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Final Water Resources Management Plan 2019

Technical Report - Demand for water

Contents

1. Introduction

This technical report sets out our approach to deriving robust resource zone level[1] forecasts of demand for water[2], including how we will help manage that demand now and in the future in our Water Resource Management Plan 2019 (WRMP19). Our approach to forecasting and managing demand in future has been informed by what customers, stakeholders and regulators have told us, including during our pre-consultation activities. Amendments have also been made to this report following consultation on our draft WRMP19 in Spring 2018.

Our demand forecasts adhere to the guiding principles and the Water Resources Planning Guideline[3] and this report aims to demonstrate the way in which we have consistently applied the latest methods and national best practice. The key components of demand for water to be forecasted[4] from a "base year" to the end of the planning period[5], as in Section 5 of the Water Resources Planning Guideline, are shown in Figure 1.

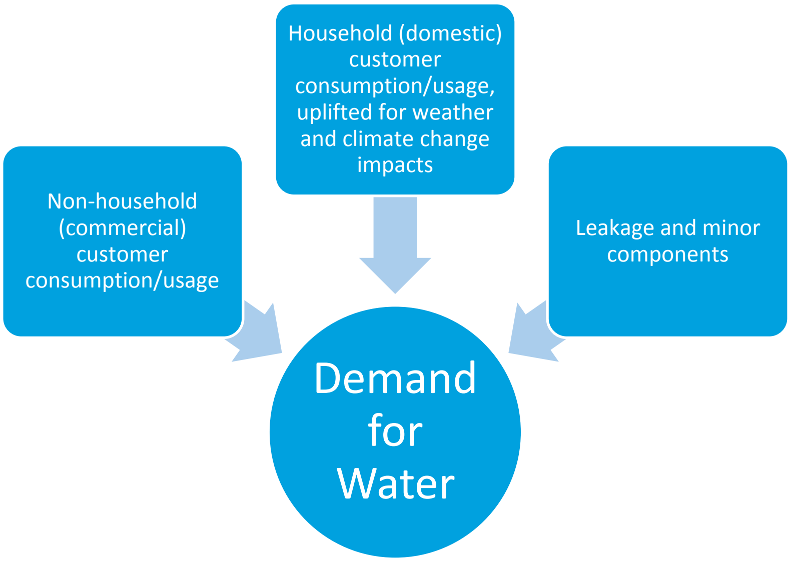


Figure 1 Building the WRMP19 demand forecast

Therefore, we require an understanding of:

1. Household (domestic) customer consumption/usage, hereafter referred to as "household consumption", including the benefits of demand management and uplifted for climate and weather impacts (i.e. reflecting "dry" weather conditions)
2. Non-household (commercial and industrial) customer consumption/usage, hereafter referred to as "non-household consumption", including the benefits of demand management
3. Leakage[6]
4. Any other losses or uses of water, such as water taken unbilled, known as "minor components"

Also, as with any long-term forecast, there is inherent uncertainty. Therefore, the understanding and representation of this uncertainty is as important as the central forecast, forming a key input to target headroom assessment and demand scenarios. Upon final adoption of WRMP19, we will continue to track, monitor and report demand on an annual basis as part of the Annual Water Resources Management Plan review process.

[1] As well as at Demand Monitoring Zone (also known as Distribution Monitoring Zone) level to support resilience assessments that use "peak" type uplifts. We currently have 33 Demand Monitoring Zones.
[2] The treated, or "potable", element of which is known as "distribution input". However, the term "demand for water" is sometimes expanded to cover "non-potable demand" (coved in Section 9) as well.
[3] Water Resources Planning Guideline (Environment Agency, 2018)
[4] For the "baseline" scenario, before any strategic choices (e.g. around leakage) are taken, and "final planning" scenario, where the benefit or impact of any strategic choices are included
[5] Our demand forecast "base year" was 2015/16 for the draft Water Resources Management Plan, and has subsequently changed to 2016/17 for the final Water Resources Management Plan as explained later in this report. The planning period is to, at least, the year 2044/45.
[6] Water leaks from our network of pipes and customer supply pipes

1.1 Changes from draft to final WRMP

Change	Reason	Update(s)	Relevant section(s)
Rebase using Regulatory Reporting data 2016/17 and update to leakage "base year"	We stated that we would likely do this to incorporate more recent demand data	The term "base year" now refers to 2016/17. For leakage our "base year" is a three year average (2015/16, 2016/17 and 2017/18) to represent an average year and reduce the variability that can arise due to weather influence.	All sections (leakage "base year" update is covered in Section 4.6)
Estimation of the impacts of climate change on future demand forecasts	Recommendation 5.3 raised by the Environment Agency in consultation to ensure compliance with Defra WRMP Direction 3(e)	Added chart to show the impact of climate change on demand for water.	Section 7.2
Details of the planned implementation of our metering strategy, including the costs of installing and operating these meters	Recommendation 5.4 raised by the Environment Agency in consultation to ensure compliance with Defra WRMP Direction 3(f)	Added more information on the costs of installing, maintaining and operating our meter stock.	Section 2.2
Assessment of the cost-effectiveness for each type of household metering, including selective and optant metering	Recommendation 5.5 raised by the Environment Agency in consultation to ensure compliance with Defra WRMP Direction 3(h)	Included additional detail in summarising the decision making process and explain how we arrived at our metering strategy and provide additional information related to the costs and benefits of different options.	Section 2.2
Clarity on whether leakage benefit is expected from planned non-supply demand balance actions that we are undertaking	Minor Issue 4 raised by the Environment Agency	Added text to confirm how the leakage benefit from planned non-supply demand balance actions is included.	"Pressure management costs and parameters" section of Appendix A
Exploration of the use of Minimum Achievable Levels of Leakage (MaBL) within the SELL calculation	Minor Issue 5 raised by the Environment Agency	Included additional text to explain how the options selected are going to help explore potential reductions in background leakage over time that are not achievable through current policy options.	"Policy minimum" section of Appendix A
Clarity on how burst frequencies and costs are integrated with the SELL	Minor Issue 6 raised by the Environment Agency	Included additional text to clarify how burst frequencies and costs are integrated with the SELL	"Survey efficiencies and leakage detection costs" section and "Burst frequency distribution" section of Appendix A
Clarity on which mains renewal schemes have been incorporated into the SELL optimisation and the drivers for these	Minor Issue 7 raised by the Environment Agency	Updated text to confirm that mains renewal options were included as options, but rejected at secondary screening due to high cost.	"Mains rehabilitation costs and parameters" section of Appendix A
Explanation of very high non-household population as a percentage of total population	Minor Issue 11 raised by the Environment Agency	Added text to explain the reasons behind the high non-household population as a percentage of total population.	Section 3.1.1
Explanation of increasing occupancy rate	Minor Issue 12 raised by the Environment Agency	Added text to explain the reasons behind the increasing household occupancy rate	Section 2.1.3
The "base year" leakage figure, 448 Ml/d is based on a three year rolling average and is higher than the reported 2016/17 actual performance figure, 439 Ml/d.	Raised by Ofwat in consultation	Justified our approach in setting to provide an average baseline starting position to represent an average year, due to the variability that can arise due to weather influence.	Section 4.6
Clarity on how non-household retailer engagement has influenced the demand forecast.	Raised by Ofwat in consultation	We have added more information on how retailer engagement influenced our demand forecast, as well as the further engagement that has occurred since we published our draft WRMP19.	Section 3.2

Change	Reason	Update(s)	Relevant section(s)
After two decades of falling demand, the daily demand for water appears to have "troughed" in 2014 with a higher level of demand in 2015. While this is only a slight upturn, the reasons behind it need to be properly understood.	Raised by Windermere Lake Cruises in consultation	Demand forecasting is subject to inherent uncertainty, accounted for in target headroom (see Section 10). Short-term fluctuations may be contrary to long-term forecasts or trends based on a range of external factors. As described in Section 1.3, since 2015/16, we have also seen further short-term increases in demand that we will continue to monitor closely as part of the Annual WRMP process. We will also continue work to further explore the drivers behind these patterns (see Section 2.6.1), recognising the demand management response to changing demand trends is important to ensure an ongoing supply-demand balance.	Section 1.3 covers the "base year" update, Section 2.6.1 covers a different approach to forecasting household consumption and Section 10 covers our assessment of uncertainty to inform scenarios

1.2 Resource zones

Following our WRMP19 Water Resource Zone Integrity review, as documented in our *Final WRMP19 Technical Report - Supply forecasting*, we have four resource zones:

- The Strategic Resource Zone (sometimes abbreviated to "SRZ"), a combination of the old Integrated and West Cumbria Resource Zones as defined in the 2015 Water Resources Management Plan (WRMP15). This reflects completion of the Thirlmere transfer scheme by March 2021, and supplies over 98% of customers;
- The Barepot Resource Zone (sometimes abbreviated to "BRZ"), a newly created resource zone containing industrial customers on non-potable supplies[7] (covered in Section 9.2);
- The Carlisle Resource Zone (sometimes abbreviated to "CRZ"); and
- The North Eden Resource Zone (sometimes abbreviated to "NERZ").

1.3 Historic trends, WRMP15 review and key changes for WRMP19

As shown in Figure 2, large leakage reductions in the 1990's, as well as metering and water efficiency activity, have contributed to demand for water being significantly lower than in the recent past.

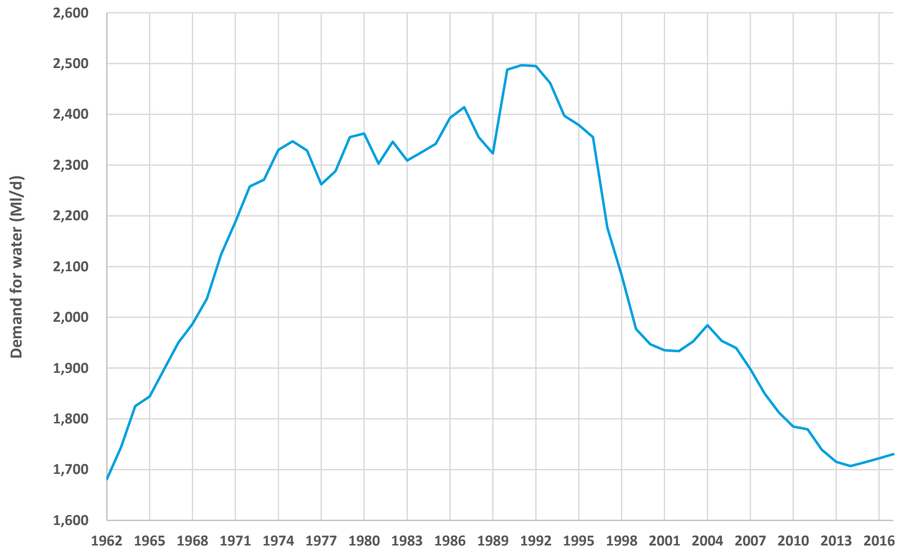


Figure 2 Annual average demand for water back to 1962

[7] Although, in the WRMP process, non-potable water supplied is taken away from available supply, this report discusses non-potable supply from the customer perspective and, therefore, refers to it as "non-potable demand". It's also worth noting that raw water and potable imports and exports are covered in the *Final WRMP19 Technical Report - Supply forecasting*.

As mentioned in Section 4.3.8 of our *Final WRMP19 main report*, year on year the demand for water can fluctuate and in the last few years we have seen slight increases in demand, as shown in Figure 3.

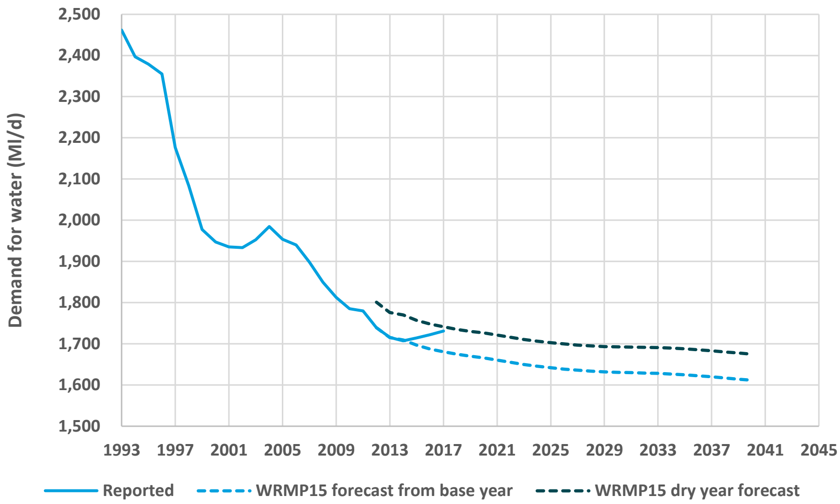


Figure 3 Reported demand for water shown with our WRMP15 forecasts

From Figure 2 and Figure 3, it is clear that there are year on year fluctuations in demand for water, due to factors such as weather. However, in the last few years we have seen slight increases in demand for water (similar to those previously observed between 2001 and 2005 on the graph). While our forecasts aim to account for the long-term trend and take account of plausible uncertainty in target headroom within our planning process, we are alert to the fact that this could be the start of an upward trend. This is a key reason for reviewing our WRMP on a regular basis and we will continue to monitor demand for water, assessing it against our demand forecast, as part of our annual review process.

For WRMP19, the overall reduction in demand for water has not only influenced the starting point of our demand forecast, via the use of this data to inform the base year, but also helps inform the forward look. Table 1 shows this and other key changes made for WRMP19.

Table 1 Key changes to approaches and methodologies for WRMP19

Change ID	Change	Rationale	Key section
DFM1	Used data from Regulatory Reporting 2016/17 for base year data	Reported data, measured where possible, should always form the basis of any demand forecast	1.3.1
DFM2	Based our forecast population and property figures on local plans published by Local Authority Districts and Unitary Authorities	In line with the guidance from the Water Resources Planning Guideline and the WRMP19 Methods – Population, Household Property and Occupancy Forecasting UKWIR report (UKWIR, 2015)	2.1
DFM3	Remodelled the uptake of the Free Meter Option (sometimes referred to as "FMO") and included the uncertainty around the benefit, in terms of consumption reduction, in target headroom.	Following feedback from the Environment Agency and the findings in our previous annual reviews, when comparing actual levels to our forecast levels	2.2.6 and 10
DFM4	Remodelled household consumption, including the creation of a Multiple Linear Regression (MLR) model	In line with the guidance from the WRMP19 Methods – Household Consumption Forecasting, previously Demand Forecasting Methods UKWIR report (UKWIR, 2015)	2.4 and 2.6.1
DFM5	Remodelled non-household consumption	To reflect the latest economic position and sectoral trends	3.3
DFM6	Reassessment of the Economic Level of Leakage (ELL) and Sustainable Economic Level of Leakage (SELL)	WRMP15 advice item and further feedback from the Environment Agency around incorporating the findings of the SELL recommendations report, as well as our own methodological improvements	4.3
DFM7	Remodelled the relationship between weather variables and consumption of water	In line with updated UKWIR guidance and utilising the latest capabilities of the Met Office	7.1.2
DFM8	Revised our design "dry year"	Following a WRMP15 advice item and further feedback from the Environment Agency	7.1.3

1.3.1 Key base year data

Table 2 shows the key components of demand for the base year of our demand forecast.

Table 2 Key components of demand from Regulatory Reporting 2016/17 Table 10b in megalitres per day (Ml/d)

Component	Strategic	Carlisle	North Eden	Region
Unmeasured household consumption	594.2	10.1	1.1	605.4
Measured household consumption	274.3	3.9	0.5	278.7
Unmeasured non-household consumption	10.2	0.2	0.1	10.5
Measured non-household consumption	349.9	7.1	1.2	358.2
Total leakage	431.0	5.3	3.1	439.3*
Minor components	37.0	0.9	0.5	38.4
Demand for water	1696.6	27.5	6.5	1730.5

* Please note that, in setting the baseline for total leakage, we have used a three year average to reduce the impact of weather variability. This is explained in Section 4.6.

In our region, 51% of demand for water is from households, 21% is from non-households and 28% is related to leakage and minor components. These proportions have been relatively consistent since the large leakage reductions in the 1990's.

1.3.2 Key new research projects for WRMP19

Table 3 shows a list of the demand related UKWIR projects carried out to inform WRMP19 and, specifically, what components or elements of our WRMP they have informed or impacted. A full list of all demand related UKWIR projects can be found in Appendix E.

Table 3 Demand related UKWIR projects carried out to inform WRMP19

Year	Manual/report name	Manual/report reference	Key components/elements that are informed/impacted
2015	WRMP19 Methods – Population, Household Property and Occupancy Forecasting	15/WR/02/8	Deriving population, household property and occupancy forecasts (see Section 2.1)
2015	WRMP19 Methods – Household Consumption Forecasting, previously Demand Forecasting Methods	15/WR/02/9	A key change for WRMP19 and informed the choice of approach for household consumption forecasting (see Section 2.4.1)
2015	Economics of Supply Pipe Leakage	15/WM/08/56	Informed our assessment of customer supply pipe repair policy (see Section 4.2)
2016	Integration of Behavioural Change into Demand Forecasting and Water Efficiency Practices	16/WR/01/15	Informed our customer behaviour, occupancy and ownership survey (see Section 2.1.3 and 2.4.3)
2016	WRMP 2019 Methods – Decision Making Process: Guidance	16/WR/02/10	Informed the thinking for our WRMP19 problem characterisation and approach selection documented in our *Final WRMP19 Technical Report - Options appraisal*
2016	WRMP 2019 Methods – Risk Based Planning	16/WR/02/11	Informed the thinking for our WRMP19 problem characterisation and approach selection, documented in our *Final WRMP19 Technical Report - Options appraisal*
2017	Consistency of Reporting Performance Measures - Leakage	17/RG/04/5	Informed our approach to leakage convergence (see Section 4.9)

2. Household consumption

This section covers how we have derived our forecast of measured and unmeasured household consumption, including the incorporation of the benefits of customer metering and our water efficiency activities.

2.1 Population, properties and occupancy

This section covers how we have derived our WRMP19 population and property forecasts to ensure we support the growth predicted by Local Authority Districts and Unitary Authorities within our region, in line with Defra's guiding principles[8]. Throughout this section, we refer to two main types of population and property forecast, as shown in Table 4.

Table 4 Types of population and property forecast

Forecast type	Description
Trend-based	Replicates the latest subnational population projections[9], including those for the Welsh Government, from the Office for National Statistics (sometimes referred to as "ONS"). The trend-based population forecast is reconciled to the latest mid-year population estimates[10] and the forecast horizon is extended beyond the projection horizon (of 2039) to match the WRMP19 planning period. This population forecast, as well as information from the latest Department for Communities and Local Government (sometimes referred to as "DCLG") household projections[11], forms the basis of the trend-based property forecast.
Plan-based	This property forecast uses future housing growth evidence from the Local Development Plans of just over 50 Local Authority Districts and Unitary Authorities (sometimes referred to as "LADUA"), as well as 3 National Park Authorities (sometimes referred to as "NAP"). For years beyond each Local Development Plan period, the annual housing growth reverts to the trend-based forecast. In terms of population forecasting, the plan-based forecast is informed by the trend-based forecast, but assumes a higher net in-migration, in line with the increased number of properties being forecast in the Local Development Plans. Our engagement with Local Authority Districts and Unitary Authorities is documented in 2.1.1 and a full list of the Local Authority Districts and Unitary Authorities in our region can be found in Appendix G.

For each of our resource zones with household (domestic) customers, we have:

1. Derived a trend-based population and property forecast, as described in Table 4;
2. Engaged with Local Authority Districts and Unitary Authorities (see Section 2.1.1) and collated the available data from the property forecasts in Local Development Plans, to form the basis for a plan-based population and property forecast;
3. Engaged with and sought endorsement from our household customer retail team (known as "Domestic Retail"), including the review of several household property forecasting assumptions (see Section 2.1.2), against the trend-based/plan-based forecasts;
4. Derived an occupancy forecast informed by Department for Communities and Local Government projections and a household customer behaviour, occupancy and ownership survey for the our region (see Section 2.1.3);
5. Carried out an assessment of our unallocated population, such as irregular migrants[12] and short-term residents. Although, as discussed in Appendix B, we use per household consumption (PHC), rather than per capita consumption (PCC), in our Water Balance, so the impact of this population on reported levels of household consumption is likely to be minimal, only warranting sensitivity testing of our household consumption forecast (see Section 2.6); and
6. Assessed the ranges/uncertainty (see Section 9).

[8] Department for Environment, Food & Rural Affairs (abbreviated as "Defra") Guiding principles for water resources planning (published in May 2016)

[9] At the time of writing, this was the 2014-based subnational population projections (published in May 2016). It's worth noting that the 2016-based national population projections (published in October 2017), which will eventually inform the 2016-based subnational population projections, estimate lower population growth than the 2010-based, 2012-based and 2014-based population projections.

[10] At the time of writing, this was the 2015 mid-year population estimate (published in June 2016)

[11] At the time of writing, this was the 2014-based household projections (published in July 2016)

[12] Typically refers to migrants in a country who are not entitled to reside there, either because they have never had a legal residence permit or because they have overstayed their time-limited permit.

2.1.1 Engagement with Local Authority Districts and Unitary Authorities

We have worked with Edge Analytics and CBRE Ltd to ensure we are using the most up-to-date information from Local Development Plans. We have been through a stringent process of reviewing the available data for all the Local Authority Districts and Unitary Authorities in our region (see Appendix G for the full list). This data has formed the basis to our plan-based property and population forecast.

We also engage with Local Authority Districts and Unitary Authorities on a business as usual basis and have used this opportunity to provide updates on our progress with WRMP19.

2.1.2 Household types and property forecasting assumptions

This section covers the occupied household types we base our household consumption forecast around, as shown in Table 5, and some key household property forecasting assumptions, as shown in Table 6.

Table 5 Occupied household types with key information

Household type	Description and key information
Unmeasured	At present, the majority[13] of households in our region do not have a water meter, however the number of unmeasured households is expected to reduce markedly as customers continue to opt to be measured. There will also be a net reduction due to demolition or conversion.
Measured (Metered When Built Pre 2010)	Households built between 1989/90 and 2009/10 that were compulsorily measured.
Measured (Metered When Built Post 2010)	Households built after 2009/10 that were compulsorily measured, but have also been designed to be water efficient, as required under Part G of the Building Regulations.
Measured (Optant)	Households where the customer(s) have opted to be measured. We have offered a Free Meter Option (FMO) scheme for households since April 2000, in accordance with the Water Industry Act 1991. The forecast numbers of optants across the region are shown in Section 2.2.6.
Demand Management	About 4000 households that owned garden sprinklers were compulsorily measured during the 1995/96 drought, but this programme was discontinued as it was seen as a “tax” on honest customers who informed us that they owned a garden sprinkler and was not an economic supply-demand measure.

Table 6 Household property assumptions, with a description for each

Household property forecasting assumption name	Description
Deletions	Household properties that have been demolished or are forecast to be demolished in the WRMP19 planning period.
New household connections	Household properties that are forecast to be connected in the WRMP19 planning period.
Void or voids	Unoccupied or empty household properties or household properties that are forecast to become unoccupied or empty in the WRMP19 planning period.

Deletions have been forecast based on our latest best estimate for 2016/17. Over the longer term, we have forecast unmeasured household deletions to reduce, as the outright number of unmeasured household properties decreases, and measured household deletions to increase as there are more measured household properties, due to new connections and the impact of the Free Meter Option (see Section 2.2.6).

In line with the Water Resources Planning Guideline, our forecast of new household connections has currently been informed by the plan-based property forecast. However, as shown in Figure 4, the plan-based property forecast creates a large peak in new household connections.

[13] At 2015/16, regional metering penetration (excluding voids) was around 40%

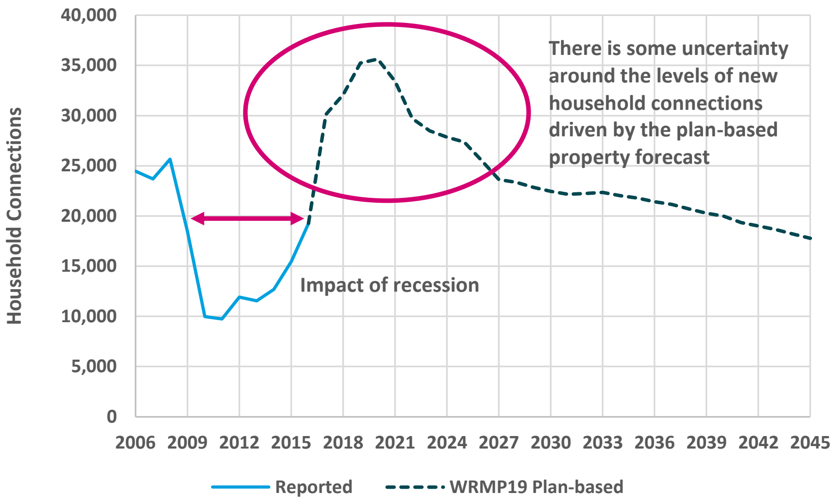


Figure 4 Reported new household connections, with the plan-based forecast of new household connections for WRMP19

Whilst being based on Local Authority Districts and Unitary Authorities plans for the future, there is uncertainty in whether this level of household new connections will be achieved, given we have not seen similar levels for many years[14]. This is not so much of an issue for the longer term forecasting used for the WRMP, but for shorter term forecasting this creates a potential issue. Therefore, for our next business plan (covering 2020/21 to 2024/25), we have the profiled the plan-based forecast to ensure the level of household new connections is sensible, based on historic data and forecast achievable levels, using information from the house building industry.

For the last 5 years, approximately 6% of unmeasured household properties have been classified as void. This is forecast to increase to just over 9% in the next few years, due to a full verification of occupier details, and we have forecast this percentage to be maintained though the WRMP19 planning horizon. Similarly, over the same period the average percentage of measured household properties classified as void has been approximately 4%. We have forecast this to increase slightly, due to the verification mentioned previously, and remain at this level for the WRMP19 planning horizon.

2.1.3 Occupancy and household size

Occupancy rates are informed using two main sources of information:

1. A household customer survey, discussed fully in Section 2.4.3, to inform the base year occupancy for different household types (see Table 5 for the different household types) and information from our last four occupancy surveys is used to verify occupancy rate forecasts; and
2. The most recently published Department for Communities and Local Government headship rates[15] inform our forecast of occupancy rates and, therefore, assumptions around the change in household size.

The occupancy rates for the different household types from our last four occupancy surveys are shown in Figure 5. There has been a decline in all occupancy rates signifying a regional change in household size, due to, for example, the development of large blocks of flats in the population centres that tend to have a lower occupancy.

[14] On reviewing data back to the late 1990's, the highest level of new household connections has been just over 25,000 in 2007/08.
[15] At the time of writing, these were the Department for Communities and Local Government headship rates from the 2014-based household projections (published in July 2016)

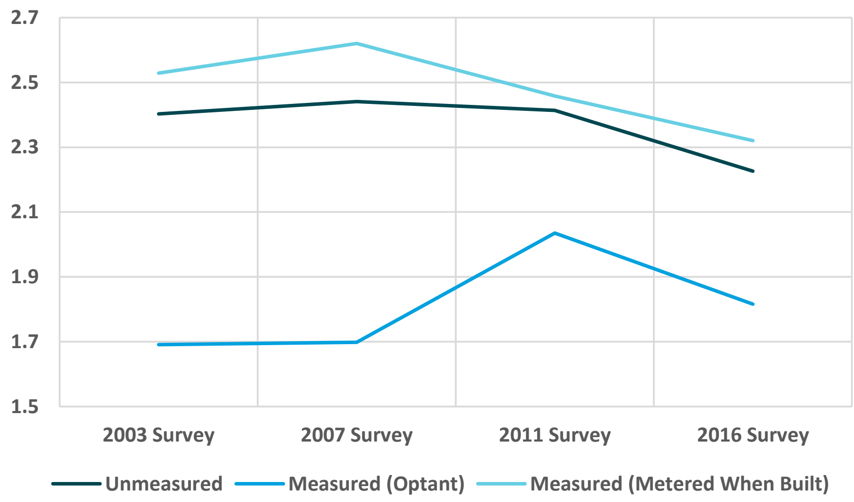


Figure 5 Household occupancy rates from our last four occupancy surveys

The occupancy rates from our 2016 household customer survey for WRMP19 are shown in Table 7 and are broadly consistent across all our resource zones.

Table 7 Household occupancy rates from our WRMP19 Household Customer Survey

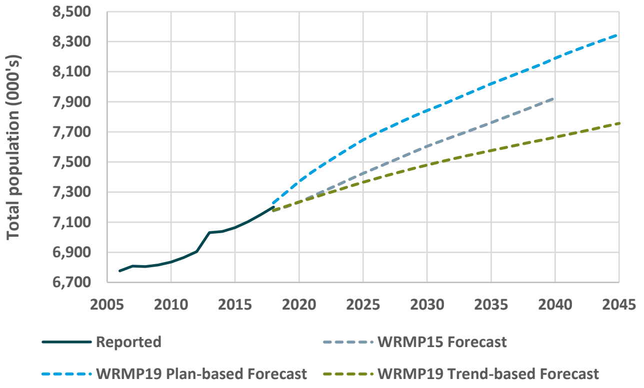
Resource Zone	Unmeasured	Measured (Optant)	Measured (Metered When Built)
Strategic Resource Zone	2.3	1.8	2.4
Carlisle Resource Zone	2.2	1.8	2.3
North Eden Resource Zone	2.2	1.8	2.3
Region	2.2	1.8	2.3

Overall, we are forecasting total occupancy (accounting for non-households) to decrease over the planning period. However, we are forecasting a very slight increase in household occupancy from 2.19 to 2.24, due to measured (optant) occupancy, which we have modelled as increasing to a point where it converges with unmeasured occupancy. The measured (metered when built) and unmeasured occupancy rates continue to reduce over time.

2.1.4 Forecast

Figure 6 shows the reported total population and household properties (excluding voids) for our region, as well as our different forecasts to 2044/45, including:

- The forecast from our previous WRMP, "WRMP15"; and
- The plan-based and trend-based forecast, created for WRMP19 and discussed above.



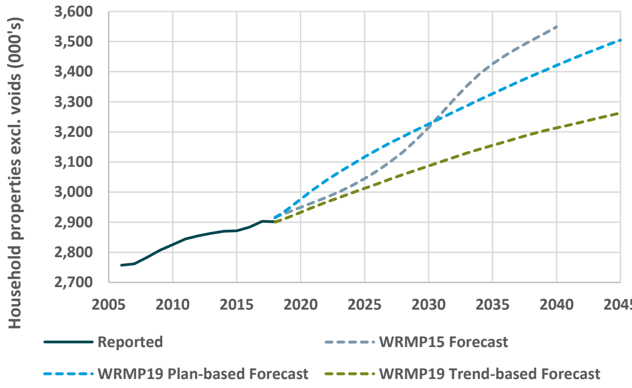


Figure 6 Reported and forecast total population[16] and household properties to 2044/45

Table 8 shows the reported and plan-based scenario data broken down by resource zone.

Table 8 Reported[17] and plan-based population and household property forecast by resource zone to 2044/45

	2016/17	2020/21	2025/26	2030/31	2035/36	2040/41	2044/45
Strategic Resource Zone							
Total population	7,026,586	7,301,526	7,551,216	7,732,309	7,906,330	8,075,297	8,198,640
Household population	6,251,288	6,417,733	6,644,423	6,844,697	7,062,916	7,294,858	7,480,982
Household properties (excl. voids)	2,850,641	2,936,046	3,064,811	3,167,296	3,265,343	3,356,176	3,421,763
Household occupancy	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Carlisle Resource Zone							
Total population	109,877	117,287	123,395	128,284	130,955	132,873	133,820
Household population	100,251	107,711	114,129	119,823	123,529	126,575	128,301
Household properties (excl. voids)	46,841	49,060	52,175	54,833	56,700	58,065	58,799
Household occupancy	2.1	2.2	2.2	2.2	2.2	2.2	2.2
North Eden Resource Zone							
Total population	13,691	14,619	15,202	15,661	16,011	16,213	16,264
Household population	11,674	12,524	13,122	13,669	14,110	14,424	14,573
Household properties (excl. voids)	5,418	5,669	5,966	6,203	6,384	6,517	6,577
Household occupancy	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Region							
Total population	7,150,154	7,433,432	7,689,812	7,876,254	8,053,296	8,224,384	8,348,723
Household population	6,363,213	6,537,968	6,771,675	6,978,189	7,200,555	7,435,857	7,623,856
Household properties (excl. voids)	2,902,900	2,990,776	3,122,952	3,228,332	3,328,428	3,420,758	3,487,139
Household occupancy	2.2	2.2	2.2	2.2	2.2	2.2	2.2

Full details of our forecast population, number of properties and occupancy by property type and resource zone can be found in Appendix H.

2.2 Customer metering and tariffs

We recognise the important contribution of economic customer metering and tariff actions in achieving and maintaining an adequate supply-demand balance in each of its four water resource zones. It plays a key role in our demand management plans.

Effective metering contributes to the overall reduction in consumer demand and plays a key role in the WRMP. Compulsory metering of new premises was introduced in 1990 after the introduction of community charge and the

[16] Of which around 90% is household population, the rest falls into measured non-household and unmeasured non-household population
[17] It's worth noting that we have applied the updated WRMP19 occupancy rates to 2015/16 for consistency

cessation of applying rateable values. The Water Industry Act 1999 gives customers the right to opt to have a water meter fitted for free: this is often called the “Free Meter Option”. Our Free Meter Option policy was introduced in April 2000 and it we have committed to fit a meter where it is reasonably practicable and not unreasonably expensive to do so. If meter fit is not possible we will bill the customer based on an assessed charge. The assessed charge requirements are stated in the charges scheme and are based on type of property (detached, semi or other), or we have a single person tariff if the customer lives alone (in any type of property).

2.2.1 Consideration of metering options and strategies

In line with The Water Resources Management Plan (England) Direction 2017, this section covers our estimate of the number of household (domestic) properties which will become metered during the WRMP19 planning period. It also covers our estimate of the reduction in household consumption, as a result of the increase in the number of properties becoming metered.

Table 9 sets out the metering options and sub-options that were considered through the options identification and appraisal processes.

Table 9 Consideration of potential metering options

Metering option	Sub option	Primary screening	Secondary screening	Average AISC at capacity (p/m3)	Comment[18]
Change of occupier	Change of occupier metering	In	Out	153#	Screened out on cost/benefit (AISC rank)
Optant	Refer a friend	In	Out	125#	Screened out on cost/benefit (AISC rank)
	Enhanced promotion	In	Out	910#	Screened out on cost/benefit (AISC rank)
	Targeting customers with definite financial savings	In	Out	928#	Screened out on cost/benefit (AISC rank)
	Promotion linked to mains or service renewal	In	In	58#	Feasible (constrained) option
	Optant promotion (baseline activity)	n/a	n/a	see note	See note on lowest bill guarantee
Selective	See notes below (baseline activity)	n/a	n/a	n/a	See notes below.

- These are the weighted average AISC values across all water resource zones.

These options were further subdivided by resource zone and are included in the *Final WRMP19 Technical Report - Options identification*.

The promotion of the Free Meter Option (“FMO”) forms part of our baseline activity. However, we are continuing to develop ways of promoting the update of meters to customers. Since July 2017, we have been trialling a ‘lowest bill guarantee’ (formerly referred to as the ‘price promise’). This is a new offer aimed at unmeasured customers that would likely benefit if they moved onto metered charges. The guarantee makes a promise to customers that, if they opt for a meter, we will monitor their charges, and will charge them the lesser of their new measured charge or their old rateable value based unmeasured charge. This two year commitment goes much further than existing “right to revert” schemes widely available across the industry, where customers can choose to go back to unmetered charges after one or two years, but are still liable for higher charges during the period that they have a meter.

The scheme has been developed in direct response to customer research which indicated that one of the biggest barriers for customers opting for a meter is the fear of larger future charges. By introducing a way for customers to have clarity on future charges we hope to help them overcome this loss aversion, nudging them into a choice which is better for their household, and thereby open up metered charging to a larger group of customers. Using detailed information on customers’ likely consumption patterns, household occupancy rates and existing property rateable values we have been able to target promotion of the ‘lowest bill guarantee’ to those customers most likely to

[18] It’s worth noting that, although some metering options have not been directly selected through our options appraisal process, such as metering promotion linked to mains/service pipe renewal activities, these could be considered for implementation to bolster our baseline activities if, for example, our water efficiency objectives were not being met.

experience lower bills with a meter. This provides the opportunity for more customers to gain greater control of their future charges, whilst preserving the water efficiency incentives that a meter offers.

To test the new proposition, we offered the lowest bill guarantee to customers between July and October 2017. During this period we observed a 26% increase in meter take up, with 98% of participating customers' seeing a bill reduction when compared to their old rateable value, indicating that we have targeted the right groups of customers. This new proposition has the potential to prove a highly effective intervention for low occupancy households that face affordability challenges, but have historically been reluctant to opt for a free water meter.

In the AMP7 investment period (covering 2020/21 to 2024/25), we plan to offer the 'lowest bill guarantee' more widely, and will target promotion of the scheme to those customers who our information indicates are both likely to be facing affordability challenges and would likely experience lower bills when on measured charges.

We propose to continue with selective metering of properties with potential for exceptionally high consumption e.g. with swimming pools, in line with Section 3.4 of our 2017/18 Household Charges[19]. This also sets out the usual criteria for metering of properties and includes:

- New properties;
- Premises that have been separated into multiple premises.

