# Draft Water Resources Management Plan 2019

*Technical Report - Target headroom*

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## Contents

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## 1. Introduction

This document covers the approach to, and assessment of, uncertainty within the supply and demand forecasts for derivation of an appropriate target headroom allowance in our draft Water Resource Management Plan 2019 (WRMP19). Target headroom is the buffer which is incorporated into water resource planning to protect customers from the uncertainties associated with the supply and demand forecasting over the planning horizon. Specifically, it is defined in the UKWIR 2002 guidance[1] as:

> *"the minimum buffer that a prudent water company should allow between supply and demand to cater for specified uncertainties (except for those due to outages) in the overall supply-demand balance".*

Potential uncertainties include political, social, environmental, climate change and technical factors, such as the error associated with a measurement that may significantly influence components of the supply-demand balance.

The need for target headroom was recognised by the Environment Agency and water companies during preparation of the 1999 WRMPs, and was endorsed by government ministers in Maintaining Public Water Supplies (DETR, 1999) stating that a precautionary approach is necessary "in view of the vital importance of maintaining supplies". Principle Guidance from ministers (Defra, 2004) required water companies "to plan to have sufficient headroom and use appropriate methodologies and guidance to achieve this".

There have been some significant changes in the treatment of uncertainty in water resources planning since the 1998 guidance[2]. In particular, there are new methodologies for assessing the effects of climate change and the preparation of a new target headroom assessment methodology in 2012 (Water Resources Planning Tools). All assessments have been completed in line with the Environment Agency / Natural Resources Wales *Water Resources Planning Guidelines*[3] (or 'planning guidelines'), and the relevant supporting UKWIR methodologies.

Determining target headroom consists of the following basic steps:

- Collate data and information on each area of uncertainty in the supply and demand forecasts;
- Combine all of these data into a single distribution of uncertainty for each year in the planning period; and
- For each year, select an appropriate level of risk to incorporate into the supply demand balance.

These steps are described in detail in the following sections. Target headroom is not the only way that we deal with uncertainty in WRMP19. We also assess a number of supply-demand balance scenarios for stress-testing purposes. Some are linked to our target headroom assessment, for example our "high demand" scenario assumes that we would experience the maximum level of demand in our uncertainty window. Our scenario work is outlined in the *Draft WRMP19 Technical Report – Options appraisal*.

## 2. Methodology and approach

There are several methodology guidance documents which can be used to define the target headroom allowance. The 2002 methodology was developed by Mott MacDonald for UKWIR to address the acknowledged shortcomings of the previous, "practical methodology" produced by UKWIR in 1998. It provides a more robust and explicit assessment of headroom issues than the previous method. A new method of assessing the WRMP evaluation process has been published[4], the 'problem characterisation decision process'[5] which was used this time to decide how headroom was calculated. From the 'problem characterisation decision process' it was determined that the 2002 methodology was appropriate for this WRMP.

[1] An Improved methodology for assessing headroom – Report Ref No. 02/WR/13/2
[2] UKWIR (1998) A Practical Method for Converting Uncertainty into Headroom
[3] Water Resources Planning Guideline (Environment Agency, 2017)
[4] Water Resources Planning Tools 2012 – Report Ref. No. 12/WR/27/6
[5] WRMP 2019 Methods – Risk Based Planning – UKWIR Report Ref. No. 16/WR/02/11

For each of our resource zones the components were assessed and the data input into a model to calculate the final target headroom. Monte-Carlo analysis is used to combine the risks from each component of uncertainty to give an overall distribution for headroom uncertainty. This is achieved by running thousands of trials in which values for each uncertainty component are randomly selected from within the component distributions and then combined to give an overall headroom distribution.

The analysis is repeated for each year of the planning horizon. To produce a distribution of uncertainty from these distributions, percentiles are chosen to determine the level of uncertainty, balancing the risk and cost for the customer, company and environment. This involves consideration as to whether headroom alone is driving investment, or if it represents a significant proportion of a resulting deficit (Section 4). Another aspect is considering when in the time horizon the impacts are being driven, so that we aren't investing now for uncertainty that may reduce in time. The uncertainty (buffer) is added to the demand forecast.

## 2.1 Approach

The overall method and components remained the same as WRMP15 in line with the UKWIR (2002) methodology. The target headroom was calculated for each of the four resource zones (Strategic, Barepot, Carlisle and North Eden), over a 25 year planning horizon (2021-2045), and beyond to 2080.

The components suggested in the methodology to consider, and where appropriate, include in the calculation of target headroom are shown below:

**Supply related:**

- S1 Vulnerable surface water licences
- S2 Vulnerable groundwater licences
- S3 Time-limited licences
- S4 Bulk imports
- S5 Gradual pollution of sources causing a reduction in abstraction[6]
- S6 Accuracy of supply-side data
- S7 Single source dominance and critical periods
- S8 Uncertainty of impact of climate change on source yields
- S9 Uncertain output from new resource development

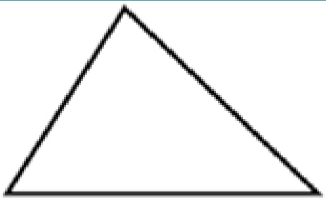
**Demand related:**

- D1 Accuracy of sub-component data
- D2 Demand forecast variation
- D3 Uncertainty of impact of climate change on demand
- D4 Uncertain outcome from demand management measures

A probability distribution has been developed for each component to quantify the extent and likelihood associated with the uncertainty, depending on their characteristics. See Table 1 for common probability distribution functions. When determining the supply and demand forecasts the confidence in each element of the forecast dictates the parameters of uncertainty. The triangular distribution is the most frequently used, with the upper and lower bounds defined by the supply and demand forecasting confidence. This link between all of the supply demand balance elements is an effective way of avoiding double counting uncertainty. Monte Carlo modelling was carried out (using @Risk Palisade software) for each resource zone on an annual basis over the planning horizon to determine the overall uncertainty distribution. For each resource zone, 10,000 trials were performed to derive the overall distribution for year.

[6] This is location specific, and dependant on the catchment management section of the guidance.

*Table 1 Common probability distribution functions (from UKWIR Water Resources Planning Tools (2012) Economics of Balancing Supply and Demand (EBSD) Report)*

| Type | Basic Shape | Description | Application |
|---|---|---|---|
| **Triangular** |  | Most easily defined continuous distribution. Defined by a least likely, most likely and maximum likely value. Can be skewed either way | Forecasting situations where the supply or demand value can be any value within a range and the most likely value can be estimated. May not be appropriate if highly skewed |
| **Normal** |  | Symmetrical continuous distribution defined by a mean and standard deviation | Most commonly applied to random uncertainties (known unknowns) |
| **Log-Normal** |  | Skewed continuous distribution defined by a mean and standard deviation | Forecasting situations where there is a large difference between the maximum and the most likely values such that a triangular distribution is considered unsuitable |
| **Exponential** |  | Continuous distribution defined by rate. Minimum value always equals 0 | Forecasting situations where the most likely and minimum values are zero, but there is a possibility of a large positive value |
| **Discrete/ Custom** |  | Non-continuous distribution defined by values and probabilities | Forecasting situations where specific values apply and values between do not. For example, chance events where the outcome is a particular value or zero |

There have been relatively minor changes and refinements to the methods used to calculate the uncertainties associated with each of the headroom components, the details of which are outlined in the following sections.

