elements of Methodology

Uncertainties have been assessed for every year within the planning horizon.

Once information on the sources of uncertainty for each headroom component had been collated, a probability distribution was defined for each of the components uniquely identified in the Issues Proforma spreadsheets. To define the probability distribution, information was sought from relevant reports, data and expert knowledge within NW as to the most appropriate type to best fit the data and situation.

Probability distribution profiles can be continuous or non-continuous. In many circumstances continuous distributions will be more appropriate for assessing headroom uncertainty. These allow any value between the stipulated values to be applied to the probability, whereas a non-continuous distribution only allows probability to be determined for the particular values stipulated.
An 'Input Proforma' spreadsheet was completed for each individual headroom component identified within the Issues Proforma spreadsheets, in order to allow the data, probability distributions and specific parameters to be documented and the decisions for these choices to be transparent and auditable. The sheets include specific sections to document meetings and discussions used to progress the particular component, relevant reports and data applied.

The individual headroom components were grouped on a resource zone basis and inserted into a purpose-built spreadsheet produced by Mott MacDonald as part of the UKWIR project (UKWIR, 2002). The probability distributions, parameters and relationships between components form the basis of the Monte Carlo simulation, which determines the overall Headroom Uncertainty by adding the individual headroom components together. The software package Crystal Ball® 11.1.2.4.850 was used within the spreadsheet environment to allow the Monte Carlo simulations to be run. When run, Monte Carlo randomly selects numbers from the probability distribution assigned to each component, effectively simulating a 'what if' scenario. The Monte Carlo simulation derives headroom uncertainty for each year within the planning horizon. The simulation was run through 10,000 iterations for each of the NW resource zones, in order to gain a suitable level of consistency in the results.
The Monte Carlo simulation was re-run excluding the climate change components S8 (uncertainty of impact of climate change on DO) and D3 (uncertainty of impact of climate change on demand). The headroom uncertainty figures with and without climate change were compared for every year within the planning horizon to analyse the significance of climate change.

7.3 Form of Output – Trend Charts and Sensitivity Analysis

The results from the Monte Carlo simulation are expressed in terms of percentiles for every year within the planning horizon.

7.3.1 Trend Charts

The percentile envelopes of headroom uncertainty can be plotted in Crystal Ball® as a 'headroom uncertainty trend chart', which indicates how the uncertainty in headroom varies throughout the planning horizon, under the analysis for each resource zone.

When interpreting such Crystal Ball® trend charts it should be recognised that:

- Headroom uncertainty has been defined for all years within the planning horizon;
- The various certainty bands indicated are represented by all the range of values between and including the indicated upper and lower bounds;
- The certainty bands above are not the same as percentiles but are related as follows:
  - The 10% certainty band in red equates to the difference between the 45th and 55th percentile (i.e. 5% either side of the median value);
  - Similarly the junction between the yellow and blue shaded areas is the 80th percentile at the top of the chart and the 20th percentile and the bottom of the chart;
- Upper percentiles have been considered as choices for target headroom.

When determining which of the upper percentiles of headroom uncertainty should be used for target headroom, NW has recognised that this choice is important given that it reflects the level of risk the Company is willing to accept. It should be recognised that this choice may directly affect investment decisions and the driving supply demand balance scenario. The upper percentiles reflect return periods as indicated in table 7.1 below.

Table 7.1 Return Periods

Percentile	Return Period
50	1 in 2
75	1 in 4
80	1 in 5
90	1 in 10
95	1 in 20
96	1 in 25
98	1 in 50

The return periods can be viewed as the probability for each year of headroom uncertainty not falling within a respective defined envelope. The 90th percentile has been chosen throughout the planning horizon as the basis for defining 'target headroom' for both of NW's resource zones.

NW believes that the use of the 90th percentile across the planning horizon is justified due to the supply surplus being present in all WRZs and the target headroom remaining essentially constant or only increasing slightly over the planning horizon.

7.3.2 Sensitivity Analysis

The UKWIR methodology includes an inherent assumption that all components identified are of an equal weighting unless related through overlapping, correlations or dependency. The creation of sensitivity charts from the Monte Carlo simulation allows sensitivity analysis to be performed for each component through the use of correlation coefficients. A sensitivity chart has been created for the planning period using the data from the end of each AMP, for each resource zone. This shows how the percentage contribution of each target headroom component varies over the planning horizon.

The UKWIR 2002 methodology (UKWIR, 2002) suggests the checking of headroom components contributing to over 25% of overall uncertainty, to ensure they are realistic. Where sensitivity analysis has highlighted such components, stringent checking has occurred and it has been determined that the parameters input to the probability distributions are realistic. Where a headroom component contributes over 50% to overall headroom uncertainty, the methodology suggests that further investigations to confirm or refine estimates may be justified.

7.4 Headroom Uncertainty Results

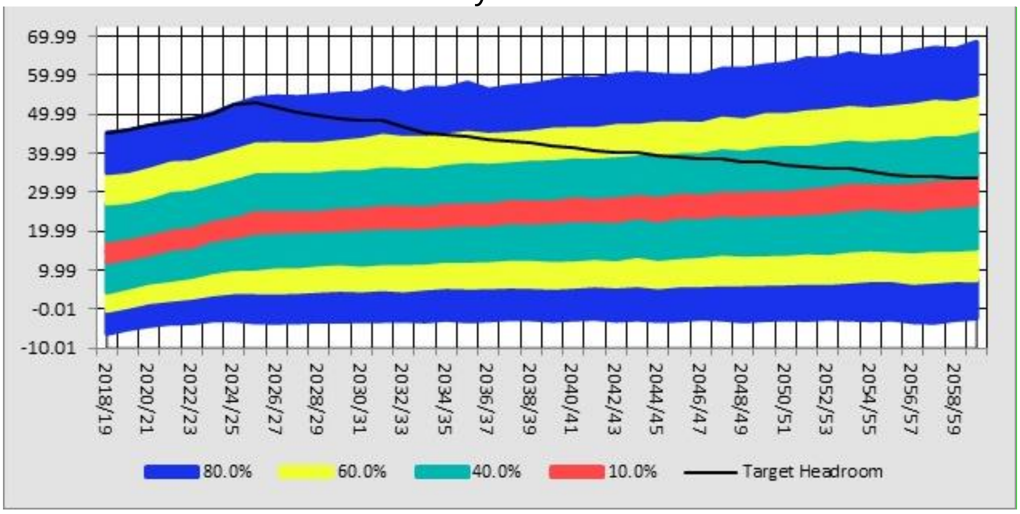
The results of the headroom assessment for each resource zone are indicated on the following pages, along with explanatory text.