We do not currently have a driver for compulsory metering on a large scale, beyond the criteria set out in our Household Charges. However, further into the planning horizon this may become a consideration and requirement, but would be covered through future WRMP planning cycles. The selective metering policy is part of baseline, and is considered the right thing to do. A number of additional selective metering options were considered, but these were screened out at the primary screening phase as being impractical and unlikely to deliver benefit, so were not progressed forward to having costs and benefits assessed.

In AMP7, we are planning to spend circa £79m on the installation of meters on new developments, for customers that opt to have a meter fitted under our Free Meter Option scheme and maintenance of our existing meters. The costs through the planning period to the end of AMP11 (in 2044/45) are shown in Table 10. It should be noted that, as part of our business planning processes these figures may change, and are provided here as an indication of current cost estimates (particularly in the longer term).

Table 10 The costs[20] of delivering our metering programme from AMP7 to AMP11 and operating our meter stock

AMP	Time covered	Forecast number of Free Meter Option meter fits[21]	Cost of installation and maintenance of meters[22] (£m)	Cost of reading meters[23] (£m)
AMP7	2020/21 to 2024/25	179,885	79	3.6
AMP8	2025/26 to 2029/30	167,849	118	3.4
AMP9	2030/31 to 2034/35	147,225	130	3.0
AMP10	2035/36 to 2039/40	129,424	128	2.3
AMP11	2040/41 to 2044/45	112,524	169	1.4

2.2.2 Metering policy drivers

There are three main drivers for our metering policy:

[19] There is a link to the charges scheme for 2017/18 document on our website here: https://www.unitedutilities.com/my-account/your-bill/our-charges-20172018/

[20] Assuming no reduction in costs due to innovation and not accounting for inflation

[21] The figures presented in this column are "in year" figures totalled for each AMP. The WRMP19 planning tables show "average year" figures, as these are the figures used in consumption forecasting. The difference is that "in year" figures are the number of meter fits by the end of each financial (or "fiscal") year, whereas, "average year" figures show the number of fits half-way through a financial year. We use "average year" figures for consumption forecasting, as meters fitted in the latter part of the financial year will not contribute as greatly to a consumption reduction in that financial year.

[22] The increase in these costs AMP by AMP is due to the greater number of meters that need to be maintained, as well as the battery life on AMRs being exhausted and requiring a meter exchange. Although, innovation in this area may reduce these costs over time.

[23] The decrease in these costs AMP by AMP is due to the greater number of automatic meter reading (AMR) meters, which cost less to read than visual read meters. Although, innovation in this area may reduce these costs over time.

- Regulatory and policy;
- Business; and
- Customer and stakeholder.

Regulatory drivers

The following legislation sets out our requirements to maintain customer meters and provide customers with the option to be metered:

- Water Industry Act 1991 section 144A, Right of consumer to elect for charging by reference to volume;
- Water Industry Act 1991 section 45, Duty to make connections with main;
- Water Industry Act 1991 section 55, Supplies for non-domestic purposes; and
- The Water Resource Management Plan (England) Direction, Defra 2017

Business drivers

- Ensuring our water resources are sustainable and resilient by creating a financial incentive for customers to reduce demand;
- Improved accuracy of calculated leakage volume, by increasing the number of metered customers. An improvement in the accuracy of consumption volumes will improve the accuracy of the water balance and hence the calculation of leakage. Better information will inform the assessment of the economic level of leakage as well as operational targeting of leak detection and repair resources. A better estimate of leakage enables targeted leakage reduction; and
- Customer engagement associated with meter installation, which can help to highlight the benefits of water efficiency to customers.

Customer and stakeholder drivers

- Demonstrating responsible stewardship of the water and wastewater networks we operate;
- Listening to what our customers and stakeholders tell us through the Customer Experience programme, which helps us to become the North West's leading service provider; and
- Aiming to achieve our objectives without adding to the burden on household budgets.

2.2.3 The requirement for metering

Studies into the savings achieved from metering have shown varied degrees of benefits. The long-term effects must be considered, as savings may not be sustainable over a long period. Experts previously thought that there was a "bounce back" associated with metering, i.e. the benefit of metering being reduced over time. However, our studies of optant properties have shown no evidence of "bounce back".

We focus on metering customers because:

- Reducing demand can help to improve security of supply and reduce the impact on the environment through lower abstraction;
- Metering and reducing water use can help cut greenhouse gas emissions associated with abstracting, supplying water, treating water and wastewater, and heating water in homes and businesses;
- Metering gives us better information about customer water use and can help plan and operate our networks more efficiently, whilst reducing losses and leaks;
- Metering provides customers with accurate information about their water use and allows them to be billed on the amount used. This can be a key element in behaviour change as rateable value or assessed charges do not encourage water efficient behaviour;
- Metering programmes can consider both current and future opportunities for variable tariffs; and ensure that people who are unable to afford their bills are protected through appropriate tariffs;
- Where we install meters we can ensure a range of water efficiency measures are put in place to enhance the benefits of metering;
- Opportunities to link smart metering for water and energy could be applied to all large scale metering programmes as a Smart Water Industry architecture is defined and implemented. Until such time, our

position is to continue with automatic meter reading (AMR)[24] in its current form, using walk/drive by technology, until such time as energy smart metering is rolled out nationally. Please refer to Section 11 for more details on innovation projects we are planning in the area of smart metering; and

- Customers save not only on their water bills, but also on their energy usage. It is, therefore, an overall financially attractive option for many customers. There are also benefits to the environment from reduced carbon emissions.

There are, however, additional factors which we have to take into consideration when reviewing our approach to metering:

- Not all customers will benefit financially from being on a meter, those with a large household who are currently on a low rateable value may not benefit;
- There are cost implications of increased numbers of customer meters that need to be reflected in business planning;
- There is a general customer apathy to metering, despite the potential financial benefits it could bring; and
- The North West is not classified by the Environment Agency as water stressed area, which means we have no legal right introduce compulsory metering policy.

2.2.4 Current metering policies

It is widely accepted that customers with a meter use less water than those without one. Several studies have evaluated the effect of metering on water consumption confirming that this is the case. Results from key studies can be found in Appendix D. Metering is also an opportunity for customer engagement, which if sustained, can be useful for promoting water efficiency. Metered customers are able to review the impact of their behaviour on their bills, and metering also gives us the opportunity to use flexible tariffs based on consumption patterns. “Paying for what you use” is a well-supported principle.

Our metering aims are to:

- Maximise the cost effectiveness of customer metering and tariffs to assist in achieving and maintaining adequate supply-demand balances, in accordance with the UKWIR / Environment Agency national best practice methodology “Economics of Balancing Supply and Demand”;
- Carry out action plans that are consistent with national best practice; and
- Target demand management activities in those water resource zones where supply-demand deficits exist or are anticipated to occur in the near future where it can be identified that customers will realise the benefits of taking up metering opportunities.

Our metering policy is to:

- Meter all new household properties. Our policy for new build is to install meters in an above ground location (internally, or in a wall mounted meter box that allows easy access to read the meters for both the customer and the company). All new meter installations are AMR enabled;
- Provide a Free Meter Option scheme for household customers. Since April 2000 we have actively promoted this scheme to customers. Our preferred meter location position is inside a property and all meters are AMR enabled;
- Meter all new non-households;
- Replace any faulty household and non-household meters;
- Offer unmeasured household customers an alternative choice of tariff (i.e. assessed charges) in the small number of instances where metering is not practically possible (circa 15%);
- Accurately read all household water meters with the use of AMR, where AMR meters are installed;
- Meter existing unmeasured non-households where possible. All industrial premises and the majority of commercial and public service premises are already metered following a programme in recent years to compulsorily meter all non-households where practical. Each year we still undertake a number of

[24] Automatic meter reading (AMR) enable to obtain meter readings remotely, without gaining access to property. Most of our AMR meters are read every two weeks using devices attached to council bin wagons.

compulsory meter installations, these are usually from properties that have been altered or merged. Those that remain un-metered tend to be relatively small water users where the installation is either not possible or disproportionately costly; and
- Have the majority of industrial and commercial customers, who consume over 20 Ml per annum, on enhanced AMR to enable remote automated meter readings and updated data every 15 minutes to monitor usage via a web portal service.

To improve our efficiency we are currently assessing the most cost effective ways of reducing the length of time a customer will be required to wait for a meter. We will test working to different levels of service during peak times (March – June) and during off peak times where volumes of work are reduced.

Our policy is to always try to install a water meter internally, at the point of the initial survey and we forecast c.60 per cent of meters will be installed in this location. If no internal installation is possible, e.g. in case where the meter may cause customer issues due to aesthetic or other operational reason, we will look to install a water meter externally, ordinarily in the public footpath. If an underground meter box has previously been installed at the premises (e.g. due to previous service renewal activity), this will always be considered as the first point of installation.

All water meter installations will be Automated Meter Read (AMR) equipped to allow greater frequency of data collection and more efficient meter reading. More granular data will also help us identify when customers' consumption changes or "leak alarms" are triggered so we can proactively notify customers of the changes. AMR will also help to reduce the number of estimated bills customers receive and will play a key role in leakage detection as the availability of frequent data and alarms allows leaks to be detected earlier than when a bill is generated.

Other metering policies have been considered but have not justified implementation to date, in some cases due to the constraints of the Water Industry Act 1991.

We are currently trialling a new metering proposition – the 'lowest bill guarantee' (formerly referred to as the 'price promise'). It has been developed on the back of research we have done recently and "Tell Me" emails (see Section 2.3.1) ,which showed that customers worry that they may end up paying more for their water if they change to a meter, even though they may be better off. The new proposition was developed to overcome this barrier.

With the lowest bill guarantee, if customers aren't saving money once the meter's been fitted, we will only charge them what they are currently paying on a fixed annual bill. We'll apply this automatically so there is no need for the customer to contact us. We'll do this for two years and during this time customer can choose to switch back to a fixed annual bill if they think they won't be better off on a metered charge. We're also trialling the price promise together with an installation of water efficiency devices at the point of meter installation to further enhance customer experience, water efficiency behaviour and financial savings for customers.

2.2.5 Current performance

We continue to measure all new households and non-households, and under our Free Meter Option scheme household customers can opt for a meter. Each year, in June, we report our performance against forecasts in the annual updates of our water resource management plan (published as the Annual Water Resources Review[25]). Table below shows the new number of new properties and the uptake under our Free Meter Option scheme over the last five years.

[25] https://www.unitedutilities.com/corporate/about-us/our-future-plans/water-resources/

Table 11 Historical metering performance

Property type	2012/13	2013/14	2014/15	2015/16	2016/17
New households	11,560	12,677	15,451	19,273	19,947
Household optants	48,437	43,734	40,102	27,197	32,447
New non-households	719	668	690	719	793

We have made significant improvements to our free meter offer; in particular we have:

- Employed agents trained in the free meter installation process, and made improvements to contractual arrangements with the supplier we use to carry out meter installs which has helped us to significantly improve the speed of installation and reduce drop off rate (the number of customers that resign from the installation);
- Promoted the Free Meter Option within normal billing contacts, including promotion on all envelopes used during our main billing;
- Targeted 55,000 customers to promote metering via a range of media (email, letter, text) where we believe these customers would be better off with a meter; and
- Promoted our Free Meter Option across the region on a series of 25 billing roadshows and carried out 28,000 Town Action Plan Affordability visits to promote all of the customer assistance schemes we currently have available, which includes the Free Meter Option.

We continue to offer an extended period of 24 months for all customers to switch back from being metered to unmetered. This gives customers time to decide whether they will benefit from being on a metered tariff. Details on the projections of meter penetration are described in Section 2.2.6.

2.2.6 Free Meter Option forecast

We have worked with Artesia Consulting to model the uptake of the Free Meter Option to ensure that we have a realistic and robust view of the potential numbers of customers who would be willing to opt for a meter each year. This involved the analysis of large amounts of data and exploration of several different modelling techniques[26], with the resultant regional forecast shown, with historically reported numbers of meter optants, in Figure 7.

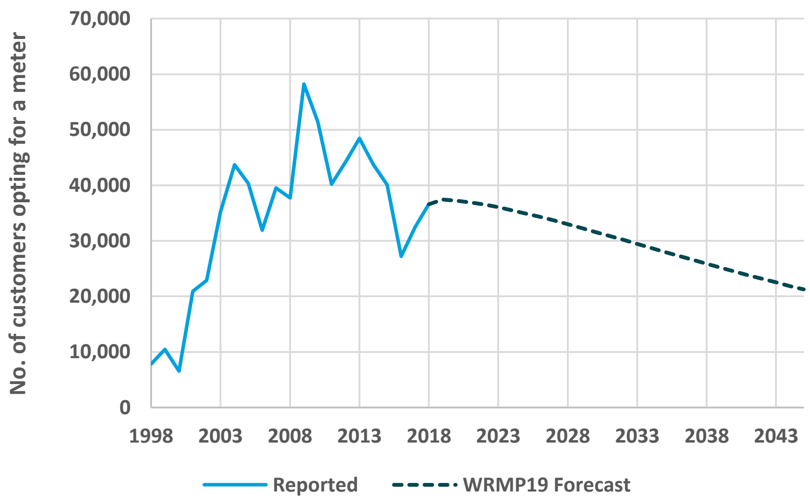


Figure 7 Reported and forecast number of customers opting each year

As with demand for water, there are year on year fluctuations in the number of customers opting for a meter. This is driven by factors such as population age and dynamics, as well as economic factors such as unemployment. The

[26] Including survival type models, logic and logit (regression) models

decline in customers opting over the planning horizon is due to an ever shrinking base of unmeasured customers. Table 12 shows how this forecast looks by resource zone.

Table 12 Forecast number of meter optants by resource zone

	2016/17	2020/21	2025/26	2030/31	2035/36	2040/41	2044/45
Strategic Resource Zone	32,065	36,576	33,998	30,583	26,989	23,533	20,973
Carlisle Resource Zone	351	294	301	293	280	264	253
North Eden Resource Zone	31	24	22	20	19	18	17
Region	32,447	36,895	34,321	30,896	27,288	23,815	21,243

We represent the benefits of metering using a "property swap" method, where the property moves from the unmeasured housing stock into the measured (optant) housing stock. Figure 8 shows the impact of this movement, along with the metering of newly built household properties, on metering penetration in our region and the reduction in household consumption associated with it.

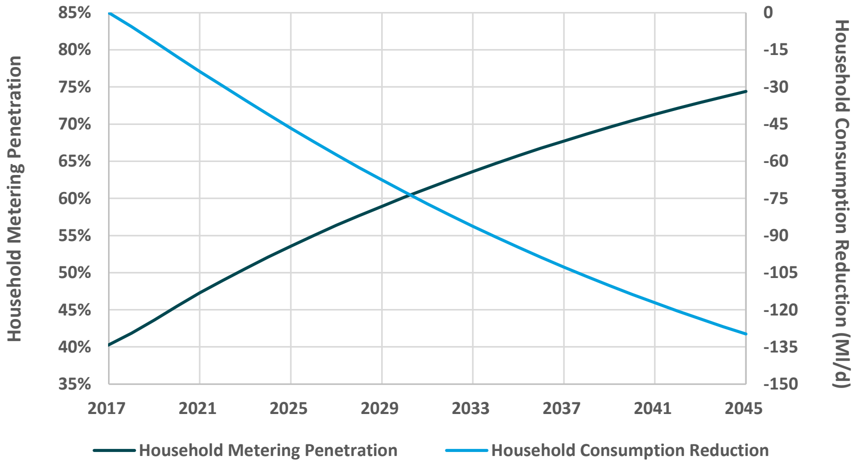


Figure 8 The forecast impact of metering penetration on household customer consumption

2.2.7 Automated Meter Reading (AMR)

With the continual growth of metering and automated meter reading (AMR) stock throughout AMP5 (covering 2010/11 to 2014/15) and AMP6 (covering 2015/16 to 2019/20), we developed and implemented a unique approach for reading AMR enabled meters by working in partnership with Local Authorities within our region. To date we have installed over c.650 data collection devices on Local Authority refuse vehicles and currently have the ability to read over 400,000 water meters each week through using data signals collected from water meters as refuse vehicles collect household waste. We are continuing to roll-out AMR enabled meters to new and replacement meter installations, and are continuing to work with councils within our region to further grow our 'passive' meter reading solution. This development follows the successful piloting of a small trial undertaken on 7,000 properties in 2013.

Data collected from the water meter includes meter readings, stopped meter alerts and leakage alerts. Alongside the installation of data loggers and AMR meters, we have developed a web based portal to allow call agents to better handle customer contact and billing queries from customers who have AMR enabled water meters.

Figure 9 AMR portal – example screenshot

We also proactively inform customers where we identify a leak, and inform them of their potential increase in bill due to the presence of the leak. We are also planning provision consumption of data to customers in the form of a web application and/or smart-phone application and also to make this data visible via a customer portal.

2.2.8 Tariffs

Our current charges are to set to be consistent with our revenue controls published by Ofwat on 12 December 2014, and are prepared in accordance with its legal obligations.

Charges are set in accordance with the general charging principles of:

- Fairness and affordability;
- Environmental protection;
- Stability and predictability; and
- Transparency and customer-focused service.

The charges for water services can be summarised as follows:

- Unmeasured charges – a standing charge for water plus charges based on a charging value (a rateable value or a charging value assessed from a business rateable value);
- Assessed charges – for customers who would like to have a meter but it is not possible, a fixed charge is applied based on property type or occupancy for a single occupier;
- Measured household charges – a combination of standing charges, a fixed charge and volumetric charges for water and sewerage services;
- Measured non-household charges – a combination of standing charges, a fixed charge and volumetric charges. Different volumetric charges apply for different categories of non-household customers, based on the volume of water used (Select 50, Select 180, Select 750 and Select Plus); and
- Non-potable volumetric charge – supplies of non-potable water for non-domestic purposes are charged a standing charge and a volumetric charge.

A number of schemes exist to support vulnerable customer groups, such as:

- Watersure – intended to support customers that have a low income and use higher than average amounts of water due to a large family or medical conditions. The scheme allows the customer to pay a charge based on the average annual household bill;
- Help to pay scheme – developed to help eligible household customer who are entitled to receive Pension Credit to pay their water bill, based on a fixed charge; and
- Support tariff – designed for customers on low income who are struggling to pay their water bill, based on a fixed charge (six different levels of fixed charge).

Customer tariff actions

For AMP7 (covering 2020/21 to 2024/25), our charges will be set to be consistent with UUW's revenue controls as per the PR19 final determination to be published by Ofwat. This includes the introduction of a separate control for water resources, which should help deliver resilient water resources for customers and the environment in the long-term.

We will continue to review all charging policies annually and monitor the developments of tariffs in the industry and other industries were applicable. We will continue to review the effectiveness of alternative tariffs for different groups of customers and explore innovative approaches for charging, including exploring opportunities to encourage the better use of water:

- considering offering developers discounted infrastructure charges for water efficient connections; and
- trialling a basis of charge for non-household sites with rainwater harvesting systems which use rainwater for flushing toilets etc., but where the overflow does not flow to sewer.

2.3 Engaging with the retailer and household demand management

This section describes our approach in helping manage customer consumption in households. It has been written in partnership with our household customer retail team to ensure a consistent forecast and the delivery approach between our WRMP and the retail section of our business plan.

2.3.1 Water efficiency in households

As a water company we have a statutory duty to promote the efficient use of water as required by the Environment Act 1995 and the Water Industry Act 1991.

We consider it a priority to engage at an early stage with customers and stakeholders, so future options or schemes can be developed with their views and interests taken into consideration. We have carried out research (described in more detail below) with our customers to understand who our audience is (for water efficiency messages), how water use varies across life stages and what the key influences are on water use behaviour as well as motivations for saving water.

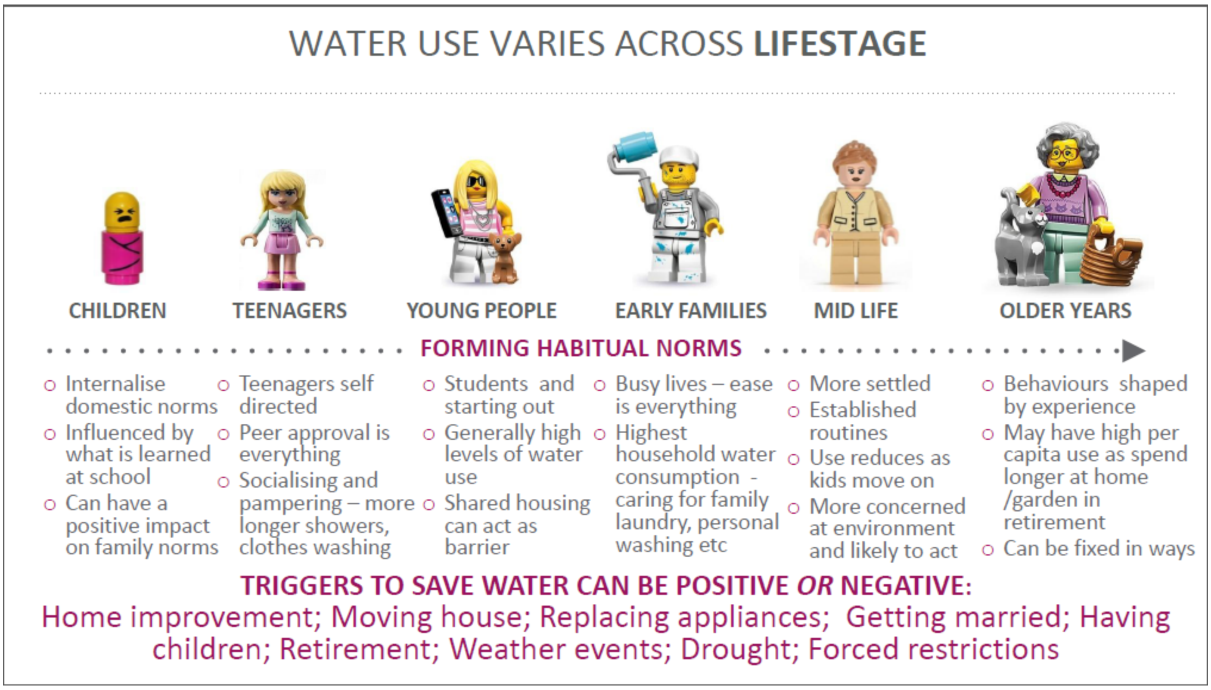


Figure 10 Customer segmentation

We recognise the important contribution water efficiency actions have in achieving and maintaining an adequate and sustainable supply-demand balance in each of our water resource zones. Although there are no mandatory water efficiency targets imposed by Ofwat since 2015/16, in our demand forecast we have committed to continue to achieve, as a minimum, an annual saving of 1 litre per property per day[27] through the planning horizon.

We have a number of policies that impact directly on the water efficient behaviour of our customers. These include policies related to water efficiency, supply pipe repairs and replacement, sustainability and carbon emissions, and a Free Meter Option scheme.

Building on previous activities we continue to:

- Supply free, easy to install water efficiency devices which can be ordered via agents, online or picked up at events we attend (for example Trafford Armed Forces day, Disability Awareness day in Warrington, Tatton Flower Show and many more);
- Run our education programme for primary schools across the North West. The workshop is extremely interactive and covers a number of topics from Key Stage 2 Science and Geography such as the water cycle, water safety, what not to flush and water efficiency. At the end of the workshop each child is provided with a pack that contains a booklet reiterating the important messages, a set of water efficiency trump cards and a toothy timer to encourage them to turn off the tap while brushing their teeth; and
- Carry out free visits to customers' homes to fit free water efficiency devices.

[27] To this we apply a decay rate or half-life of two and a half years to represent factors, such as the deterioration in water efficiency products over time.

Figure 11 Products used in our water efficiency education programme

In 2017, we also ran a roadshow during main billing (February/March), holding events in town centres and shopping centres across the region to offer customers an opportunity to speak to us and ask any questions about their bills. We discussed tariffs that may be available to specific customers and promoted water efficiency and free water saving devices to help customers reduce their water and energy bills to help them save money. This was popular with customers and we plan to run this again during main billing.

In 2016/17, an initiative called “Tell Me” was introduced which encourages agents to highlight any issues they come across, feedback from customers, or ideas for improvement in Customer Services. The points raised are reviewed by our Customer Services Director who then ensures they are actioned. As a result of this there have been a number of issues resolved and new initiatives put in place to improve customer service and this will continue going forwards. For example we received customer feedback about our metering information and we used this to change website customer journeys, and in the development of the price promise proposition (refer to Section 2.2.4 for more detail).

Table 13 below shows the savings made through various water efficiency activities and products distribution since 2015.

Table 13 Water efficiency savings since 2015

Water efficiency activity	Number	Saving (Ml/d)
Cistern devices distributed to customers	67,860	0.72
Water efficiency customer self-audits	242,792	2.06
Water butts distributed to customers	2582	0.01
Water Efficiency Education Programme, pupils visited	18,431	0.87
Other promotional events	3,168	0.02
Crystal packs / water sticks distributed to customers	4256	0.00
Retrofit devices distributed to customers	153,871	2.20
Total	**492,960**	**5.88**

We are mindful that in order to maintain the long term forecast we need to keep our approach fresh. We are constantly looking for ways to enhance our offering to customers through research and partnership working. We have recently undertaken research into attitudes towards water efficiency and metering to inform a joined up communications strategy for water efficiency, metering and water demand using segmentation to target groups of customers with tailored messaging, this includes community groups. The aim of the research was to understand the benefits, barriers and motivations to desired behaviours and willingness to act to achieve greater water efficiency. We worked with groups of customers and undertook qualitative research which included four co-design workshops to explore reactions to initial propositions; and a quantitative survey with 1,200 face to face interviews to identify priorities.

The research showed that attitudes to water are deeply ingrained and water is seen as a basic human right. There is low interest for most people unless supply is threatened, most use water freely and without thought, however most people do not set out to consciously waste water. Metering is the biggest influence on attitudes and behaviours and the main motivation for saving water is cost saving. The main barrier to saving water is subconscious habits that prevent action and for unmetered customers the barriers to saving water outweighs the benefits and perception that, with the amount of rainfall in the North West, water cannot possibly be scarce. To change behaviour, we need to increase benefits, reduce the barriers to saving water and increase environmental awareness.

The recommendations from the research and strategy work include:

- Targeting specific audiences with priority behaviours and driving motivation by making it easy to act whilst reframing water saving tips, tools and gadgets to focus on personal benefits;
- Making saving water personal with reports on usage for metered customer which shows water saving;
- Engaging communities of interest and making valuing water as social as possible through education, workplace advocates and community outreach around water resources; and
- Working with partners to collaborate to achieve shared goals.

In seeking to identify effective methods for future use, we trialled a whole community approach in a Cumbrian town to roll out a programme of home water audits to reduce water use in households in the local area. The key objectives of the trial were to:

- Raise awareness of the campaign and embed key messages;
- Create community ownership of action among the people of the town; and
- Encourage residents to sign-up for a free home check.

We have identified and contacted 24 community organisations out of which 11 agreed to support the campaign. Unfortunately, while community networks were happy to support the campaign, securing deep commitment was a challenge. Three potential community delivery partners were approached, however none of these could commit to recruiting members to undergo training to enable them to cascade the campaign messages to peers within the timescales. We therefore adapted the delivery method to place more responsibility on street teams, however the lack of any committed community partners clearly reduced the impact of the campaign and made it hard to explore the impact of a whole community approach to saving water.

Figure 12 Promoting water efficiency at local events

Figure 13 Examples of our marketing material

We are using feedback from the research and activities to refresh and update our messaging and marketing material. We are also using it to update the design and content of our bills, this includes information that is tailored to the customer, based on information we hold on them and covers water saving advice and information about meters.

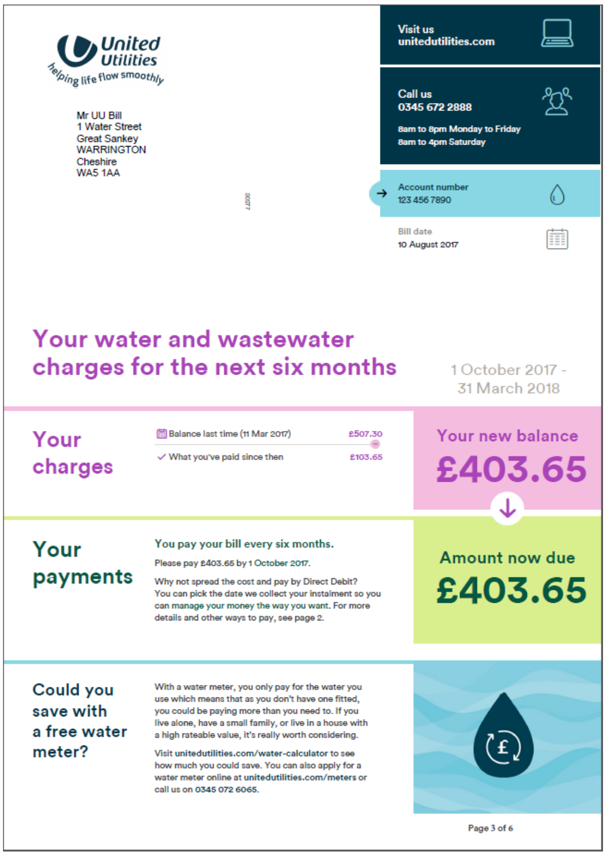


Figure 14 New bill format, with visible water meter promotion

Figure 15 New bill insert, showing water efficiency messages

We are also incorporating behavioural economics and trialling activities and communications to further understand what is most successful in reducing water use by changing behaviour.

We continue to develop our digital strategy to widen our reach with customers and increase the channels we use to communicate which is more inclusive of our younger customers. This has included the introduction of web chat, improvements to My Account and launch of a customer app. It has also incorporated wider use of social channels for promotion of water efficiency items which link directly to the online ordering facility for free pack devices.

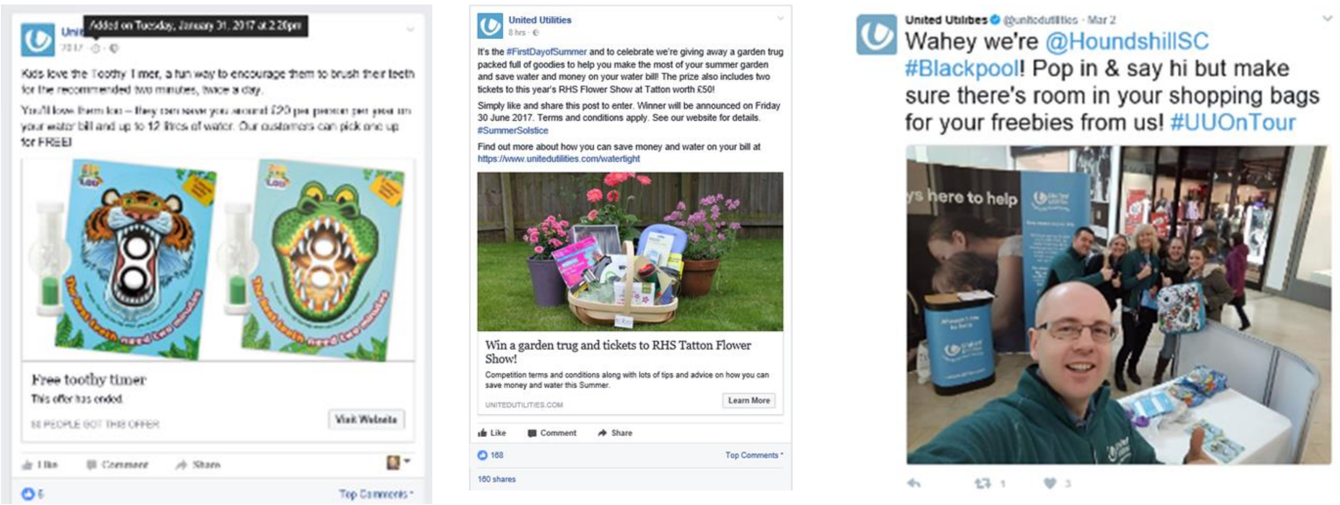


Figure 16 Examples of our digital campaigns

As we develop the digital channels we are also currently planning a yearlong trial, which is due to start in January, 2018 to provide water use data to approximately 100,000 customers via the app. The aim of this is to give customer greater control of their water use and their bills. We will be trialling a number of interventions with customers via the app to help customers reduce their water use through behavioural change.

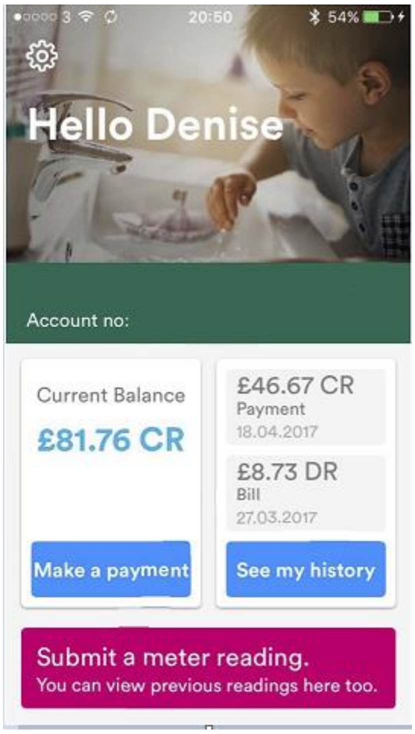


Figure 17 Screenshot of our latest app

We have also changed our web analytics package to be able to improve reporting on visitors to the website and to allow continuous improvement on the content and customer journeys on our website. For example, we can track customer journeys and see where users drop out before completing the action and can make changes where this commonly happens. This was used on the metering pages and content was updated.

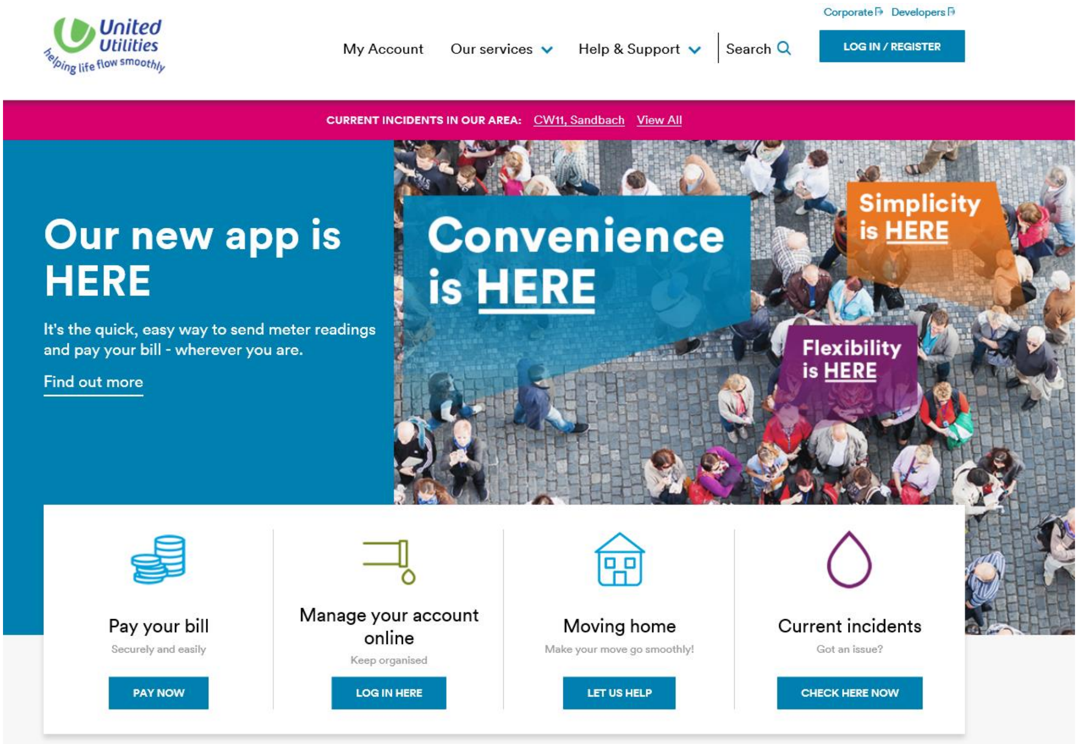


Figure 18 Our new website

We are also trialling a new metering proposition 'the price promise' (see Section 2.3.1 for more detail) which includes water efficiency devices fitted free of charge. The aim of it is to help customers save even more money on their bill and to encourage them to change their behaviour to reduce their water use.

We have developed a number of water efficiency options for inclusion in the supply-demand forecast. The costs and benefits of these options were assessed using actual company data wherever possible. Full assessment of the social and environmental costs was completed for any option that passed the primary screening process and these costs were accounted for in the option appraisal process. Further detailed on the options assessed as part of this process are included in *Final WRMP19 Technical Report – Options identification.* Water efficiency options are fully considered as part of appraising options for inclusion in our preferred plan (*Final WRMP19 Technical Report – Options appraisal*).

Sustainable economic level of water efficiency (SELWE) programme in West Cumbria

This WRMP19 is based upon a future Strategic Resource Zone following the delivery of the Thirlmere transfer project by March 2022. As explained in the *Final WRMP19 Technical Report – West Cumbria legacy,* we will continue to apply the existing demand management commitments in this zone based on WRMP15 until the new Strategic Resource Zone is formally adopted in the Annual WRMP process.