The target headroom components can be seen in the Section 3. Aside from a general refresh of the supporting datasets, for WRMP19 the headline changes in approach are:

- 2080s UKCP09 projections selected for calculating the impact of climate change on deployable output in line with the latest regulatory guidance and using the latest water resources and hydrological model outputs (WRMP15 used projections for the 2030s). As a major headroom component, this has been a key driver of change in distributions and the size of target headroom. More information on the detail of climate change assessment can be found in the *Draft WRMP19 Technical Report – Supply forecasting*;
- The accuracy of bathymetry data was added as an inherent supply-side uncertainty (albeit the impact of this addition is small);
- A refresh of the estimate of uncertainty based on the latest inflows[7] data, testing and appraisals. In particular, completing updates/revisions to inflow data and undertaking additional behavioural testing of the latest inflows methods. Better understanding of how hydrological data uncertainty differs between different inflow derivation types has been accounted for;
- As part of the latest demand forecasting, we explored whether other attributes of demand uncertainty should be included in item D2, for example, underground supply pipe leakage (USPL) and minor components; and
- As part of the change to water resource zones, consideration as to how the inclusion of West Cumbria supply area affects the Strategic Resource Zone.

[7] The calculation of unmeasured inflows into a reservoir from a water balance equation (change in storage plus compensation plus abstraction.

## 3. Components

A summary of the key supply and demand side uncertainty components included in the target headroom assessment is provided below.

### 3.1 Supply side components

This section outlines the uncertainty components for our supply forecasts (the baseline assessments are documented in the *Draft WRMP19 Technical Report – Supply forecasting)*. For the Strategic and Carlisle Resource Zones, the components which have been included in this section relate directly to the uncertainty in the inputs into the supply side modelling software, Aquator™ (this is a software package used to simulate our water resource systems in these more complex zones). Several aspects of the data input into the model are measured, the potential errors within these measurements are accounted for in this section of headroom. Not all of the components apply for North Eden and Barepot; where they do apply this has been called out and the uncertainty calculated.

#### 3.1.1 S1: Vulnerable surface water licences

In accordance with the planning guidelines, no allowance has been made for uncertainties surrounding reviews of our abstraction licences. We are in continual dialogue with environmental regulators regarding the sustainability of our abstraction licences and any potential future need for changes. The Environment Agency provides sustainability changes to the water companies via the Water Industry National Environment Programme (WINEP). Any potential changes are identified well in advance of any implementation, which also allows for a process of determining the most appropriate changes, further investigations and potential mitigations. With regards the Water Framework Directive, our assessment in the plan shows that whilst there is some residual risk associated with the current abstraction licences, overall the operation of the licences, the reductions already noted by the Environment Agency and the schemes identified for AMP6 should be enough to mitigate against any significant risks to the Water Framework Directive water bodies and they are therefore compliant with the requirements of the Water Framework Directive[8]. Therefore, on this basis there is no need to include this element in target headroom.

#### 3.1.2 S2: Vulnerable groundwater licences

The planning guidelines, as detailed above in Section 3.1.1, also applies to this section. Therefore, there is no need to include this element in target headroom.

#### 3.1.3 S3: Time-limited licences

The planning guidance states that '*time-limited licences which are due to expire during the period covered by the plan*' should be considered.

In dialogue with the Environment Agency we believe that renewal would occur if we were able to show:

- There is no damage to the environment;
- The need for the abstraction can still be justified; and
- Water is being used efficiently.

It is believed the only reason a licence would not be renewed would be due to a change in environmental conditions, such as climate change or where concerns are noted in relation to environmental objectives, e.g. Water Framework Directive (WFD). Engagement with the Environment Agency regarding renewing licences indicates there is not an issue at this time. The uncertainty in the impact of climate change is already accounted for in the headroom calculations in component S8. The only aspect which may potentially be incorporated into this component is Water Framework Directive. In conjunction with the Environment Agency, a review of the potential licences which may be affected has been undertaken. This work feeds into the WRMP as a supply demand scenario rather than target headroom uncertainty, and as such is outlined in the *Draft WRMP19 Technical Report – Supply forecasting*.

Abstraction reform has not been included as part of the headroom calculation, to ensure there is no impact on deployable output. This is in line with the planning guidance, *'you should not plan for any changes to deployable*

[8] Conclusion drawn from the *Draft Water Resources Management Plan 2019: Water Framework Directive Assessment* which is published alongside our *Draft Water Resources Management Plan 2019* and the accompanying technical reports.

*output as a result of abstraction reform'*. It also states not to include uncertainty about sustainability changes within headroom (which are included in the WRMP as a supply demand balance scenario).

#### 3.1.4 S4: Bulk imports

This is the uncertainty in the supply of an import into our network from another water company. All of our bulk imports are contractual agreements, and they have therefore been treated in the same way as our own abstraction licences with no uncertainty included in headroom. No issues with the availability of our imports has been raised as part our dialogue with the relevant companies.

#### 3.1.5 S5: Gradual pollution of sources causing a reduction in abstraction

This is the uncertainty in the deterioration of surface and groundwater sources due to pollution that will impact on the yield from that source. For this assessment the surface and groundwater sources were assessed separately; where the yield is constrained by licence or water treatment work capacity it was not included in the final data.

As part of the review of surface water sources, 21 catchments were highlighted within safeguard zones where there is deteriorating water quality (e.g. colour or algae). As well the safeguard zone designation with the Environment Agency, risks are also mitigated through local algae management plans, catchment management interventions (for example, through our Sustainable Catchment Management Programme (SCaMP)) and treatment capabilities at our water treatment works. Due to these mitigations, we have not identified the need to include potential uncertainty around loss of yield for this component at this time, and therefore these sites are not accounted for in this component of headroom.

All groundwater sources were reviewed to determine if there is uncertainty associated with the deterioration of:

- Groundwater quality due to natural processes or anthropogenic activities; and
- The physical structure of groundwater assets (boreholes, wells, adit systems), beyond general maintenance.

The review resulted in applying uncertainty associated with future deployable output due to water quality risks. This was forecast for three specific periods in time: start of planning period (2020/21), middle of planning period (2029/30) and end of planning period (2044/45). For the supply-demand balance, linear interpolation was used between these periods to scale the risk accordingly. The risk assessments were supported by analysis of historical and current trends of raw water pollution monitoring. This review took into account any catchment measures/investigations into the water quality and the potential reduction these projects have on the rate and severity of the pollution on the groundwater sources.

From the review it was determined that there was uncertainty associated with the deterioration of 23 boreholes in the Strategic Resource Zone and one borehole in the North Eden zone. Figure 1 shows the potential pollution identified for those boreholes in the Strategic Resource Zone where there is uncertainty in the level and timescale of deterioration.