7.4.1 Kielder Resource Zone

Using the chosen percentile (the 90th percentile in 2018/19 reducing to the 55th percentile in 2059/60) the target headroom ranges from 45.25Ml/d in 2018/19 to 33.53Ml/d in 2059/60. This represents 6.8% and 4.3% of WAFU in 2018/19 and 2059/60, respectively.

Figure 7.1 below shows how the uncertainty in headroom varies throughout the planning horizon, along with the chosen headroom values.

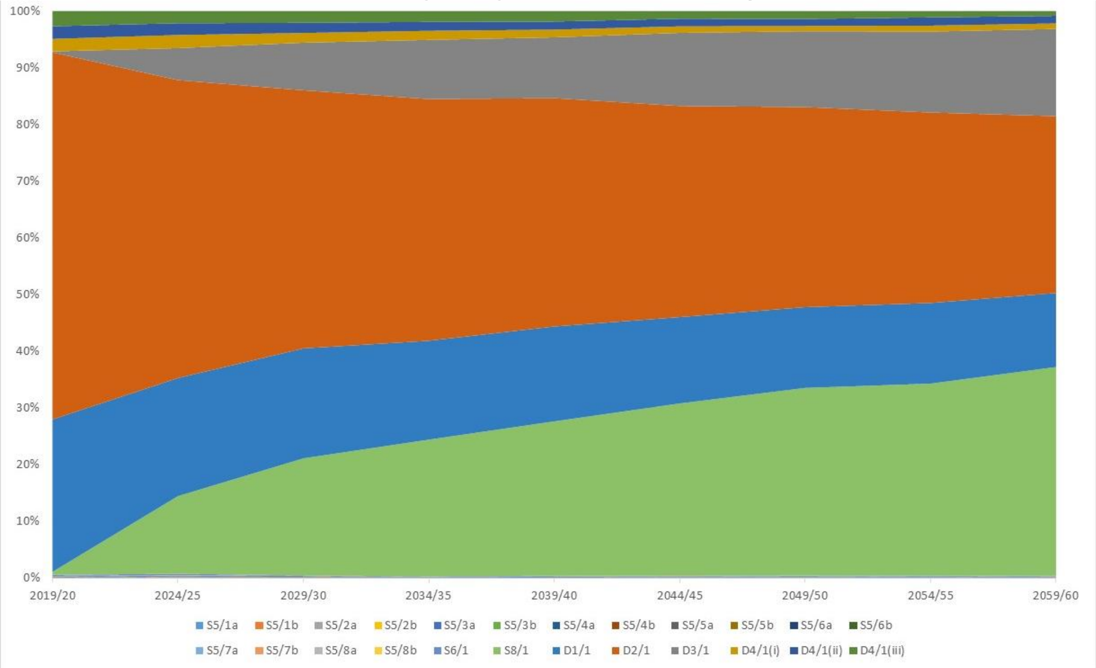
Figure 7.1.Kielder Headroom Uncertainty



The gradual rise in uncertainty over the planning horizon is largely due to the increasing impact of climate change on supply side components.

At the start of the planning horizon demand forecast variation (D2/1) contributes the greatest proportion of overall uncertainty, with the significance of this component gradually decreasing from 65% in 2019/20 to 31% in 2059/60.
The significance of the uncertainty of supply and demand climate change components (S8/1 and D3/1) gradually increases over the planning horizon. The uncertainty of the impact of supply side climate change on the Kielder System increases over the planning horizon, from 0% in 2019/20 to 33% in 2059/60, and the uncertainty of the impact of demand side climate change on the Kielder System increases over the planning horizon, from 0% in 2019/20 to 14% in 2059/60.
The significance of the uncertainty of distribution input arising from meter inaccuracy (D1/1) gradually decreases over the planning horizon, from 27% in 2019/20 to 13% in 2059/60.
It is considered realistic that the components mentioned above are the most significant factors of uncertainty in the Kielder resource zone and are represented in figure 7.2 below.

Figure 7.2 Kielder WRZ Percentage Significance of Components

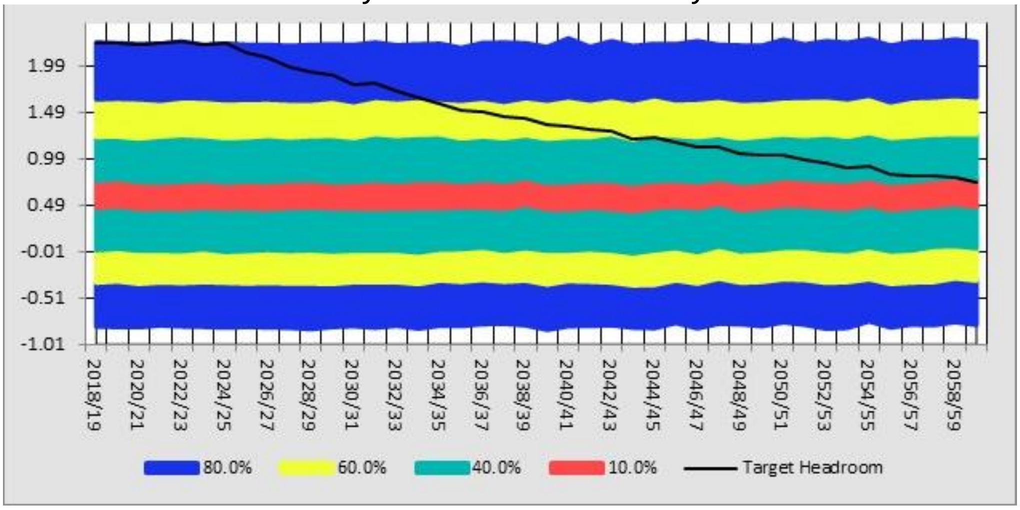


7.4.2 Berwick & Fowberry Resource Zone

Using the chosen percentile (the 90th percentile in 2018/19 reducing to the 55th percentile in 2059/60) the target headroom ranges from 2.24Ml/d in 2018/19 to 0.73Ml/d in 2059/60. This represents 19.3% and 6.4% of WAFU in 2018/19 and 2059/60, respectively.