As part of WRMP09, we included additional water efficiency activities in West Cumbria, which was also continued in WRMP15. The annual SELWE target of 0.066 Ml/d has been included in the baseline demand forecast for the WRMP15. We have over achieved this this target each year since 2015.

Due to sensitive nature of the environment in West Cumbria and pressure to reduce abstraction from Ennerdale as far as practicable we are committed to continue to deliver enhanced level of water efficiency in West Cumbria until the delivery of the new Thirlmere pipeline.

We will continue to:

- Attend local events where we will distribute water efficiency devices and provide advice on how to save water;
- Organise water efficiency give away days through local supermarkets; and
- Promote our Free Meter Option.

2.4 Forecasting method

2.4.1 Forecasting methods review

In our WRMP19 initial 'problem characterisation'[28], as documented in our *Final WRMP19 Technical Report - Options appraisal*, all of our resource zones were considered to be of "low level concern", based on complexity factors and strategic needs. However, when large scale water trading was considered in the Strategic Resource Zone, the level of concern moved to "moderate".

At WRMP15, we used micro-component analysis[29] to model and forecast household consumption. For WRMP19, in line with UKWIR guidance[30], we carried out a household consumption forecasting methods review with Artesia Consulting in July/August 2016. The main observation from this review was that regression modelling and micro-component analysis were suitable approaches for all resource zones. The simpler macro-component analysis approach was also a potential for low level concern resource zones. However, as micro-component analysis, which we used at WRMP15 and which has been used in the UK water industry for many years, scored comparably well for the low level and moderate level concern resource zones, this supported its continued use for the WRMP19 household consumption forecast.

[28] This is a term used in WRMP19 UKWIR industry methodologies, whereby companies consider the risks and complexity of their resource zones to target the most appropriate approaches plan decision-making and appraisal methods.
[29] Sometimes abbreviated to "MCA", this is modelling changes in sub-components of household water consumption, for example water used by toilet flushing, showers, baths, washing machines, dishwashers, or external water use (including garden watering).
[30] WRMP19 Methods – Household Consumption Forecasting, previously Demand Forecasting Methods (UKWIR, 2015)

For our final WRMP19, we have developed a regression, namely a multiple linear regression (MLR), model to allow us to verify and/or further understand the uncertainty in the household consumption forecast from our micro-component analysis. The development and results from our regression modelling is explained further in Section 2.6.1.

2.4.2 Applied method

As discussed, we have applied micro-component analysis, which is calculated by multiplying estimates[31] of the ownership, frequency of use and amount of water per use of water using appliances (known as “micro-components”), with:

- Base year (and forecast) appliance ownership, generally being informed by a customer survey (see Section 2.4.3); and
- Base year (and forecast) frequency of appliance use and amount of water per appliance use, generally informed by industry-wide evidence/predictions (e.g. the UK Government Market Transformation Programme) and some more specific research (see Appendix E).

We have followed the guidance in the Water Resources Planning Guideline[32], which requires water companies to prepare a table of micro-component water consumption for unmeasured households and measured households for each resource zone. We have compiled the data in the categories shown in Table 14.

Table 14 Categories of water using appliance or “micro-component”, with our assumed key driver and mapping to the Water Resources Planning Guideline (WRPG) categories

Our categories of water using appliance or “micro-component”	Key driver (person or property)	WRPG category
Toilet	Person	WC flushing
Washing Machine	Property	Clothes washing
Electric Shower	Person	Personal washing
Mixer/pumped shower	Person	
Bath	Property	
Hand basin	Person	
Kitchen Sink Use (with dishwasher)	Property	Dishwashing
Kitchen Sink Use (no dishwasher)	Property	
Dishwasher	Property	
Hosepipe	Property	External use
Garden sprinkler	Property	
Miscellaneous	Property	Miscellaneous (internal) use

We have undertaken a separate micro-component analysis for each of the household types shown in Table 5.We have, therefore, identified different Ownership (**O**), Frequency (**F**) or Volumes (**V**) values for different house types to take account of the different characteristics and the effect of metering on water use rates. The average daily water use by an appliance in a particular type of home can be calculated as:

$$O * F * V$$

Where: **O** = estimated percentage of houses that own the appliance (%)

F = estimated average frequency of use (uses per day)

V = estimated average volume per use (litres per use)

[31] Therefore, have a degree of uncertainty
[32] Water Resources Planning Guideline (Environment Agency, 2018)

As shown in Table 14, we've assumed a key driver for certain appliances, based on our understanding certain water using appliances are used. Therefore, in some cases **F** is assessed as the frequency of use per person and in some cases it can be assessed as the frequency of use per household property, in which case an average occupancy is then used to convert it to frequency of use per person. The total per capita consumption (l/hd/d) is calculated as the sum of micro-component volumes:

O*F*V for baths + O*F*V for showers + etc.

Total per capita consumption values are individually calculated for each year.

2.4.3 Customer survey

In consultation with DJS Research Ltd and using the standard UKWIR questionnaire[33] as a starting point, we designed a questionnaire to be used to survey over 2000 household customers[34] across our resource zones. The survey questionnaire was shared with YourVoice[35] (previously referred to as our "Customer Challenge Group" or "CCG") and the Environment Agency, with all comments being incorporated before the survey was undertaken.

Participant data was used to allow us to attain a spread of customer types according to resource zone, household type and metered status.

Table 15 Number of household customers surveyed

	Strategic Resource Zone	Carlisle Resource Zone	North Eden Resource Zone
Number of household customers	1488	499	95

As well as informing our occupancy rates, this survey helped us understand the ownership and frequency of use of water using appliances. Examples of the results for ownership are shown in Figure 19 and Figure 20.

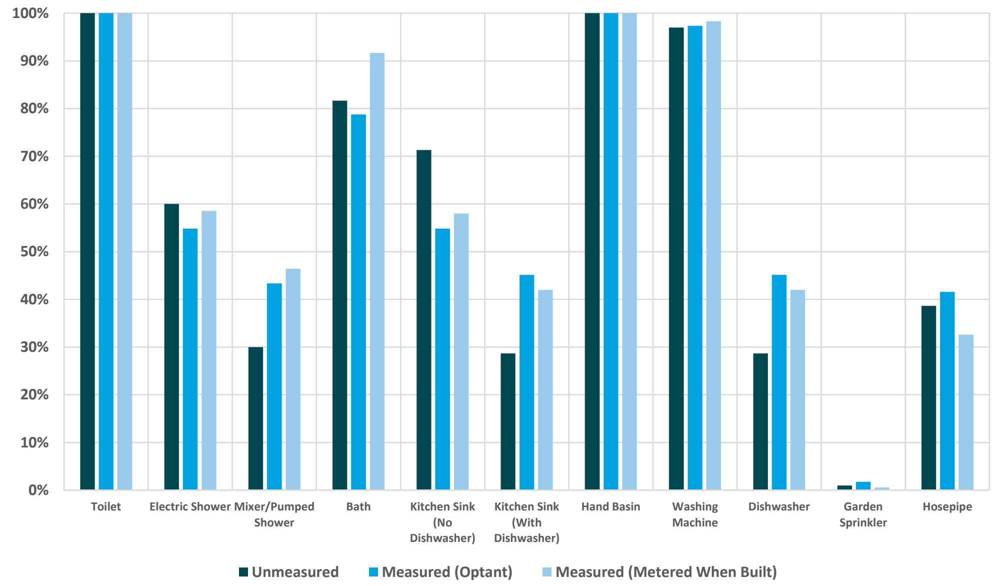


Figure 19 Ownership of different water using appliances in our Strategic Resource Zone

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[33] UKWIR longer form questionnaire from the Integration of Behavioural Change into Demand Forecasting and Water Efficiency Practices (UKWIR, 2016)

[34] Surveys were carried out by telephone and 2,082 customers were surveyed in total

[35] https://www.unitedutilities.com/corporate/about-us/performance/yourvoice/

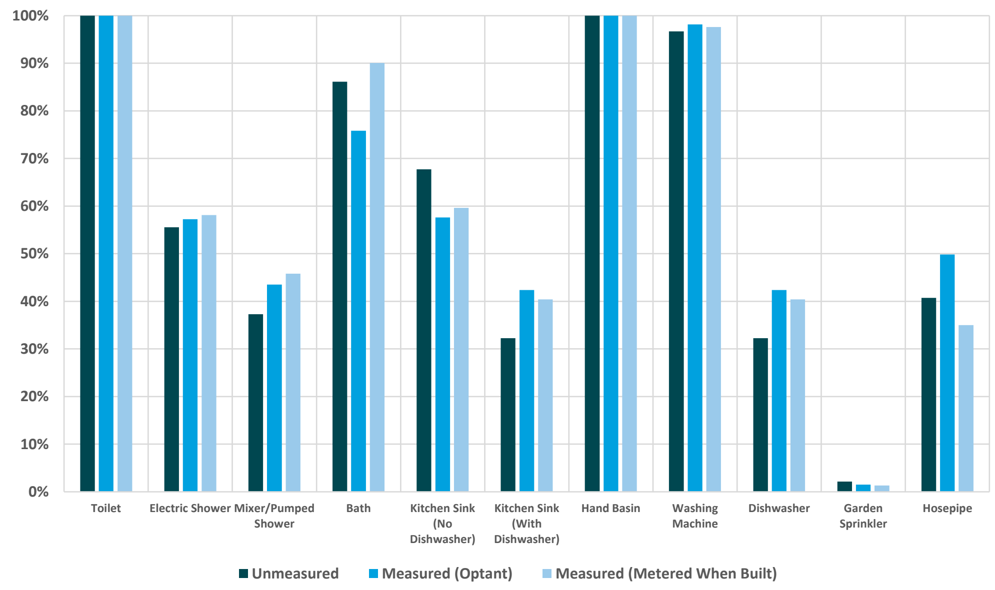


Figure 20 Ownership of different water using appliances in our Cumbrian Resource Zones (Carlisle and North Eden)

2.5 Central forecast from the base year

Table 16 shows our central forecast of measured and unmeasured household consumption for each resource zone from the base year of 2016/17. The increase in measured household consumption is due customers moving into new properties in our region as well customers opting for a meter, which also results in a decrease in unmeasured household consumption.

Table 16 Our central forecast of measured and unmeasured household consumption for each resource zone, prior to the application of any demand uplifts to account for climate change and weather variation

	2016/17	2020/21	2025/26	2030/31	2035/36	2040/41	2044/45
Strategic Resource Zone							
Measured household consumption (Ml/d)	274	323	384	436	485	531	563
Unmeasured household consumption (Ml/d)	594	538	473	415	364	320	289
Total household consumption (Ml/d)	**868**	**861**	**858**	**851**	**849**	**850**	**852**
Measured per household consumption (l/prop/d)	238	232	227	224	222	221	221
Unmeasured per household consumption (l/prop/d)	350	348	344	341	337	335	333
Average per household consumption (l/prop/d)	**305**	**293**	**280**	**269**	**260**	**253**	**249**
Measured per capita consumption (l/h/d)	118	113	110	107	105	103	102
Unmeasured per capita consumption (l/h/d)	152	151	151	150	150	149	149
Average per capita consumption (l/h/d)	**139**	**134**	**129**	**124**	**120**	**117**	**114**
Carlisle Resource Zone							
Measured household consumption (Ml/d)	3.9	4.7	5.6	6.5	7.2	7.7	8.1
Unmeasured household consumption (Ml/d)	10.1	9.8	9.2	8.7	8.1	7.6	7.3
Total household consumption (Ml/d)	**14.0**	**14.4**	**14.9**	**15.2**	**15.3**	**15.3**	**15.3**
Measured per household consumption (l/prop/d)	235	234	230	228	225	224	223
Unmeasured per household consumption (l/prop/d)	333	336	333	329	326	323	321
Average per household consumption (l/prop/d)	**299**	**294**	**285**	**276**	**269**	**264**	**260**
Measured per capita consumption (l/h/d)	111	108	106	104	103	101	101
Unmeasured per capita consumption (l/h/d)	155	152	152	151	151	151	151
Average per capita consumption (l/h/d)	**139**	**134**	**130**	**126**	**124**	**121**	**119**
North Eden Resource Zone							
Measured household consumption (Ml/d)	0.5	0.6	0.7	0.7	0.8	0.8	0.9
Unmeasured household consumption (Ml/d)	1.1	1.1	1.0	1.0	1.0	0.9	0.9
Total household consumption (Ml/d)	**1.6**	**1.7**	**1.7**	**1.7**	**1.8**	**1.8**	**1.8**
Measured per household consumption (l/prop/d)	237	236	233	231	229	228	227
Unmeasured per household consumption (l/prop/d)	338	341	337	335	333	330	329
Average per household consumption (l/prop/d)	**298**	**295**	**287**	**281**	**276**	**272**	**270**
Measured per capita consumption (l/h/d)	110	107	105	104	103	102	101
Unmeasured per capita consumption (l/h/d)	157	154	154	153	153	152	152
Average per capita consumption (l/h/d)	**139**	**134**	**130**	**128**	**125**	**123**	**122**
Region							
Measured household consumption (Ml/d)	279	329	391	444	493	539	572
Unmeasured household consumption (Ml/d)	605	549	484	425	373	328	297
Total household consumption (Ml/d)	**884**	**877**	**874**	**868**	**866**	**867**	**869**
Measured per household consumption (l/prop/d)	238	232	227	224	222	221	221
Unmeasured per household consumption (l/prop/d)	349	348	344	340	337	334	332
Average per household consumption (l/prop/d)	**305**	**293**	**280**	**269**	**260**	**253**	**249**
Measured per capita consumption (l/h/d)	118	113	110	107	105	103	102
Unmeasured per capita consumption (l/h/d)	152	151	151	150	150	149	149
Average per capita consumption (l/h/d)	**139**	**134**	**129**	**124**	**120**	**117**	**114**

In terms of average per capita consumption in our region, we currently benchmark as being around industry average when looking across the water industry as a whole[36]. We are committed to working with our household customer

[36] Analysing data from https://discoverwater.co.uk/amount-we-use

retail to continue to reduce average per capita consumption, utilising metering (as discussed in Section 2.2) and innovative water efficiency initiatives (as discussed in Section 2.3).

2.6 Scenarios and sensitivity

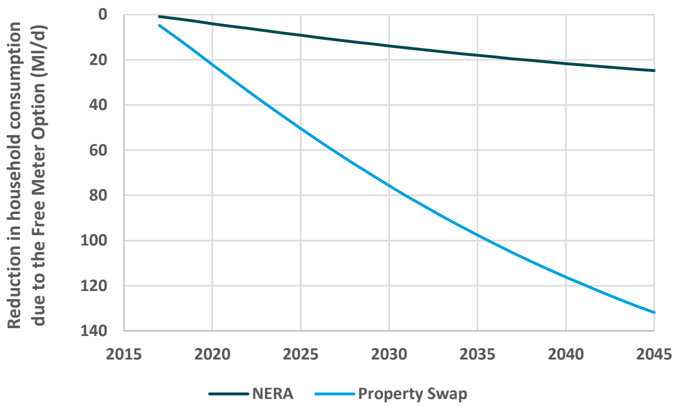
Following an audit of our household consumption forecast model by Artesia Consulting in July 2017, our model was stated as being comprehensive, in that it:

- Includes ownership (**O**), volume per use (**V**) and frequency of use (**F**) data for 12 micro-components, that when summed give the per household consumption for the resource zone being analysed;
- Is built at household level and includes micro-components (toilets, shower use and wash basins) that vary with occupancy, a similar approach to the Artesia Consulting per household consumption models;
- Varies frequency of use by occupancy, an important consideration;
- Is segmented by each resource zone and by property type, with each property type having separate assumptions relating to ownership, volume per use and frequency of use; and
- Uses ownership data derived from a customer survey, with volume per use and frequency of use being derived from industry standard data.

We were recommended to carry out two sensitivity tests and these were:

- The benefit of the Free Meter Option, considering the NERA study[37] and the impact of the Free Meter Option on unmeasured occupancy; and
- Testing different micro-component rates of change, guided by the rates of change being used by Artesia Consulting.

These two sensitivity tests had a material impact on the household consumption forecast, as shown in Figure 21, representing an inherent uncertainty in forecasting and warranting inclusion in the target headroom assessment so that this is appropriately factored into the supply-demand balance. This is documented further in Section 10 and in *Final WRMP19 Technical Report - Target headroom.*



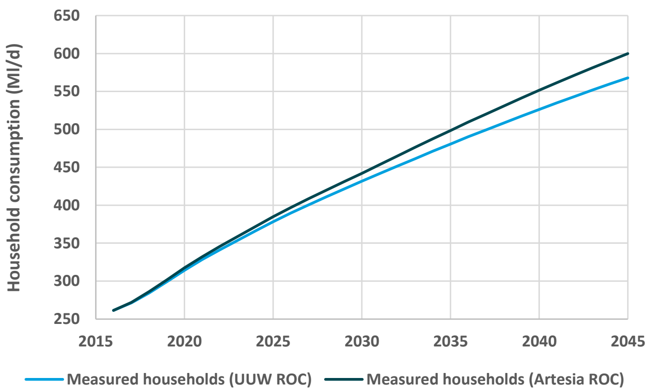


Figure 21 Sensitivity tests on the benefit of the Free Meter Option (circa. 100 Ml/d difference by 2044/45) and different micro-component rates of change, guided by the rates of change being used by Artesia Consulting (circa. 30 Ml/d difference by 2044/45)

We also carried out sensitivity tests around unallocated population (52,759 irregular migrants, short-term residents and people with second addresses), as discussed earlier, but the impact on the household consumption forecast was relatively minimal (circa. 6 Ml/d) and not considered to require inclusion in the target headroom assessment.

[37] The Impact of Household Metering on Consumption: Empirical Analysis (A Final Report for United Utilities Water) (NERA, 2003)

2.6.1 Multiple Linear Regression (MLR) modelling

We have worked with Artesia Consulting to produce a baseline household consumption forecast for the majority of our region[38], using multiple linear regression (MLR) modelling, which is suitable for resource zones with medium to high levels of water resource planning concern. We did this to complement our core demand forecasting approach, and provide further confidence around our base forecasts. The exercise had the potential to further develop our understanding of demand patterns, particularly against a backdrop of slightly elevated short-term demand compared to previous expectations.

MLR modelling has been successful in producing a robust model that integrates the impacts of drivers such as occupancy, number of properties, population and weather in a dynamic model, which can be used to forecast household consumption. The MLR model has been developed using household level consumption and survey data available for 2015/16, and validated using consumption data for 2016/17. Results indicate a good correlation between consumption and population, properties, employment rate and washing machine frequency. Outputs have been compared to 10 years of historic consumption at a zonal level and a residual model has been incorporated to the MLR to further explain other drivers of consumption, such as average maximum temperatures and rainfall.

In addition to the functional advantages of an MLR model, it is possible to quantify model error and model performance can be tested throughout the build process. Artesia Consulting have validated the MLR model and tested its performance using various metrics. Firstly, the model was constructed using standard statistical methods. Secondly, the model and its coefficients were tested using resampling techniques which ensures that the model is not highly dependent on the data which has been used to create it. Then, the model was tested spatially, using cross validation. Finally, the model was validated temporally, by applying the model to historic data and forecasting forwards to the current year, and comparing with reported figures.

Artesia Consulting observed that, in general, both methods display similar downward trends in per household consumption. A volumetric comparison of baseline household consumption forecast from the MLR model, with the baseline household consumption forecast from the micro-component analysis, are shown in Figure 22. It can be seen that the MLR model outputs fall well within the range of the “Upper” demand scenario (see Section 10), and thus the tolerances also included in target headroom, from the micro-component analysis and tested in this WRMP.

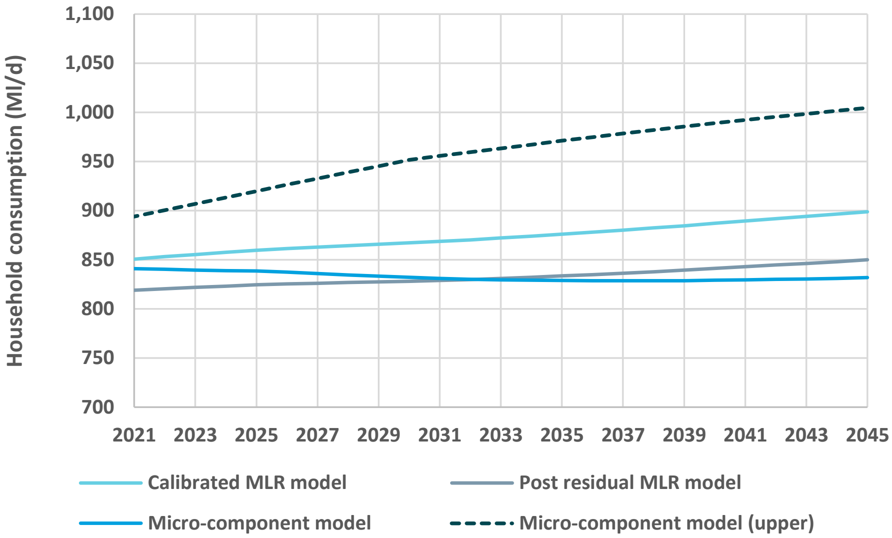


Figure 22 Calibrated and post residual multiple linear regression (MLR) model household consumption forecast for the majority of our region compared to the micro-component analysis household consumption forecast, used to inform our overall demand forecast (as documented in Section 10, “upper” refers to the high demand scenario tested in this WRMP)

[38] The model has been built for the current Integrated Resource Zone, which will be combined with the West Cumbria Resource Zone into the Strategic Resource Zone on completion of the Thirlmere transfer scheme (see Section 1.2).

3. Non-household consumption

This section covers how we have derived our forecast of measured and unmeasured non-household customer consumption, including the incorporation of the benefits of customer metering and our water efficiency activities.

3.1 Eligibility review

From April 2017, non-household customers[39] were able to choose their water and wastewater retailer. As the incumbent water supplier or wholesaler, we are still responsible for delivering the water to the customer, continuing to forecast and plan for non-household customer consumption in our region.

In line with part 17C of the Water Industry Act 1991 and with Ofwat's supplementary guidance on assessing whether non-household customers in England and Wales were eligible to switch their water and wastewater retailer, we carried out a full eligibility review in 2016. We worked with Sagacity Solutions Ltd, applying Ofwat's guidance around "principle" or "predominant" use via these key principles:

- Properties or premises listed only on business rates were classed as non-household and are eligible to switch retailer;
- Certain properties listed on Council Tax, but billed as a non-household are eligible to switch retailer, including nursing homes, purpose built student accommodation and farms;
- It is the legal responsibility of the retailer to only provide services to non-household customers;
- We only have a licence to provide retail services to household (domestic) customers; and
- The eligibility of mixed usage premises was determined by principle or predominant water usage.

The final stage, if principle or predominant water usage could not be established, was to engage directly with the customer and carry out site visits to establish eligibility. The resulting property movements are shown in Table 17. The majority of movements related to smaller properties or premises, such as small shops, change of use and non-working farms. Therefore, the impact of the eligibility review on non-household customer consumption was minor, with no noticeable step change in the reported levels of consumption between 2015/16 and 2016/17.

Table 17 Movement of properties or premises from household to non-household and vice versa

	Active	Void[40]	Total
Previously classed as household, but now classed as non-household and eligible to switch retailer	475	1,282	1,757
Previously classed as non-household, but now classed as household and not eligible to switch retailer	1,467	134	1,601

3.1.1 Non-household population

As discussed in Section 2.1, in terms of forecasting total population (household and non-household), the plan-based forecast is informed by the trend-based forecast, but assumes a higher net in-migration, in line with the increased number of properties being forecast in the Local Development Plans.

To calculate the base year household population, household occupancy rates, as shown in Section 2.1.3, are multiplied by the number of household properties. For 2016/17, the calculation was:

[Total number of household properties] x [Average household occupancy] = [Household population]

2,902,900 x 2.19 = 6,363,213

[39] All business customers and public sector, charitable and not-for-profit organisations in areas of England and Wales served by water undertakers that are wholly or mainly in England.
[40] Unoccupied or empty properties

However, our total population estimate, using Office for National Statistics (sometimes referred to as "ONS") 2015 mid-year population estimate (published in June 2016) was 7,150,154. Therefore, this resulted in a non-household population of 786,941. We are forecasting non-household population to remain relatively constant over the planning period.

3.2 Engaging with retailers and non-household demand management

The general duty to promote the efficient use of water under section 93A of the Water Industry Act 1991 applies to both the incumbent water supplier or wholesaler and the retailer. Through the WRMP19 process have engaged with non-household retailers, requesting information on planned water efficiency activities to allow us to detect any potential shifts in future non-household consumption. We have also noted that the largest non-household retailer operating in our region, offer a range of water efficiency services on their website and we will continue to work with all non-household retailers to help promote and potentially target water efficiency activity.

At this time, the non-household retail market in England is in its relative infancy, we have identified no tangible or quantifiable change in water efficiency practices. Therefore, for WRMP19, we have dealt with the impact of competition on water efficiency using scenarios and sensitivity testing, discussed further in Section 3.5. We will continue to engage with non-household retailers throughout the WRMP process and in future planning cycles, as the market evolves.

3.2.1 Further engagement during and after consultation

Above we stated that we "identified no tangible or quantifiable change in water efficiency practices" and, therefore, in our non-household consumption forecast, we have incorporated a continuation of the water efficiency trends we have seen historically. However, we have also included water efficiency scenarios (covered in Section 3.5) to show the potential in this area and we are working directly with non-household retailers to explore this further.

Since consultation, we have had several discussions with the majority of retailers operating in our region and have spoken with Waterwise to understand the potential for an industry-wide approach to non-household water efficiency. These engagement activities, as well as the key discussion topics are shown in Table 18, and will continue as the non-household retail market in England develops.

Table 18 Further engagement during and after consultation

Activity	Discussion topics and key notes
Conference calls with individual retailers (May to June 2018)	Water efficiency strategies that are being developed; Opportunities for wholesalers, retailers and customers to deliver water efficiency strategies together; and Intelligent rainwater harvesting systems
Discussion with Waterwise[41] (July 2018)	Waterwise Retailers Leadership Group for Water Efficiency (26 June 2018); and Potential to map out some water efficiency communications that all water companies could use
Conference call with 9 of the retailers operating in our region (August 2018)	Wholesaler water efficiency communications; Potential for water efficiency incentives; Value added services (VAS) and ensuring the wholesaler does not encroach on retailer VAS space; Meter reading; and Rainwater harvesting trials

[41] http://www.waterwise.org.uk/

3.3 Forecasting method

3.3.1 Measured

As at WRMP15, we have worked with Experian to understand how non-household consumption changes with economic trends by sector. For this, we use a modelled[42] relationship between historic[43] non-household consumption by sector and some key economic metrics, including:

- Total output in the non-service sector (measured using GVA[44]), known as "output growth"; and
- Full-time equivalent employment in the service sector, known as "employment growth".

We have also reviewed the customer segmentation, in line with the Water Resources Planning Guideline, choosing the continued use of Standard Industrial Classification (sometimes "SIC") categories, as we have data by Standard Industrial Classification category reconciled to our Regulatory Reporting data back to 2003/04.

3.3.2 Unmeasured

During the 1990's, we carried out an extensive programme of metering non-household properties, wherever practicable. Therefore, the number of properties remaining unmeasured is small[45] and shrinking as, each year, a small number of customers are converted to measured, where feasible. Consequently, this is a relatively small component of the non-household consumption forecast.

Water consumption by unmeasured non-households in the "base year" has been calculated from the number of properties and the estimated average consumption, based on data for similar properties that have been measured in the past. Forecast values have been based on the growth for measured non-households to ensure a consistent economic outlook.

3.4 Central forecast from the base year

Figure 23 shows our central forecast for measured and unmeasured non-household consumption over the planning horizon.

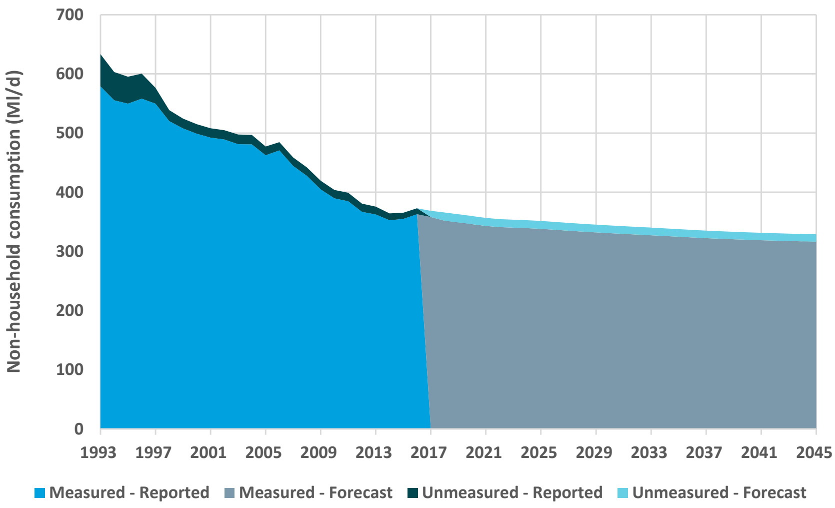


Figure 23 Reported and forecast non-household consumption

Table 19 shows this same forecast by resource zone to 2044/45.

Table 19 Reported and forecast non-household consumption by resource zone to 2044/45

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[42] Specifically, econometric models, which, in this case, aim to simplify the real world into a relationship between economic metrics or variables and consumption of water.
[43] Data from Regulatory Reporting, back to 2003/04
[44] Gross Value Added
[45] At Regulatory Reporting 2016/17, there were 14,468 unmeasured non-household properties and 148,791 measured non-household properties

	2016/17	2020/21	2025/26	2030/31	2035/36	2040/41	2044/45
Strategic Resource Zone							
Measured non-household consumption	350	336	329	323	317	312	310
Unmeasured non-household consumption	10	13	13	13	12	12	12
Total non-household consumption	360	349	342	335	329	325	322
Carlisle Resource Zone							
Measured non-household consumption	7.1	6.4	6.2	6.0	5.8	5.6	5.5
Unmeasured non-household consumption	0.2	0.3	0.3	0.3	0.3	0.2	0.2
Total non-household consumption	7.3	6.7	6.5	6.2	6.0	5.9	5.7
North Eden Resource Zone							
Measured non-household consumption	1.2	1.1	1.0	1.0	1.0	1.0	1.0
Unmeasured non-household consumption	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total non-household consumption	1.3	1.1	1.1	1.1	1.1	1.0	1.0
Region							
Measured non-household consumption	358	343	337	330	324	319	317
Unmeasured non-household consumption	10	14	13	13	13	13	12
Total non-household consumption	369	357	350	343	336	332	329

In the following sections, we discuss how the different non-household sectors have influenced this forecast, with a full sectoral breakdown of the forecast shown in Appendix I.

3.4.1 Service sector

Despite the relatively strong employment growth seen in our region, water consumption in the service sector declined by 1.3% between 2011/12 and 2014/15. All service sectors, with the exception of the 'other services' sector[46], recorded a decrease in water consumption over the same period. Water efficiency appears to explain part of the decline, water efficient gains measured by water consumption per employed person indicates average water efficiency savings of around 2.6% per annum.

The forecast reflects the increasing economic dominance of the service sector with more stable water consumption relative to the non-service sector. Water consumption in the service sector is set to decline by 4.2% in the next 30 years from 176 Ml/d in 2014/15 to 169 Ml/d in 2044/45. The non-household consumption in the service sector is expected to be 1.4% higher in 2039/40 compared to our WRMP15 forecast.

3.4.2 Non-service sector

Water consumption in the non-service sector has declined marginally since the WRMP15 study from 154 Ml/d in 2011/12 to 150 Ml/d in 2015/16, representing a 2.7% decline over the period. The relatively minor reduction can be explained in three parts:

- GVA growth for the non-service sector shows signs of stabilisation, remaining flat;
- After observing a period of significant water efficiency gains, identified in the WRMP15 study, the recent water efficiency gains measured by water consumption per unit of output indicates a 2.5% increase in the period (2011/12 to 2015/16), which translates to average water efficiency gains of around 0.8% per annum compared to the 3.1% estimated for the period between 2003/04 to 2011/12; and
- The real term water tariff increase has been low since 2009 by historic levels, which made water relatively less expensive and thus reduces some of the incentive to focus on water efficiency.

The downward trend in water consumption in the non-service sector will continue albeit at a slower pace. Water consumption is set to decline by 22.5% in the next 30 years from 150 Ml/d in 2014/15 to 116 Ml/d in 2044/45. The

[46] This sector comprises establishments engaged in providing services not specifically provided for elsewhere in the classification system.

model predicts higher water consumption in the non-service sector compared to the WRMP15 forecast, resulting in water consumption that is 3.9% higher in 2039/40 than the WRMP15 forecast.

3.5 Scenarios and sensitivity

Figure 24 shows all the scenarios considered as part of our non-household consumption modelling.

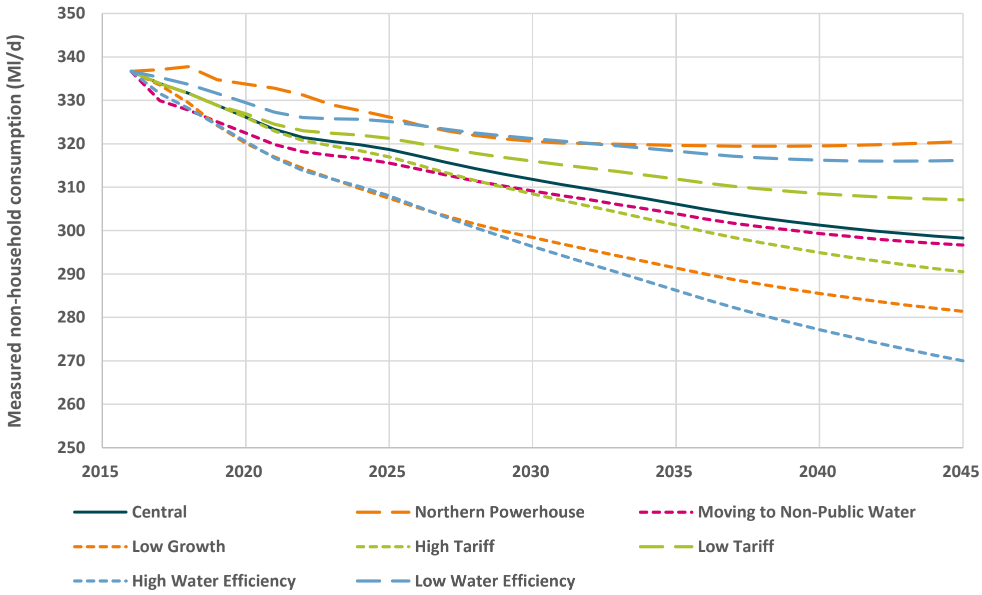


Figure 24 Scenarios considered as part of our non-household consumption modelling

The sections below describe the creation and reasoning behind each of these scenarios and Section 10 shows how we've included the uncertainty from these scenarios in the target headroom assessment.

3.5.1 Economic growth and the "Northern Powerhouse"

The "Northern Powerhouse" scenario assumes good early progress on negotiating new trade arrangements with the European Union (EU), perhaps similar to the existing European Economic Area (EEA) member status for the UK, but including a provision for some emergency brakes on migration. It also assumes promising initial discussions with other major trading partners such as the US, China and the Commonwealth countries, although actual deals would take longer to agree. In the medium to long-term, the UK economy will slowly return to long-term growth rates of 2.5% projected by the Office for Budget Responsibility (OBR) which is at the high-end of the UK's average long-term growth path. Further to this growth, the scenario envisages that the northern regions (North West, North East and Yorkshire & the Humber) undergo a period of economic transformation and fulfil the aspirations of the vision set out in HM Treasury analysis.

The "Low Growth" scenario assumes that negotiation with the EU has proved difficult, raising concerns for a possible 'hard-Brexit' and with the UK perhaps relying on World Trade Organization (WTO) rules to trade with the EU. This has led to a further fall of the value of sterling and the loss of consumer and business confidence which undermine both consumer spending and business investment. In this case, the UK could enter a period of recession for the next 12 to 24 months and permanently lower the nation's growth potential. The UK economy gradually emerges from the recession stabilising at a below trend growth trajectory until the end of the forecast period.

3.5.2 Water efficiency and tariff scenarios

The water efficiency scenarios explores the potential water efficiency benefits of increasing competition within the water industry, leading to savings for customers. The water efficiency benefit of increasing competition for our customers was calculated, based a similar study conducted in Scotland, to be 1.08% per annum. We have applied this saving in the "High Water Efficiency" scenario to understand the potential impact. However, as noted in Section 3.1, the non-household retail market in England is in its relative infancy and we have identified no tangible change in water efficiency practices. Therefore, even though "High Water Efficiency" is the extreme of the potential lower measured non-household consumption scenarios, we used the "Low Growth" scenario to inform out target headroom assessment, as documented in Section 10.

3.5.3 Customers moving from and/or to non-public water source

As suggested by the Water Resources Planning Guideline[47], we examined the potential impact of customers substituting water from a public source to a non-public source or vice versa. The scenario was developed using results from a National Farmers Union (NFU) survey, related to the proportion of respondents that have active abstraction licences, as an indication of the potential scope for customers in the agricultural industry[48] to access non-public water sources. The impact of this scenario in the context of other non-household consumption scenarios is relatively minor, as shown in Figure 24.