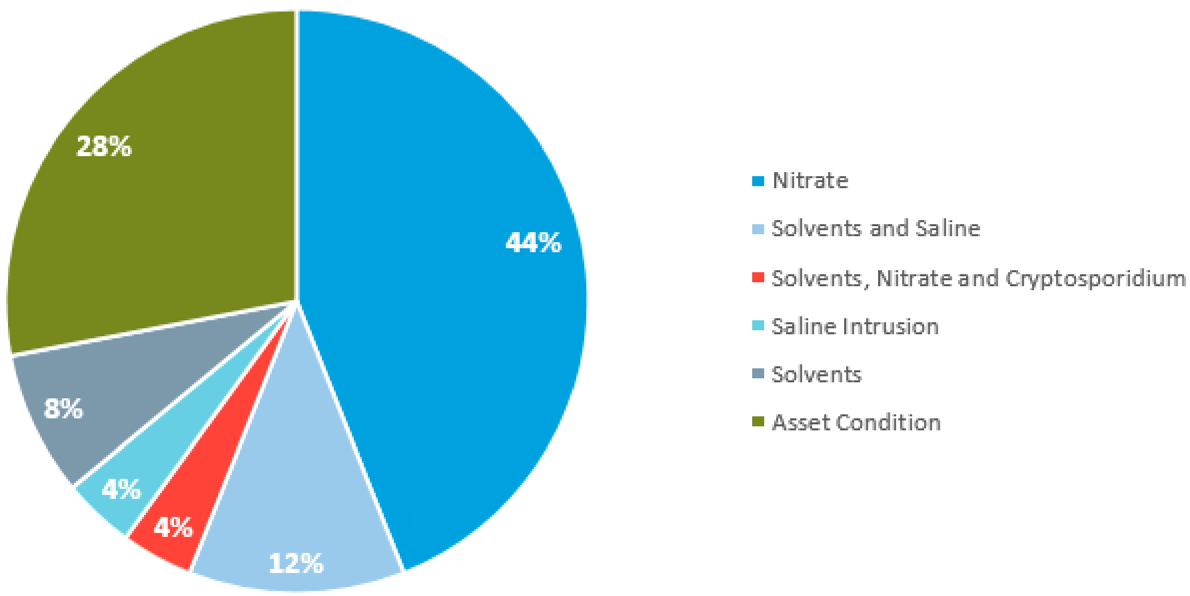



*Figure 1 The percentage of each type of pollution identified for the boreholes in the Strategic Resource Zone assessed as having a potential impact on deployable output*

### 3.1.6 S6: Accuracy of supply-side data

We identified several components in the supply capability calculations where there was uncertainty in the data, these are detailed below:

- Hydrological data uncertainty (inflows/time series data);
- Modelling and operational uncertainty;
- Process and raw water losses;
- Groundwater data uncertainty;
- Compensation over-release;
- Demand saving uncertainty; and
- Bathymetry uncertainty.

Depending on the resource zone in question, the categories detail above have been included.

#### *3.1.6.1 Hydrological data uncertainty (inflows/flow time series data)*

In our Aquator™ models the amount available for abstraction is determined from historic data which is based on inflows to reservoirs and flow time series for rivers and boreholes. There is an inherent uncertainty associated with inflow derivation methods and data used. The inflows and rainfall-runoff models have been refreshed, and where possible improved, sensitivity testing has also been carried out on the data. 10% uncertainty has been applied to the Strategic, Barepot and Carlisle Resource Zones; this is due to the potential error in the measurement of the source data and the water balance calculations undertaken. There are no inflows for North Eden, which consists only of boreholes, and the constraints are related to licence limits or physical capacities rather than hydrological constraints; therefore there is no uncertainty in this respect.

#### *3.1.6.2 Modelling and operational uncertainty*

The Aquator™ model is a water resources simulation package. It includes control curves / operating policies for reservoirs which are derived as a guide to protect against minimum historic inflows. Operating to these in drought events of differing hydrological patterns could result in less than 'optimal' operation without taking into account other 'real-world' factors in reality. In a drought event, decisions will be made operationally based on the evidence available and the availability of water resources across the zone at the time. An allowance has been made for this uncertainty in deployable output estimate to represent that, in a large conjunctive system, real-life decisions could vary from the operation in the model setup.

Sensitivity tests have been completed during the testing of our Drought Plan 2017, which supported agreements and further definition on our use of strategic pumped sources. Our representation of water resources management in this plan is consistent with the Drought Plan. This includes the outcomes of recent discussions with stakeholders on the operation of our strategic pumped sources.

For the Carlisle Resource Zone, in 2016 we undertook asset interventions to remove existing water quality constraints on River Eden to Castle Carrock pumping (to bolster the supply side of the balance). The project ensures that pumping the River Eden supply to Castle Carrock reservoir can be undertaken reliably at a higher storage level. Use of the pumps in line with the operation as specified in the Drought Plan has now become routine operation, and this removes an element of uncertainty around the support that the River Eden can provide to Castle Carrock included in WRMP15. Therefore, no operational uncertainty has been applied to this resource zone.

There is no model for the North Eden or Barepot Resource Zones therefore this component is not included in the headroom calculation for these zones.

#### *3.1.6.3 Process and raw water losses*

The uncertainty for process and raw water losses has been broken down into two elements: the process loss uncertainty and the raw water loss uncertainty. For the raw water loss element of the uncertainty, a Background and Burst Estimation (BABE) calculation was used, with an uncertainty of +/-25%. The process losses were calculated by breaking down where potential losses occur, through use of a questionnaire to the water treatment work (WTW) technical officers. Given the questionnaire style of data collection a 10% uncertainty was applied to the responses provided by the technical officers. The uncertainties calculated for the process loss and raw water loss for each WTW were then translated into the uncertainty for each water resource zone. For Barepot Resource Zone, no process losses were accounted for as it is non-potable water, with coarse screens being the only treatment.

#### *3.1.6.4 Groundwater data uncertainty*

For groundwater the uncertainty is in the hydrological data. It was found that for most sites the licence or physical asset capacities are the constraints. The uncertainty is based on the measurement of the groundwater data. A 10% uncertainty has been applied to the deployable output of the groundwater sources, this is supported by the groundwater assessments for climate change where most sources showed minimal sensitivity to groundwater levels.

#### *3.1.6.5 Over-release (compensation and hands-off flow)*

The uncertainty associated with the compensation over-releases consists of the:

- Accuracy of measurement of the river flows to identify an over-release to apply in supply modelling; and
- Variance around the over-release given operations to ensure that the statutory compensation amount is always released.

To calculate the compensation over-releases they were grouped into reservoir categories and an average of that category was then applied to all compensations within that grouping. The uncertainty was calculated as the minimum and maximum percentage over-release of the relevant category. We did not apply the statutory compensation as the minimum range, as it is expected that there would always be an over-release to ensure compliance with the licence.

For the hands-off flow buffer, a different method was used as it does not have a 1:1 ratio with the yield unlike the compensation releases. For the hands off flow, our Aquator™ model was used to calculate the deployable output with and without the buffers in the model. This has been individually modelled for both the Strategic and Carlisle Resource Zones, the North Eden Resource Zone sources are boreholes only. For Barepot Resource Zone this has not been included, as the deployable output is based on the minimum amount that could be abstracted from the river.

#### *3.1.6.6 Demand saving uncertainty*

As part of the Aquator™ model during periods of dry weather, customers are encouraged to become more water efficient and a saving is applied at drought trigger 4 as a demand saving reduction. Only the Strategic Resource Zone has demand saving applied; this is explained in the *Draft WRMP19 Technical Report – Supply forecasting*. The expected saving due to demand saving restrictions is subject to uncertainty, yet can have an impact on the assessment of deployable output. In the baseline Aquator™ model, a 5% saving at drought trigger 4 (mandatory temporary use ban) has been included throughout the year, in line with the Drought Plan 2017. Sensitivity testing determined the uncertainty, with a lower limit test of 3% saving at trigger 4 and an upper limit of 5% saving at trigger 3; this equates to a -31Ml/d and 12Ml/d range. Given historic data analysis there is no evidence that there are any significant demand savings from the implementation of temporary use bans in the Carlisle Resource Zone.

#### *3.1.6.7 Bathymetry uncertainty*

Bathymetry was added to the headroom calculation, as the uncertainty in this component can impact the overall reservoir storage, dead water storage and thus yield. We did this for completeness alongside inflows uncertainty. As with any measurement undertaken there is an inherent uncertainty in the equipment's accuracy. For a bathymetry survey it is a combination of multiple equipment accuracy, weather influence and human error. These are usually reported as part of the bathymetric survey reports and a review of our current bathymetric survey reports provided an uncertainty of the measurements undertaken. Using the uncertainty quoted an uncertainty percentage was calculated (+/- 1.47%). It was assumed that there was a one to one relationship between the storage and yield of the reservoirs.