Figure 7.3 below shows how the uncertainty in headroom varies throughout the planning horizon, along with the chosen headroom values.

Figure 7.3 Berwick and Fowberry Headroom Uncertainty

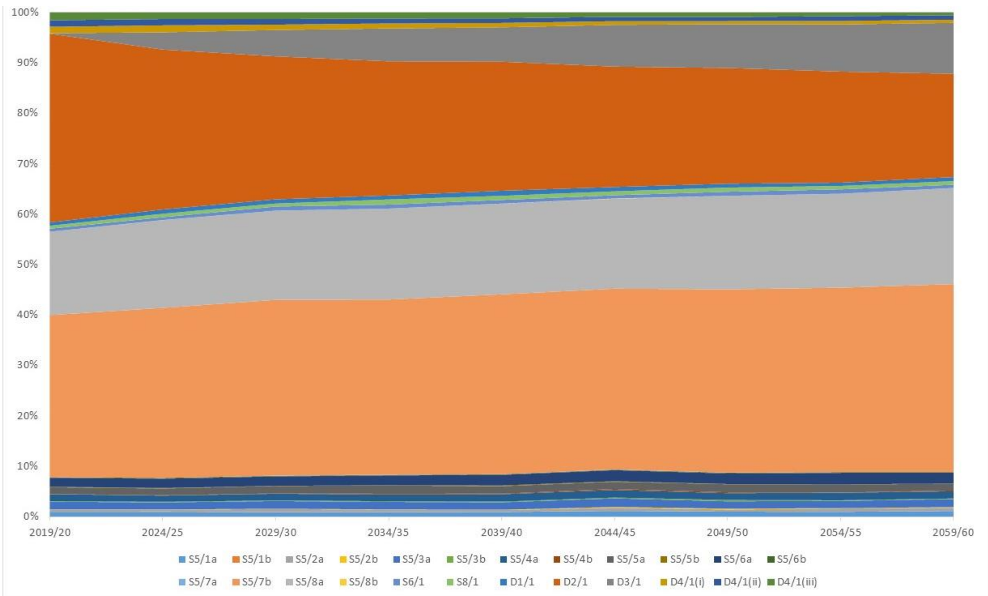


As can be seen the uncertainty over the planning horizon remains largely consistent.

At the start of the planning horizon demand forecast variation (D2/1) contributes the greatest proportion of overall uncertainty, with the significance of this component gradually decreasing from 37% in 2019/20 to 20% in 2059/60.
The significance of the uncertainty of the effect of climate change on demand (D3/1) gradually increases over the planning horizon, from 0% in 2019/20 to 10% in 2059/60.

It is considered realistic that the components mentioned above are the most significant factors of uncertainty in the Berwick and Fowberry resource zone and are represented in figure 7.4 below.

Figure 7.4 Berwick and Fowberry WRZ Percentage Significance of Components



7.5 Sensitivity Analysis of Climate Change

In the Kielder WRZ the difference between the headroom figures with and without the climate change components was found to be 18.3Ml/d in 2059/60, this is due to the increasing impact of climate change on source yields in the WRZ.

In the Berwick and Fowberry WRZ the difference between the headroom figures with and without the climate change components was found to be negligible, this is due to there being no impact of climate change on source yields, and only a minimal effect of climate change on demand in the WRZ.

The impact of climate change on the baseline supply demand balance is explained in more detail in chapter 8.

7.6 Comparison with 2014 Periodic Review (PR14)

Table 7.2 below provides comparison between the above results for PR14 and those determined for PR19:

Table 7.2 Target Headroom Comparison

Zone	Target Headroom (Ml/d)			
	PR14 base year	PR19 base year	PR14 end of planning horizon	PR19 end of planning horizon
Kielder	13.1	45.25	32.4	33.5
Berwick & Fowberry	0.72	2.24	0.75	0.73

The target headroom in the base year for each resource zone is higher for PR19 than PR14 for both water resource zones, this is due to utilising the more recent UKWIR guidance for this WRMP.

8.0 BASELINE SUPPLY DEMAND BALANCE

The baseline dry year supply and demand data determined in the previous chapters has been used to produce a Baseline Dry Year Supply Demand Balance for each of the Water Resource Zone (WRZ)s. All the known changes to Water Available for Use (WAFU) and the known baseline demand management policies have been included in these calculations.

The baseline supply demand balance calculation is to identify whether a WRZ is predicted to have a supply deficit at any point over the planning horizon. For each WRZ, a supply demand balance graph has been prepared. The key features on each of the graphs are:

- the ‘target headroom’ profile which has been added to the constrained dry weather demand forecast;
- any sustainability reductions and other reductions on Deployable Output (DO) have been assumed as highlighted in Section 3;
- the demand forecasts include the assumptions on water efficiency savings from the Company’s baseline demand management; and
- climate change has been built into the supply, demand and target headroom forecasts as outlined earlier in this document.

The initial supply demand balance graphs for each WRZ are presented in the following sections along with commentary on the key features of interest.

8.1 Kielder Water Resource Zone

Figure 8.1 below shows a gentle decreasing trend in WAFU. This is due to climate change reducing the DO of the surface water treatment works due to licence constraints.