[47] Water Resources Planning Guideline (Environment Agency, 2018)

[48] We also considered the power generation sector (for instance, Rocksavage Power Station and Sellafield). However, our business as usual engagement has not highlighted this as a major issue.

4. Leakage

4.1 Background

Balancing the supply and demand of water is fundamental to our obligations to maintain a reliable supply to customers and to safeguard the environment. Leakage management contributes to the overall reduction in demand and has played a key role in reducing demand in the past and maintaining a supply-demand balance since the 1990s.

For the purpose of the WRMP, leakage is defined as loss of water from any point downstream of the distribution input meter at a Water Treatment Works, up to the internal stop tap in a customer property. This includes leakage from trunk mains and service reservoirs, known as upstream leakage. It also includes leakage from distribution pipes, connections to properties (communication pipes) and the associated customer supply pipes, known as supply pipe leakage (or customer side leakage). Raw water losses upstream of Water Treatment Works are considered separately.

Leakage management plays a key role in fulfilling the supply demand balance. Leakage reduction can be achieved incrementally and is one of the most flexible options considered in the WRMP as it can be scaled over time. In an uncertain future, incremental and flexible water resource solutions have an important value in terms of an alternative to the need for long-term fixed solutions. This will help us to be robust to the various risks and uncertainties such as the impact of climate change on the supply demand balance.

Figure 25 below shows the contribution of each of the components to the total leakage that is occurring on the distribution network.

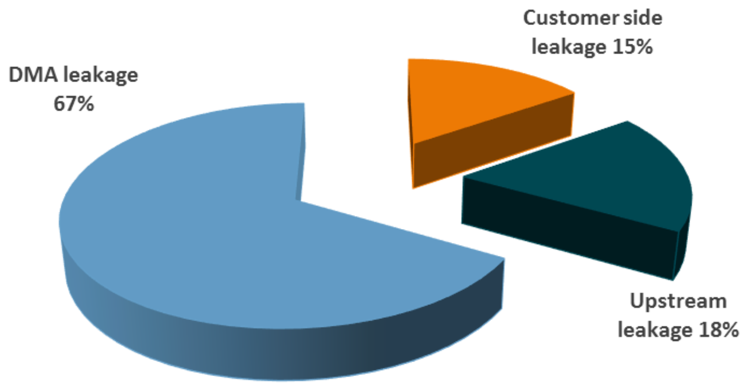


Figure 25 Leakage components 2016/17

As shown in Figure 26, we have significantly reduced leakage over the last 25 years, more than halving leakage from 945 Ml/d in 1992/93 to 462 Ml/d in 2007/08. Leakage has continued to decrease and, in 2016/17, we have achieved our lowest ever level of 439 Ml/d, giving a three year average leakage of 448.2 Ml/d. Despite this, in 2017/18 we experienced three separate freeze thaw events during the winter, with the March 2018 event being the most significant. This resulted in a deterioration in performance to 454 Ml/d, but still within our target. Leakage performance can vary from year to year due to such weather impacts.

Our leakage performance been achieved and maintained through expenditure on a combination of measures in accordance with national best practice. For example, we have:

- Installed a comprehensive network of over 2,500 district meters (cellular telemetry data loggers) that use GPRS technology to continuously monitor water use and leakage in each district of around 1,200 properties across the region;

- Installed over 4,000 pressure management valves and other pressure reducing methods to optimise water pressure across our distribution networks;
- Employed a large leak detection workforce of around 150 full-time equivalent personnel who have been trained and equipped with the latest leak detection techniques;
- Provided a free telephone service for customers to inform us of leaks, and a free supply pipe repair service for households; and
- Maintained a sophisticated leakage information system that analyses 15-minute flow and/or pressure data from over 6,000 sites across the region. This identifies the areas where high leakage is occurring and directs our leak detection activities.

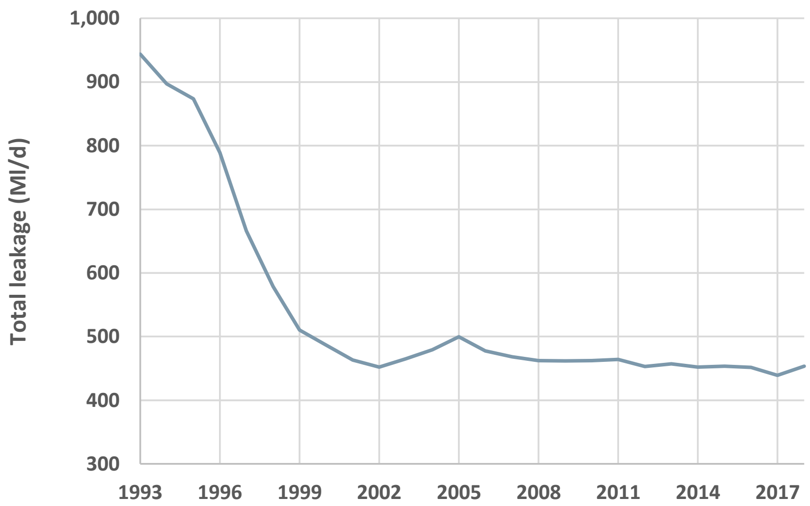


Figure 26 Leakage performance 1993 to 2018

4.2 Leakage management

At each price review we agree with Ofwat a leakage target which is derived using a combination of historic performance, economic appraisal and customer preferences. We employ best practice, follow UKWIR approved methodologies where appropriate and ensure that adequate resources are deployed to maintain our leakage levels below the agreed target. Leakage management is well governed with operational review on a weekly basis, water balance reporting on a monthly basis and management reviews on a monthly basis or more often if required.

We have achieved our regulatory leakage target for over 10 years, despite experiencing three severe winters in 2009/10, 2010/11 and 2017/18. This has been achieved by carrying out an extensive range of leakage control actions, at significant cost. We are continually striving to improve and ensure that we are operating as efficiently and effectively as possible. This meant that we have managed to achieve steady reductions in leakage over the past few years and our lowest ever leakage in 2016/17. In 2017/18, we experienced a series of freeze-thaw events, the most severe in March 2018, and this resulted in higher leakage levels than the previous year, but still remains below our target.

We are planning to maintain this level of performance through 2018/19 and 2019/20, and have committed significant operational and capital resources to achieve this through:

- Maintenance of our existing district metered areas (DMAs);
- Widespread pressure management (region wide pressure management programme is being delivered in AMP6, covering 2015/16 to 2019/20);
- Good quality data and robust maintenance of our leakage management and information systems;
- Efficient leakage detections and repair using latest technologies;
- Replacement and refurbishment of poor performing mains;
- Providing free supply pipe repairs for domestic customers; and

- Rising customer and community awareness (Leakline campaigns).

District metered areas (DMA) leakage

Our network is divided into over 2500 district metered areas (DMAs) and around 4500 discrete pressure areas (DPAs, pressure managed sections of DMAs). DMAs are formed by dividing the network into manageable units covering between 900 and 2000 properties. This makes leakage targeting and burst localisation more efficient. Leakage levels for DMAs are calculated on a daily basis using the minimum night flow (MNF) method consistent with the industry best practice[49].

Large customers that have a significant impact on the DMA's minimum night flow are continuously monitored to enable more accurate leakage estimation. Estimates of domestic and commercial use are determined by a thorough sampling and statistical methodology in line with UKWIR recommendations[50].

We use DPAs to manage pressure in our network as it is a proven method of reducing leakage and ensuring customers receive the right level of service. As part of AMP6 (covering 2015/16 to 2019/20), we are currently delivering a region wide pressure management programme which will significantly increase the number of properties within pressure managed areas. We will build around 800 new pressure management schemes and optimise just over 300 existing ones. Deployment of remote telemetry loggers since 2005 has significantly improved leakage and pressure monitoring.

We use Netbase, a sophisticated leakage management software widely used across the UK and internationally, to analyse data and monitor leakage performance. Netbase links to our corporate systems and brings together information on assets, areas and flow and pressure measurements and analyses the 15-minute flow and pressure data in each DMA and DPA on a daily basis. This enables rapid targeting of areas showing a sudden rise in the minimum flow. The application is also used to direct leakage reduction activities and report leakage and distribution input trends.

[49] (UKWIR, 2011)
[50] (Water UK, 2016)

Upstream leakage

We have the largest network upstream of DMAs of all UK water companies. The identification and detection of non-visible leaks on trunk mains is more difficult than for local distribution mains, which are predominantly downstream of DMA meters. This is because larger pipe diameters absorb the noise generated by the leak more readily than smaller pipe diameters, thus hindering the leak detection equipment. To target leakage efficiently the upstream network is also divided into units which are called tiles. Each tile is continuously monitored using remote telemetry logged data. Metered data is analysed and validated each week by the Regional Upstream Losses Coordinator. This enables the effective and efficient targeting of leakage on different trunk main tiles.

We use a wide range of standard technologies and techniques for leak detection to maximise our effectiveness. These include:

- Sounding;
- Step testing (including mobile step testing devices);
- Zero pressure testing;
- Mass balance;
- Meter verification;
- Leak noise correlators;
- Ground noise microphones;
- Acoustic loggers; and
- In pipe acoustic sensors (e.g. WRc Sahara® device).
- Remote sensing e.g. satellite imagery
- Sniffer dogs

Large service reservoirs are monitored for overflows on a daily basis through telemetry alarms and can also be identified through routine analysis of the upstream tiles. We have an ongoing reservoir cleaning and maintenance programme where drop tests are undertaken and large reservoirs are also inspected for safety.

Customer side leakage

Supply pipe leakage can be considerable and recognising this, in May 1996 we were the first company to introduce a region-wide free repair service. We continue to provide support and assistance in accordance with regulatory and customer expectations. Recognising the feedback from customers and relevant contact data, we set up a proactive customer contact team to keep customers informed, have a single point of operational response and ultimately resolve issues quicker so that leaks are not perceived to be left running for a long time. Each month we repair or replace on average 180 supply pipes. Customers can replace their lead supply pipe at their own cost and once the new pipe is installed by the plumber we will connect it and replace any remaining lead pipe beyond property boundary for free, subject to acceptance onto our Lead and Common Supply Pipe replacement (LCSP) scheme. Since privatisation we have replaced over 600,000 lead supply pipes (we estimated it to be half of all lead supply pipes). We are also actively mitigating public health risk from lead pipes by controlling plumbosolvency in our distribution network.

We provide a freephone 'Leakline' service for customers to report leaks. The service is actively promoted through telephone directory entries, information leaflets, customer billing information and our website, where a leak can also be reported using an online form https://www.unitedutilities.com/help-and-support/got-a-problem/report-a-leak/report-a-leak-form/. Over 50% of leaks repaired by us each year are reported by customers.

Following the recommendation of the recent UKWIR report on the economics of supply pipe losses[51] we commissioned a project to explore the impact of changing our current policy on supply pipe repairs. The optimal approach, taking account of social and environmental costs, is to maintain our current policy for both household and

[51] (UKWIR, 2015)

non-household properties. The model was also used to test a number of scenarios for inclusion in the water resource management plan option identification process[52], these are:

- Introduction of proactive monitoring;
- Replace rather than repair supply pipes for household; and
- Offer a free repair policy for non-households.

4.3 Economic appraisal of leakage

The primary objective of the economic appraisal is to determine the economic level of leakage required to provide reliable supplies to customers at least-cost over a 25-year planning horizon. The long-run economic level of leakage is defined as the point that represents the lowest total cost, including options such as pressure management. The inclusion of externalities such as social, environmental and carbon costs enable a sustainable economic level of leakage (SELL) to be derived.

There are drivers that may push us to go beyond our SELL, as has been a key consideration elsewhere in this plan:

- Customer preferences, including customer 'willingness to pay' or benefit valuation
- Supply demand deficit (or resilience / environmental drivers) and a need to reduce demand
- Regulatory or policy drivers

We have followed the "best value" supply-demand planning approach recommended in the latest UKWIR guidance[53]. This approach aims to provide the most cost effective and sustainable long term solution. It is based on a combination of core methods which seek to minimise the net present value of the cost of all the investment required to maintain a supply-demand balance over the 25 year period, augmented with extended methods to ensure best value for customers and environment. Leakage reduction options form a key part of the appraisal process, whether this be to meet a supply-demand deficit, meet customer and stakeholder expectations or benefit the environment. More detail on how we considered leakage reduction options can be found in *Final WRMP19 Technical Report - Options appraisal*.

Full account has been taken of the Ofwat Leakage Methodology Review (the "Quinquepartite" Reports)[54] and subsequent guidance. In particular, the principles detailed in the report on *Providing best practice guidance on the inclusion of externalities in the ELL calculation*[55] and the recommendations in "*Review of the calculation of sustainable economic level of leakage and its integration with water resource management planning"* (SMC, 2012)[56] have been followed to establish a sustainable economic level of leakage.

[52] (Crowder Consulting, 2016)
[53] (UKWIR, 2016), (UKWIR, 2016)
[54] (Ofwat, 2007)
[55] (Ofwat, 2008)
[56] (SMC for EA, Ofwat, Defra, 2012)

Table 20 Short run ELL and SELL

		Strategic	Carlisle	North Eden	Region
PR19	**ELL (Ml/d)**	471.5	7.4	2.9	481.8
	SELL (Ml/d)	**453.5**	**6.8**	**2.8**	**463.2**
PR14	**ELL (Ml/d)**	671.5	7.8	2.9	682.9
	SELL (Ml/d)	595.9	7.2	2.6	605.7

The main reason for the significant reduction in ELL and SELL between PR19 and PR14 is exclusion of repair costs when producing the active leakage control (ALC) curve[57]. This is based on the assumption that the natural rate of rise in leakage (NRR)[58] is a function of infrastructure condition and is not significantly impacted by reducing or increasing leakage levels, i.e. the same number of leaks has to be repaired each year just to counteract the NRR, irrespective of the absolute level of leakage.

Following the recommendations of the SMC report, we have improved our model so that now pressure management and mains rehabilitation are also incorporated into the analysis. This ensures that the benefits of the various leakage management options are not double counted.

The ELL model was used to develop a number of leakage reduction options for inclusion in the option appraisal process (please see our *Final WRMP19 Technical Report - Options appraisal*). The costs and benefits of these options were assessed using actual company data, keeping it consistent with the ELL assessment. Full assessment of the social and environmental costs was completed for each option and these costs were accounted for in the option appraisal process.

4.3.1 Sensitivity analysis of the SELL

There is an inherent uncertainty in all of the ELL/SELL analysis components as there is a level of estimation in each one. Analysis was carried out to examine the sensitivity of the leakage profile to a number of key components of the ELL analysis. Figure 27 bellow shows results for the Strategic Resource Zone.

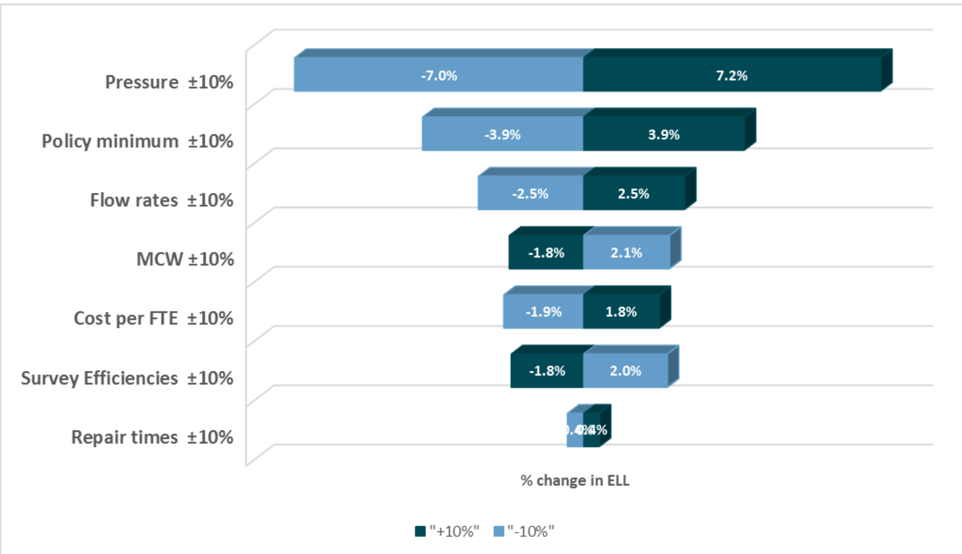


Figure 27 Sensitivity analysis of the SELL

57 Active leakage control curve (ALC) is showing the relationship between leakage and cost
58 NRR is the rate at which leakage would rise if no proactive leakage detection was carried out

The ELL is most sensitive to changes in pressure and policy minimum. For example, a 10% increase in pressure would increase the ELL by 7%. A 10% increase in policy minimum would have similar effect of the ELL, causing a 6% increase. A 10% increase in marginal cost of water has no significant impact on ELL causing only 1.8% decrease. This is due to total cost curve being relatively flat around the minimum point.

4.3.2 Upper and Lower bands for ELL and SELL

A Monte Carlo simulation was used to assess the upper and lower bands for ELL and SELL.

A set of confidence levels was set for the 7 components identified in the sensitivity analysis. This was done using internal subject matter expertise, accounting for the amount of data used when deriving the particular component, difficulty level of the analysis and the amount of validation required in the assessment.

Table 21 90% confidence limits

Component	90th CL%	Reason
Pressure	1%	Data mostly based on logged data, robust validation processes in place.
Infrastructure condition factor (ICF)	2%	Output from the minimum historic analysis, a lot of data inputs so potential errors, also estimation involved but the analysis is robust and a lot of validation is carried out.
Flow rates	5%	Output from NRR analysis, reliant on accuracy of burst data and leakage detection data, a lot of data cleansing required. The analysis is very subjective at individual DMA level.
Marginal cost water (MCW)	2%	Obtained from Production Planning, validated data set, data improved a lot over the past few years, since Production Planning initiative was launched.
Cost per Full Time Equivalent (FTE)	2%	Subject to various assumptions, especially for the managerial time allowance.
Survey efficiencies	10%	Very difficult to estimate, as assumes that survey in a particular DMA will always take the same amount of time, and this is not the case in practice. Therefore, large uncertainty band.
Repair times	5%	Derived as part of the NRR analysis using data extracted directly from SAP. Reliant on very accurate logging of burst types etc., therefore some assumption had to be made to group bursts in categories required for the analysis.

A normal distribution was applied to each component using the confidence limits above. A Monte Carlo simulation was run on the ELL model, randomly selecting each component from its distribution. The results below are based on 1000 simulations and show upper and lower bands based on 90% confidence limits.

Table 22 Upper and lower band for ELL and SELL

WRZ	ELL (Ml/d)			SELL (Ml/d)		
	Central	Upper	Lower	Central	Upper	Lower
Carlisle	7.4	7.7	7.1	6.8	7.1	6.6
North Eden	2.9	3.0	2.8	2.8	2.9	2.7
Strategic	471.5	486.8	456.3	453.5	467.6	439.5
Company	**481.8**	**497.4**	**466.2**	**463.2**	**477.6**	**448.8**

The figure below shows an example of a normal distribution of ELL and SELL for Strategic resource zone (shown as histogram and as continuous distribution).

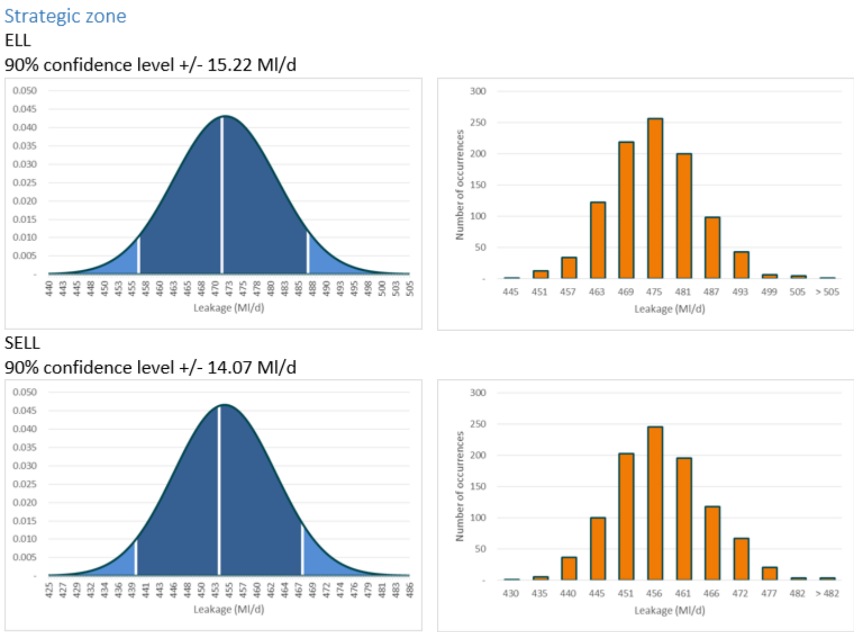


Figure 28 Normal distribution of ELL and SELL

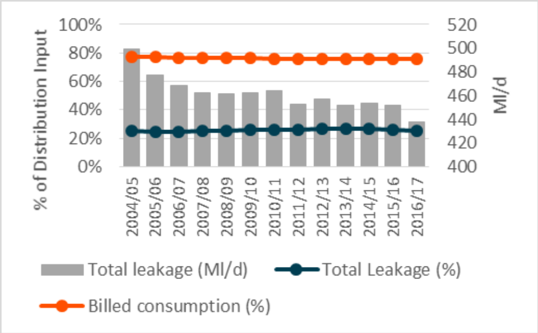
4.4 Risks and uncertainties

There are a number of risks and uncertainties surrounding the economic level of leakage appraisal. The analysis is very complex and requires a lot of data inputs that can themselves carry a high level of uncertainty, for example leak flow rates, survey efficiencies and repair times have to be derived at a resource zone level while in real life each leak will be different, detection efficiency will vary at DMA level and estimate of repair time relies on accuracy of the job management system. For more detail on the economic appraisal of leakage please refer to Appendix A.

4.5 Benchmarking

Due to the wide range of systems and the different statistics available, benchmarking leakage performance is challenging and subject to misinterpretation. This section aims to walkthrough the different comparisons made in the UK and elsewhere.

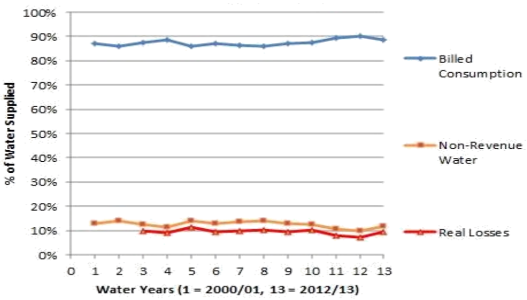
Although, there is a wide range of leakage performance indicators in use e.g. % of system input, per km of mains, per km of system (mains + services), per connection, per billed property – none of these provide an equitable means of comparing leakage between systems and countries. Due to underlying differences in the components of leakage and influential parameters such as pressure, leak run times and meter penetration, different statistics can show individual systems, companies/utilities or countries to perform differently relative to their peers. For example, urban areas with high consumption tend to favour “leakage per property” while areas with low property density turn to “per km of main”. % of system input can mask true level of leakage reduction as it is also heavily influenced by consumption, please see Figure 29 below.



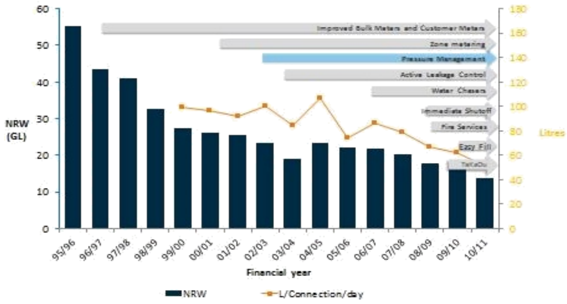
Left: In the last twelve years our total leakage – in Ml/d - has been reduced by 12%. However, this has been matched by a fall in consumption, and hence system input, so leakage as percentage of system input has remained constant. This shows why reporting leakage in % is a poor incentive on performance and can be misleading.

Below left: Yarra Valley Water faced a severe drought in the 2000s, forcing them to take the multiple steps to improve their water efficiency. Non revenue water was cut by 75% (as shown on the chart).

Below right: Yarra Valley Water's successful water efficiency measures meant that percentage losses remained constant.



From Lambert (n.d.)



From Lambert (n.d.)

Figure 29 Leakage reported as a percentage of water supplied hides holistic management of limited water resources

The recently published EU Reference Document 'Good Practices on Leakage Management'[59] provides a recent evidence-based 'fit for purpose' review of the leakage performance indicators for different objectives. These are shown in Figure 30 below.

OBJECTIVE	GOOD PRACTICE PERFORMANCE INDICATOR FOR LEAKAGE, FIT FOR PURPOSE						
	Volume per year	litres/ service connection	m^3/km mains	litres/ billed property	% of System Input Volume	% of Water Supplied	Infrastructure Leakage Index, with Pressure
SET TARGETS AND TRACK PERFORMANCE, FOR AN INDIVIDUAL SYSTEM	YES, for large systems	YES*	YES*	YES (UK)	NO	NO	Only if all justifiable pressure management completed
TECHNICAL PERFORMANCE COMPARISONS OF DIFFERENT SYSTEMS	NO	NO	NO	NO	NO	NO	YES
DRAW GENERAL CONCLUSIONS FROM SINGLE OR MULTIPLE SYSTEMS	NO	NO	NO	NO	NO	NO	YES, together with other context factors
* Choose services connection density > 20/km; if not, choose mains; or base choice on country custom and practice							

Figure 30 Leakage performance indicators fit for purpose[60]

Infrastructure Leakage Index (ILI) is listed as the only indicator suitable for comparisons of different systems. It was developed by the International Water Association (IWA) Task Force in 1999 and quickly became popular in countries

[59] (EU, 2015)
[60] (EU, 2015)

such as Australia, New Zealand, AWWA (North America), and is now widely calculated and increasingly adopted throughout Europe and internationally (Austria 2009, Croatia 2009, Denmark 2014, Germany due 2017/18, Italy 2016, and Malta 2003)[61]. The advantage of using ILI for company comparisons is that it allows to account for all 4 key parameters influencing leakage i.e. pressure, number of connections, meter location, mains length, whereas the indicators mentioned in the beginning of this section are limited to only one parameter.

Due to UK water companies having limited data on number of connections, as regulatory reporting in the UK uses billed properties, the assessments of ILI might not be fully representative and can make international comparisons less meaningful. Another factors that can contribute to less meaningful comparison are, for example:

- Company size (generally European utilities are a lot smaller and it would be extremely difficult, impossible even, to find a utility in Europe of similar size to ours); and
- Meter penetration (with the UK having the second lowest meter penetration in Europe).

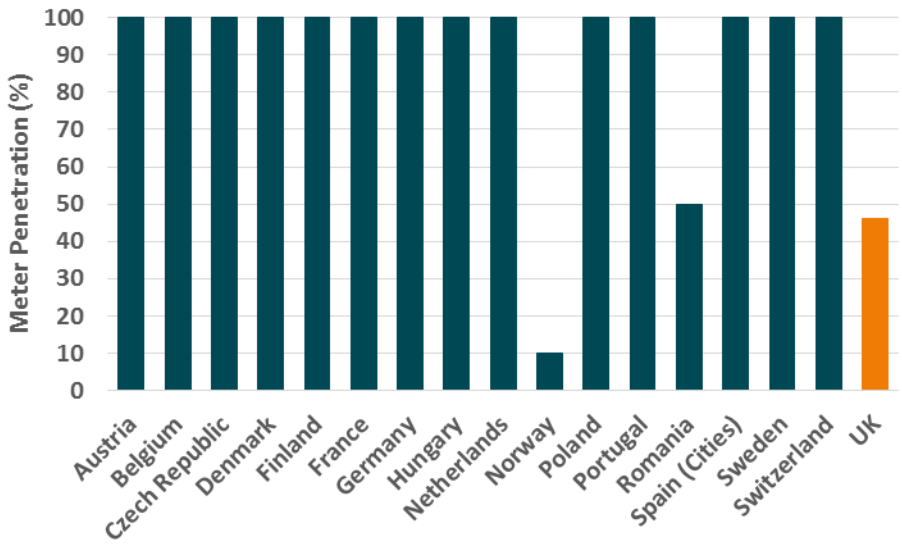


Figure 31 Meter penetration in European countries[62]

Figure 32 below shows how we compare with individual utilities in other countries[63] using ILI as performance indicator. Our current estimate of ILI is significantly below the average calculated using data for utilities in countries included in the graph below. Our estimate of ILI is at similar level if compared to other large European Economies such as Germany or France. Note, that the data presented for each individual country reflects anonymous utilities in that area included in the report, therefore in some cases individual countries will appear more than once on the graph.

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[61] http://www.leakssuite.com/welcome/
[62] http://www.harvesth2o.com/rainwater_harvesting_UK.shtml and Ofwat
[63] http://www.miya-water.com/user_files/Data_and_Research/miyas_experts_articles/2_NRW/06_International Benchmarking of Leakage from Water Reticulation Systems.pdf, anonymous data for individual utilities in other countries

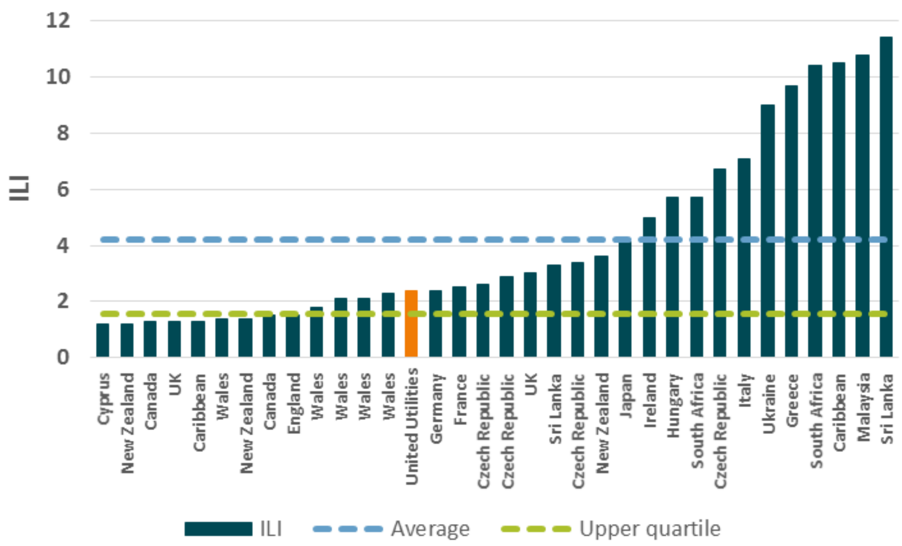

Figure 32 International ILIs[64]

For national comparisons, Ofwat historically used combination of two leakage performance indicators, leakage in litres per property and leakage in cubic meters per kilometre of main. This was done with a view that scoring companies using a combination of these two KPIs will remove some of the bias that can potentially be introduced if using only one. Figure 32 below shows how we compare to other water companies using 2017/18 reported leakage[65] and how our position will change following the delivery of AMP7 (covering 2020/21 to 2024/25), AMP8 (covering 2025/26 to 2029/30) commitments, as well as those in future AMP periods (to 2044/45). Dashed lines on the graph represent lines of equal leakage equivalent to good, average and poor infrastructure condition factor (ICF) respectively. Blue dots refer to other companies based on other companies current performance using the most up to date information reported for 2017/18.

It is worth noting that, generally, companies closer to the origin on the graph below are the ones facing deficits currently or in the very near future. This means that the for the last two AMP periods, or potentially for longer, they have been focusing their efforts on increasing meter penetration (some companies have been granted right to universal metering) and leakage reduction. Historically, our supply-demand balance position has not resulted in deficits to address for the majority of the region, and we have consistently achieved or outperformed our regulatory targets agreed with Ofwat at the last two periodic reviews.

As mentioned in Section 4.7 below, we are mindful that we have to balance any leakage reduction aspirations against customer affordability and other business priorities, we have therefore gone for a phased approach. This pace will enable the business to adjust to delivering the proposed scale of leakage reductions, ensuring that we take advantage of innovation and emerging technologies, which should make achieving reductions more affordable and efficient over time as part of the most cost-effective long-term plan. Achieving our commitment over the planning horizon will move us closer to the industry average. Our future leakage plans are outlined in Section 4.7.

[64] ILI for United Utilities was calculated as ratio of distribution losses to unavoidable annual real losses (UARL) using FY17 data
[65] Data from http://discoverwater.co.uk/

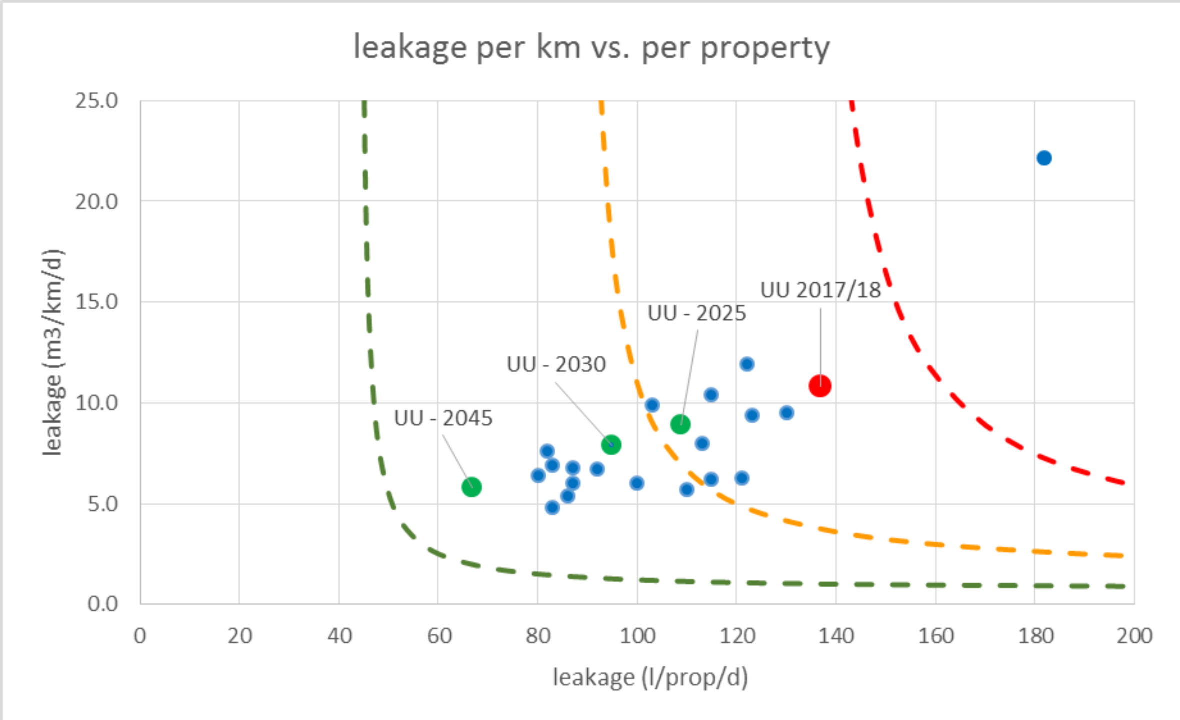

Figure 33 Industry comparison leakage per km vs. leakage per property[66]

4.6 Current performance and "base year" total leakage

Due to our current leakage levels being significantly below the short-run SELL, which has been calculated at 463.2Ml/d, and the current regulatory target of 462.7 Ml/d, we have used a three-year rolling historic average to represent "base year" total leakage. This means that even before a further consideration of leakage reductions as a key strategic choice in this plan (see Section 4.7), our leakage commitment going forward would be just over a 14 Ml/d reduction from our WRMP15 target.

Table 23 below shows our leakage performance for the last 3 years[67] and "base year" total leakage.

Table 23 Annual leakage performance at Company level

	2015/2016	2016/2017	2017/2018	"base year"[68]
Total leakage (Ml/d)	451.9	439.2	453.5	**448.2**

In our draft WRMP we proposed base year using the three year average of 2014/15, 2015/16 and 2016/17 giving 448.24 Ml/d. By taking the average of 2015/16, 2016/17 and 2017/18 the three year average is almost the same at 448.20 Ml/d.

Further justification to this approach is through normalisation of the 2017/18 leakage profile. The later winter freeze-thaw event followed what had been a relatively normal winter until late February, with some freeze-thaw events from December. It would normally be expected from late February that leakage levels would be recovered and gradually reduce through March and April back to the starting position. Removal of the March 2018 freeze-thaw peak with a reduction back to the starting point for the year, effectively normalising the profile, would have reduced leakage for 2017/18 from 453.5 Ml/d to 448.7 Ml/d. This further supports that the baseline derived through the

[66] Discover Water, FY18 data, https://www.discoverwater.co.uk/leaking-pipes
[67] Data from Regulatory Reporting Table 10
[68] This is based on a three year average to provide a baseline that represents an average or normal year. Normalisation of 2017/18 data supports the baseline taken from a three year average of FY16/FY17/FY18, and is also consistent with the three years FY15/FY16/FY17.

three-year average is an appropriate starting position from which significant further leakage reductions have been considered.

4.6.1 Water resource zone level "base year" total leakage

The table below shows our AMP6 (2015-2020) forecast from WRMP15 and our leakage performance over the previous four years at water resource zone level. Note that when the regional base year is calculated using a company level water balance, and compared to the water balance of individual zones, there is a very minor discrepancy due to the maximum likelihood estimation (MLE) process. The summation of the post-MLE total leakage for the separate zones will not sum precisely with the post-MLE regional total leakage. The difference is less than 0.5 Ml/d over time, but is noted in case such comparisons or checks are made.