### 3.1.7 S7: Single source dominance and critical periods

This is not included in the methodology as detailed in the 2002 UKWIR methodology[9] because it is already accounted for in the supply-demand balance in the outage calculation.

### 3.1.8 S8: Uncertainty of impact of climate change on source yields

Since the last plan there has been a significant change in the planning guidelines as to how to calculate the impact of climate change and incorporate it into the plan. The main change as detailed in the *Draft WRMP19 Technical Report – Supply forecasting*, is the calculation of the impact of climate change in 2080 and then scaling this back through the horizon to 1975. This results in a higher level of impact from climate change at the beginning of the planning horizon. Each of the water resource zones were analysed individually with varying levels of model complexity depending on the zone.

Due to the sheer number of projections, the complexity of the Strategic Resource Zone network and difficulties experienced during WRMP15, an emulator (simplified model) was created by Atkins using their Pywr software. This allowed 100 climate change scenarios to be modelled to help determine the shape of the headroom distribution (Figure 2). This is an enhancement over the WRMP15 method of modelling only 20 scenarios, which is a small number of values from which to create a distribution. Following this a representative 20 scenarios (see *Draft WRMP19 Technical Report – Supply forecasting*) were modelled using the detailed Aquator™ model to improve the position of the distribution.

In summary, we used a combination of a large number of Pwyr model runs with lower accuracy and a small number of Aquator™ scenarios with higher accuracy to get the best overall result with the computing resources available. The headroom uncertainty was calculated using the difference between the deployable output impact of climate change and the potential distribution of that impact.

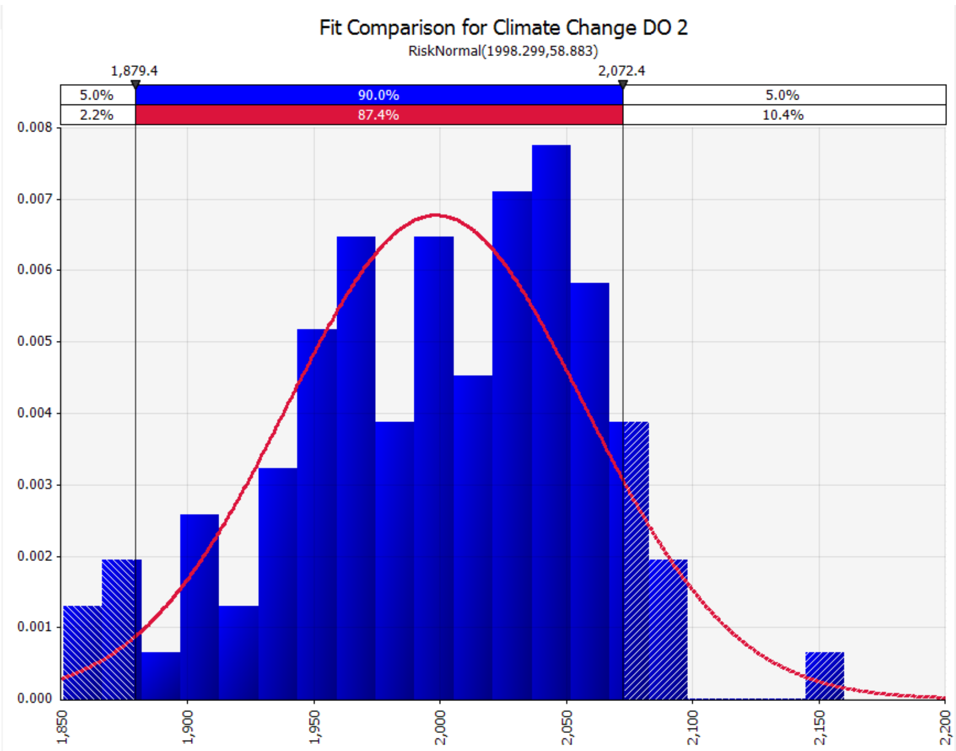
The climate change impact for the Carlisle Resource Zone was modelled using only an Aquator™ model and 20 scenarios. From this a discrete distribution was determined and applied to the headroom calculation. Building on our work in the Strategic Resource Zone, for future WRMPs we may look to increase the number of scenarios modelled to help define the shape of the distribution.

For the Barepot Resource Zone, the same approach as for the Carlisle Resource Zone was used. However, it found that there were negligible impacts of climate change on the zone and it was therefore not included in headroom.

For the North Eden Resource Zone, the climate change modelling showed that the constraints were the licences and physical asset capacities, and that any impact from climate change was not seen in the deployable output. Therefore, there is no climate change impact in the headroom calculations.

[9] An improved methodology for assessing headroom – Report Ref. No.02/WR/13/2




Statistics Grid

| | Input | Normal |
|---|---|---|
| Minimum | 1,850.79 | −∞ |
| Maximum | 2,160.21 | +∞ |
| Mean | 1,998.30 | 1,998.30 |
| Mode | ≈2,005.50 | 1,998.30 |
| Median | 2,005.50 | 1,998.30 |
| Std Dev | 58.88 | 58.88 |
| Skewness | -0.4089 | 0.0000 |
| Kurtosis | 3.0214 | 3.0000 |
| Left X | 1,879.4 | 1,879.4 |
| Left P | 5.0% | 2.2% |
| Right X | 2,072.4 | 2,072.4 |
| Right P | 95.0% | 89.6% |
| Dif. X | 192.91 | 192.91 |
| Dif. P | 90.0% | 87.4% |
| 1% | 1,850.79 | 1,861.32 |
| 5% | 1,879.44 | 1,901.45 |
| 10% | 1,911.91 | 1,922.84 |
| 15% | 1,938.65 | 1,937.27 |
| 20% | 1,953.93 | 1,948.74 |
| 25% | 1,955.84 | 1,958.58 |
| 30% | 1,967.30 | 1,967.42 |
| 35% | 1,971.12 | 1,975.61 |
| 40% | 1,984.49 | 1,983.38 |
| 45% | 1,997.86 | 1,990.90 |
| 50% | 2,005.50 | 1,998.30 |
| 55% | 2,013.14 | 2,005.70 |
| 60% | 2,024.60 | 2,013.22 |
| 65% | 2,030.33 | 2,020.99 |
| 70% | 2,037.97 | 2,029.18 |
| 75% | 2,041.79 | 2,038.01 |
| 80% | 2,049.43 | 2,047.86 |
| 85% | 2,057.07 | 2,059.33 |
| 90% | 2,066.62 | 2,073.76 |
| 95% | 2,072.35 | 2,095.15 |
| 99% | 2,085.72 | 2,135.28 |

*Figure 2 The Strategic Resource Zone distribution from the 100 emulator results*

### 3.1.9 S9: Uncertain output from new resource development

In the baseline supply-demand balances we are forecasting a surplus in all resources zones (see *Draft Water Resources Management Plan 2019*), hence there is no driver for new resource development in this context. However, we do have a strategic choice to continue to explore water trading (see *Draft Water Resources Management Plan 2019*) and, if it were to happen, this would likely involve new resource development. At this stage the nature and timing of trading options is still under development and as such we have not included an allowance for uncertainty in target headroom. In any case, uncertainty in the Strategic Resource Zone for trading options is dealt with in part through direct simulation of key uncertainties (drought risk and climate change) in the extended methods process[10]. Furthermore, as we consider the main uncertainty / risk would be linked to the effects of climate change, we included a specific analysis step in option secondary screening[11] to remove any options which were deemed as being at high risk from climate change.