Figure 8.1 Supply Demand Balance – Kielder WRZ

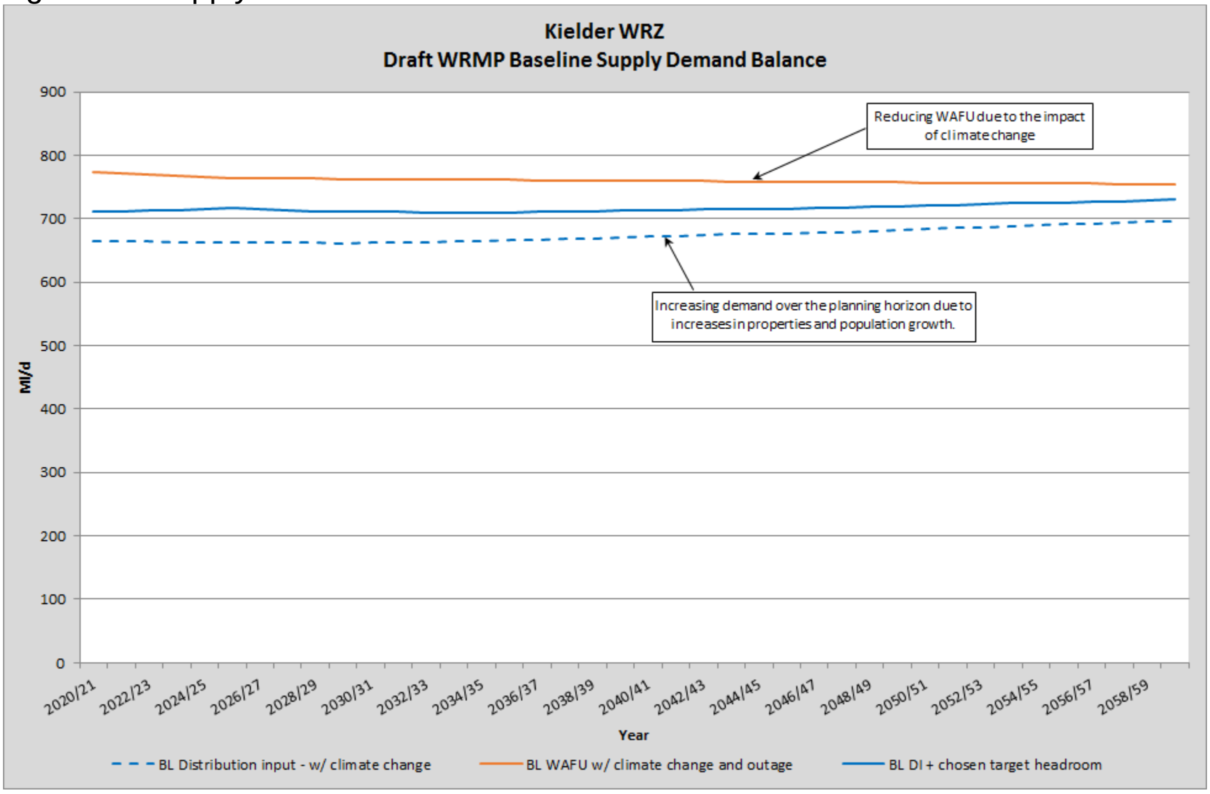


Table 8.1 Kielder WRZ Supply Surplus

Kielder WRZ	End of AMP6	End of AMP7	End of AMP8	End of AMP9	End of AMP10	End of Planning Horizon	End of 40 Year Planning Horizon
Year	**2019/20**	**2024/25**	**2029/30**	**2034/35**	**2039/40**	**2044/45**	**2059/60**
Balance of Supply (excluding headroom)	111.47	102.25	101.04	96.69	89.23	81.80	57.91
Balance of Supply (including headroom)	65.64	49.90	52.08	51.77	47.89	42.55	24.39

Given the supply surplus, no supply schemes will be required.

8.2 Berwick and Fowberry Resource Zone

Figure 8.2 below shows WAFU remaining relatively level.

Figure 8.2 Berwick and Fowberry WRZ Supply Demand Balance

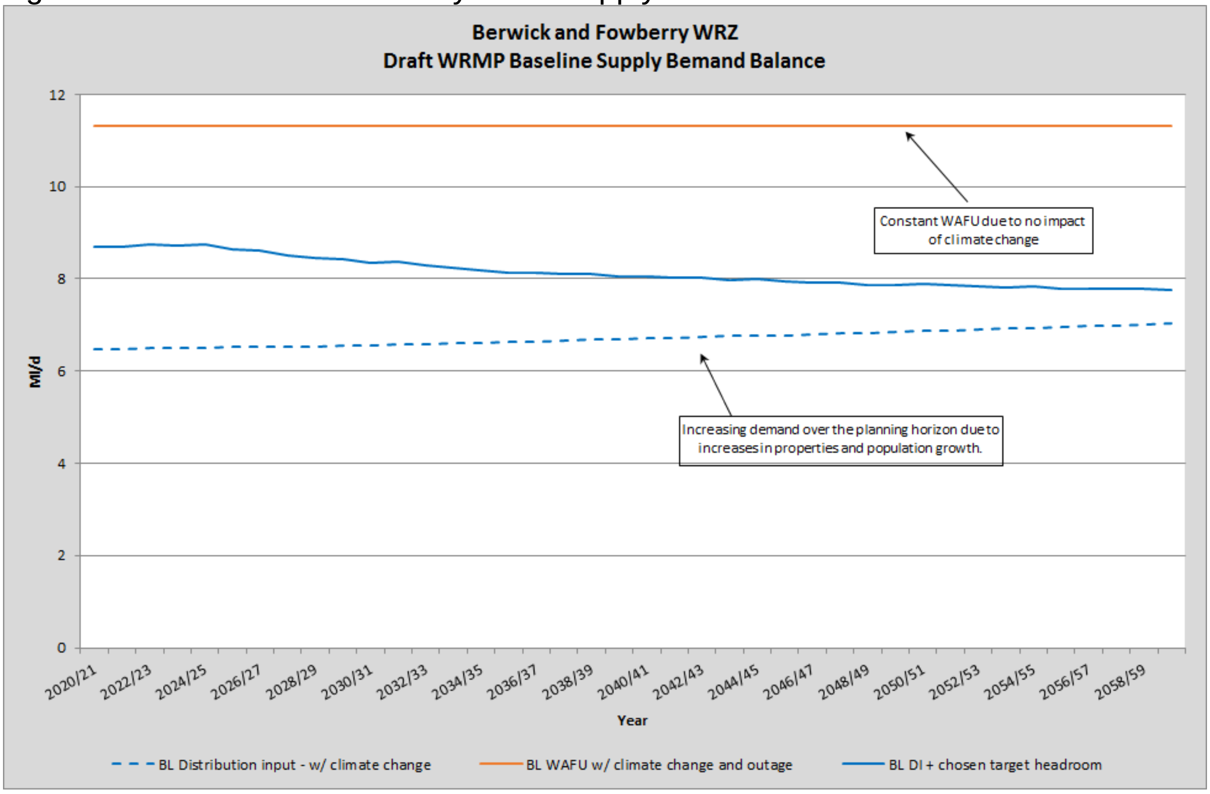


Table 8.2 Berwick and Fowberry Supply Surplus.