Table 24 Annual leakage performance at water resource zone level

Total leakage (Ml/d)	AMP6 forecast	2014/2015	2015/2016	2016/2017	2017/2018	"base year"
Strategic	441.9	445.4	443.5	430.8	445.3	439.9
Carlisle	4.8	5.6	5.9	5.3	5.4	5.5
North Eden	2.0	2.6	2.6	3.1	3.0	2.9

The "Base year" for the Cumbrian zones is also calculated as a 3-year rolling average, which gives higher leakage level than the current WRMP15 forecast.

Our network is split into 34 Demand Monitoring Zones. When comparing leakage performance across our Region, Carlisle is a frontier of all our rural zones, with total leakage expressed in both l/prop/d and m3/km/d well below industry average[69].

The WRMP15 forecast for North Eden is based on historic reported performance in 2003/04. However, we have made significant improvements in the way we collect and process data since, making leakage estimates more robust. Latest review of minimum historic carried out by Crowder Consulting shows that current forecast is basically equal to the revised policy minimum (see Figure 34 below), making it practically impossible to maintain. It should also be noted that North Eden is a small, but very rural zone, with only 17 properties per km (Company average is 89 properties per km). This makes leakage detection very challenging.

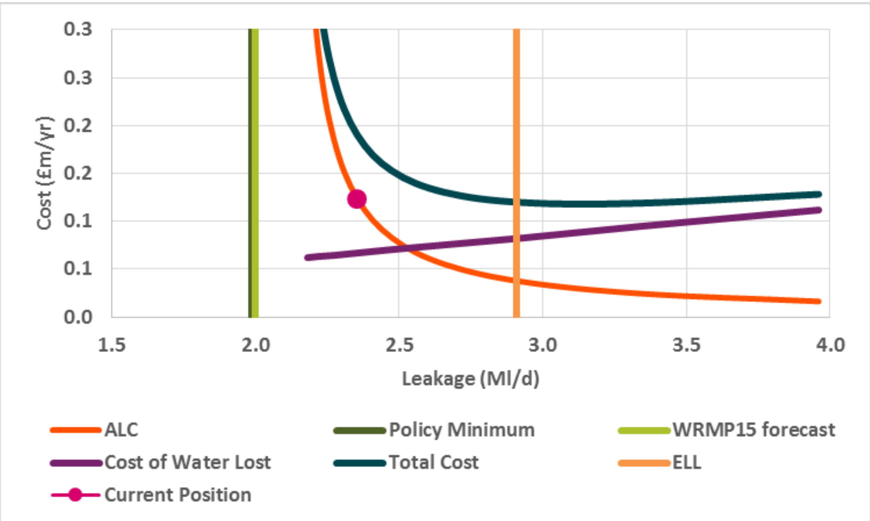

Figure 34 Total cost curve and ELL for North Eden

[69] Carlisle: 92.0 l/prop/d, 4.4 m3/km/d; Industry average: 107.0 l/prop/d, 8.2 m3/km/d; based on FY17 data from https://www.discoverwater.co.uk/leaking-pipes

We have decided to use this review and set achievable forecasts, noting that the new forecasts are still below the economic level of leakage for both zones. This ensures appropriate incentive on our performance.

We will continue our efforts is all Cumbrian zones and continue to report on all leakage and demand related activities in the water resource management plan annual reviews. Delivery of AMP7 (covering 2020/21 to 2024/25) leakage reduction, as described in the following sections, will be one of our biggest challenges in the coming years and we have to ensure that our resources are deployed in most efficient way to maximise the benefits, where there is potential for further reductions and where they can be achieved and maintained.

The current leakage levels used in this appraisal are consistent with those completed annually as part of our regulatory reporting process and consistent with leakage levels reported in annual reviews of the water resource management plan. Detail on the water balance calculations, definitions of the components and an outline of the assessment approach are explained in detailed in Appendix B – Water Balance.

4.7 Leakage forecast and setting stretching targets

Our current leakage levels are significantly below the short-run sustainable economic level of leakage, which has been calculated at 463.2 Ml/d. This demonstrates that further leakage reduction in itself is not economic or self-financing through reduced water production costs, prior to taking account of the wider value customers place on reducing leakage. For more detail on the economic appraisal of leakage please refer to 12.

Regulators and government outline leakage as an area of focus, for example, in their guiding principles Defra states:

> *"We want to see the downward trend for leakage continue and you must consider leakage management fully as an option to balance supply and demand. We expect you to ensure that total leakage does not rise at any point in the planning period…. Challenging leakage objectives should be informed by your customers' views on leakage and also be based on the potential for innovation in future."*

Various pieces of customer research carried out for WRMP19 and PR19 suggest that leakage reduction is high priority for our customers, and there is willingness to pay in this area. By way of examples, in customer research carried out for us by Verve (Water Talk Customer Panel survey, completed in June 2017), customers rank the importance of leakage reduction highly against other services areas. Leakage reductions are ranked below 'providing safe, clean drinking water' and 'providing a reliable water/wastewater service', yet higher than a range of other service areas. Similarly, a customer panel survey carried out for us by Verve also suggests that 93% percent of customers think that we should do more to reduce leakage. Stakeholders similarly see leakage reductions as an important priority area of focus in the water resource management plan. The full detail of our customer and stakeholder engagement is included in *Final WRMP19 Technical Report - Customer and stakeholder engagement*.

From a short run economic point of view, further leakage reduction is not cost-beneficial based on SELL alone. However, we recognise that background leakage is based on our policy minimum, and that technology and innovation may find more efficient and effective ways of tackling leakage than at present. This manifests itself as background leakage that cannot be managed through find and fix activities alone. We are also facing a tighter supply-demand balance than previously forecast, with a small baseline deficit in our Strategic Resource Zone later in the planning horizon, and this, combined with other considerations is a driver to do more in reducing leakage.

Customers value leakage reduction options over and above supply side options to manage supply-demand balance deficits. Stakeholders, including regulators, have challenged us to do more and we also recognise that technology and innovation has the potential to change the economics of leakage management in the future, and make reductions more affordable over time.

We have set out in more detail our justification for our preferred plan in *Final WMRP19 Technical Report -Options appraisal.* However, it is worth noting here that there is no single reason to justify significant reductions in leakage from our baseline position. Rather, a number of factors have been considered on balance to determine our future proposals:

- Political – there is a policy driver from government to push for reductions in demand and in particular leakage.
- Environmental – there are net benefits to the environment through reductions in leakage with less water abstracted.
- Social – the general public and customers support reductions in leakage.
- Technological – we are anticipating significant improvements in efficiency and effectiveness as new technology and innovation results in an ability to reduce leakage for lower costs than we expect to see at the present time.
- Economic – the longer-term deficit in our Strategic Resource Zone requires some investment to resolve, and customer valuation of leakage options ahead of supply-side options is a very strong basis for making a significant reduction in leakage. Scenario analysis also shows the potential for reductions in leakage to offset deficits caused in future due to other uncertainties such as climate change or higher demand.

After thorough analysis, as well as careful consideration of all the factors, we are proposing a 91.2 Ml/d reduction in AMP7 (covering 2020/21 to 2024/25), and a total reduction from the baseline of 448.2 Ml/d, of 189.6 Ml/d by 2044/45. The AMP7 reduction equates to 20% from baseline when using annual leakage estimates, and just over 40% by 2044/45.

Table 25 Forecast leakage reductions up to 2044/45

	2020/21	2024/25	2029/30	2044/45
Total leakage (Ml/d)	448.2	357.0	335.9	258.6
% reduction from WRMP19 baseline	0%	20%	25%	42%

Figure 35 shows historical leakage performance, scenario selected for final planning and how it relates to our current commitment (and that at the draft plan stage before consultation). The long-term position is subject to review in future planning cycles as the supply-demand balance position evolves, along with changes in technology.

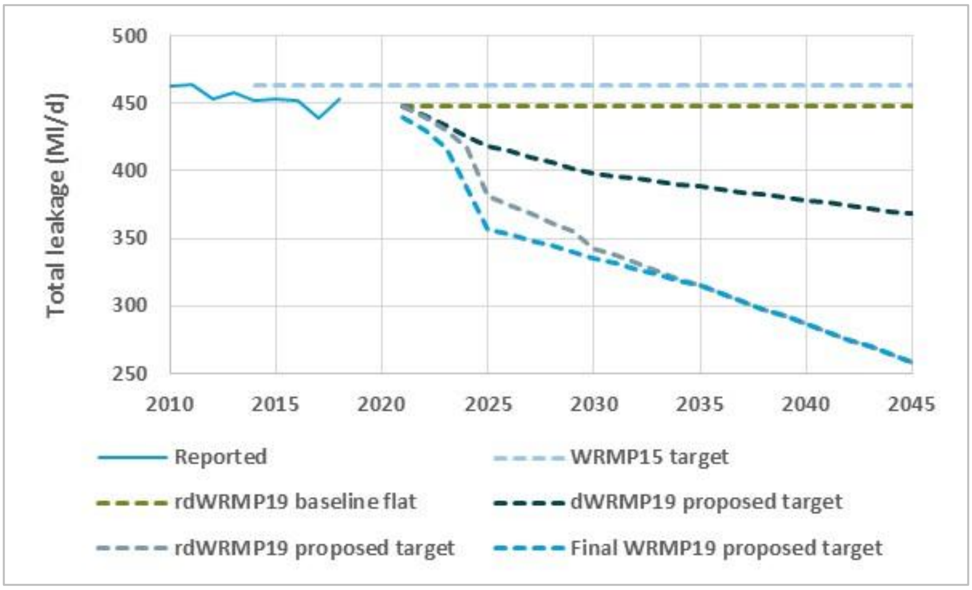

Figure 35 Reported total leakage and our Final WRMP19 proposed target (incorporating a 20% leakage reduction in AMP7), against our WRMP15 target (sometimes referred to as our "current commitment"), a flat target from the Final WRMP19 baseline[70] and our Draft and Revised Draft WRMP19 proposed targets

[70] Three year average total leakage, based on reported total leakage for 2015/16 to 2017/18, and lower than our current commitment.

This proposal is a key strategic choice in our plan for consultation, and Section 6.2 of the *Final WRMP19 main report* summarises the reason for this proposal. Further detail on the scenarios tested and the cost-effectiveness of the selection is presented in *Final WRMP19 Technical Report - Options appraisal.*

4.8 Delivering enhanced leakage reduction

We are committed to sustainably reducing leakage in the long-term and we recognise the need to innovate, build upon and improve from current techniques, processes and solutions. To do this cost-effectively we will apply a number of targeted detection and repair innovations as part of our leakage strategy. In order to achieve significant leakage reductions included in our demand forecast we will increase our find and fix resources to levels estimated by the ELL model. This will enable us to make the required transition in AMP7 (covering 2020/21 to 2024/25) in a twin track approach that also starts to make significant changes in the roll out of new technology and innovative approaches. In the longer-term, the scale of the step-change in leakage levels requires us to work differently and seek new innovations, particularly if it is to be delivered in a way that is affordable to customers.

Through a review of policy minimum we have identified over 200 DMAs with potential recoverable leakage, i.e. DMAs where there is a potential to go beyond current lowest achieved night lines. We will carry out a detailed review of these DMAs to better understand the underlying data and challenge the achieved minimum night flows, where appropriate.

A large proportion of our leak detection still relies heavily on technicians "sounding" our mains. This involves walking the length of mains within a District Metering Area (DMA) and placing a listening rod on any available fittings to try and identify the tell-tale sound of a leak. This requires a substantial amount of experience on the technicians' behalf to recognise the difference between ambient noise from the environment, such as traffic or street lights, and the sound of a leak. An added problem is that the noise produced by some leaks is so slight that it is almost inaudible for a technician to identify. We are therefore looking to new and innovative ways to help detect leaks such as:

- **Acoustic loggers -** Installing the loggers on fittings throughout DMAs allows loggers to fulfil a similar role to leakage technicians, effectively listening for the same noise that would be detected using a listening stick. If that noise is picked up an alarm can be triggered and a point of interest raised for one of our technicians to investigate. These loggers are more sensitive than human ears, and the algorithms which are used to analyse the sound files are able to distinguish between what may be background noise and the constant noise created by a leak, as they can detect changes in the network day after day.
- **Sniffer dogs -** We are collaborating with Cape SPC who have trained dogs to detect explosives, gas, drugs and bedbugs to see if they can adapt their techniques to find leaks. The dogs have been trained to detect the chlorine in potable water and are helping to locate leaks on mains in rural locations where conventional leak detection using standard approaches and techniques may prove difficult.
- **Satellite detection -** We are currently trialling satellite imagery for leak detection with a company called Utilis. They use ground penetrating radar from Japanese satellite ALOS 2 to detect water just below the ground. Taken from satellite mounted sensors, the raw imagery is then overlaid on GIS systems and then processed by Utilis' unique algorithms to generate points of interest which are used by our leakage teams.
- **Customer side leakage -** As part of our third-party options engagement and business innovation processes, we have identified a potentially promising new technology to tackle customer side leakage. This would seek to use a non-intrusive device to identify properties with potential customer side leakage and a specialist contractor to repair or replace customer supply pipe, or resolve any issues with internal plumbing.

We are currently in the process of trialling and understanding the full benefits, and how determining how best to utilise such technology, and it is likely that we will see our strategy evolve and improve over the coming years. It is anticipated that this technology will complement our existing leakage detection methods and help us achieve the stretching targets we have set ourselves by increasing the efficiency of our leakage teams and helping them to locate leaks which are undetectable by other means. We expect that improvements in technology will help us challenge what is currently seen as background leakage and develop a greater understanding of what constitutes this element of leakage, as it may be a combination of long running and difficult to detect leaks, weeps and seeps from joints, plumbing losses or night use.

Implementing acoustic loggers will initially allow non-reported leaks which may have been running in an area for a long time to be found and fixed hopefully bringing leakage in these DMAs down to the lowest levels we can achieve. From this point the loggers provide constant monitoring of the DMA allowing us to respond quickly to leaks as they happen, reducing the time required to detect the leak substantially and requiring less intervention by our leakage technicians. For instance, in areas such as town centres where it may be very difficult for our technicians to easily access or work, due to traffic or access issues. However, with loggers deployed into these areas we only have to intervene or deploy to these areas when we are confident we have a leak.

Acoustic loggers offer the greatest benefits in identifying leaks quickly, however, they require a significant amount of investment and will not provide value for money in all DMAs. Therefore, we will look to deploy these in areas which require a significant time investment by our teams at present in order to maintain leakage. This will allow our detection resources to target the remaining DMAs, which it should be possible to search quicker and more efficiently by using satellite data.

We are proposing to reduce leakage by just over 40% by 2045, and some of the leakage reduction options that are currently considered more uncertain are likely to help us achieve this. Over time we expect to see new options, or find existing approaches, such as smart metering, become more affordable and we will adapt our plans to achieve our targets in the most efficient way.

The roll out of smart networks and smart metering is expected to develop over the coming years, and the benefits this may bring for leakage management are not yet fully clear. It is theoretically possible to have smart DMAs where, through high levels of metering and enhancements in the amount of data that is collected from the network (with near real time or real time pressure and noise sensors), potentially repairs could be scheduled and carried out without the requirement for active leakage control. We are committed to trialling such technology and developing our strategies from the present and through AMP7 (2020-2025 investment period). We are active participants in research, both within our own company through engaging with suppliers and carrying out different trials, but also with the wider industry.

Whilst we are setting an ambitious target to reduce leakage by 20% by the end of 2024/25, this will not result in us reaching the current upper quartile position when comparing to the industry, using leakage per property or metres cubed per km of network. Above we describe the twin-track approach of using some tried and tested approaches, with a significant programme that focuses on technology and innovation. Reducing too far too quickly would increase the risk of inefficiency in the approach taken as decisions could be made to adopt unproven technology, processes or techniques.

The justification for our stretching leakage reduction target is set out in our *Final WRMP19* main report and for our current programme of options to achieve this in our *Final WRMP Technical Report – Options appraisal*.

4.9 Leakage convergence

Ofwat has supported companies working together, co-ordinated by Water UK, and with UKWIR to agree a consistent definition of leakage. This new methodology was published by UKWIR in 2017 and incorporated in the Ofwat methodology for the PR19 Business Plan in setting outcomes for the period 2020/21 to 2024/25.

We are in the process of shadow reporting against this updated definition to Ofwat, and will continue to do so until 2020. It is important to note that this change will increase or reduce the baseline slightly, but will not affect the longer-term reduction which will see the same level of reduction achieved, following the reporting methodology change.

For our draft plan, we had assessed the overall impact of this reporting change on distribution input and confirmed that this was not material for the options selected in our preferred plan[71].

In our final plan, we report leakage using the current (otherwise known as 'old') definition. There were some significant improvements in data between 2016/17 and 2017/18 that were implemented towards leakage convergence. We reported total leakage of 453.5 Ml/d for 2017/18, and under the new definition through shadow reporting, reported 449.4 Ml/d. The difference between 2017/18 total leakage and shadow reported leakage is our best current estimate of the change we will see through reporting using the new methodology.

The difference between the old and new definitions, based on the latest and best currently available data, is a very minor reduction of 4.1 Ml/d. This represents a variance of less than 1%, and with a very close water balance gap observed for shadow reporting. We can expect some minor changes as a longer time series of data are collected for some the components where improvements have been made. The two methods are currently relatively close and we therefore do not have any information at the current time to suggest there will be a material change to post-MLE total leakage.

[71] As was covered in *Draft WRMP19 Technical Report – Options appraisal*

5. Minor components

The minor components of the water balance are shown in Table 26.

Table 26 Minor components of the water balance

Component	Definition (from our Regulatory Reporting Methodology)
Distribution system operational use	Water knowingly used by a company to meet its statutory obligations, particularly those relating to water quality. This includes, amongst other things, service reservoir cleaning, mains flushing/air scouring, swabbing, draining networks, discharges to control pH or other chemical parameters.
Water taken legally unbilled	This should include all water supplied to customers for legitimate purposes which is unbilled. It can include public supplies for which no charge is made (some sewer flushing etc.), uncharged church supplies, fire training and fire-fighting supplies where these are not charged irrespective of whether or not they are metered.
Water taken illegally unbilled	Illegally taken water, reported and included in the water delivered total and based on actual occurrences using sound, auditable identification and recording procedures. In 2012/13, the method and quantities of water taken illegally unbilled were subject to a detailed review by Atkins Limited, on our behalf. From year to year are adjusted based on information from our revenue assurance activities and records of water use that is unbilled. Regulatory Reporting is subject to a fully auditable process and subject to robust governance procedures.

As at WRMP15, to forecast minor components we have kept them consistent with the base year data. However, as an improvement for WRMP19, we have assessed the potential uncertainty around the base year data using the maximum and minimum reported value over the last 5 years. This has been used to inform our target headroom assessment, as noted in Section 10.

6. Overall baseline and final planning demand forecast from the base year

Table 27 shows the baseline demand forecast from the base year for all resource zones, broken down to show the different components of demand for water and how they are forecast to move over time. This is prior to the application of any demand uplifts to account for climate change and weather variation. These uplifts are discussed further in Section 7.

Table 27 Baseline demand forecast from the base year for all resource zones (in megalitres per day)

	2016/17	2020/21	2025/26	2030/31	2035/36	2040/41	2044/45
Strategic Resource Zone							
Measured household consumption	274	323	384	436	485	531	563
Unmeasured household consumption	594	538	473	415	364	320	289
Measured non-household consumption	350	336	329	323	317	312	310
Unmeasured non-household consumption	10	13	13	13	12	12	12
Total leakage	431	440	440	440	440	440	440
Minor components	37	47	47	47	47	47	47
Total demand for water	1,697	1,697	1,687	1,673	1,665	1,661	1,661
Carlisle Resource Zone							
Measured household consumption	3.9	4.7	5.6	6.5	7.2	7.7	8.1
Unmeasured household consumption	10.1	9.8	9.2	8.7	8.1	7.6	7.3
Measured non-household consumption	7.1	6.4	6.2	6.0	5.8	5.6	5.5
Unmeasured non-household consumption	0.2	0.3	0.3	0.3	0.3	0.2	0.2
Total leakage	5.3	5.6	5.6	5.6	5.6	5.6	5.6
Minor components	0.9	1.1	1.1	1.1	1.1	1.1	1.1
Total demand for water	27.5	27.9	28.0	28.1	28.0	27.9	27.7
North Eden Resource Zone							
Measured household consumption	0.5	0.6	0.7	0.7	0.8	0.8	0.9
Unmeasured household consumption	1.1	1.1	1.0	1.0	1.0	0.9	0.9
Measured non-household consumption	1.2	1.1	1.0	1.0	1.0	1.0	1.0
Unmeasured non-household consumption	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total leakage	3.1	2.8	2.8	2.8	2.8	2.8	2.8
Minor components	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total demand for water	6.5	6.1	6.1	6.1	6.1	6.1	6.1
Region							
Measured household consumption	279	329	391	444	493	539	572
Unmeasured household consumption	605	549	484	425	373	328	297
Measured non-household consumption	358	343	337	330	324	319	317
Unmeasured non-household consumption	10	14	13	13	13	13	12
Total leakage	439	448	448	448	448	448	448
Minor components	38	48	48	48	48	48	48
Total demand for water	1,731	1,731	1,721	1,708	1,699	1,695	1,695

Table 28 shows this same table with our proposed leakage reduction targets included in our preferred plan, as discussed in Section 4.7, and the impact that has on demand for water.

Table 28 Final planning demand forecast from the "base year" for all resource zones (in megalitres per day)

	2016/17	2020/21	2025/26	2030/31	2035/36	2040/41	2044/45
Strategic Resource Zone							
Measured household consumption	274	323	384	436	485	531	563
Unmeasured household consumption	594	538	473	415	364	320	289
Measured non-household consumption	350	336	329	323	317	312	310
Unmeasured non-household consumption	10	13	13	13	12	12	12
Total leakage	431	431	344	323	301	273	251
Minor components	37	47	47	47	47	47	47
Total demand for water	1,697	1,688	1,591	1,556	1,526	1,495	1,472
Carlisle Resource Zone							
Measured household consumption	3.9	4.7	5.6	6.5	7.2	7.7	8.1
Unmeasured household consumption	10.1	9.8	9.2	8.7	8.1	7.6	7.3
Measured non-household consumption	7.1	6.4	6.2	6.0	5.8	5.6	5.5
Unmeasured non-household consumption	0.2	0.3	0.3	0.3	0.3	0.2	0.2
Total leakage	5.3	5.6	5.6	5.6	5.5	5.0	5.0
Minor components	0.9	1.1	1.1	1.1	1.1	1.1	1.1
Total demand for water	27.5	27.9	28.0	28.1	27.9	27.3	27.2
North Eden Resource Zone							
Measured household consumption	0.5	0.6	0.7	0.7	0.8	0.8	0.9
Unmeasured household consumption	1.1	1.1	1.0	1.0	1.0	0.9	0.9
Measured non-household consumption	1.2	1.1	1.0	1.0	1.0	1.0	1.0
Unmeasured non-household consumption	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total leakage	3.1	2.8	2.8	2.8	2.7	2.7	2.7
Minor components	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total demand for water	6.5	6.1	6.1	6.1	6.1	6.1	6.0
Region							
Measured household consumption	279	329	391	444	493	539	572
Unmeasured household consumption	605	549	484	425	373	328	297
Measured non-household consumption	358	343	337	330	324	319	317
Unmeasured non-household consumption	10	14	13	13	13	13	12
Total leakage	439	439	353	332	309	281	259
Minor components	38	48	48	48	48	48	48
Total demand for water	1,731	1,722	1,625	1,592	1,560	1,528	1,505

7. Demand uplifts and dry year demand forecast

7.1 Dry year uplift and weather patterns

The sufficiency of our supply-demand balance is most critical in prolonged "hot" and "dry" periods. In such conditions availability in our water sources is reduced and higher consumption occurs, due mainly to the much increased watering of gardens. The Environment Agency requires water companies to report on dry year demand[72], generally explained as a period of low rainfall and "unconstrained" or "unrestricted" demand.

7.1.1 Weather in a dry year

The severity of "hot", "dry" weather such as that which occurred in the summer of 1995 occurs relatively infrequently. For example, the summers of 1976 and 1984 were similarly hot and dry, as demonstrated by Table 29.

Table 29 Comparison of weather data recorded at Manchester Airport for hot, dry summers[73]

Parameter (covering May to August)	1976	1984	1995	2003
Total Rainfall (mm)	158.8	116.4	130.5	239.2
Average temperature (°C)	20.7	19.5	20.8	20.1
Days with temperature above 22°C	50	44	49	38
Days with temperature above 25°C	29	12	31	14
Maximum temperature (°C)	32.2	29.4	31.7	32

It was the dry autumn and winter of 1995/96 following the hot, dry summer that made the 1995/96 drought more prolonged than previous drought events. This can be seen in the daily maximum temperatures recorded at Manchester Airport in 1995, as shown in Figure 36. The summer of 2003 was significantly hotter and drier than average in North West England, with particularly high temperatures experienced in early August. This resulted in elevated demand for water as confirmed by our household water consumption monitors.

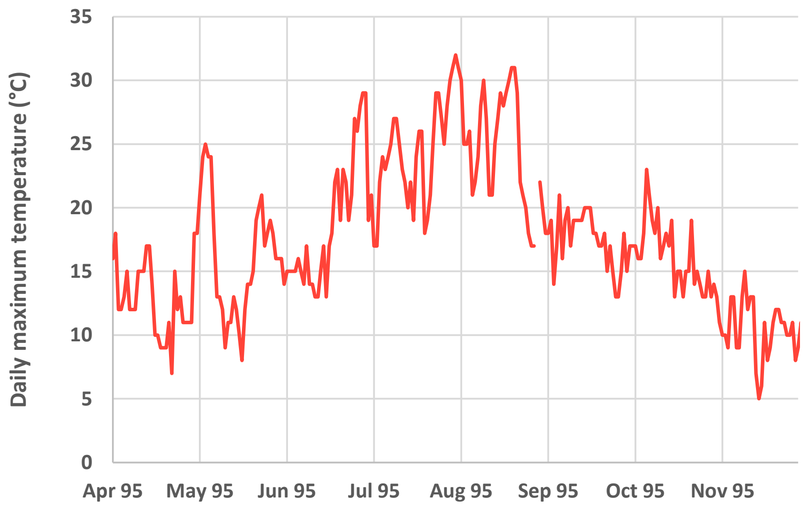

Figure 36 Daily maximum temperatures at Manchester Airport April to December 1995

7.1.2 Modelling the impact of weather on demand for water

At WRMP15, we worked with the Met Office on an innovative way of understanding the impact of weather on demand for water. This involved the use of their Demand-WIM (Weather Intelligence Model), which can determine relationships between demand for water and weather parameters[74]. The demand for water, attributed to these

[72] Full term is "dry year annual average"
[73] All data have been provided by the Met Office
[74] Sometimes termed "weather variables" or "weather observations", this refers to the record of, for example, the maximum temperature each day

weather parameters is termed "weather dependent usage". The Demand-WIM was calibrated to weather parameters, such as air temperature and rainfall, using around 10 years of data on demand for water.

Another key finding from this work was that, although some elements of non-household consumption are likely to increase during dry weather (e.g. due to watering of golf courses, sports pitches, gardens of non-household premises etc.), the analysis concluded that no significant weather signal could be identified in non-household consumption. Therefore, any increase in weather dependent usage is attributed solely to household consumption and this component is uplifted as such.

For WRMP19, we have worked with the Met Office again and the Demand-WIM has been revisited, including an assessment of spatial variability, a full data update and a recalibration of the model. On testing there were six weather parameters that clearly showed a relationship to demand for water and these were:

- Maximum daily temperature;
- Minimum daily temperature;
- Percentage of resource zone, across which rainfall occurred (key to understanding spatial variability);
- Three day average temperature;
- Three day average rainfall; and
- Soil moisture deficit.

Figure 37 clearly shows how the relationship between maximum daily temperature and demand for water is used to model a much increased weather dependent usage on "hotter" days.

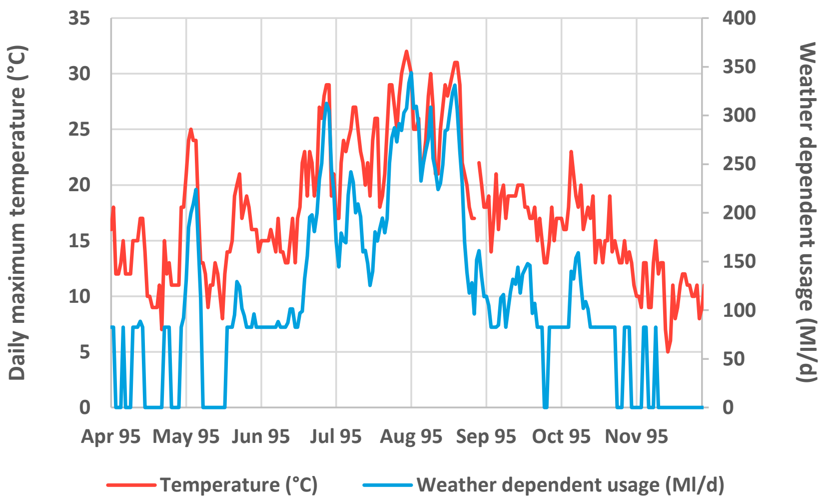

Figure 37 Daily maximum temperatures at Manchester Airport April to December 1995, with modelled weather dependent usage from April to December 1995

7.1.3 Our design dry year

At WRMP15, we used the weather dependent usage seen in the summer of 1995/96 (adjusted to remove the impact of the hosepipe ban[75]) to define the dry year. An advice item in the Environment Agency Advice Report on our WRMP15 referred to our choice of dry year as risk-averse and said that, for WRMP19, we should review the approach of using a drought year as our dry year.

Our rationale at WRMP15 was that the baseline supply availability in the regional supply-demand balance for the WRMP is defined by a drought year, namely 1984. We also account for the benefits of a temporary use ban, previously "hosepipe ban", when defining that supply availability. Therefore, it seemed appropriate to "align" supply availability and demand for water to account for drought years. Although, admittedly different specific years.

Following the advice item, along with WRMP19 pre-consultation feedback and further discussions with the Environment Agency, we gave further consideration to a percentile approach, utilising the output from the Demand-WIM. On discussion with the Met Office and with other water companies, we consider a percentile approach to be a justifiable, based on two major advantages:

1. Choosing a percentile from a statistical distribution allows us to align risk across our WRMP and is less dependent on the characteristics of a single year; and
2. The 95th percentile weather dependent usage falls between 1984 (the year that influences our baseline supply availability in the regional supply-demand balance) and 1989 (a dry year in which we were able to maintain supplies without a hosepipe ban[75] because of our integrated water supply network).

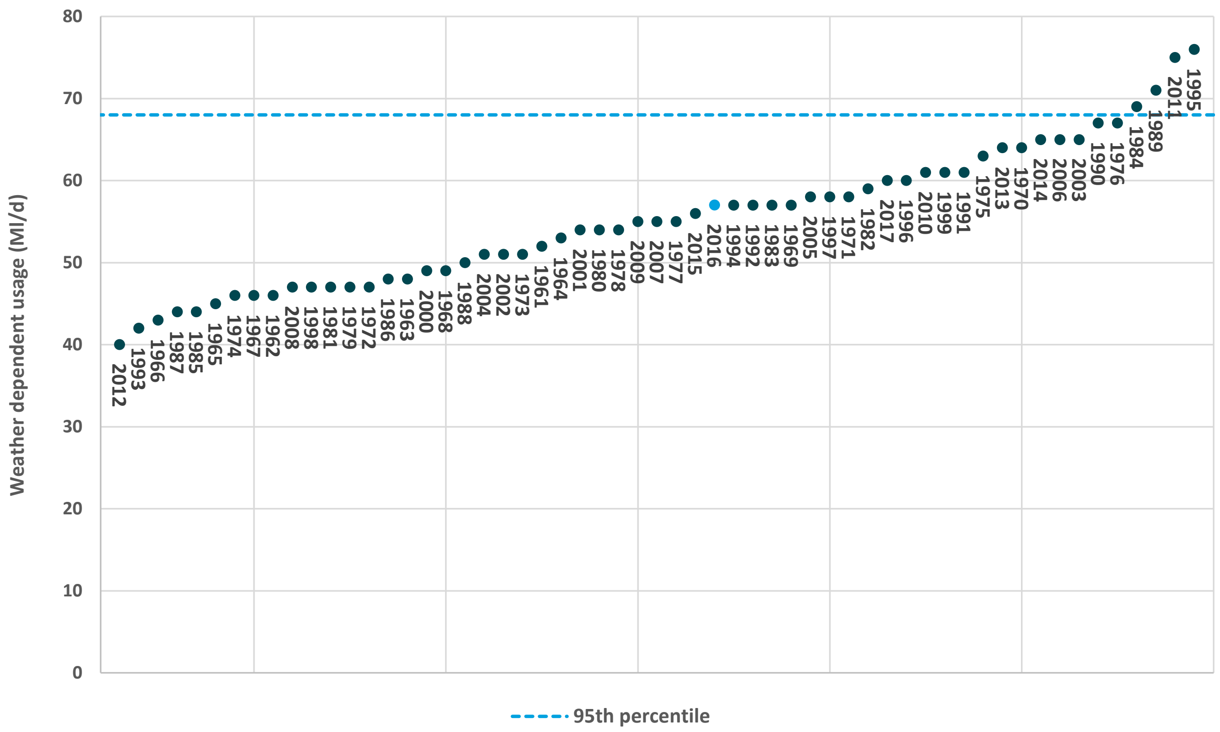

Figure 38 Modelled weather dependent usage for each year[76] with a full set of available weather data

Using the 95th percentile weather dependent usage, leads to a 1% uplift[77] on the household consumption forecast from the base year ("2015" on Figure 38).

[75] Now referred to as a "temporary use ban"
[76] On this chart, for example, 2016 refers to the financial year 2016/17, as the key period for weather dependent usage is the summer months
[77] With a modelled uncertainty of ± 3%

7.2 Climate change demand uplifts

As the principal source of climate change demand uplift information, we have included the findings from the Impact of Climate Change on Water Demand UKWIR project[78] to determine the climate change uplift to apply to household consumption. The 50th percentile annual average estimated impacts, for the North West England river basin, from the Severn Trent Water relationship[79] have been included in our baseline "dry year" demand forecasts (50th percentile minimum deployable output estimated impacts have been included in our "critical period" forecasts for the Carlisle Resource Zone). The impact of climate change on dry year consumption is shown in Figure 39 and, by 2045, the impact is 7 Ml/d.

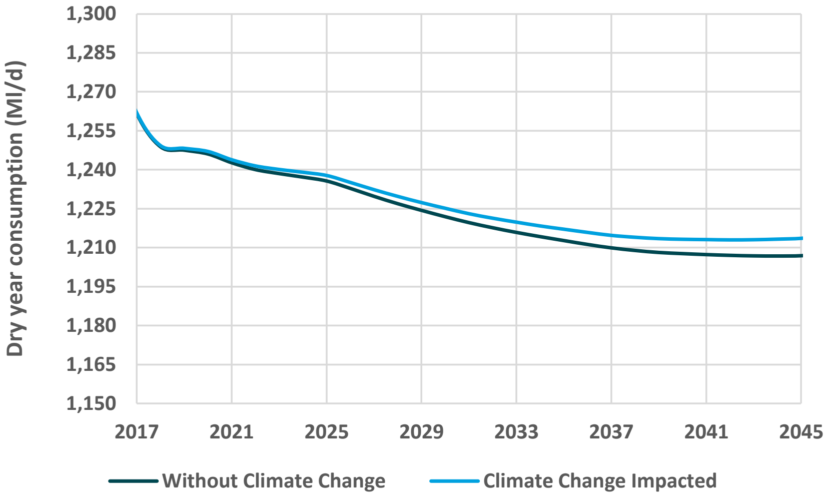

Figure 39 Impact of climate change on dry year consumption

The uncertainty in the potential climate change impact on demand for water has been included as part of the assessment of target headroom (see Section 10).

7.3 "Critical period" and "peak" type uplifts

We use the term "critical period" to refer to the two to three month period where the key source(s)[80] in our more "flashy" resource zones[81] goes from full to emergency storage levels. This period is used to define a two to three month "peak" type demand, which could potentially coincide with the "critical" time for the water resources systems. For the Carlisle Resource Zone, the "critical period" relates to the drawdown of Castle Carrock Reservoir through 1976, a "critical" event for this water resources system. Using water resources models, we have calculated the critical period of this event to be 95 days (or around 13 weeks).

Using this critical period, we have derived a factor to uplift demand by comparing the average demand over the critical period with the average annual demand for water each year. Figure 40 shows this factor for demands back to 2000/01. This critical period is applied to dry year household and non-household consumption and, with leakage and minor components, this constitutes the critical period demand for water.