[10] *Draft WRMP19 Technical Report – Options appraisal*
[11] *Draft WRMP19 Technical Report – Options identification*

## 3.2 Demand side components

A summary of the key demand side uncertainty components included in the target headroom assessment is provided below. Further information on the base assessments and a detailed account of uncertainty derivation is also included in the *Draft WRMP19 Technical Report – Demand for water*. The uncertainty has been informed through running scenarios / sensitivity testing when building the demand forecasting model.

### 3.2.1 D1: Accuracy of sub-component demand data

This reflects the fact that demand cannot be measured with total accuracy due to error in meters and measurement. To align with the uncertainty applied to our regulatory reporting data, an allowance of up to +/-1.02% of normal year demand (central forecast) has been applied to each of the resource zones using a triangular distribution to cover meter inaccuracies that may impact upon demand based data.

### 3.2.2 D2: Demand forecast variation

This section relates to a range of forecasting uncertainties in the household, non-household and minor components of demand. The *Draft WRMP19 Technical Report – Demand for water* gives an overview of how the central forecast for each component is derived. Around this central demand, upper and lower-bound forecasts were calculated for the uncertainty.

The upper target headroom forecast consists of the following factors:

- Unmeasured occupancy increases, associated with the Free Meter Option;
- Lower household consumption reduction, demand savings from the Free Meter Option and micro-component rates;
- Non-household consumption - 'Northern powerhouse' high economic growth scenario;
- Upper-bound 'dry year' uplift factor applied to household consumption/usage (+3%); and
- Five year maximum annual average value on minor components.

The lower forecast consists of the following factors:

- Use of "trend based" population and property forecast;
- Non-household consumption - Low economic growth scenario;
- Lower-bound 'dry year' uplift factor applied to household consumption/usage (-3%); and
- Five year minimum annual average value on minor components.

The variation between the upper, central and lower forecasts has been accounted for in the headroom assessments using triangular distribution.

This component was not relevant for the Barepot Resource Zone as it is a non-potable supply only.

### 3.2.3 D3: Uncertainty of climate change on demand

This uncertainty relates to the impact weather and climate change has on demand. For the upper forecast the 90$^{th}$ percentile impact and for the lower forecast the 10$^{th}$ percentile impact were used from the impact of Climate Change on Water Demand UKWIR project, accounting for the 'Northern Powerhouse' and 'lower' demand scenarios.

For the Barepot Resource Zone, based on historic trends in use, there is no clear weather/climatic response on the industrial consumption/usage and climate change impacts are assumed to be negligible.

### 3.2.4 D4: Uncertainty in benefit of demand-side solutions

As per new resource development (Section 3.1.9) there are no supply-demand balance drivers for demand-side solutions. However, we have a strategic choice to enhance leakage reduction and uncertainty / reliability has been a key factor in defining our leakage reduction programme (see *Draft Water Resources Management Plan 2019*). There is considerable uncertainty in some of our leakage reduction options, particularly those related to innovative technologies or third party suppliers. Whilst we are keen to explore these options, at this stage we are unable to determine the level of uncertainty associated them, but we plan to run a number of trials to help establish this.

## 3.3 Inter-dependency, correlation and mutual exclusion

### 3.3.1 Inter-dependency

As with WRMP15, no components are dependent on another component.

### 3.3.2 Correlation

In view of the positive correlation between climate change effects on demand and supply, a correlation coefficient of 0.75 has been applied in the Monte Carlo modelling for the S8 and D3 components. This allows for climate change effects resulting in concurrent higher demand and lower deployable output. This is consistent with the approach taken for WRMP15.

### 3.3.3 Mutual exclusion

As with WRMP15, no components are mutually exclusive.

# 4. Percentile Choice

Once all the components as detailed above have been input into the headroom model a percentile choice is incorporated into the calculation to determine the confidence or level of risk that we will plan for. Depending on the amount of surplus available in the supply-demand balance the percentile choice can determine the amount of investment that goes into the plan over the planning horizon; it is therefore a carefully considered choice. Our percentile choice has been informed by interpretation of our data (position of central forecast and uncertainty), industry benchmarking and aligning with the planning guidelines (or supporting UKWIR methodologies).

These glide paths ensure an appropriate balance between taking adequate measures to safeguard the reliability of supply to customers and the avoidance of unnecessary costs. The factors which influence the choice of risk levels include:

- **Customer requirement for reliable, continuous supply of water:** This requirement has been consistently expressed by customers, for example, in customer surveys undertaken for the WRMP and business plan;
- **Consequences of failure to provide adequate supplies:** These are likely to include more frequent temporary use bans or drought orders/orders than the target level of service, and an elevated risk of needing extreme measures such as rota-cuts, standpipes or bowsers in severe droughts. Each of these would result in adverse or potentially hostile reaction from customers. Significant extra costs are also incurred when the possibility of drought emerges. These costs include additional publicity and promotion of water efficiency, short-term uneconomic demand management activity, contingency works to increase water availability in locations most severely affected etc.;
- **Period of time required to plan and implement the optimal supply-demand solution (e.g. new water supply schemes, leakage reduction or other demand management programmes):** A higher risk can be adopted in longer term planning, beyond the scheme planning and implementation horizon, as there is an opportunity to wait and see how some of the uncertainties develop before needing to commence detailed planning;
- **The financial and/or environmental costs of providing supply-demand solutions:** The extent of financial and environmental costs may affect customers' willingness (or not) to accept a higher risk on the future achievement of the target level of service. For example, if major schemes with high costs are required to resolve potential future supply-demand uncertainties, customers may prefer that we delay expenditure until the issues are more certain, but if lower costs/impacts are involved customers are more likely to require that schemes be implemented to ensure adequate future levels of service; and
- **The scale of future uncertainties:** In accordance with regulatory guidance we have made no allowance for abstraction reform. Similarly, we have not sought to include uncertainty for unknown potential changes to environmental or other legislation.

We select a percentile for each year in the planning period. In the previous WRMP two separate "glide paths" of percentile choices were used in the final data, a constant 50$^{th}$ percentile for the climate change uncertainty component and 95-70$^{th}$ percentile (from 2020-2045 respectively) for all other components. This was due to the previous risk of undertaking significant future investment on the basis of very uncertain climate change analysis (carried over from WRMP09 to WRMP15). In WRMP19, however, we now have a better understanding of climate change uncertainty, and a 50$^{th}$ percentile choice would be inappropriate. We therefore decided to use the same glide path for all components.

For this plan a variety of glide paths were considered and sensitivity testing was carried out across the risk profile to identify the target headroom risk values from the probability distributions of headroom uncertainty, see Figure 3[12]. The graph shows the impact in Ml/d on the Strategic Resource Zone supply-demand balance depending on the percentile chosen. The higher the percentile chosen the higher the confidence in the uncertainty calculated and in the supply and demand data. This is one reason why the percentile paths usually decrease over the planning horizon, as there is less confidence that the uncertainty calculated in 25 years' time is as accurate as in five years. Another reason for the percentile to decrease over the planning horizon is so that the headroom does not drive potentially unnecessary investment, as described above in relation to climate change.