Berwick and Fowberry WRZ	End of AMP6	End of AMP7	End of AMP8	End of AMP9	End of AMP10	End of Planning Horizon	End of 40 Year Planning Horizon
Year	2019/20	2024/25	2029/30	2034/35	2039/40	2044/45	2059/60
Balance of Supply (excluding headroom)	4.86	4.81	4.77	4.71	4.62	4.55	4.29
Balance of Supply (including headroom)	2.63	2.58	2.88	3.12	3.27	3.33	3.55

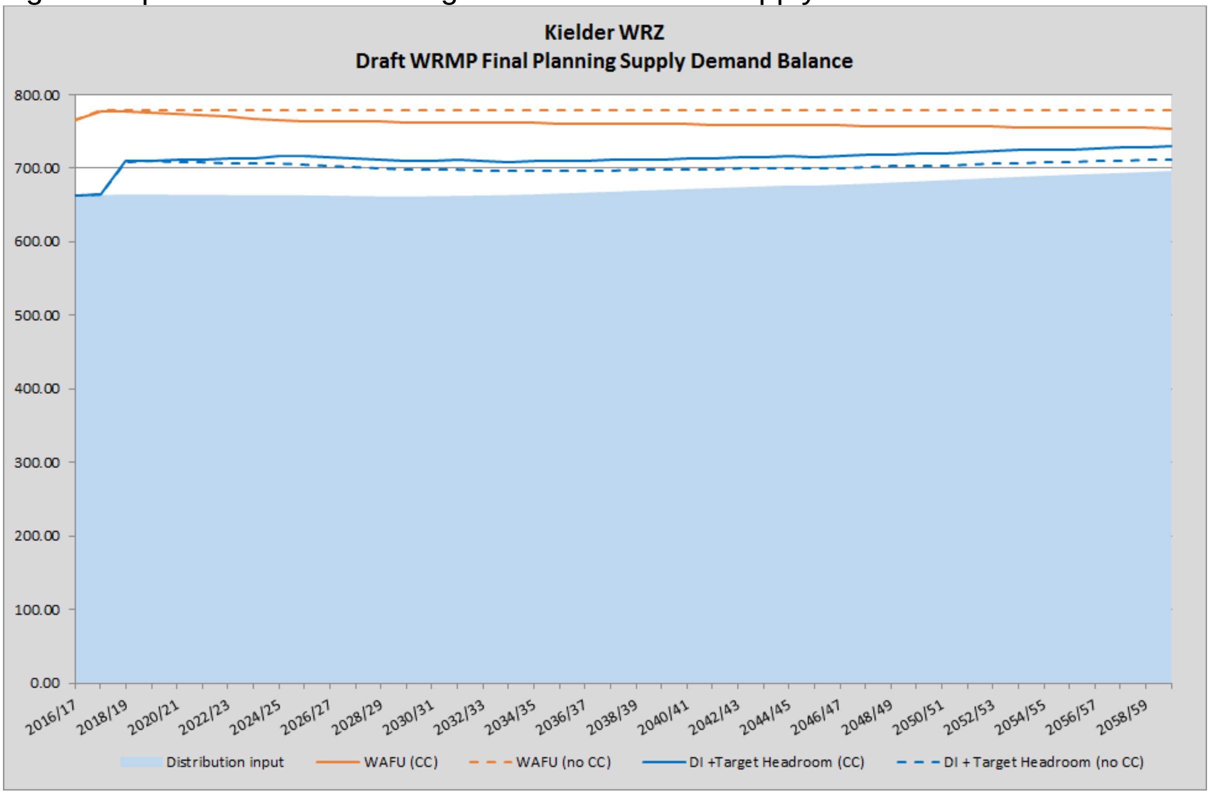
Given the supply surplus, no supply schemes will be required.

8.3 Impact of Climate Change on the Overall Supply Demand Balance

8.3.1 Kielder Water Resource Zone

As explained in the Climate Change section above the impact on the Kielder Zone is minimal with an estimated reduction in DO of 2.8% in 2059/60, therefore if climate change is not included in the supply demand balance calculation it would result in an increase of 23.5Ml/d to the surplus value in 2059/60. This is shown in Figure 8.3 below.

Fig 8.3 Impact of Climate Change on Kielder WRZ Supply Demand Balance



8.3.2 Berwick and Fowberry Resource Zone

The assessment of the vulnerability within the Berwick and Fowberry zone to climate change is low. Current information does not allow a detailed analysis of the effect of this on the performance of the aquifer, however based on the evidence of climate change on the remainder of NW's area of supply and the level of surplus in the zone we would not expect that climate change would affect the ability to supply water in the zone.

8.4 Sensitivity to Climate Change on the Baseline Supply Demand Balance

8.4.1 Kielder Water Resource Zone

There is no significant difference in the supply demand balance between the scenarios with or without climate change.

8.4.2 Berwick and Fowberry Water Resource Zone

There is no significant difference in the supply demand balance between the scenarios with or without climate change.

8.5 Sensitivity to Indicative Sustainability Reductions

The Water Resource Planning Guidelines (WRPG) states that water companies should work out the impact of possible sustainability changes identified in the PR19 Water Industry National Environment Programme (WINEP) on WRZ deployable output through scenario testing.

NWs WINEP2 includes 7 Sustainable Change investigations in the Kielder Zone which will investigate alterations to compensation releases from a number of NW's impounding reservoirs. Currently there is no values placed on these changes so the effects cannot be assessed.