[78] Impact of Climate Change on Water Demand (UKWIR, 2013)
[79] The Impact of Climate Change on Water Demand UKWIR project provides a choice between the Thames Water model relationship and Severn Trent Water model relationship. At WRMP15, we chose the Severn Trent Water model relationship due to the close spatial location of our region to the Severn Trent Water region.
[80] Generally, the source(s) that defines deployable output and, therefore, supply capability
[81] Flashy refers to water sources that recede and recover in a short period of time and, at WRMP15, this would have referred to both the Carlisle Resource Zone and the West Cumbria Resource Zone

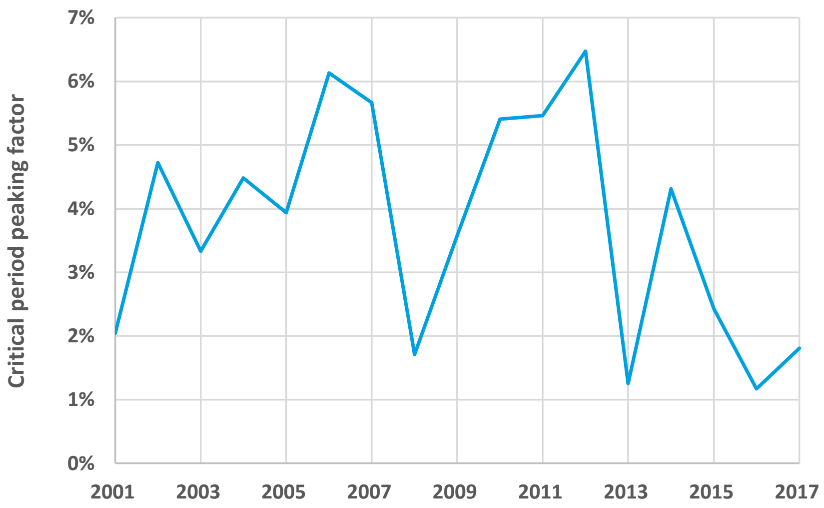

Figure 40 Carlisle Resource Zone "critical period" peaking factor for 2000/01 to 2016/17

Although they are not key for WRMP long-term supply-demand needs, peak type demands (e.g. "peak day", "peak week", "peak month") are used in our asset planning, to ensure there is sufficient production (e.g. water treatment works etc.) and service reservoir capacity to meet demand peaks at local (or "sub-zonal") level. This is a key part of our wider water supply resilience assessment and is covered further in our *Final WRMP19 Technical Report - Water supply resilience*.

It is also worth noting that, at the time of writing, we are experiencing periods of increased demand caused by an extended period of above average temperatures and low rainfall across the North West. To date, having assessed data to the end of June 2018, the scale of demands experienced are consistent with those expected within the WRMP19 forecasts and modelling. Therefore, it is too early to conclude if current events warrant any update to the demand forecasts until we have observed a full year of data. We will consider the implications of the current event in the next Annual WRMP review.

8. Overall baseline and final planning dry year demand forecast

Table 30 shows the baseline dry year demand forecast for all resource zones, broken down to show the different components of demand for water and how they are forecast to move over time.

Table 30 Baseline dry year demand forecast for all resource zones (in Megalitres per day)

	2016/17	2020/21	2025/26	2030/31	2035/36	2040/41	2044/45
Strategic Resource Zone							
Measured household consumption	277	327	389	443	493	539	573
Unmeasured household consumption	600	544	479	421	369	325	294
Measured non-household consumption	350	336	329	323	317	312	310
Unmeasured non-household consumption	10	13	13	13	12	12	12
Total leakage	431	440	440	440	440	440	440
Minor components	37	47	47	47	47	47	47
Total demand for water in a "dry year"	1,706	1,706	1,697	1,685	1,678	1,675	1,676
Carlisle Resource Zone							
Measured household consumption	3.9	4.7	5.7	6.6	7.3	7.8	8.2
Unmeasured household consumption	10.2	9.9	9.3	8.8	8.2	7.7	7.4
Measured non-household consumption	7.1	6.4	6.2	6.0	5.8	5.6	5.5
Unmeasured non-household consumption	0.2	0.3	0.3	0.3	0.3	0.2	0.2
Total leakage	5.3	5.6	5.6	5.6	5.6	5.6	5.6
Minor components	0.9	1.1	1.1	1.1	1.1	1.1	1.1
Total demand for water in a "dry year"	27.6	28.0	28.2	28.3	28.2	28.1	28.0
Total demand for water in a "critical period"	29.0	29.4	29.6	29.8	29.7	29.6	29.5
North Eden Resource Zone							
Measured household consumption	0.5	0.6	0.7	0.8	0.8	0.9	0.9
Unmeasured household consumption	1.1	1.1	1.1	1.0	1.0	0.9	0.9
Measured non-household consumption	1.2	1.1	1.0	1.0	1.0	1.0	1.0
Unmeasured non-household consumption	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total leakage	3.1	2.8	2.8	2.8	2.8	2.8	2.8
Minor components	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total demand for water in a "dry year"	6.5	6.1	6.2	6.2	6.2	6.2	6.1
Region							
Measured household consumption	282	332	396	450	501	548	583
Unmeasured household consumption	612	555	490	430	379	334	302
Measured non-household consumption	358	343	337	330	324	319	317
Unmeasured non-household consumption	10	14	13	13	13	13	12
Total leakage	439	448	448	448	448	448	448
Minor components	38	48	48	48	48	48	48
Total demand for water in a "dry year"	1,740	1,740	1,732	1,720	1,712	1,710	1,710

Table 31 shows the final planning dry year demand forecast for all resource zones, broken down to show the different components of demand for water and how they are forecast to move over time.

Table 31 Final planning dry year demand forecast for all resource zones (in Megalitres per day)

	2016/17	2020/21	2025/26	2030/31	2035/36	2040/41	2044/45
Strategic Resource Zone							
Measured household consumption	277	327	389	443	493	539	573
Unmeasured household consumption	600	544	479	421	369	325	294
Measured non-household consumption	350	336	329	323	317	312	310
Unmeasured non-household consumption	10	13	13	13	12	12	12
Total leakage	431	431	344	323	301	273	251
Minor components	37	47	47	47	47	47	47
Total demand for water in a "dry year"	1,706	1,697	1,602	1,568	1,539	1,509	1,487
Carlisle Resource Zone							
Measured household consumption	3.9	4.7	5.7	6.6	7.3	7.8	8.2
Unmeasured household consumption	10.2	9.9	9.3	8.8	8.2	7.7	7.4
Measured non-household consumption	7.1	6.4	6.2	6.0	5.8	5.6	5.5
Unmeasured non-household consumption	0.2	0.3	0.3	0.3	0.3	0.2	0.2
Total leakage	5.3	5.6	5.6	5.6	5.5	5.0	5.0
Minor components	0.9	1.1	1.1	1.1	1.1	1.1	1.1
Total demand for water in a "dry year"	27.6	28.0	28.2	28.3	28.1	27.6	27.5
Total demand for water in a "critical period"	29.0	29.4	29.6	29.8	29.6	29.1	29.0
North Eden Resource Zone							
Measured household consumption	0.5	0.6	0.7	0.8	0.8	0.9	0.9
Unmeasured household consumption	1.1	1.1	1.1	1.0	1.0	0.9	0.9
Measured non-household consumption	1.2	1.1	1.0	1.0	1.0	1.0	1.0
Unmeasured non-household consumption	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total leakage	3.1	2.8	2.8	2.8	2.7	2.7	2.7
Minor components	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Total demand for water in a "dry year"	6.5	6.1	6.2	6.2	6.1	6.1	6.1
Region							
Measured household consumption	282	332	396	450	501	548	583
Unmeasured household consumption	612	555	490	430	379	334	302
Measured non-household consumption	358	343	337	330	324	319	317
Unmeasured non-household consumption	10	14	13	13	13	13	12
Total leakage	439	439	353	332	309	281	259
Minor components	38	48	48	48	48	48	48
Total demand for water in a "dry year"	1,740	1,731	1,636	1,604	1,573	1,543	1,521

9. Non-potable demand

Although, in the WRMP process, non-potable water supplied is taken away from available supply, this section discusses non-potable supply from the customer perspective and, therefore, refers to it as “non-potable demand”. It’s also worth noting that raw water and potable imports and exports are covered in the *Final WRMP19 Technical Report - Supply forecasting*.

As all our non-potable demand is from non-household customers, we worked with Experian to forecast non-potable demand using a similar economic output based approach as we’ve used for non-household consumption. We reviewed historic data, which indicated that the non-potable demand is mainly in three major sectors:

- ‘Paper (manufacture)’;
- ‘Fuel refining and Chemicals’; and
- ‘Rubbers, plastics and man-made materials (manufacture)’.

According to Experian forecasts, the output of all these three sectors are forecast to increase over the planning period and, therefore, the non-potable demand is forecast to increase accordingly.

9.1 Strategic Resource Zone

Following the approach outlined above, Figure 41 shows our forecasted non-potable demand for the circa. 50 non-household customers in our Strategic Resource Zone.

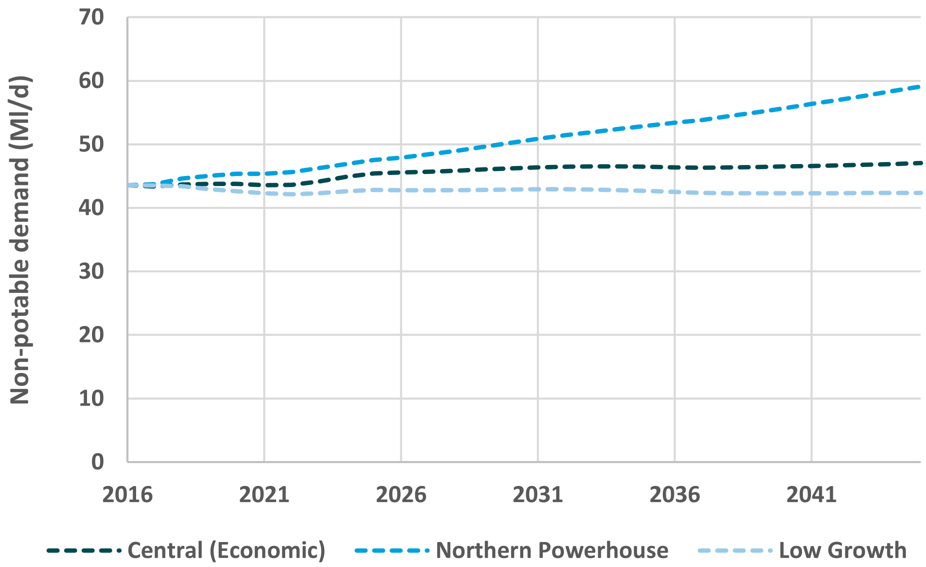

Figure 41 Forecast Strategic Resource Zone non-potable demand

9.2 Barepot Resource Zone

The results from the economic output based approaches for the generally indicate non-potable demand to be increasing In the Barepot Resource Zone. This is because the output of the industry sectors (or categories) that the customers in the Barepot area operate within are all forecast to increase over the forecast period and, therefore, the non-potable demand is forecast to increase accordingly. However, this assessment does not account for the future water needs of an individual customer and is best applied to a larger sample of customers, as in the Strategic Resource Zone. For this reason, the demand profile for the Barepot Resource Zone has been based on the supply agreement with the industrial customers. A flat demand of 26.9 Ml/d has been applied over the planning period.

10. Allowing for uncertainty (target headroom and scenarios)

No forecasts can be totally accurate and include inherent uncertainty. For example, non-household consumption forecasts are dependent upon economic growth that is subject to significant uncertainty over the planning horizon. In part, this is why WRMP are reviewed every 5 years, supported by an annual review process. However, it is also important and appropriate to reflect this uncertainty either in target headroom (informed by sensitivity tests, where appropriate), and/or through the scenarios or plan testing framework. Figure 42 shows the overall range of uncertainty in our WRMP19 demand forecast.

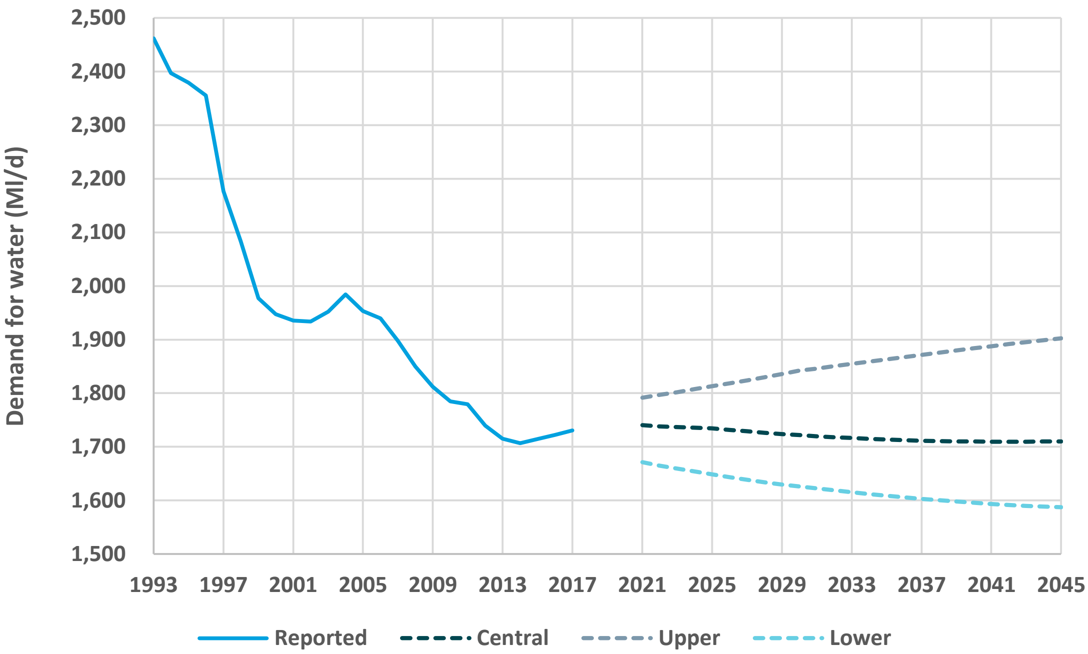

Figure 42 Reported regional demand for water, with the central forecast of dry year demand for water, as well as the upper (accounting for the "Northern Powerhouse" scenario, discussed in Section 3.5.1) and lower forecast of dry year demand for water[82]

Table 32 documents the key demand influences or components, including the related uncertainties, as well as how they have informed the scenarios and target headroom.

Table 32 Key demand influences/components, related uncertainties and scenarios

[82] The different starting point for each forecast relates to the inherent uncertainty in the starting point, for example, the uncertainty in the dry year uplift that has been applied to demand for water

Demand influence/ component	Our approach at WRMP15	Our approach at WRMP19	Target headroom uncertainty or scenario
Base year data	In the Integrated Resource Zone, an allowance of up to ±1% of normal year demand (central forecast) was made to cover meter inaccuracies that may impact upon demand base data. For the smaller Carlisle, North Eden and West Cumbria Resource Zones, an allowance of up to ±2% was made.	In all resource zones, an allowance of up to ±1.02% (as documented in *Final WRMP19 Technical Report - Target headroom*) of base year demand has been made to cover meter inaccuracies that may have impacted upon base year demand data. This is consistent with our Regulatory Reporting process.	**D1**
Population, property and occupancy forecast (impacts household consumption)	25% uplift and reduction on the population and property annual growth forecasts.	**Upper forecast:** Unmeasured occupancy increases, associated with the Free Meter Option (recommended from the Artesia Consulting review documented in Section 2.6) **Lower forecast:** Use of the "trend-based" population and property forecast (as documented in Section 2.1)	**D2 and "Upper" (accounting for the "Northern Powerhouse") and "Lower" demand scenarios**
Household consumption	N/A	**Upper forecast:** Lower household consumption reduction, associated with the Free Meter Option and micro-component rates of change uncertainty (recommended from the Artesia Consulting review documented in Section 2.6)	**D2 and "Upper" (accounting for the "Northern Powerhouse") and "Lower" demand scenarios**
Non-household consumption	The non-household low and high price forecasts were applied as these generated the highest and lowest level of demand from non-household customers.	**Upper forecast:** "Northern Powerhouse" high economic growth scenario (as documented in Section 3.5.1) **Lower forecast:** "Low Growth" economic scenario (as documented in Section 3.5.1)	**D2 and "Upper" (accounting for the "Northern Powerhouse") and "Lower" demand scenarios**
USPL	N/A	N/A	**N/A**
Minor components	N/A	**Upper forecast:** 5 year maximum annual average value (as documented in Section 5) **Lower forecast:** 5 year minimum annual average value (as documented in Section 5)	**D2 and "Upper" (accounting for the "Northern Powerhouse") and "Lower" demand scenarios**
"Dry year" uplift	Upper and lower bound "dry year" uplift factor applied to household demand	Upper bound dry year uplift factor (+3% from the central) and lower bound dry year uplift factor (-3% from the central) dry year uplift factor, provided by the Met Office and applied to household consumption.	**D2 and "Upper" (accounting for the "Northern Powerhouse") and "Lower" demand scenarios**
"Critical period" uplift	N/A	N/A	**N/A**
Climate change uplift	The uncertainty in potential impacts on water demand, as represented by the lower and upper impacts derived from the Impact of Climate Change on Water Demand UKWIR project, was included	**Upper forecast:** 90th percentile impact from the Impact of Climate Change on Water Demand UKWIR project[83], was included **Lower forecast:** 10th percentile impact from the Impact of Climate Change on Water Demand UKWIR project[83], was included	**D3 and "Upper" (accounting for the "Northern Powerhouse") and "Lower" demand scenarios**

More detail on our assessment of target headroom can be found in *Final WRMP19 Technical Report - Target headroom*.

[83] Impact of Climate Change on Water Demand (UKWIR, 2013)

11. Innovation projects

New technologies are continually being reviewed and implemented wherever there is scope to improve our efficiency. Innovation is inherent in what we do, and this can be seen through our evolving and improving demand forecasting approach each planning cycle. In this section we provide some key examples of other innovations related to demand and demand management that may inform our future plans and activities.

Connected homes and smart metering

We have been working with other organisations on options for establishing a water smart metering capability. To date, the focus has been on understanding the lessons learned from the energy sector as well as the advances already made by other water companies in this area. Through a series of trials we aim to unlock a number of benefits for customers, and maximise the value of smart metering for companies and customers that wish to pursue the technology. We also see merit in establishing a universal smart metering architecture for the industry.

Unlocking the value of new data flows enabled by smart meters could deliver substantial benefits, by for example putting customers in control of consumption and enabling more efficient solutions in areas such as water capacity and demand management.

Customer side leakage quantification trials

It has become apparent that technology is now in development in the marketplace to provide a battery-powered sensor, logging technology and an analytical method that enables flow past boundary boxes to be assessed in a non-intrusive way without a meter. We have identified five areas for investigation in order to understand the benefits of using this technology. This work has led to commissioning five pilot studies to:

- Show whether apparent DMA network leakage is actually consumption;
- Monitor flows on long services in rural areas/plastic pipes in others;
- Estimate the flow rate on suspected supply pipe leaks;
- Show flow patterns on a sample of industrial properties; and
- Monitor a sample of small area monitors to determine usage and leakage.

We have received some very useful insight into the characteristics of flows past customer stop taps and the variation in the behaviour between customers. Further work is required to develop and test a more cost effective way of carrying out surveys and speed up data processing.

Tackling customer side leakage club project

The prime objective of the project was to develop a methodology which can be applied routinely by water companies at an economic affordable cost to:

- Understand whether some of the flow into the DMA that we currently think is network leakage, is actually a combination of events beyond the customer stop tap i.e. genuine use, plumbing losses, and relatively small supply pipe leaks;
- Locate properties with continuous flow; and
- Understand the pattern of consumption in individual properties.

This project was carried in collaboration with five other water companies and was part funded by Innovate UK.

Save Water – in pipe assessment tool

The project is aimed to develop a technology to assess pipe condition in live mains.

This project is an example of how we collaborate with academia and other organisations to develop technology to answer some of our key challenges. Development of an in pipe assessment tool for use on "live" mains. The equipment will help determine mains in need of replacement prior to leaks breaking out. This will lead to a reduction in water losses and reduce interruptions to supply. Various techniques exist using cameras and ultrasonics to produce a "condition assessment", however the techniques do not produce the data equivalent to non-destructive testing (NDT) such as man entry into pipes or exposing pipes and testing from outside, both of which are time consuming and expensive.

This technology is still in development and the live trial is planned in the Cheshire area.

The SAVE Water project is a unique offering to the water industry not only in the UK but internationally. The technology derived from the project will be the first in-pipe assessment vehicle which will work in live conditions (no customer interruption) and deliver a full sensing package of optical and acoustic inspection while also carrying out a complete structural assessment of the pipe material and any associated linings, both factory and retrospectively applied. This technology builds on recent advances in live inspection equipment deployed in higher value industries such as oil and gas and is a much more affordable technology which will enable wide scale entry into the UK water sector. International exploitation is clearly identified and can be demonstrated by the consortium who have already entered international markets with other live in-pipe technologies.

This project is being carried out in collaboration with Liverpool John Moores University, Balfour Beatty and JD7.

Event Response planning (STREAM)

The project is aimed to understand whether we can improve on the length of time required to identify leaks in the network so that any disruption for our customers can be minimised or avoided completely. The work is carried out in collaboration with University of Exeter (WISE, Stream project).

The aim of this project is to develop an innovative and smart system to enhance operational efficiency and customer service. Building on from our in-house developed event recognition system (ERWAN) and using data from additional sources such as supervisory and control data acquisition (SCADA) systems and hydraulic simulation models, pressure and flow monitoring sensors and smart metering solutions (Automatic Meter Reading, AMR) to become more efficient at detecting changes in the network and locating where the event is so that it can be rectified before impacting the customer.

With increasing measurement points, the potential benefits of near real-time hydraulic models can be realised in which measured data is regularly streamed into a model to set and update simulation of boundary conditions. Pressure data has been found to be extremely useful in this case for model calibration and fault finding. Availability of a stream of continuously updating flow and pressure data enables calibration to current, rather than historic measurements, allowing a continuous and iterative process, and reflecting ever changing dynamics in the network caused, for example, by changes to valve positions, the timing of pump operations or the turnover rate of service reservoirs.

While various components of these areas of work have been proven at conceptual, and some even at prototype stage, the true potential and value will be realised when they are combined and delivered as part of an integrated, harmonious package. The fusion, integration and development of a systems approach will be at the heart of this research.

Event Management and Post Event Response Planning for Intelligent Water Networks

Collaboration with Sheffield University (Stream project)
Question this project is trying to answer: Can we develop a system that can plan the most effective and efficient response when an event happens in our water network?

The water industry in the UK and worldwide faces considerable challenges in making use of the real-time data that is collected in water distribution networks. The industry has a pressing need to use this data to improve response to various events in pipe networks (e.g. pipe bursts or equipment failures). We have developed, together with University of Exeter, the Event Recognition System (ERWAN), a novel technology that can detect and locate incidents and events in timely and reliable manner. What is currently lacking is the methodology for effective, optimised and automated response to these events.

The real-time event management and post event response planning technology developed in this project will provide an objective and scientifically sound methodology to increase efficiencies and demonstrate the benefits of optimised and automated event management ultimately enabling us to:

- Respond to customer issues quicker (contributing to an increase in customer satisfaction);
- Improve the ability of resources (planning responses to events better and optimal use of the resources available); and
- Reduce investment through quick and improved responses (contributing to a reduction in customer bills).

This technology also has the ability to be used across the UK and global water industry in the emerging smart water systems market.

The project will attempt to understand:

- What is the best way to respond to various events that may occur in a water distribution system? How can optimal operational interventions be identified and in a timely and automated way? What company data and resources (systems and people) need to be used in the process and how?;
- How should the identified response strategies be presented to the control room operator so that he/she can make an effective ultimate decision on how to deal with each event?; and
- What are the likely benefits and costs of new technology? How will the technology be effectively delivered in to the control room (people, processes and systems)?

Gas detection

CEO Challenge "*Improve our Customer Side Leakage (CSL) performance"*

The CEO Challenge were engaged to improve the current Customer Side Leakage. The team reviewed over 15 technologies that could be used to detect leaks. Subsequently, the team researched the capabilities of Gas Detection identifying success criteria to enable a trial which could comprehensively analyse the credentials of the product. The main benefits of the technology are increase in amount of leaks located, improved competency of UU employees and improved leak detection arsenal of UU employees.

Satellite imagery for leakage detection

We are currently trialling satellite technology that uses ground penetrating radar from Japanese satellite ALOS 2 to determine the spectral signature of chlorinated water just below the ground. The assumption is that this technology should help us to identify leaks quicker therefore significantly shorten current location times. The results of the trial should be available early in 2018.

Pressure management valves

As part of our continuing innovation we are now replacing the older generation of flow modulation units with the next generation. The new units give us added functionality that allows us to optimise remotely from an office based environment rather than having to travel to site, set up traffic management and lift lids to change the settings. There are also self-learning algorithms that utilise the recorded critical point data to allow for more accurate and calmer optimisation of the network. As well as this we are also installing closed loop control systems that maintain a set pressure at the critical point by sending live data back to the control unit on the pressure management valve and adjusting the outlet pressure accordingly. All this additional data that we are recording every 15 minutes is also utilised by our event recognition system to understand issues that may be occurring on our network before it impacts the customer. This data can them help them deploy a technician to site to rectify a potential issue without the customer ever being aware.

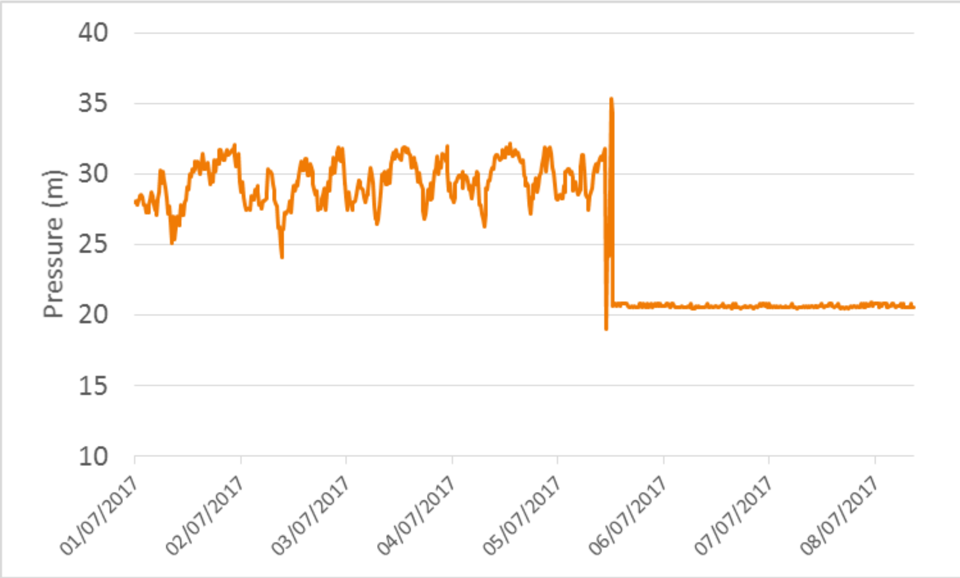

Figure 43 Pressure before and after optimisation

Network visualisation project

As part of the our Intelligent Network management for Water (IWNM) programme, we have developed a map based tool which takes data from a number of existing corporate systems to provide a single geographic view of network activities. The tool supports more informed customer calls, enables proactive network management both of which positively contribute towards our SIM and ODI targets. The project is currently being rolled out and we are in a process of developing and e-learning package to support the roll out. Figure shows feedback from users

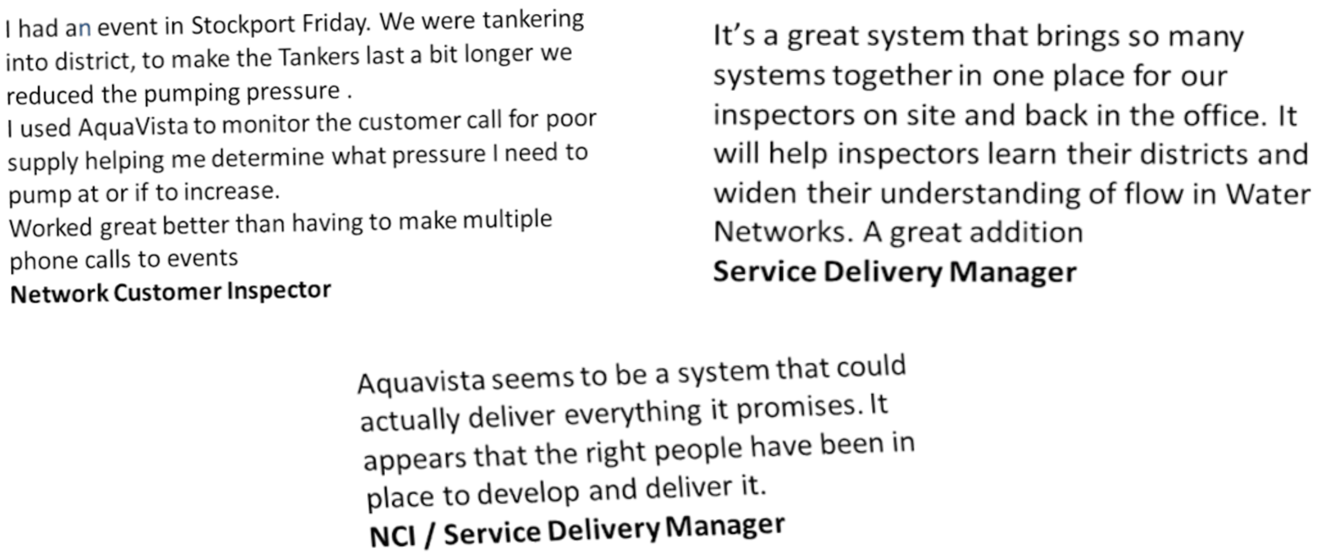

Figure 44 INMW Network visualisation

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Appendix A – Economic appraisal of leakage

Method

We have developed a model that finds the minimum cost of operating a network by optimising active leakage control (ALC), pressure management and mains rehabilitation using a direct optimisation formulation. The leakage level at this minimum cost is equal to the short run ELL and the marginal cost-benefit of the selected leakage reduction schemes is equal to the marginal cost of water. This method ensures that the benefits of each the interventions are not double counted.

Each Water Resource Zone (WRZ) is assessed separately and the results amalgamated to provide company level short run ELL and short run SELL.

The diagram below shows an overview of the process adopted for this assessment, which maps to the following description of activities / approach. The methodology, assumptions, data and calculations used in the model was subject to an external review and assurance.

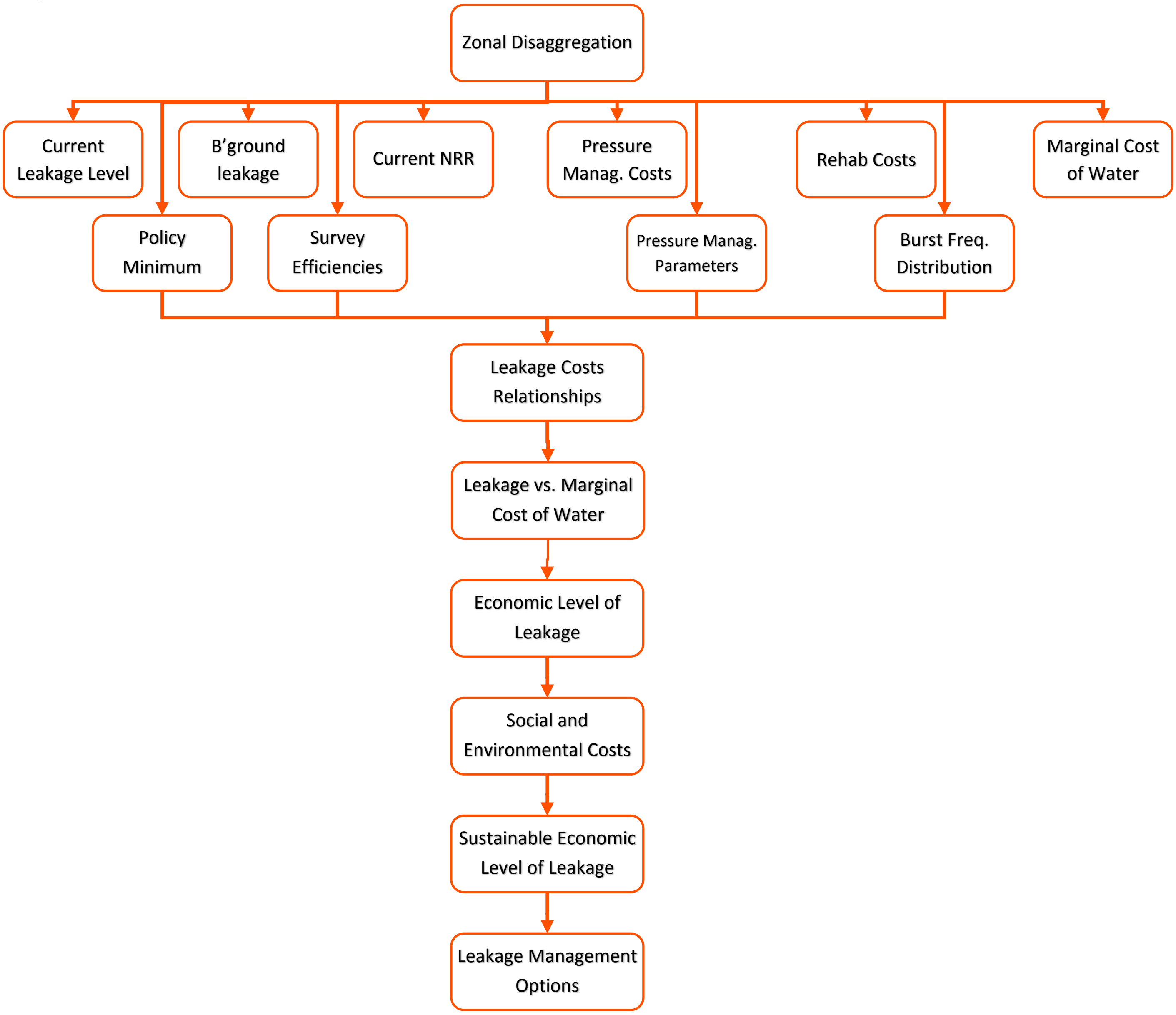

Figure 45 Process Overview

Zonal disaggregation

We currently have four Water Resource Zones (WRZ's), of which the Integrated Resource Zone is the largest, covering approximately 95% of water supply in the area. The completion of the Thirlmere Transfer will result in merging West Cumbria with the Integrated Zone. We are now calling this the Strategic Resource Zone to draw distinction with the previous zones. For more details please refer to Section 3 of our WRMP19 main report.

The UKWIR/Environment Agency definition of a WRZ (UKWIR/Environment Agency Definitions of Key Terms for Water Resources Practitioners) is as follows:

> *"The largest possible zone in which all resources, including external transfers, can be shared and, hence, the zone in which all customers will experience the same risk of supply failure from a resource shortfall"*

Water saved by leakage control in one zone cannot be used to supply customers in a different resource zone. Therefore we address the supply-demand balance and the ELL separately in each WRZ as it is the most appropriate level and is consistent with regulatory reporting requirements

Current leakage levels

DMA leakage

We have over 2800 DMAs covering 99% of properties. Each DMA has monitored net flows. We use Netbase leakage management software to monitor and manage leakage levels in DMAs. Therefore, Netbase was used as a primary source of information on DMA leakage and characteristics for this study. Netbase follows methods outlined in Managing Leakage[84] to calculate leakage at DMA level.

The minimum night flow (MNF) is calculated as a fixed one hour average flow between 03:00 and 04:00 using the DMAs net flow (calculated as the difference between the flows at the inlet and outlet meters, using 15-minutes raw data). If there is a logged user within the DMA, then its data is subtracted from the net flow before the MNF is derived. From this net MNF value the night use allowances for household and non-household properties are then deducted to provide a night leakage value for the DMA. To arrive at the daily leakage value a DMA specific hour to day factor is applied (hour to day factors are routinely reviewed by our leakage analysts). Where data was missing or a DMA was not operable the leakage values are estimated based either on the DMA's previous operable data or the zonal average figures.

We carry out a full water balance reconciliation each financial year for Regulatory Reporting purposes. For this assessment, current position (i.e. leakage level and operating costs) was derived using last 3 to 5 years of data.

Trunk main and service reservoir losses

Following recommendations in the SMC report[85], we have used tile analysis to estimate the level of trunk mains and service reservoir losses. We have made significant investments in our upstream infrastructure and production planning processes and through this achieved substantial reductions in our upstream leakage over the past few years. Our current levels of upstream losses are lower than estimates derived using burst and background estimation method used in the last assessment.

The tile balance approach consists of using actual meter data to calculate DMZ and Aqueduct losses. One of the big advantages of this method is that it allows UU to actively target areas where real losses occur. The burst and background estimation (BABE) method just gives the company one figure and doesn't give any indication of where the losses actually occur.

Policy minimum

The 'current policy minimum' is defined in the Tripartite Report[86] as the lowest level of leakage which can be achieved through intensive active leakage control using conventional active leakage control methods, 'current'

[84] (UKWIR, 2011)
[85] (SMC for EA, Ofwat, Defra, 2012)
[86] (Water Research Centre for Ofwat, EA and Defra, 2002)

technology and 'reasonable' effort. Policy minimum is one the most critical aspects in establishing the economic level of leakage.

Policy minimum is calculated as background leakage plus leakage from customer reported burst plus leakage from detected busts as they await repair plus trunk main and service reservoir losses. There is also a variable amount of unreported (detected) leakage that can be identified through additional effort in active leak detection.