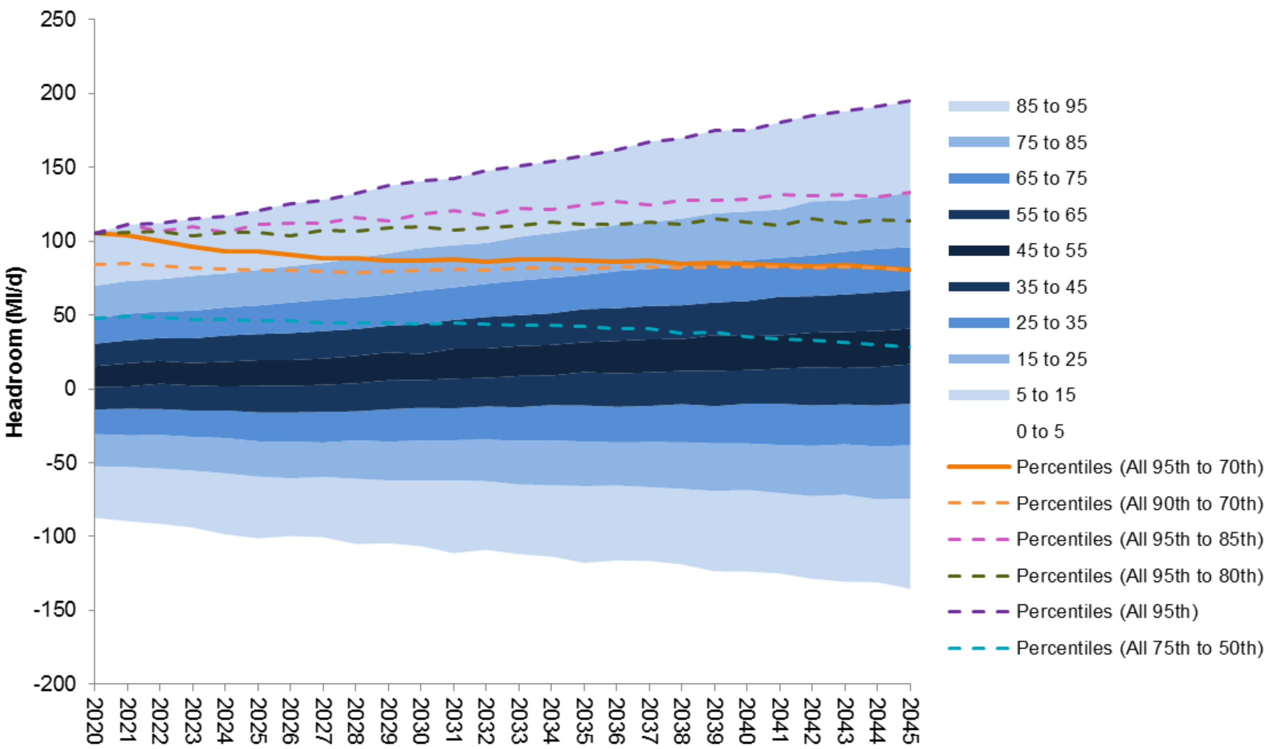



*Figure 3 Illustrative results for headroom uncertainty for the Strategic Resource Zone with various risk profiles considered*

A varying level of headroom risk over the planning horizon has been applied with a higher level of risk in future years than at present for the Strategic and Carlisle Resource Zones, 95$^{th}$ to 70$^{th}$ percentile (solid orange line in Figure 3). Therefore only 5% risk is applied at the beginning of the planning horizon (2019/20) and *via* an increasing profile, 30% at the end of the planning horizon (2044/45) as outlined in Table 2. This increase in profile is to account for the opportunity for our plans to be modified and adapted to changing circumstances, to prevent the risk of planning long-term investment on the basis of high uncertainty. This percentile choice does not trigger any deficit and hence investment in these resource zones.

A different approach of a continuous percentile choice of 5% uncertainty (95$^{th}$ percentile) was chosen for the North Eden and Barepot Resource Zones, see Table 3. Initially for the North Eden Resource Zone we applied the 95$^{th}$ to 70$^{th}$ percentile glide path, however, it resulted in a minuscule level of target headroom in 2045. Following engagement with the Environment Agency, a constant 95$^{th}$ percentile was applied throughout the planning horizon.

[12] In line with the UKWIR WR27 methodology

This reflects that the uncertainty in the North Eden Resource Zone does not increase into the future to the same extent as the Strategic and Carlisle Resource Zones as supplies are limited by abstraction licences and physical capacities rather than climate change. The situation is the same in the Barepot Resource Zone, hence the same principles and glide path were applied.

*Table 2 Summary of risk profile used to derive target headroom values for Strategic and Carlisle Resource Zones*

| | 2019/20 | 2029/30 | 2039/40 | 2044/45 |
|---|---|---|---|---|
| **Risk of understating the supply-demand balance** | 5% | 17% | 26% | 30% |
| **Headroom uncertainty percentile** | 95th percentile | 83rd percentile | 74th percentile | 70th percentile |

*Table 3 Summary of risk profile used to derive target headroom values for North Eden and Barepot Resource Zones*

| | 2019/20 | 2029/30 | 2039/40 | 2044/45 |
|---|---|---|---|---|
| **Risk of understating the supply-demand balance** | 5% | 5% | 5% | 5% |
| **Headroom uncertainty percentile** | 95th percentile | 95th percentile | 95th percentile | 95th percentile |

Figure 4 shows the illustrative results for headroom uncertainty for the Strategic Resource Zone as well as the results of the selected risk profile:

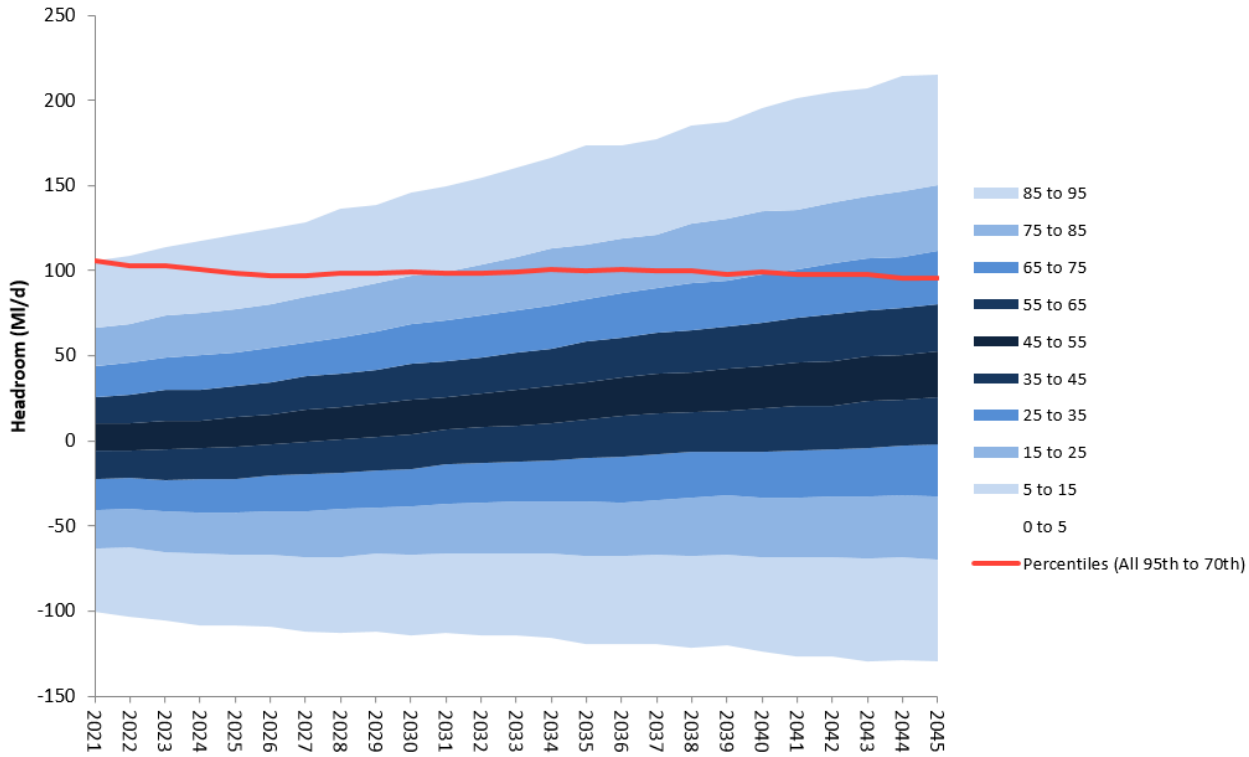



*Figure 4 Illustrative results for headroom uncertainty with risk profile for the Strategic Resource Zone*

## 4.1 Component breakdown across planning period

The breakdown of components that make up the target headroom across the planning horizon is shown for each of the resource zones in the figures below. For the Carlisle and Strategic Resource Zones there is a large influence from climate change; this is as expected due to the large proportion of water which comes from surface water. The other two major components are S6 and D2 the supply and demand forecast modelling uncertainty; a large proportion of this is due to the inherent uncertainty in modelling. Barepot Resource Zone is composed of only S6.