In Berwick the ongoing investigation will determine NW's licenced abstraction limit which is currently assumed to drop to 9.5 Ml/d. Given that the DO for Berwick is not licence constrained this reduction will not affect the supply demand balance.

8.6 Water Framework Directive Water Body Deterioration Risk

8.6.1 Background

An objective of the Water Framework Directive is to prevent deterioration of the status of all surface water and groundwater bodies. The WRPG requires water companies to show in their WRMPs how they will manage the risk of deterioration due to the increased utilisation of abstraction licence annual licenced quantities.

The WRPG confirms that a planned increase in abstraction should be used as the trigger to assess whether increased abstraction poses a deterioration risk to the status of water bodies. The Environment Agency's (the Agency) approach allows full licenced quantities to be used to meet inter-annual fluctuations in demand that may arise between dry, normal and wet years. However, a sustained increase in abstraction to meet growth in demand could be considered to pose a deterioration risk where, for example, river flow falls consistently below an Agency defined threshold called the Environmental Flow Indicator (EFI).

It is therefore possible to undertake a risk assessment to provide an indication of the level of deterioration risk in each of NW's water resource zones in the first instance simply by reviewing the baseline distribution input forecast. This along with previous risk of deterioration assessments are considered for each of the WRZs below.

Kielder WRZ

NW's dry year distribution input in 2020/21 is forecast to be 660.50 Ml/d and calculated to fall by some 6% to 617.42 Ml/d by the end of the 25 year planning horizon. Further calculations show it to rise to 637.26 Ml/d by 2059/60 still below the current value.

Berwick and Fowberry WRZ

The dry year distribution input for 2020/21 is forecast to be 6.75 Ml/d falling to 6.25 Ml/d by 2045/46 and similar to Kielder increasing by 2059/60 to 6.50 Ml/d again still below the current value

8.6.2 Summary

Baseline distribution input forecasts for both the WRZs indicate that distribution input will fall during the statutory minimum 25 year planning period. Consequently, we conclude that there is not a risk of Water Framework Directive (WFD) water bodies in these WRZs deteriorating as a result of NW's abstractions.

9.0 OPTIONS APPRAISAL

The supply demand balance demonstrates a surplus of supply for both Water Resource Zones over the planning horizon through to 2060. As such there are no plans to develop new water resources and therefore there are no resource schemes to appraise and no demand actions beyond NW's proposed water efficiency, leakage and metering strategies.

10.0 FINAL WATER RESOURCES STRATEGY

10.1 Final Planning Supply-Demand Balance

10.1.1 Overview

NW has carefully followed the WRPG and believes it has prepared a robust draft WRMP. The baseline supply demand balance in Section 8 of this report has confirmed the nature of the balance of supply for each WRZ. A final planning scenario supply demand balance calculation has been prepared for each of the WRZ's which includes a final plan DI forecast based on the Company's leakage, metering and water efficiency strategies (see section 5) going forwards.

A final planning scenario supply demand balance graph and tabled summary data (with and without target headroom) is presented for each WRZ in the following sections.

10.1.2 Kielder WRZ

The baseline supply demand balance graph for the Kielder WRZ showed that a supply surplus was maintained across the full planning period.

The final plan supply demand balance shown in Figure 10.1 below shows a greater supply surplus across the planning period from 2020 to 2060. This is because while household property and population increases, water demand is reduced as a result of the Company's final plan water efficiency and leakage strategies.