It is not possible to operate at the policy minimum leakage as it would require leakage in all DMAs to be held constantly at the lowest level ever achieved. The policy minimum represents a theoretical minimum level of leakage that could only be achieved under the current policy if infinite resources were deployed on active leakage control.

All components of policy minimum leakage levels, except for trunk main and service reservoir losses, were assessed in 2016 using the analysis period April 2011 to March 2015. The methodology for assessing policy minimum has not changed since the previous ELL assessment.

Background leakage

Background leakage is the collective sum of numerous minor leaks and seepages from valves, joints, hydrants, stop-taps, meters and other fittings. These leaks rarely exceed 100 l/hr and are not normally individually identifiable from DMA night flow measurements.

Background leakage was derived from actual minimum historic night flows, i.e. the lowest net night flow achieved between January 2015 and December 2015 for each DMA. A statistical routine was used to eliminate erroneous data and manual checks were carried out on the results to ensure correctness. This approach is consistent with Tripartite[87] guidance. Background losses at resource zone level are calculated as the sum of the values from individual DMAs.

Table 33 Background leakage

Resource Zone		Strategic	Carlisle	North Eden	Region
Background leakage PR19	Ml/d	207.5	3.0	1.4	211.9
	l/prop/d	64.8	54.6	203.0	64.9
Background leakage PR14	Ml/d	202.9	2.8	1.2	206.9
	l/prop/d	63.3	51.8	181.1	63.4

Background leakage has risen very slightly from 63.3 l/prop/day to 64.8 l/prop/day since the PR14 review. The level of background leakage is expected to rise over time with a strategy of maintaining serviceability across the distribution network, as new development increases the length of network overall, and new pipes are not free of background leakage, with joints being a particular problem.

Background leakage is based on current policy. One of the key issues with the SELL is that the theoretical level of background leakage that can be achieved may be expected to be lower. The SELL is directly related to the level of background leakage, however, the only way to practically reduce policy minimum is to investigate further what currently manifests itself as background leakage actually is. It is likely to be a combination of a number of components:

- Undetectable losses such as weeps and seeps from joints.
- Plumbing losses
- Night use

[87] (WRc, 2002)

- Long running leaks that have not been located using existing approach/policy/technology.

Using the Unavoidable Annual Real Losses (UARL) formula, we estimate background leakage could potentially be 140 Ml/d. This is 72 Ml/d lower than our background leakage assessed through current policy minimum. There are a range of factors and variables that may explain the differences between the policy minimum level and the theoretical level:

- The level of metering penetration, as increased levels of metering are likely to strip out long running, but low volume losses on supply pipes or plumbing losses if this impacts on customer bills.
- The level of background leakage will be impacted by network pressure, which will vary across companies.
- DMA size will be a factor in explaining why policy minimum may be higher as larger DMAs are less efficient and difficult to manage.
- Network age, characteristics and performance.
- The supply pipe policy over time can influence background leakage levels.
- The leakage management policies will influence policy minimum, and this will be historically influenced by water resources drivers, with some companies having a historic supply-demand driver to reduce leakage.

We have included a stretching reduction of 20% by 2024/25, and we are including a range of new technologies and exploring third party options. We expect some of these trials and the wider roll out of new technology, to challenge what we currently see as being background leakage. Our proposed reduction of just over 40% longer term equates to 190 Ml/d, and almost certainly a significant proportion of this reduction will be tackling what is currently background leakage derived through our current policy minimum. We expect over time to be able to quantify background leakage far more robustly than we can at the present time, and expect the true level of background leakage to fall somewhere between our current policy minimum, and the UARL level. We cannot predict at this time, what this level might be.

As we find economical ways of reducing background leakage, this will over time naturally lead to a reduction in the SELL, through innovation. Irrespective of the difference between current policy minimum and theoretical background levels of leakage, we have set out an ambitious and stretching target, based on a range of considerations and drivers. Basing SELL on an entirely theoretical level of background leakage would reduce the short run SELL. There would be an unacceptable risk in basing our SELL on the UARL level, given the considerations above and factors that may explain this difference. This level may in part be unachievable due to a range of factors, but also could result in an inefficient approach being taken to leakage management. Instead, we have based our SELL on policy minimum, and set a stretching target, and included a twin track approach of existing and new technologies/innovation. The latter includes tools which are helping to better understand at a DMA level the components of leakage and the water balance, and offer ways of firstly understanding the difference between policy minimum and background leakage, but also solutions to manage and reduce it, which is essential when setting a meaningful SELL.

Natural rate of rise (NRR)

The natural rate of rise of leakage is the rate at which leakage would rise if no proactive leakage detection was carried out. Proactive leakage detection has to be carried out in order to hold leakage at a defined level. The natural rate of rise of leakage the predominant driver in assessing the cost of proactive leakage detection. The assessment of the natural rate of rise of leakage is therefore critical.

The NRR was derived separately for each DMA by analysing the rise of the minimum night flow values between periods of leakage detection using the same date range as for the analysis of background leakage. This methodology follows best practise defined in the UKWIR report on Natural Rate of Rise in Leakage[88]. DMA specific NRR values and estimates of background leakage were then used to derive a set of best estimates of the company specific unreported and reported burst flow rates, which were subsequently used in the ELL/SELL model to derive the levels of reported and unreported leakage included in the policy minimum (please see Figure 51).

Table 34 Natural rate of rise of leakage

Resource Zone		Strategic	Carlisle	North Eden	Region
NRR PR19	Ml/d/yr	204.9	2.5	2.0	209.4
	l/prop/d/yr	64.0	45.1	296.6	64.2
NRR PR14	Ml/d/yr	167.4	4.2	1.6	173.2
	l/prop/d/yr	52.3	77.6	228.1	53.7

Table 35 Average leak flow rates

Resource Zone		Strategic	Carlisle	North Eden	Region
NRR PR19	l/hr	1,115	1,092	2,063	1,113
NRR PR14	l/hr	961	1,300	994	958

Trunk main and service reservoir losses (upstream losses)

Trunk main losses and service reservoir losses have been provided by our Upstream Losses Co-ordinator and are based on FY16 reported figures.

Figure 46 Upstream losses

Resource Zone		Strategic	Carlisle	North Eden	Region
Upstream losses PR19	Ml/d	81.1[89]	0.8	0.3	80.1

[88] (UKWIR, 2005)
[89] Includes aqueduct losses

Components of policy minimum

Figure 47 shows each component of leakage expressed as a percentage of the total leakage. It can be seen from the chart that the percentage of unreported leakage is the highest in the Strategic Zone at 38%. Strategic and Carlisle zones have similar levels of background leakage, at around 57%, while background leakage in North Eden is slightly higher at 63%. Level of reported leakage is the highest in North Eden at just over 5% and around 3% in the remaining two resource zones.

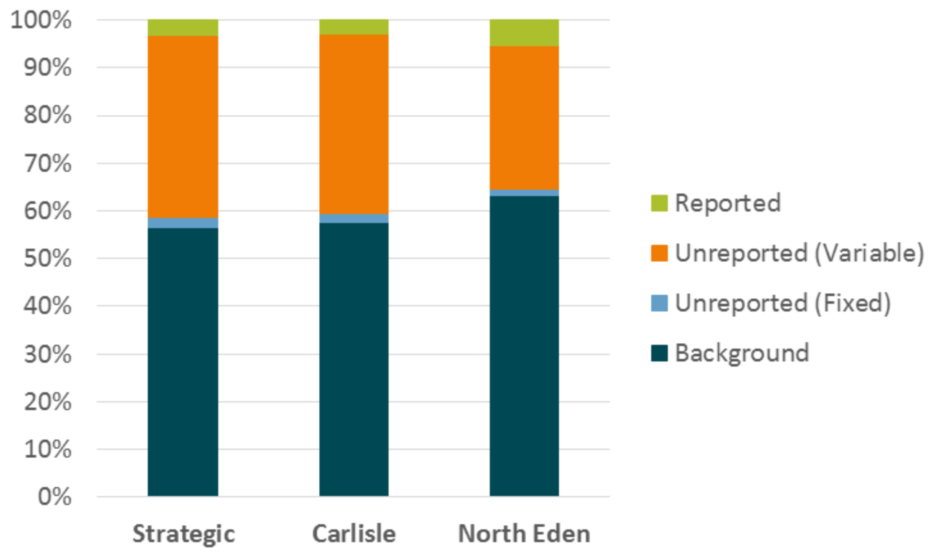

Figure 47 Components of total leakage

Regionally the policy minimum leakage is 232 Ml/d, which is equivalent to 71 l/prop/d[90].

Table 36 Policy minimum

Resource Zone		Strategic	Carlisle	North Eden	Region
Policy Minimum PR19	Ml/d	226.9	3.2	1.5	231.6
	l/prop/d	70.8	59.0	224.4	70.9
Policy Minimum PR14	Ml/d	234.0	3.3	1.7	239.0
	l/prop/d	73.0[91]	60.7	252.6	74.0

Survey efficiencies and leakage detection costs

We have a mixture of internal leakage detection resources and external contractors, the split is approximately 23%:77%. The leakage detection rates were derived using data provided by RPS, Amey and an internal performance team. In the model a weighted average of the three derived survey rates is used.

Using provided information a set of assumptions was made to group individual survey records into detection campaigns. A relationship between the duration of a campaign and recent DMA characteristics i.e. mains length and property counts was established and calibrated against the actual data in order to find the best set of coefficients that were then used by the ELL model to estimate intervention times.

[90] Does not include upstream losses
[91] Calculated as a weighted average using PR14 data for Integrated Zone and West Cumbria Zone

This analysis was carried out assuming that on average 35% of DMA is surveyed each time. This is to reflect our leak detection strategy which is to leave the area once bursts are identified and move to another area.

The leakage detection resource costs have been based on a rate per day. The costs have been based on the following elements:

- ALC framework cost (this accounts for on cost to cover national insurance, pension, overtime, van and equipment);
- Allowances for managerial costs (our internal Operations and Asset Management costs, including on-cost); and
- An assessment of productive days taking into account statutory holidays, annual leave, sickness, training and weekends.

These cost, together with detection efficiencies and policy minimum estimates, were used to produce the active leakage control curve (please see Figure 51).

Pressure management costs and parameters

In our SELL modelling we have included the forecast benefit that will have been realised by 2019/20 through pressure management, as we have an extensive pressure management programme being delivered. This benefit has been integrated in our SELL modelling. Data associated with the benefit of pressure management has been collated from our Engineering team. This data from individual schemes was used to derive a relationship and cost curve between the number of schemes delivered and the benefit achieved. A set of coefficients were derived from a model that was calibrated against the actual data. An example of this is shown below:

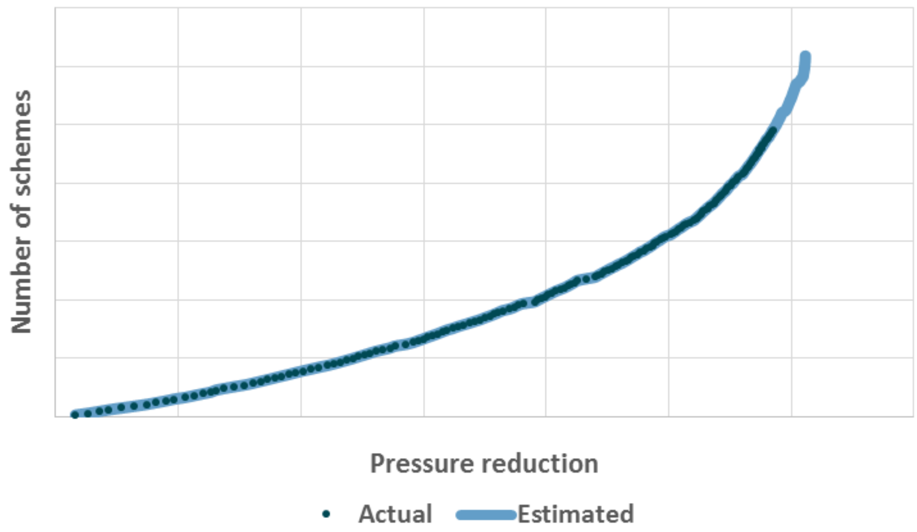

Figure 48 Pressure reduction relationship

The implementation of new schemes, and the optimisation of existing schemes has been modelled separately because of the significant difference in their cost and benefit relationship. Between 2015 and 2020 there has been a reduction in burst frequency, however, this is now stabilising.

Although there are benefits from the current programme, there are factors that are an upwards pressure on leakage, and pressure management is an activity that has offset these:

- Population and network growth – as the population and network grow through new development, we have a larger network to manage and maintain. The level of leakage on new infrastructure may be less than on older mains, but it is not zero. We have to work harder over time in order to maintain the same level of total leakage in Ml/d and offset this growth.
- There is assumed to be relatively little in terms of replacement of customer supply pipes and this represents a likely source of deterioration and another upward pressure on leakage levels.

Pressure management schemes selected for 2020 to 2025 (AMP7) may be helping to maintain the current level of service, but where they are selected as part of our programme to reduce leakage, the reduction is represented in our targets reducing over time.

Mains rehabilitation costs and parameters

It has been an assumption for the SELL process that mains rehabilitation schemes are maintaining levels of service, and leakage reduction below SELL would only result if specific options were selected in the WRMP. There are therefore no forecast plans outside of the supply-demand balance that would reduce leakage, and the benefit of mains renewal and rehabilitation is focused on maintaining levels of service for AMP6 and AMP7 rather than making an enhancement that would result in leakage benefit that would be additional to our proposed programme to reduce leakage (outlined in *Final WRMP19 Technical Report – Options appraisal*).

We have included mains rehabilitation options as explicit options for appraisal and potential selection, however, these options were screened out at the secondary screening phase as not being cost-effective. The maintenance of the distribution network is a key driver for mains replacement, when bursts, leakage, water quality as well as pressure and interruptions to supply are all considered.

As shown in Figure 49, over the course of AMP6, we have seen a reduction in mains repairs, largely driven by pressure management schemes. We are seeing performance stabilise and are forecasting this stability to continue for the remainder of this AMP6 and AMP7. Significant winter events can result in annual variability however. For AMP7 we are forecasting an increase in the number of mains repairs largely related to the extra leaks that will be detected through the transition from current baseline leakage, to lower levels of leakage in AMP7.

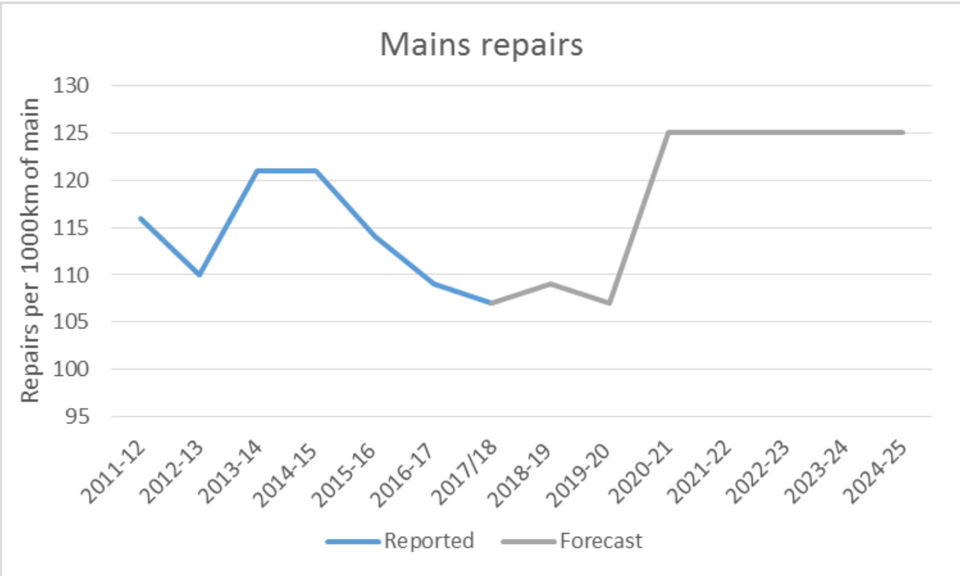

Figure 49 Number of mains repairs per 1000km of main

For mains rehabilitation for leakage reasons to have any chance of being cost effective it is essential that refurbishment is targeted at individual pipe lengths rather than total DMA rehabilitation. We have therefore created cohorts of pipes within our Discrete Pressure Areas (DPAs) based on material type. Bursts have been associated with these cohorts and the cohorts have been sorted in descending order of burst frequency. This data was used to develop a relationship between burst frequency and length of pipe cohort on the assumption that rehabilitation of a particular cohort would reduce the overall system burst frequency by the average number of bursts assessed for that cohort accounting for residual burst frequency in newly laid mains.

Burst frequency distribution

The burst frequency distribution analysis was undertaken as part of the natural rate of rise analysis. A cut of all burst repair jobs that occurred between 2012 and 2015 was loaded into Netbase and assigned to DMAs using co-ordinates. This data provided, amongst other things, the type of repair job, whether it was reported or detected and the dates the leak was raised and repaired. Figure 50 shows the percentage distribution of each burst type. There is a similar proportion of mains bursts in Strategic and North Eden zones, at around 35%. Carlisle is slightly lower at around 30%. Proportion of supply pipe bursts is the lowest in North Eden at 17%, and at around 25% in the other two zones. Carlisle and North Eden have similar proportion of communication pipe bursts at around 50%. Proportion of communication pipe bursts is approximately 10% lower in the Strategic Resource Zone.

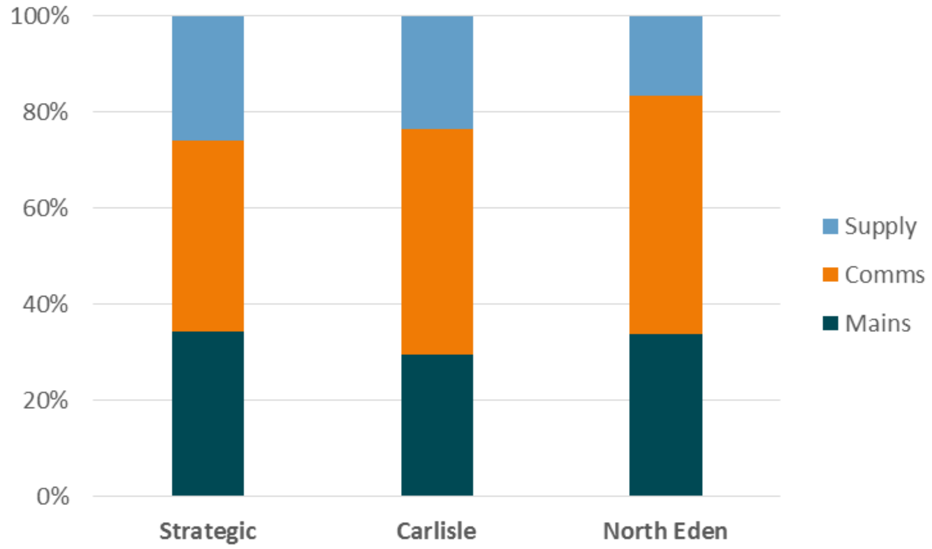

Figure 50 Burst frequency distribution

Burst frequencies, together with flow rates derived through the natural rate of rise analysis, were used in the component loss model to calculate the levels of reported and unreported leakage used in the ELL and SELL analysis.

Marginal cost of water

The marginal cost of water (MCW) is used in the assessment of the ELL as this represents the cost that would be saved by reducing leakage, which essentially is the cost of water from the most expensive source. Volume related costs such as electricity, chemicals and sludge disposal are considered in assessing the marginal cost. Fixed costs such as resources, maintenance etc. are not included as they are not affected by the change in the leakage level.

Marginal costs of water have been provided by the Production Planning team, these included uplift for distribution pumping. The analysis was carried out for 3 years 2014-2016. Although there was no significant differences between analysed years, 2016 was selected as most accurate due to extensive improvements achieved through progress made in our production planning initiative. This is also the reason for the difference if compared to the MCW used in the PR14 ELL assessment.

Economic level of leakage

The Economic Level of Leakage (ELL) is the level of leakage above which any further leakage reduction activity would cost more than the value of water saved. The value of water saved is the marginal cost of water in the network (i.e. the marginal cost of water production) plus the marginal cost of distribution (i.e. pumping within the distribution network). In theory, water should be saved at the most expensive source first. It is also likely that network pumping will be localised and it will not be possible to make all the leakage savings within the pumped DMAs and so the marginal cost of distribution pumping is added at Water Resource Zone level.

Figure 51 shows the policy minimum derived from the analysis of the minimum historic levels of leakage that includes background leakage, trunk mains and service reservoir leakage, reported leakage and the fixed element of unreported leakage. The shape of active leakage control curve (detection cost), which asymptotes to the policy minimum, is a function of the natural rate of rise of leakage and the leakage detection survey rates and costs. Both, the level of the policy minimum and the shape of the detection cost curve are also impacted by the level of pressure management and mains rehabilitation selected by the model.

The Tripartite[92] report also requires that actual cost be adjusted to represent the steady state costs (i.e. costs of maintaining the current level of leakage in a year not impacted by external events e.g. severe weather, policy changes etc.). The average of FY14 and FY15 was used to calculate the current position.

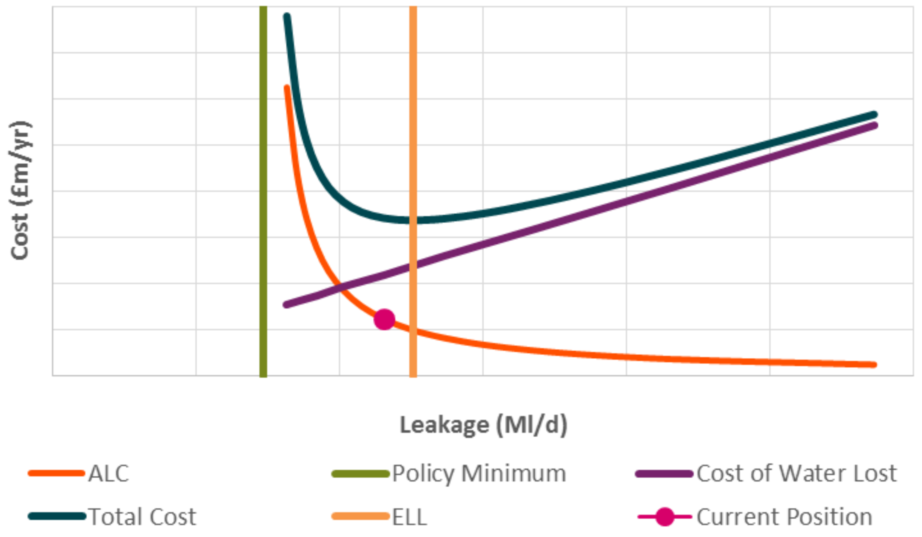

Figure 51 Illustration of the evaluation of ELL

The cost of water lost is shown on the graph as a straight line at the marginal cost of water described above. The upper curve is the total of the cost of leakage detection and the cost of water lost. The economic level of leakage is where this total cost is at minimum.

At this minimum the marginal cost of leakage control, pressure reduction and mains rehabilitation will be equal to the marginal cost of water.

Leakage repair costs are not included as the same number of leaks has to be repaired at any level of leakage and therefore the ELL is independent of the cost of repairs. However, additional transition costs are incurred in moving from one point on the curve to another. These can be estimated from the difference in leakage levels. A shift from one level of leakage to another will also incur and increase in the level of annual expenditure required to maintain that new, lower level of leakage (i.e. new steady state will be achieved).

The model was also used to develop leakage reduction packages for the three water resources zones as part of options identification. These are then considered alongside other supply-demand options as part of the options appraisal process, where appropriate.

Optimisation of ALC, pressure management and mains rehabilitation

The ELL model finds the minimum cost of operating a network by optimising active leakage control (ALC), pressure management and mains rehabilitation using a direct optimisation formulation. The leakage level at this minimum cost will be equal to the short-run ELL and the marginal cost-benefit of the selected leakage reduction schemes will be equal to the marginal cost of water. If the marginal cost of any of the leakage activities is higher than the marginal cost of water then this activity will not be considered economic and will not be selected by the model.

Sustainable economic level of leakage

The leakage cost relationship discussed above is based wholly on economics and determines short-run ELL for each water resource zone (i.e. ELL that refers to the current costs of leakage and current cost of water from existing

[92] (WRc, 2002)

supplies). The inclusion of social, environmental and carbon costs enables to assess short-run sustainable economic level of leakage.

Social, environmental and carbon impacts are examples of externalities that can impact cost-benefit of reducing leakage. The analysis of externalities was undertaken by AMEC Foster Wheeler in 2017 and was carried out in accordance with current best practice[93]. Full details of the assessment are contained in *Environmental and Social Costs of Water Resources Management Plan 2019 Supply-Demand Options.*

Carbon content of water production was derived using Energy Consumption and Greenhouse Gas Accounting collated as part of annual data submission and used together with discounted cost of carbon to calculate the marginal carbon cost of water production.

The guidance divides externalities into two groups:

1. Leakage related externalities: these relate to the effects of changes in abstraction, treatment and distribution and are subdivided into environmental and carbon associated costs.
2. Leakage management externalities; these result directly from activities such as detection, repair and asset renewals and are subdivided into social and carbon associated costs.

Table 37 Costs of social and environmental externalities

Description	Cost
Marginal carbon cost of water (£/Ml)	£15.13
Social cost of repairs (£/repair)	£294.52
Carbon cost of repairs (£/repair)	£0.82
Carbon cost of surveys (£/survey)	£3.30

[93] (Ofwat, 2008)

Appendix B – Water Balance

As explained in Section 4.2 the best practise is to estimate leakage using two nationally-agreed methods, the integrated flow approach (‘top down’) or the minimum night flow approach (‘bottom up’). This appendix details all the water balance components and explains the reconciliation process between the ‘top down’ and ‘bottom up’ estimates of leakage.

Water balance components

Distribution input

Distribution input is the amount of potable water entering the distribution system and supplied to customers.

Household measured

Household measured demand is based on metered consumption records adjusted for accruals at the financial year end to include estimates of water used but not yet charged for.

Household unmeasured

The volume of water delivered to unmeasured households is calculated from the number of properties and the average per household consumption (PHC).

The average PHC is based on our control area monitors which cover a representative sample of 73 areas (known as ‘cul-de-sacs’) and contain over 2,800 properties across the region. The methodology follows the approach set out in the UKWIR report Best Practice for Unmeasured Per Capita Consumption Monitors[94]. The methodology was reviewed in 2015/16 by Crowder Consulting Ltd. and some minor improvements have been made. We have also carried out a full review of our monitor and identified 22 areas that have to be replaced due to their meter penetration being too high. This work is ongoing and we envisage to have it completed in 2018. We also have a well-established process of maintaining our monitor, this ensures all issues are identified early and promptly resolved to maximise the number of monitors reporting accurate data.

Non household measured

Non-household measured demand is based on metered consumption records adjusted for accruals at the financial year end to include estimates of water used but not yet charged for.

Non household unmeasured

The volume delivered to unmeasured non-household is calculated from the number of unmeasured households and an estimated per property consumption. Farm troughs are calculated separately in a similar manner and added to the total.

Unbilled legal

Water taken legally unbilled includes water used for the following purposes:

- Legal standpipe usage such as use for highway washing, weed control and sewer flushing;
- Building water;
- Firefighting and training;
- Supply pipe losses at void properties; and
- Supplies to company’s own sites.

[94] (UKWIR, 1999)

Unbilled illegal

Water taken illegally unbilled includes illegal water connections, illegal standpipe and hydrant usage, and water taken by customers but unbilled due to lack of awareness that the water is not included in their bill. Quantities are derived from a combination of field surveys, estimates from existing data and our records of water use that is unbilled.

Operational use

Water taken for distribution operational use refers to water knowingly used by the company to meet its statutory obligations, particularly those relating to water quality. This includes:

- Mains cleaning and flushing;
- Mains rehabilitation;
- Service reservoir cleaning;
- Commissioning works; and
- Discharges from water quality monitors downstream of production meters.

Upstream leakage (bottom up)

Upstream leakage occurs on the network between the distribution input meters and the district meter areas (DMAs) and includes both trunk mains and service reservoirs. In the water balance, actual flow data from distribution input meters, bulk meters and district meters is used to calculate upstream leakage. This process is recognised as tile balance approach and follows the recommendations of the UKWIR latest reporting guidance for leakage[95].

DMA leakage (bottom up)

DMA leakage is calculated from measured night flows taken directly from Netbase (a corporate system used to store and analyse flow and pressure data). The DMA leakage value is based on detailed analysis of minimum night flows (MNF) with appropriate adjustments for known, or estimated zonal pressures, and deductions for relevant allowances for measured and unmeasured demands.

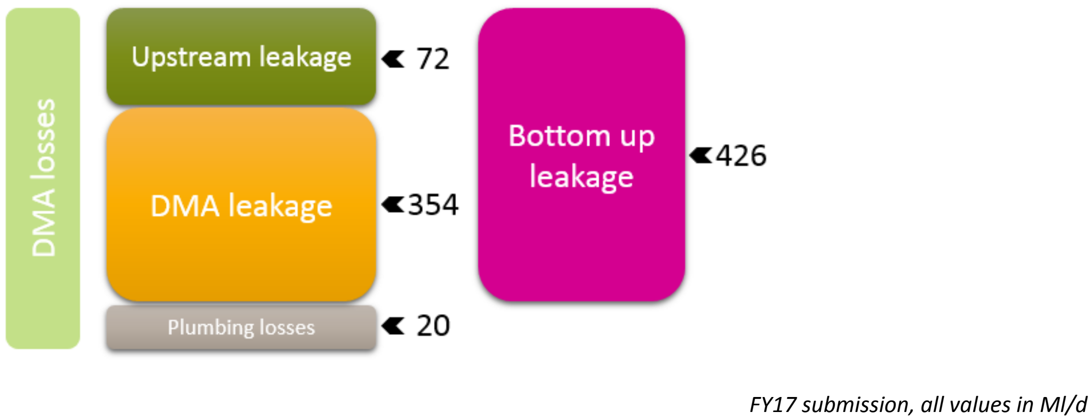

Figure 52 Bottom up leakage

Supply pipe leakage

Our supply pipe leakage was determined by Tynemarch in 2007 who also carried out a collaborative project for several other water companies to determine improved supply pipe leakage values for the 2007 Regulatory Reporting process (then known as June Return). Tynemarch used the national best practice methodology detailed in the Towards Best Practice for the Assessment of Supply Pipe Leakage[96]. We are currently in the process of tendering for a review of the estimates used in our water balance.

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[95] (UKWIR, 2017)
[96] (UKWIR, 2005)

Plumbing losses

Plumbing losses within customer properties are estimated in accordance with the Managing Leakage[97] document and are deducted from DMA leakage in the total leakage calculation. We are currently in the process of tendering for a review of the estimates used in our water balance.

Reconciliation

Where the water balance components reconcile with measured distribution input to within the tolerances identified in the Ofwat Reporting Requirements and Definitions Manual[98] (5%), we undertake a reconciliation exercise. The reconciliation is carried out using maximum likelihood estimation (MLE) in accordance with the reporting guidance and the national methodology set out in the Demand Forecasting Methodology[99].

The statistical MLE method is applied to allocate the reconciliation gap across the individual components. The allocation of the gap to these components depends on the level of confidence in the estimate for each component. The confidence levels have been assessed by in-house in consultation with the Ofwat Reporter. Details of the different components that have been identified and their associated confidence grades can be found in the table below. Figure 53 below illustrates water balance reconciliation process.

Table 38 Water balance confidence grades

Confidence grade (%)	
Measured household	3%
Measured non-household	3%
Unmeasured household	5%
Unmeasured non-household	25%
Water Taken Unbilled-legal, excl. spl[100]	10%
Water Taken Unbilled-illegal, excl. spl	50%
Operational Use	25%
Upstream Leakage	25%
DMA Leakage	5%
Distribution input	1.02%

[97] (UKWIR, 2011)
[98] (Ofwat, 2011)
[99] (UKWIR/NRA, 1995)
[100] Excluding supply pipe losses

Total leakage

The total leakage figure is derived through the water balance and for 2016/17 was 439 Ml/d as set out in Figure 53, below.

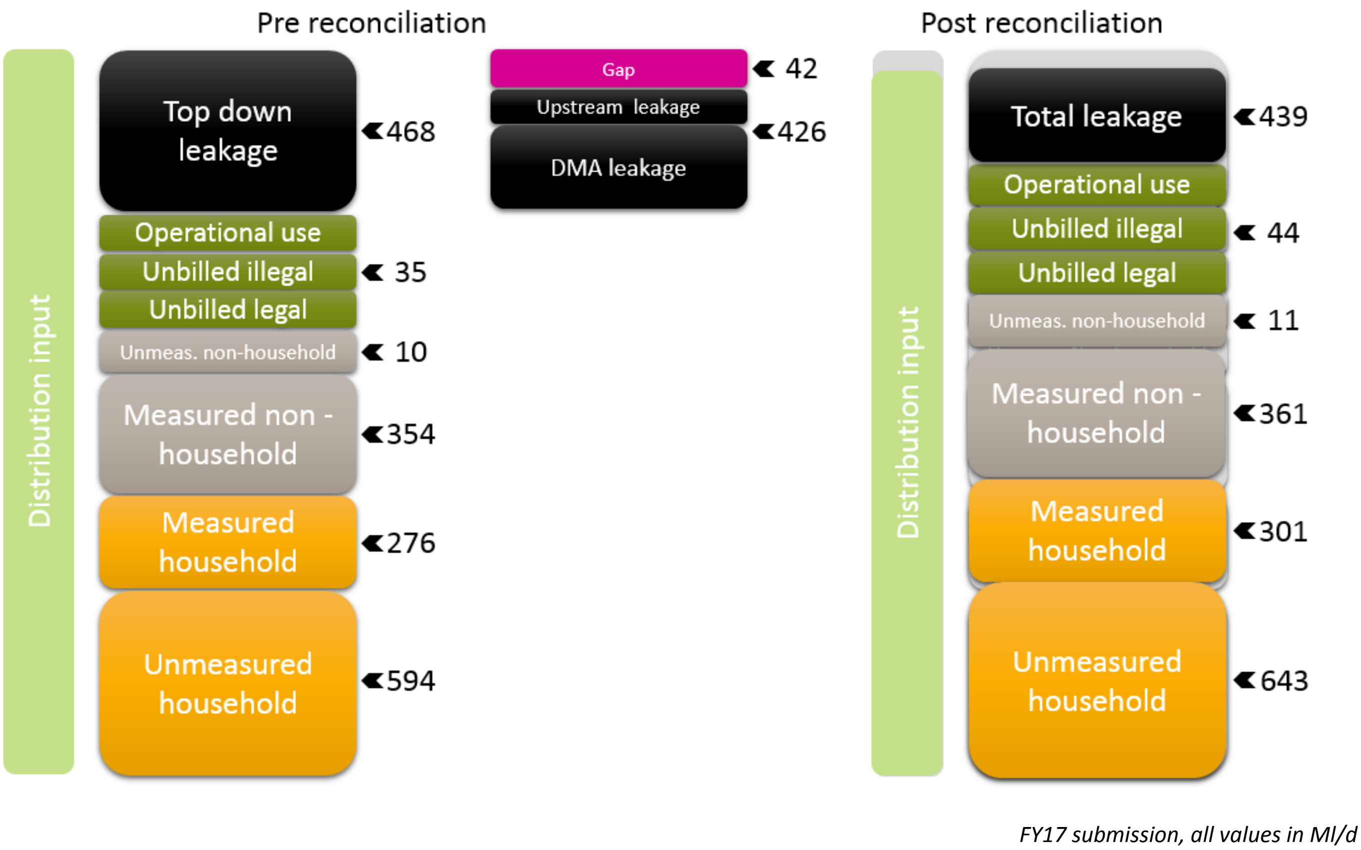

Figure 53 Water balance reconciliation

Appendix C – Leakage Convergence

Table from report submitted to Ofwat on 31st August 2017.

Component	Complaint (RAG)	Guidance requirement	Comment
Coverage		At least 95% coverage of all properties served by a company within networks having continuous night flow monitoring through the year.	Over 99% of billed household and non-households are within designated network areas where night flow is continuously monitored and reported on a daily basis.
Availability		At least 90% of all properties within continuous night flow monitoring networks shall be available for reporting night flow data through the year.	For FY17 our District Metered Areas operability was 85%.
Properties			**Overall status**
		Exclude properties that are defined as void from night use allowances unless a company can evidence any use or losses from illegal occupation.	Currently we do not have a void property flag in our leakage management software. The reason for this is that in our billing system properties are flagged as void when they cannot be billed, not necessary when they are empty. We are currently working on the best way to account for void properties in DMA leakage calculations.
Properties (continued)		Map all properties to defined zones or DMAs using geo-location or similar methods available in the industry. Check the consistency of property numbers contained within DMAs or zones against its company's billing system to ensure there is no under- or over- counting. Valid differences shall be explained. Apply leakage allowance for properties not within DMAs or monitored zones consistent with other leakage estimates. Update property data at least annually.	Our network management software is updated with a property extract from the billing system on a monthly basis. Properties are assigned to their DMAs using geo-location (there is a common unique reference that links a property record from the billing system to property seed in GIS). As the billing system is the source of property data we are confident that there are no material differences. Network not covered by DMAs is split up to UMFs (unmeasured feeds). Leakage for these areas will be estimated within our leakage management software using zonal average leakage rate in l/prop/hr (calculated using only operable DMAs within the zone).
Night flow period and analysis			**Overall status**
		Night flow data frequency shall be at least every 15 minutes. The fixed period can be varied during the year for some or all DMAs or zones to address significant changes to night use patterns such as during Ramadan.	We calculate our night line using flow data logged at 15-minute intervals and fixed hour (average between 3:00 - 4:00). We do make adjustments to the night line used for the leakage calculation over the Ramadan period and a one of adjustment for seasonal variation in leakage at year-end.