*Table 4 Summary of components*

| Supply Side | | Demand Side | |
|---|---|---|---|
| **S1** | Vulnerable surface water licences | **D1** | Accuracy of sub-component data |
| **S2** | Vulnerable groundwater licences | **D2** | Demand forecast variation |
| **S3** | Time-limited licences | **D3** | Uncertainty of impact of climate change on demand |
| **S4** | Bulk imports | **D4** | Uncertain outcome from demand management measures |
| **S5** | Gradual pollution of sources causing a reduction in abstraction[13] | | |
| **S6** | Accuracy of supply-side data | | |
| **S7** | Single source dominance and critical periods | | |
| **S8** | Uncertainty of impact of climate change on source yields | | |

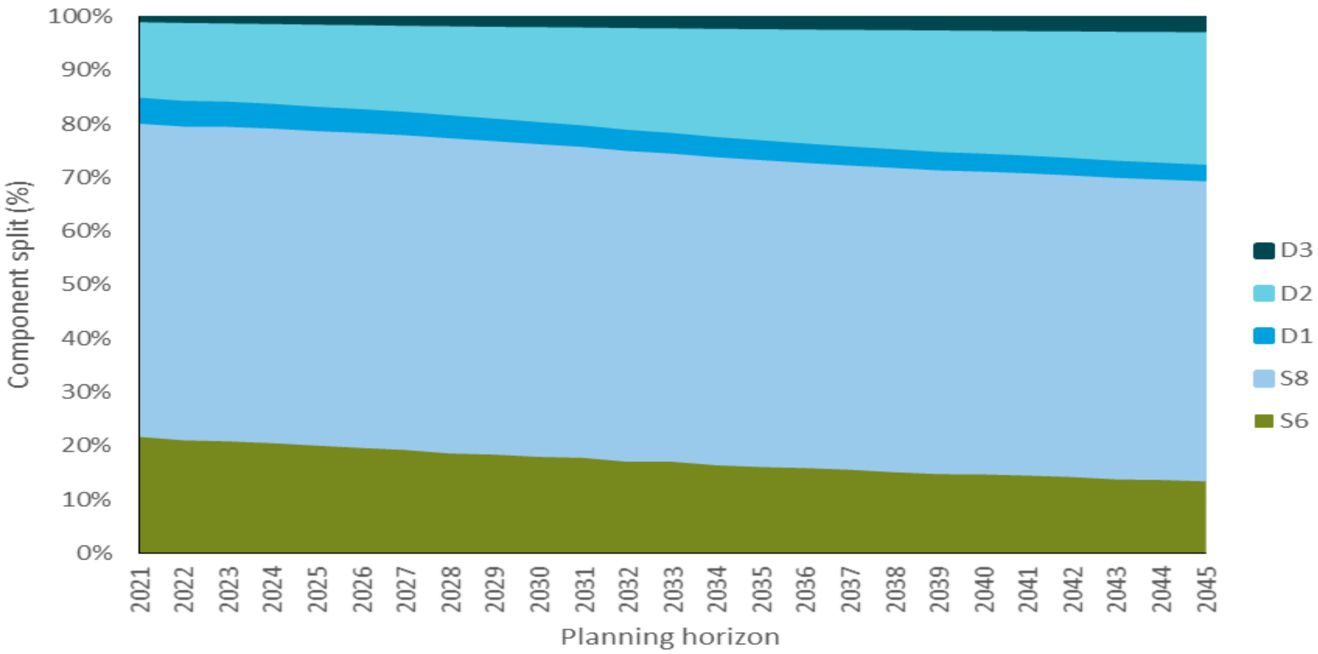



*Figure 5 Proportion of each component that makes up the target headroom across the planning horizon for Carlisle Resource Zone*

[13] This is location specific, and dependant on the catchment management section of the guidance.

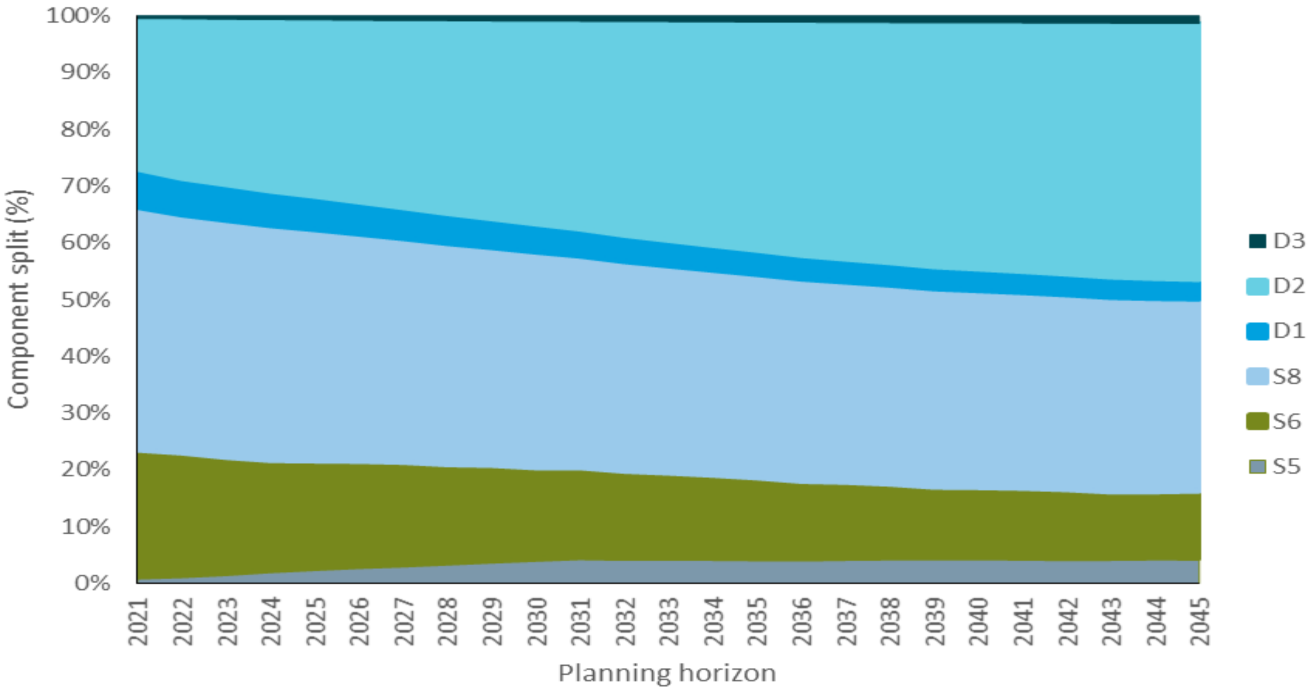



*Figure 6 Proportion of each component that makes up the target headroom across the planning horizon for Strategic Resource Zone*