Figure 10.1 Kielder WRZ Draft WRMP Final Planning Supply Demand Balance

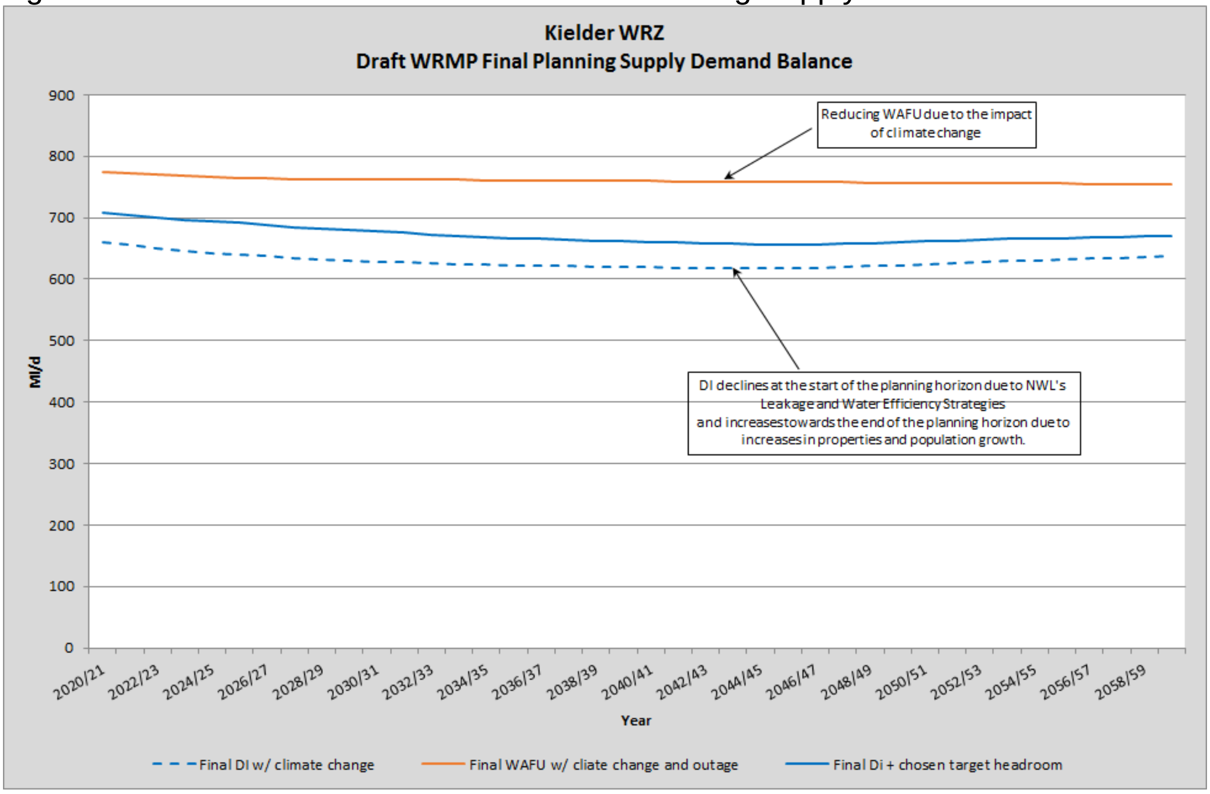


Table 10.1 Kielder WRZ Draft WRMP Final Planning Supply Surplus

Kielder WRZ	End of AMP6	End of AMP7	End of AMP8	End of AMP9	End of AMP10	End of Planning Horizon	End of 40 Year Planning Horizon
Year	**2019/20**	**2024/25**	**2029/30**	**2034/35**	**2039/40**	**2044/45**	**2059/60**
Balance of Supply (excluding headroom)	110.29	124.26	132.10	138.14	140.03	141.01	117.02
Balance of Supply (including headroom)	64.46	71.91	83.14	93.21	98.29	101.76	83.49

10.1.3 Berwick and Fowberry WRZ

The baseline supply demand balance graph for the Berwick and Fowberry WRZ showed that a supply surplus was maintained across the full planning period. The supply surplus in the final plan supply demand balance shown in Figure 10.2 below is slightly higher reflecting the Company's final plan water efficiency and leakage strategies.

Figure 10.2 Berwick and Fowberry Draft WRMP Final Planning Supply Demand Balance

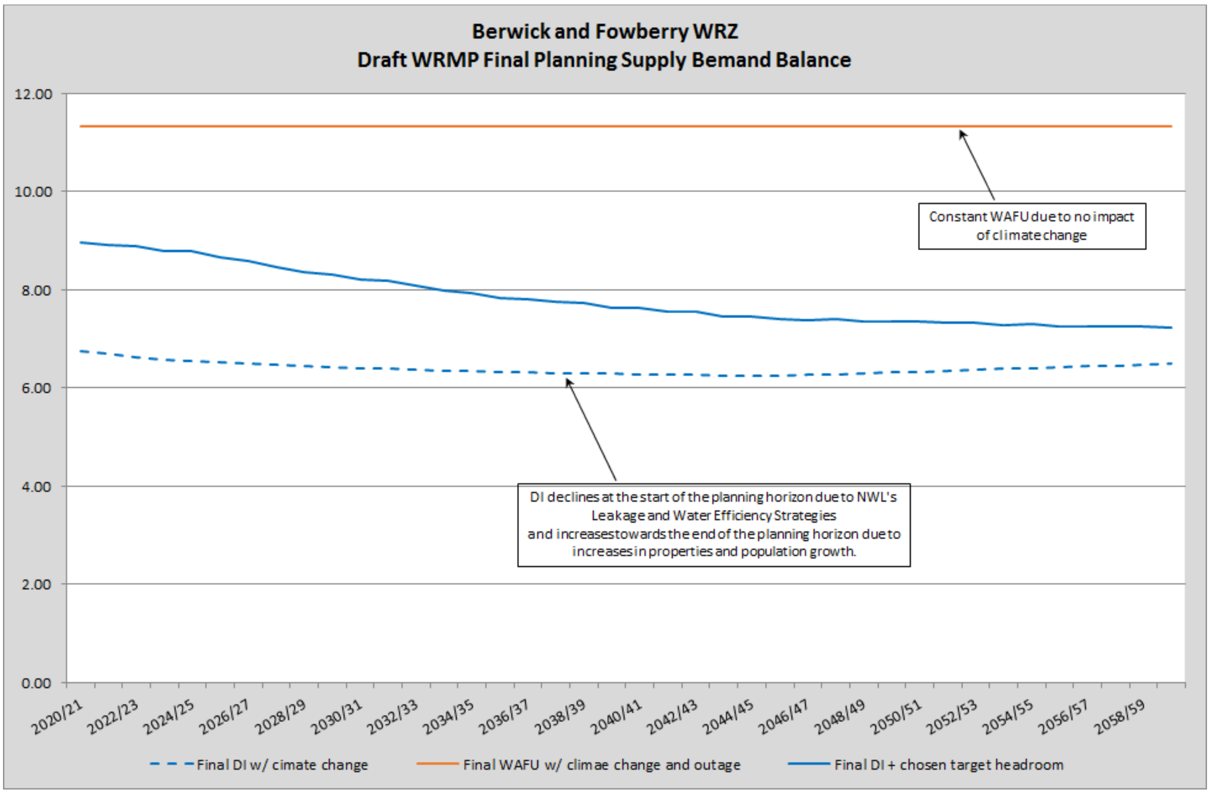


Table 10.1 Berwick and Fowberry WRZ Final Planning Supply Surplus

Berwick and Fowberry **WRZ**	**End of AMP6**	**End of AMP7**	**End of AMP8**	**End of AMP9**	**End of AMP10**	**End of Planning Horizon**	End of 40 Year Planning Horizon
Year	**2019/20**	**2024/25**	**2029/30**	**2034/35**	**2039/40**	**2044/45**	**2059/60**
Balance of Supply (excluding headroom)	4.52	4.77	4.89	4.98	5.03	5.08	4.82
Balance of Supply (including headroom)	2.29	2.54	3.00	3.39	3.68	3.87	4.08

11.0 SUMMARY

11.1 Summary

A supply and demand forecast has been prepared for each of the Company's Water Resource Zones (WRZ) for the following scenarios:

- Worst historic drought; and
- A drought with a return period of 1 in 200 Years.

NW's final plan confirms that a supply surplus will be maintained under both scenarios in both of the Company's WRZs across both the statutory minimum planning period (25 years to 2045) and the full planning period (40 years to 2060) which NW has considered in this plan.

NW has concluded that the volume of water we forecast we will need to abstract over the planning period will not lead to deterioration in the status of the water bodies from which we abstract. This is in part due to the demand savings and reductions in network losses that NW's water efficiency and leakage strategies will respectively bring.