Component	Complaint (RAG)	Guidance requirement	Comment
Night flow period and analysis (continued)		Leakage shall be derived from a fixed period during the night of at least a one hour period although up to two hours may be used.	Our night use estimates for both household and non-household properties are derived using fixed hour (average between 3:00 - 4:00), which is consistent with the way we calculate minimum night flows.
		Data infilling for a single DMA or zone shall not use more than six months of historic data before moving to area average. Data infilling taking the area average in which the DMA is located is valid if historic data is not available. When a DMA is restored to operability, for the purposes of annual average reporting, the subsequent leakage data should be used to update retrospectively the data infilling interpolating between pre- and post- data over at least one month. This is because a non-operable DMA is unlikely to be subject to detection processes and there is likely to be a natural rise in leakage over time. It is recognised that this may take time to achieve, as and when leakage software packages are updated. There is one exception where a DMA is inoperable at the end of a reporting year where alternative data infilling may be used. Where NHH properties are continuously monitored, the actual values of flow over the night flow period shall be used in place of estimates within the night flow analysis.	We do have some long term non-operable DMAs that fall outside the six month threshold. In the case where a DMA is non operable, its own historical leakage rate is used for four weeks before falling back to zone average leakage rate. Our leakage management software has no capability to in-fill non operable periods by interpolating between pre- and post- data. This will be picked up with the developer of the application in a workshop that is due to take place this autumn. Continuously logged non-household properties are accounted for in the calculation of minimum night flow.
		The night use allowance shall be adjusted regularly through summer months to allow for variable customer night use based on sample logging over the period or night use models. Weekly leakage estimates shall be used for annual reporting with no exclusions for summer months.	We do adjust the leakage calculation over the Ramadan period and also do a seasonality analysis at year-end. The seasonality analysis involves identifying periods of weather where both temperature and rain fall are very different from the long term averages. For these periods we identify DMAs where minimum night flow increased and decreased but no repair activity has taken place. We interpolate minimum night flows between pre- and post- data, calculate the difference between the actual and interpolated figures and use this to adjust DMA leakage. Our annual average leakage is based on a 52 week average with no exclusions.
		Where average night use values are applied across all DMAs, it is appropriate to include negative leakage values when compiling values of annual average leakage. The reasons for any prolonged periods of negative leakage need to be investigated and explained.	We currently do not accept negative leakage and for DMAs where negative leakage occurs we manually invalidate it and force another, non-negative day to be selected and included in the weekly calculations. Although, there is a setting in our leakage management software that enables us to accept negative leakage our current processes make it impossible to apply this retrospectively. We have introduced a

Component	Complaint (RAG)	Guidance requirement	Comment
Night flow period and analysis (continued)			new process and now our leakage analysts will ensure that any invalidation of negative leakage is flagged with appropriate comments. This will enable the invalidation process to be reverted in the shadow database and an "accept negative leakage" setting correctly applied. We will be able to fully account for negative leakage in FY18 shadow reporting.
Household night use			**Overall status**
		The values of household night use night flow shall be used with values of night flow and non-household night use for the same time period and on the same statistical basis to derive an estimate of leakage representative for the DMA or zone.	HHNU is derived using fixed hour consistent with minimum night flow analysis.
		It shall use its own data or shared data with proximate companies. National default values are not valid. It shall demonstrate that its survey is representative of the company as a whole; disaggregation of the sample by demographic factors, property type or similar represents good practice. It shall demonstrate that the sample size is sufficient to capture continuous and intermittent night use with reasonable confidence. The application of IHMs, SAMS or a combination of both. It is unlikely that the IHM on its own will be of sufficient size to capture a valid sample of intermittent use. HHNU shall be derived daily with regular, adjustment of values on a weekly or monthly frequency to reflect actual seasonal use. This may need to be done retrospectively.	We use Small Area Monitor (SAM) to derive both night use and per household consumption. The monitor uses ACORN to stratify properties into six groups. The stratification is representative of the region in terms of proportion of each property type. The night use allowances are updated and statistical significance checked on a monthly basis.
		Plumbing losses shall be included and based on the company's own data.	We are using managing leakage estimate of plumbing losses.

Component	Complaint (RAG)	Guidance requirement	Comment
Household night use (continued)			We are in a process of tendering for a review of plumbing losses and supply pipe losses.
		Continual monitoring and maintenance of IHM and SAMs monitors	We have a well-established process of actively monitoring and maintaining our SAM. This is to ensure that all issues are fixed promptly and a high number of areas is available and included in the analysis each month. We have reviewed our monitor last year and identified 22 monitors with too high meter penetration. These are currently in the process of being replaced. We have commissioned a trial to assess the use of fast logging technology on sample of our SAM. We will use results from the trial to decide whether we will roll this technology out to all our SAMs. Trial will be completed in FY18 and if successful will be rolled out in 2018/19 for inclusion in shadow reporting.
Non-household night use			**Overall status**
		The values of NHHNU night flow shall be used with values of night flow and HHNU for the same time period and on the same statistical basis to derive an estimate of leakage representative for the DMA or zone	NHHNU is derived using fixed hour consistent with minimum night flow analysis.
		It shall use its own data or shared data with proximate companies. National default values are not valid. Application of the 1999 UKWIR methodology with the appropriate time window as used for the night flow and the published outcome of further methodology development. It shall demonstrate that the stratification of non-households to a number of groups and consumption bands is representative of the varying characteristics of commercial and industrial properties. It shall demonstrate that the sample size is sufficient to capture night use by stratification with reasonable confidence. Development of a reliable and representative average billed volume (ABV) model based on data logging of the representative sample sufficient to capture demand variations with further seasonal logging where relevant. Continuously logged properties are unlikely to form part of the sample as these generally have greater consumption than the stratified samples. Direct linkage of the ABV model to a company's billing system or replacement database of billed volumes. Update the average billed volumes at least annually.	Our non-household night use model has recently been updated by an external consultant and the final report states that: *The model is now considered to be statistically stable and robust for reporting purposes, with an estimated error range in the order of +/- 10%. This is not expected to change significantly if additional samples were added, so additional sampling is not recommended at the current time*. We have commenced a project to identify our compliance against the requirements for continuously logging industrial customers. For each identified site we will look at the performance of the DMA the site is located in to understand whether there is any impact on the DMAs night line and additional logging is required.

Component	Complaint (RAG)	Guidance requirement	Comment
Non-household night use (continued)		The target threshold for continuous monitoring is where average demand of an individual non-household is greater than 24 to 48 m3/day (or night flow >1000 to 2000 l/hr) or 25% of a DMA night flow. A company should define its criteria, reflecting the impact of night use on the ability of a DMA to produce consistent and valid leakage estimates.	We have commissioned a piece of work to understand whether additional logging will be required.
Hour to day conversion			**Overall status**
		The hour-to-day factor shall be derived separately for each DMA or zone using pressure logging within each DMA. The factors shall be updated at least annually or where there are any significant changes to pressure regimes. As an alternative, hydraulic models can be used provided they have been updated to reflect the latest network reconfiguration and any pressure changes, and provided it is dis-aggregated in sufficient detail at sub-zone level.	We have DMA specific HDFs and these are routinely updated. A review is done each month for all discrete pressure areas (DPAs) where difference between static HDF (used for leakage calculations) and dynamic HDF (calculated in Netbase Summary Data application) is more than 5%. HDF is also updated following any change to the DMAs pressure regime. 98.2% of all properties are located within DPAs with permanent pressure logging. We are currently going through the process of temporary logging and updating default HDF values used in the remaining DPAs. We believe our process is very robust and the areas that are estimated are generally small and would only require an update of HDF following any changes to the pressure regime and annual updates would not bring any material change. Guidance should be updated to reflect that the update frequency should take account of area size and materiality of the change.
		An N1 value of 1.0 to 1.2 in the leakage – pressure power law relationship7 unless a company is able to demonstrate a higher or lower value would be more appropriate using its own data.	We currently use a default N1 factor of 1.25, this is not in line with the new guidance. We will look into updating N1 estimate and are currently assessing the best way to go forward. We are currently assessing the best way to update N1 factor we used in the HDF assessments.
Annual distribution leakage **Annual distribution leakage (continued)**		The average weekly data shall be derived from valid daily values of leakage using data points which are representative of the week. Where valid data is not available from three or more data points then the weekly data should be backfilled using the methods described in Section 5.4 – night flow analysis. The annual value of leakage expressed as Ml/d shall be derived from an average of the 52 week data.	Currently we use a minimum of the week to represent the weekly leakage value. Changing the way weekly average is calculated is a simple change of setting in our leakage management software.
Trunk main leakage		Company-specific data shall be used to assess the value of trunk main leakage. A proactive leakage monitoring approach shall be applied where trunk main losses form a significant element (>5%) of total leakage or the MLE water balance gap is greater than +/-2%. This approach shall be a combination of field inspections, analytical techniques, and flow balance methods. A company should have sufficient meters installed to allow flow	Our industry leading approach in calculating and managing trunk main losses fulfils the requirements of the guidance. We use tile balances and actual meter data to derive upstream losses for the entire Region. All the analysis and validation is carried out on a weekly basis by our upstream losses team.

Component	Complaint (RAG)	Guidance requirement	Comment
		balances to be calculated over 95% by volume of the trunk main network. The selection of methodology and level of leakage monitoring activities shall reflect the proportion of estimated losses in relation to total leakage and the characteristics of the network. Companies with trunk main losses greater than 5% of total leakage shall review and refresh estimates annually.	
Service reservoir leakage		Company-specific data shall be used to assess the value of service reservoir losses. Reservoirs with known high leakage, structural deficiencies or are at risk of water quality failures shall be investigated on an individual basis. Drop tests are an appropriate approach and normally carried out every five or ten years in parallel with ongoing routine reservoir inspection programmes. Drop tests shall be carried out for at least 12 hours depending on the size of the reservoir. All valves should be checked to ensure they are closed tight; and The extent of losses through reservoirs overflows should be investigated. Where reservoirs are shown to be at risk of overflowing, appropriate monitoring arrangements shall be put in place to control and minimise overflow events.	Please see comment for Trunk Main losses above. We use tile balance, therefore service reservoir losses are already included in our estimate of upstream losses. Valve checks and reservoir drop tests are part of the inspection criteria for service reservoirs. We have an ongoing service reservoir cleaning programme. We will ensure that these activities are logged against in Service Reservoir inspection.
Distribution input			**Overall status**
		Distribution input to the system shall be metered with at least daily readings at all defined locations. Meters shall be an appropriate size for the flow to be measured and located at appropriate inputs to the network confirmed by record plans. Any treatment works take-off downstream of a meter shall be excluded from the DI calculations; Data validity checks shall be carried out at least monthly. Any missing data shall be infilled using both pre- and post- data for the location over at least one month, extrapolated from pump hours or use of upstream or downstream meters.	All our DI meters are logged or on telemetry, sized appropriately for the flow and our DI figure accounts only for water delivered into the distribution network. We calculate and validate distribution input on a weekly basis and this enables us to quickly act in case there are any meter failures.
		The data transfer systems from meter output to central database shall be checked and validated on a risk-based frequency from one up to two years; Flow checks shall be carried out on DI meters consistent with the principles of the document 'EA Abstraction Good Metering Guide'9 and in particular the frequency of flow checking defined in Table 6.2 of the EA guide.	Distribution input meters are also used in tile analysis to derive upstream losses. This enables us to pick up and investigate any significant meter inaccuracies. A supply meter validation programme is being created and a steering group is being set up that will ensure this programme is being delivered and meters are verified in accordance with the EA guidelines.
Water delivered measured		Metered data as derived from a company's own billing system or from CMOS for non-households.	Metered data is derived from Alto (our billing system) for households and CMOS for non-households.

Component	Complaint (RAG)	Guidance requirement	Comment
		An estimate of supply pipe losses shall be included for internally metered properties consistent with the company's current assumption of supply pipe losses. Inclusion of any leakage allowance can be included where a rebate has been applied to a customer's bill. Meter under-registration shall be applied consistent with a company's own estimates. A company shall assume a meter under-registration not exceeding an average 3% unless it can evidence a higher value. Meter replacement consistent with a company's replacement programme.	We have not recently made any changes to the estimates of supply pipe losses. These are applied following current best practise. We are currently in the process of tendering for a review of supply pipe losses and plumbing losses estimates. For FY17 we have reported MUR of 1.67%, it is below the 3% threshold stated in the guidance. We have completed a series of meter verification tests for PR19 and will update our MUR model with results of these tests.
Water delivered unmeasured			**Overall status**
		The PCC surveys shall follow the principles set out in the UKWIR Report 'Best Practice for unmeasured per-capita consumption monitors 199910 and the more recent report Future Estimation of Unmeasured Household Consumption, UKWIR 201711	We follow the best practice in our assessment of unmeasured household consumption. We have commissioned a trial to assess the use of fast logging technology on sample of our SAM. We will use results from the trial to decide whether we will roll this technology out to all our SAMs. The trial will be completed in FY18 and if successful will be rolled out in 2018/19 for inclusion in shadow reporting.
		An estimate of PCC shall be derived from a company's own individual household monitor or small area surveys. It shall demonstrate that its survey is representative of the company as a whole; disaggregation of the sample by demographic factors, property type or similar factors represents good practice. Valid data from the survey shall be from at least 80% of monitors as an annual average measure. A company may develop and use an alternative survey as defined in the 2017 UKWIR Report. A SAM shall also comprise a representative sample of customer' characteristics. The sample size shall be sufficient to provide a statistically representative sample after allowing for outages. Quantify the uncertainty allocated to unmeasured household consumption and provide evidence to justify the uncertainty value used;	We use Small Area Monitor (SAM) to derive both night use and per household consumption. The monitor uses ACORN to stratify properties into six groups. The stratification is representative of the region in terms of proportion of each property type. Per household consumption (PHC) allowances are updated and statistical significance checked on a monthly basis.
		Where the proportion of metered properties in an area exceeds 50% of total properties then further data validity tests shall be applied.	We have reviewed our monitor last year and identified 22 monitors with too high meter penetration. These are currently in a process of being replaced and once commissioned our compliance with the guidelines will improve significantly. For any other monitors where meter penetrations exceeds the 50% stated in the guidance appropriate comments are made to justify inclusion of this monitor in the overall assessment.
		Continual monitoring and maintenance of IHMs and SAM monitors; Meters shall be selected to provide sufficient granularity to detect low continuous flows indicative	We have a well-established process of actively monitoring and maintaining our SAMs. This is to ensure that all issues are fixed promptly

Component	Complaint (RAG)	Guidance requirement	Comment
Water delivered unmeasured (continued)		of plumbing losses or leakage short duration flow variations. The value of meter under registration should be less than the company's average meter stock.	and high number of areas is available and included in the analysis each month. We update the estimate of MUR on an annual basis and it is consistent with the value used in the annual return.
		Estimate of plumbing losses shall be based on the company's own data.	We are in a process of tendering for a review of plumbing losses and supply pipe losses.
		Unmeasured non-household consumption: Where this reported volume is less than 2% of total non-household demand, data from a per property consumption study shall be refreshed every five years; Where reported volumes are greater than 2% of non-household demand, data from a property study shall be refreshed every two years.	We have completed a compulsory metering programme of all non-domestic properties. Currently approx. 9% of all our billed non-households are unmeasured. These properties remained unmeasured as it was either not possible to fit a meter (due to connectivity) or the cost of the work required to enable meter installation was too high. We have attempted to update our current allowances but due to the issues mentioned above we have been unsuccessful. Unmeasured non-household consumption currently accounts for just below 3% of total non-household demand.
Company own use			**Overall status**
		All sewage treatment sites and other key assets using greater than 10 m3/d (0.01 Ml/d) shall be metered.	We are currently working on a review of logging requirements for any of our own sites. We believe it is important to log sites that have significant impact on DMA flows and therefore leakage estimate. The impact on DMA leakage assessment and therefore leakage targeting and reporting should be the driver for additional logging requirement and not consumption threshold.
Company own use (continued)		An estimate of total company own use shall be included in the water balance, based on a clear methodology and actual data;	Our methodology of calculating operational use has remained unchanged for a number of years and it is audited for consistency and

Component	Complaint (RAG)	Guidance requirement	Comment
			robustness each year through a rigid audit and internal sign off process.
		Where an estimate of distribution operational use is greater than 0.6% of distribution input then this value needs to be clearly stated and justified. There should be no change to current assumptions unless clearly evidenced.	Operational use quoted for FY17 is below the 0.6% of DI threshold stated in the guidance.
Other own water use		Other use components should be based on a company's own data. Where an estimate of water delivered unbilled (legally and illegally) is greater than 1.8% of distribution input then this value needs to be clearly stated and justified. Estimates should be updated when there is a material increase or decrease to volumes.	Operational use quoted for FY17 was 2.1% of DI. Our methodology of calculating operational use has remained unchanged for a number of years and it is audited for consistency and robustness each year through a rigid audit and internal sign off process.
Water balance and MLE		Apply the MLE methodology and identify any water balance gap. Disclose and explain the reasons for any water balance gap exceeding 3% of distribution input. Any water balance gap in excess of the +5% gap, expressed as Ml/d, shall be added to the leakage component. Revisit all material components of the water balance where the water balance gap is >5% or < -5%.	Confidence limits used in the MLE analysis are consistent with the guidance. FY17 water balance gap was 2.4%, so below the 3% threshold quoted by the guidance.

Appendix D – Impact of metering on water consumption

Several studies have evaluated the effect of metering on water consumption and found that metered customers use less water than unmetered customers. Results from key studies can be summarised as follows:

- The National Metering Trials *(Water Metering Trials Final Report*, The National Metering Trials Working Group, 1993) covered 60,000 households in 12 trial areas across the country. It was primarily aimed at assessing the practicalities of metering on a large scale. Data on the effect of metering on water demand were assessed: there was a wide range in the results, with the average reduction in water use recorded as 11% (excluding the Isle of Wight which was a different type of trial);
- The subsequent UKWIR study *(The effect of metering on peak and average demand*, UKWIR, 1994) investigated the demand effects in more detail and observed a reduction in peak demands of about 30% in hot, dry summers and about 15% in cooler, wetter summers;
- National Economic Research Associates (NERA) *A Framework Methodology for Estimating the Impact of Household Metering on Consumption* for UKWIR (2003). The report includes a detailed literature review which concludes: "*We found the UK empirical literature on metering impact effects … usually suggests 10% to 15% savings in average demand follow from (compulsory) metering … Peak demand savings of differences were only very seldom suggested to be above 30%*.";
- As part of this work NERA carried out a detailed statistical study of the water consumption at over 1300 houses across England prior to and after opting to be billed as metered. The data was derived primarily from houses which had been part of household water consumption monitors and had subsequently taken up a meter option. The study found that meter optants tend to have significantly lower water consumption (before opting) than other billed unmeasured houses, and that water consumption reduced by an average of 9.6% after metering;
- NERA also carried out a similar detailed statistical analysis of water consumption before and after opting at 242 houses which had been part of our Household Consumption Monitor. The study (NERA, 2003) concluded that the average post-switching consumption is 91.7% of the pre-switching consumption for the same houses. This average demand reduction of 8.3% compares closely with the average value of 9.6% which NERA obtained for the country as a whole;
- Subsequently NERA carried out further analysis for UKWIR (2004). The report found that the demand reductions are sustained (and may increase) through time. There was no evidence of a "bounce-back" effect on demand even 3 years after opting;
- The UKWIR (2004) study found that the effect of metering on water consumption is greatest in summer months, with the largest average monthly reduction of 16.4% occurring in August; and
- A comprehensive review of studies on the effect of metering on water demand has been undertaken by Professor Herrington for UKWIR (2005). It concluded that the average demand reductions are typically in the 10% to 15% range for compulsory metering, and 9% to 21% for optional metering.

The work done by NERA in 2003 for UKWIR and United Utilities represents the most robust assessment in the UK to date as it is based on the most comprehensive data sets available and thorough detailed statistical analysis.

Appendix E – Further references and data sources

Guidance, methodologies and publications

Year	Report name	Author
1996	Climate change and the demand for water	Professor Herrington for Department of the Environment (now part of Defra)
2001	A scenario approach to water demand forecasting	Environment Agency
2002	Best Practice Principles in the Economic Level of Leakage Calculation	Tripartite Group
2002	Leakage Target Setting for Water Companies in England and Wales, known as the “Tripartite Report”	Ofwat, Tripartite Group
2003	The Impact of Household Metering on Consumption: Empirical Analysis (A Final Report for United Utilities Water)	National Economic Research Associates (NERA)
2003	CCDeW: Climate Change and Demand for Water	Downing et al
2005	Increasing the Value of Domestic Water use Data for Demand Management (Final Report P6832)	WRc plc
2006	Assessing the Cost of Compliance with the Code for Sustainable Homes (Final Report UC7231)	WRc plc
2007	International comparison of water and sewerage service	Ofwat
2007	Quinquepartite Report	Ofwat
2007	Providing Best Practise Guidance on the Inclusion of Externalities in the ELL Calculation	Ofwat
2008	Water and energy consumptions of dishwashers and washing machines: An analysis of efficiencies to determine the possible need and options for a water efficiency label for wet white goods	Waterwise
2008	Water Use in New Dwellings (Final Report P7694)	WRc plc
2011	Market Transformation Programme (MTP) BNWAT01 WCs: market projections and product details	Defra
2011	Market Transformation Programme (MTP) BNWAT02 Showers: market projections and product details	Defra
2011	Market Transformation Programme (MTP) BNWAT03 Baths: market projections and product details	Defra
2011	Market Transformation Programme (MTP) BNWAT04 Taps: market projections and product details	Defra
2011	Market Transformation Programme (MTP) BNWAT08: Modelling projections of water using products	Defra
2011	Market Transformation Programme (MTP) BNWAT22: Domestic water consumption in domestic and non-domestic properties	Defra
2011	Market Transformation Programme (MTP) BNW DW01: Dishwashers Government Standards Evidence Base 2009: Key Inputs	Defra
2011	Market Transformation Programme (MTP) BNW01: Combined Laundry: Government Standards Evidence Base 2009: Key Inputs	Defra
2012	Review of the calculation of sustainable economic level of leakage and its integration with water resource management planning	Defra, Environment Agency
2015	Sustainable Economic Level of Leakage (SELL) Prioritisation of the 2012 report recommendations	Environment Agency
2015	Good Practices on Leakage Management	EU Reference Document
2016	Water resources long term planning framework (2015-2065)	Water UK
2017	Planning for the future: a review of our understanding of household consumption (Final Report AR1170)	Artesia Consulting for Water UK: Water resources long term planning framework
2018	Water Resources Planning Guideline	Environment Agency

Key UK Water Industry Research (UKWIR) reports

Year	Manual/report name	Manual/report reference	Key components/elements that are informed/impacted
1995	Demand Forecasting Methodology	95/WR/01/1	A common methodology for UK water suppliers and their regulators to forecast water demands
1997	Forecasting Water Demand Components - Best Practice Manual	97/WR/07/1	Informed the approach for non-household consumption forecasting (see Section 3.3)
1999	Best Practice for Unmeasured Per Capita Consumption Monitor	99/WM/08/25	
2002	The Economics of Balancing Supply and Demand	02/WR/27/4	
2003	A Framework Methodology for Estimating the Impact of Household Metering on Consumption	03/WR/01/4	Informing meter optant forecasting, although we have worked with Artesia Consulting to develop an updated model (see Section 2.2.6)
2005	Towards Best Practice for the Assessment of Supply Pipe Leakage	05/WM/08/32	
2005	Natural Rate of Rise in Leakage	05/WM/08/33	
2006	Peak Water Demand Forecasting Methodology	06/WR/01/7	Deriving "peak" type demand uplifts (see Section 7.3)
2009	Assessment of the Significance to Water Resource Management Plans of the UK Climate Projections 2009	09/CL/04/11	Informed the "Impact of Climate Change on Water Demand" UKWIR project
2011	Managing Leakage	10/WM/08/42	
2012	Customer Behaviour and Water Use - A good practice manual and roadmap for household consumption forecasting	12/CU/02/11	Informed the "Household Consumption Forecasting" UKWIR project
2013	Impact of Climate Change on Water Demand	13/CL/04/12	Deriving climate change demand uplifts (see Section 7.2)
2014	Understanding Customer Behaviour for Water Demand Forecasting	14/WR/01/14	Informed the "Integration of Behavioural Change into Demand Forecasting and Water Efficiency Practices" UKWIR project
2015	WRMP19 Methods – Population, Household Property and Occupancy Forecasting	15/WR/02/8	Deriving population, household property and occupancy forecasts (see Section 2.1)
2015	WRMP19 Methods – Household Consumption Forecasting, previously Demand Forecasting Methods	15/WR/02/9	A key change for WRMP19 and informed the choice of approach for household consumption forecasting (see Section 2.4.1)
2015	Economics of Supply Pipe Leakage	15/WM/08/56	
2016	Integration of Behavioural Change into Demand Forecasting and Water Efficiency Practices	16/WR/01/15	Informed our customer behaviour, occupancy and ownership survey (see Section 2.1.3 and 2.4.3)
2016	WRMP 2019 Methods – Decision Making Process: Guidance	16/WR/02/10	Informed the thinking for our WRMP19 problem characterisation and approach selection, documented in our *Final WRMP19 Technical Report - Options appraisal*
2016	WRMP 2019 Methods – Risk Based Planning	16/WR/02/11	Informed the thinking for our WRMP19 problem characterisation and approach selection, documented in our *Final WRMP19 Technical Report - Options appraisal*
2017	Consistency of Reporting Performance Measures - Leakage	17/RG/04/5	

Web sources

- http://www.leakssuite.com/concepts/uarl-and-ili
- http://www.unwater.org/downloads/Water_facts_and_trends.pdf

Appendix F – Key demand related terminology and definitions

Term	Acronym (if applicable)	Meaning
Distribution input	DI	The total water put into supply, assessed from the water production flow meters at each of our water treatment works, and adjusted where appropriate to account for any potable water bulk supply imports and exports. The water production meters have been installed and are maintained in accordance with our asset standards for flow meters.
Measured		Household and non-household customers that have a meter that measures their consumption.
Total leakage		The total losses from a company's distribution system and customer supply pipes.
Netbase		Our corporate system to allow monitoring and management of leakage levels in each DMA.
District Meter Area	DMA	An area (of up to 3000 properties) where the supply to it is continuously monitored.
Demand Monitoring Zone (also known as Distribution Monitoring Zone)	DMZ	An area that is used to monitor losses and customer demand. They are largely historic, being loosely based on council boundaries, but all supply inputs and outputs are metered. DMZ size varies widely. They are now mainly used to monitor long-term trends.
Automated Meter Reading (also known as Automatic Meter Reading)	AMR	The technology of automatically collecting consumption data from water meters.
Per capita consumption	PCC	The average amount of water used by a person each day, generally presented as litres per person per day
Per household consumption	PHC	The average amount of water used in a household property each day, generally presented as litres per property per day
Water balance		Best practice is to estimate leakage and, therefore, demand for water, using two nationally agreed methods, the integrated flow approach (or "top down") or the minimum night flow approach (or "bottom up"). The difference in estimated demand for water between the "top down" and "bottom up" approaches is applied back to the components of demand using maximum likelihood estimation (MLE), based on the relative component uncertainty.

Appendix G – Local Authority Districts and Unitary Authorities

At the time of writing, our region comprises of just over 50 Local Authority Districts and Unitary Authorities (LADUA) and three National Park Authorities (NAP).

LADUA or NAP	Approximate % in our region	Local plan status as at June 2017	Local plan period as at June 2017
Allerdale	100.0%	Adopted	2011/2029
Barrow-in-Furness	100.0%	Draft	2012/2031
Blackburn with Darwen UA	100.0%	Adopted	2011/2026
Blackpool UA	100.0%	Adopted	2012/2027
Bolton[101]	100.0%	Consultation	2015/2035
Burnley	100.0%	Draft	2012/2032
Bury[101]	100.0%	Consultation	2015/2035
Calderdale	0.1%	Emerging	2015/2032
Carlisle	100.0%	Adopted	2013/2030
Cheshire East UA	100.0%	Examination	2010/2030
Cheshire West & Chester UA	72.3%	Adopted	2010/2030
Chorley	100.0%	Adopted	2010/2026
Copeland	100.0%	Adopted	2013/2028
Craven	28.0%	Consultation	2012/2032
Eden	99.9%	Examination	2014/2032
Flintshire UA	0.1%	Consultation	2015/2030
Fylde	100.0%	Examination	2011/2032
Halton UA	100.0%	Adopted	2010/2028
High Peak	68.3%	Adopted	2011/2031
Hyndburn	100.0%	Emerging	
Knowsley	100.0%	Adopted	2010/2028
Lake District	100.0%	Adopted	2010/2025
Lancaster	100.0%	Consultation	2011/2031
Liverpool	100.0%	Draft	2013/2033
Manchester[101]	100.0%	Consultation	2015/2035
Newcastle-under-Lyme	30.3%	Emerging	2013/2033
Northumberland UA	0.1%	Draft	2011/2031
Oldham[101]	100.0%	Consultation	2015/2035
Peak District		Adopted	2011/2026
Pendle	92.8%	Adopted	2011/2030
Preston	100.0%	Adopted	2003/2026
Ribble Valley	100.0%	Adopted	2008/2028
Rochdale[101]	100.0%	Consultation	2015/2035
Rossendale	100.0%	Adopted	2011/2026
Salford[101]	100.0%	Consultation	2015/2035
Sefton	100.0%	In examination	2012/2030
Shropshire UA	3.1%	Consultation	2016/2036
South Lakeland	99.9%	Emerging	
South Ribble	100.0%	Adopted	2010/2026
St Helens	100.0%	Consultation	2018/2033
Staffordshire Moorlands	17.7%	Emerging	
Stockport[101]	100.0%	Consultation	2015/2035
Tameside[101]	100.0%	Consultation	2015/2035
Trafford[101]	100.0%	Consultation	2015/2035
Warrington UA	100.0%	Adopted	2012/2027
West Lancashire	100.0%	Adopted	2012/2027
Wigan[101]	100.0%	Consultation	2015/2035
Wirral	100.0%	In preparation	2003/2028
Wrexham UA	0.1%	Draft	2013/2028
Wyre	100.0%	Emerging	2011/2031
Yorkshire Dales		Submission	2015/2030

[101] Part of the Greater Manchester Spatial Framework, which is a joint plan for Greater Manchester that will provide the land for jobs and new homes across the city region.

Appendix H – Population, number of properties and occupancy by property type

The tables below show the change in population, property and occupancy rate by type of customer and by resource zone[102].

Strategic Resource Zone	2016/17	2020/21	2025/26	2030/31	2035/36	2040/41	2044/45
Population (000's)							
Unmeasured	3,919	3,567	3,143	2,764	2,429	2,139	1,936
Measured (Optant)	1,193	1,453	1,807	2,151	2,482	2,795	3,033
Measured (Built Pre 2010)	925	917	895	875	858	843	833
Measured (Built Post 2010)	207	473	792	1,046	1,286	1,509	1,671
Demand Management	7	7	7	8	8	8	8
Non-Households	775	884	907	888	843	780	718
Total Population	7,027	7,302	7,551	7,732	7,906	8,075	8,199
Properties (000's)							
Unmeasured	1,700	1,545	1,374	1,218	1,079	955	867
Measured (Optant)	668	800	967	1,119	1,255	1,374	1,457
Measured (Built Pre 2010)	391	387	382	376	371	367	364
Measured (Built Post 2010)	88	200	338	450	557	656	729
Demand Management	4	4	4	4	4	4	4
Non-Households	158	155	163	164	165	166	166
Total Properties	3,008	3,092	3,228	3,331	3,431	3,522	3,588
Occupancy Rates							
Unmeasured	2.3	2.3	2.3	2.3	2.3	2.2	2.2
Measured (Optant)	1.8	1.8	1.9	1.9	2.0	2.0	2.1
Measured (Built Pre 2010)	2.4	2.4	2.3	2.3	2.3	2.3	2.3
Measured (Built Post 2010)	2.4	2.4	2.3	2.3	2.3	2.3	2.3
Demand Management	1.8	1.8	1.9	1.9	2.0	2.0	2.1
Non-Households (Measured)	4.9	5.7	5.6	5.4	5.1	4.7	4.3

[102] Note: Values may not sum exactly due to rounding

Carlisle Resource Zone	2016/17	2020/21	2025/26	2030/31	2035/36	2040/41	2044/45
Population (000's)							
Unmeasured	65	64	61	57	54	51	48
Measured (Optant)	11	14	17	20	24	27	30
Measured (Built Pre 2010)	18	19	18	18	17	17	17
Measured (Built Post 2010)	5	11	18	25	29	32	34
Demand Management	-	-	-	-	-	-	-
Non-Households	10	10	9	8	7	6	6
Total Population	110	117	123	128	131	133	134
Properties (000's)							
Unmeasured	30	29	28	26	25	24	23
Measured (Optant)	6	7	9	10	12	13	14
Measured (Built Pre 2010)	8	8	8	8	8	8	7
Measured (Built Post 2010)	2	5	8	11	13	14	15
Demand Management	-	-	-	-	-	-	-
Non-Households	5	5	5	5	5	5	5
Total Properties	52	54	57	60	62	63	64
Occupancy Rates							
Unmeasured	2.2	2.2	2.2	2.2	2.2	2.1	2.1
Measured (Optant)	1.8	1.9	1.9	2.0	2.0	2.1	2.1
Measured (Built Pre 2010)	2.3	2.3	2.3	2.3	2.3	2.3	2.3
Measured (Built Post 2010)	2.3	2.3	2.3	2.3	2.3	2.3	2.3
Demand Management	1.8	1.9	1.9	2.0	2.0	2.1	2.1
Non-Households (Measured)	2.2	2.2	2.1	1.9	1.6	1.4	1.2

North Eden Resource Zone	2016/17	2020/21	2025/26	2030/31	2035/36	2040/41	2044/45
Population (000's)							
Unmeasured	7.1	7.0	6.8	6.5	6.3	6.1	6.0
Measured (Optant)	1.1	1.3	1.6	1.8	2.0	2.3	2.5
Measured (Built Pre 2010)	2.7	2.7	2.7	2.6	2.6	2.6	2.5
Measured (Built Post 2010)	0.8	1.4	2.1	2.7	3.1	3.5	3.6
Demand Management	-	-	-	-	-	-	-
Non-Households	2.0	2.1	2.1	2.0	1.9	1.8	1.7
Total Population	13.7	14.6	15.2	15.7	16.0	16.2	16.3
Properties (000's)							
Unmeasured	3.3	3.2	3.1	3.0	2.9	2.8	2.7
Measured (Optant)	0.6	0.7	0.8	0.9	1.0	1.1	1.1
Measured (Built Pre 2010)	1.2	1.2	1.2	1.1	1.1	1.1	1.1
Measured (Built Post 2010)	0.3	0.6	0.9	1.2	1.4	1.5	1.6
Demand Management	-	-	-	-	-	-	-
Non-Households	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Total Properties	6.4	6.6	6.9	7.1	7.3	7.4	7.5
Occupancy Rates							
Unmeasured	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Measured (Optant)	1.8	1.9	1.9	2.0	2.0	2.1	2.2
Measured (Built Pre 2010)	2.3	2.3	2.3	2.3	2.3	2.3	2.3
Measured (Built Post 2010)	2.3	2.3	2.3	2.3	2.3	2.3	2.3
Demand Management	1.8	1.9	1.9	2.0	2.0	2.1	2.2
Non-Households (Measured)	2.4	2.6	2.5	2.4	2.3	2.2	2.1

Appendix I – Measured non-household consumption[103] by Standard Industrial Classification categories

The figures in the table below are in megalitres per day (Ml/d).

Sector	2016/17	2020/21	2025/26	2030/31	2035/36	2040/41	2044/45
Agriculture, horticulture, forestry & fishing	24	21	18	15	13	11	10
Extraction of minerals and energy producing materials	0	0	0	0	0	0	0
Food and drink (manufacture)	39	39	40	41	41	41	41
Textile, fur and leather (manufacture)	1	1	1	1	0	0	0
Other manufacturing	4	3	2	2	1	1	1
Paper (manufacture)	7	6	5	5	4	4	4
Fuel refining	3	4	5	6	8	10	12
Chemicals, rubbers, plastics and man-made materials (manufacture)	35	32	30	27	24	22	20
Non-metallic minerals (manufacture)	4	4	4	4	3	3	3
Basic metals, fabricated metal products and machinery (manufacture)	5	4	4	4	3	3	3
Transportation and manufacture of transport equipment	13	13	13	13	13	13	14
Electricity, gas and water supplies	8	8	8	8	8	8	8
Construction	1	1	1	1	1	1	1
Wholesale and retail	19	19	18	17	16	16	15
Hotels, bars and restaurants	42	43	44	45	46	46	47
Other services	75	75	76	78	79	81	82
Education and health	41	38	35	32	29	27	25
Unallocated	13	13	13	13	13	13	13
Total	334	323	317	311	305	301	298

[103] It's worth noting that these figures do not account for meter under-registration, as well as other reconciliations as part of the Water Balance process.