11.2 Works Between Draft and Final Water Resources Management Plan

Once indicative values for the changes in compensation flows from some impounding reservoirs in the Kielder WRZ which are included in WINEP have been obtained NW will assess the implications on DO although it is not anticipated there will be any negative implications.

NW recognises that an improved approach is required to assessing the impact of climate change on its surface water resources. Therefore, a full suite of rainfall-runoff models are being developed, for all catchments that are included in the Kielder WRZ Aquator model, these will cover the period from 1920 to date will be developed between the draft and final Plan.

11.3 Annual Review of this Water Resources Management Plan

Once published, this WRMP will be reviewed annually in line with the Agency's guideline. All appropriate out turn data (for example, leakage, metering, abstraction and progress with implementing the WINEP) will be reported. We will consult with the Agency should we wish to make any material changes to NW's plan.

12.0 REFERENCES

AMEC (2013) (for Environment Agency) Impact of Climate Change on Water Levels, Final Report

BRE (2003) Water Efficient Housing: Dual Flush WC Assessment

DEFRA; Downing T. E. et al. (2003) CCDew: Climate Change and Demand for Water

DEFRA (March 2011) Market Transformation Programme BNWAT01 WCs: market projections and product details, http://efficient-products.defra.gov.uk/cms/product-strategies/viewall/briefing-note#viewlist

DEFRA (March 2011) Market Transformation Programme BNWAT08 Modelling projections of water using products, http://efficient-products.defra.gov.uk/cms/product-strategies/viewall/briefing-note#viewlist

DEFRA (March 2011) Market Transformation Programme BNWAT03 Baths: market projections and product details, http://efficient-products.defra.gov.uk/cms/product-strategies/viewall/briefing-note#viewlist

DEFRA (March 2011) Market Transformation Programme BNWAT02 Showers: market projections and product details, http://efficient-products.defra.gov.uk/cms/product-strategies/viewall/briefing-note#viewlist

DEFRA (March 2011) Market Transformation Programme BNWAT04 Taps: market projections and product details, http://efficient-products.defra.gov.uk/cms/product-strategies/viewall/briefing-note#viewlist

DEFRA (March 2011) Market Transformation Programme BNW DW01 Dishwashers: Government Standards Evidence Base 2009: Key Inputs, http://efficient-products.defra.gov.uk/cms/product-strategies/viewall/briefing-note#viewlist

DEFRA (March 2011) Market Transformation Programme BNW01: Combined Laundry: Government Standards Evidence Base 2009: Key Inputs, http://efficient-products.defra.gov.uk/cms/product-strategies/viewall/briefing-note#viewlist

DEFRA (March 2011) Market Transformation Programme BNWAT06: Domestic water use in new and existing buildings, Supplementary briefing note,http://efficient-products.defra.gov.uk/cms/product-strategies/viewall/briefing-note#viewlist

DEFRA, Agency, OFWAT (2002) Best practice principles in the economic level of leakage calculation by WRc with Stone and Webster Consultant

Agency(2008) Water Resources Planning Guideline

Agency(June 2012) Water Efficiency Evidence Base - Review and Enhancement

Agency(2013) Climate change approaches in water resources planning – Overview of new methods

Agency(2016) Water Resources Planning Guideline

Agency(2017) Water Resources Planning Guideline: Interim Update

Agencysupporting document to WRPG 2019 – Outage

Agencysupporting document to WRPG 2019 - Resource zone integrity

Agencysupporting document to WRPG 2019 - Drought plan links

Agencysupporting document to WRPG 2019 - Drought options

Agencysupporting document to WRPG 2019 - Climate change

Agencysupporting document to WRPG 2019 - Leakage

Agencysupporting document to WRPG 2019 - Sustainable abstractions

Herrington P. Department of the Environment (1996) Climate Change and the

Demand for Water.

Ofwat (2017) Delivering Water 2020: consultation on PR19 methodology

UKWIR (1995b) Outage Allowances for Water Resource Planning

UKWIR (1998) Best Practice for Unmeasured Per Capita Consumption Monitors

UKWIR (1998a) A Practical Method for Converting Uncertainty into Headroom

UKWIR (2002) An Improved Methodology for Assessing Headroom

UKWIR (2012) Customer behaviour and water use, UKWIR, Agency, Tynemarch Systems Engineering Ltd, 12/CU/02/11.

UKWIR (2013) Impact of climate change on Water demand – Main Report, UKWIR, Agency, RPS, HR Wallingford, WRc plc, Lancaster Environment Centre, Callidus.

UKWIR(2016) WRMP19 Methods-Household Demand Forecasting, UKWIR, Agency, Artesia Consulting Ltd, Waterforte Consulting Ltd, 15/WR/02/9.

UKWIR (2016) WRMP19 Methods-Risk based planning

UKWIR, 2016, WRMP19 Methods - Decision making process guidance (16/WR/02/10)

UKWIR (2016) Integration of behavioural change into demand forecasting and water efficiency practices, UKWIR, Agency, CC Water. (Report reference number 16/WR/01/15.

Waterwise (2007) A Best Practice Guide for Water Efficiency Programmes

Waterwise (2008) Water consumption of components of domestic demand

WRc (2009) Review of Meter Under-registration

13.0 APPENDICES

APPENDIX 1: WATER RESOURCES PLANNING TABLES

Completed Tables

A series of Water Resources Planning (WRP) tables represent the supply demand balance of the plan for each of the Company's Water Resource Zones (WRZ)s and also provide information for organisations to understand and appraise the plan.

A suite of tables is available in an individual workbook for each water resource zone.

The fundamental basis of the tables is the dry year annual average scenario and both baseline and final planning data are presented within the same workbook for each resource zone.

No critical period scenarios were appropriate for any of the NW resource zones. The tables have been provided on CD to regulators in the first instance.

Copies of these tables are available on request.

APPENDIX 2: SECURITY INFORMATION

This draft WRMP has been independently security checked for NW by the Company's Security Certifier from ch2m and was also subject to final approval by DEFRA prior to release into the public domain.

As a result of this process no information was removed from the WRMP.