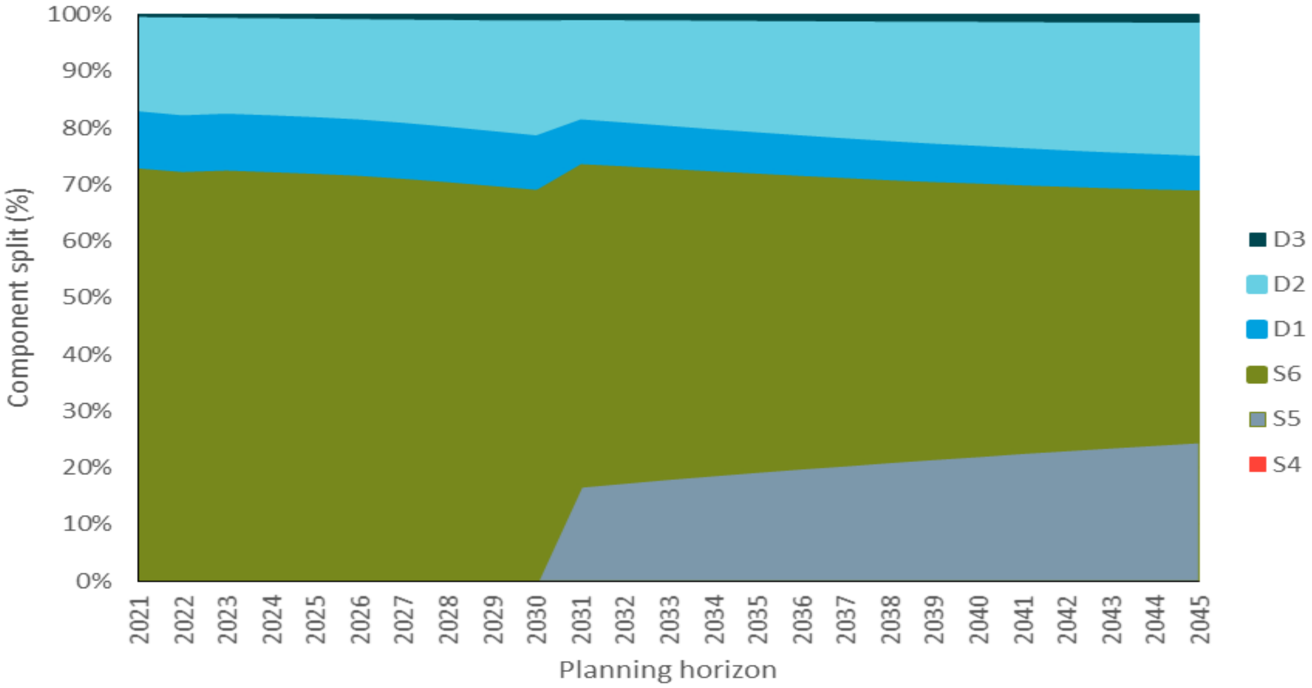



*Figure 7 Proportion of each component that makes up the target headroom across the planning horizon for North Eden Resource Zone*

## 5. Sensitivity analysis

As discussed previously, the risk profile we used to derive our headroom values for the Strategic and Carlisle Resource Zones reduces from the 95th percentile at the beginning of the planning horizon to the 70th percentile by the end of the planning horizon, i.e. less confidence in our supply-demand balance in the longer term. For the North Eden and Barepot Resource Zones a continuous 95th percentile was used.

Varying risk percentile profiles have been investigated on the impact of the baseline supply-demand balance. For the Strategic and Carlisle Resource Zones risk profiles of 95th to 80th percentile and 95th to 60th percentile were tested, Table 5 shows the resulting differences in supply-demand balance. The sensitivity testing showed that 95th to 70th percentile risk profile represented an appropriate level of confidence, with both zones remaining in surplus whilst ensuring a relatively high confidence in meeting the supply-demand balance.

If the 95th to 80th percentile risk profile had been chosen there would have been a deficit in the Strategic Resource Zone which would have driven investment, as shown in Figure 8. If we were to use the 95th to 80th percentile choice, it would drive investment around 2040, which could not be justified; i.e. we would be investing on the basis of future uncertainty which we would better understand in future WRMPs (process repeated every five years). However, it should be noted that if the strategic choice to implement further leakage reductions under the preferred plan is adopted (following consultation on the plan), that there is no supply-demand balance deficit under the 95th to 80th percentile choice.

*Table 5 The impact varying risk profiles have on the baseline supply-demand balance (Ml/d)*

| Water Resource Zone | Risk Percentile profiles | Target headroom values (Ml/d) | |
|---|---|---|---|
| | | 2020/21 | 2044/45 |
| Strategic | 95th to 80th | 105.8 | 129.5 |
| | 95th to 70th | 105.8 | 95.5 |
| | 95th to 60th | 105.8 | 66.5 |
| Carlisle (Critical Period)[14] | 95th to 80th | 2.55 | 2.07 |
| | 95th to 70th | 2.55 | 1.07 |
| | 95th to 60th | 2.55 | 0.27 |

[14] the Critical period is the time taken in our flashy resource zones for sources to go 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. Further detail in *Draft WRMP19 Technical Report – Demand for water*

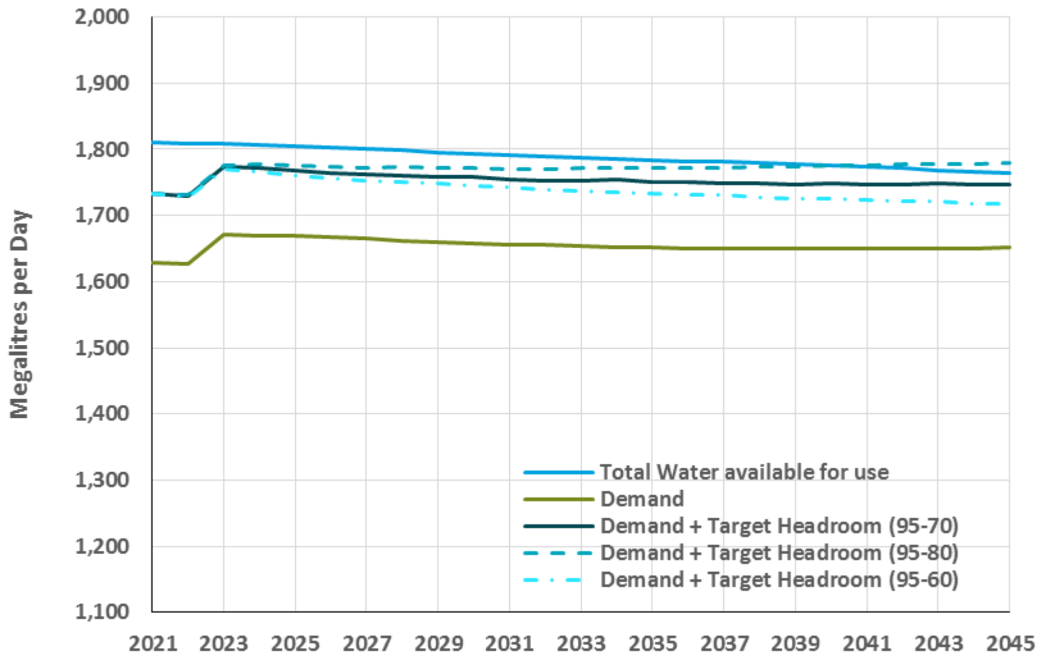



*Figure 8 Strategic Resource Zone baseline supply-demand balance with different risk profiles for target headroom*

For Carlisle the sensitivity testing shows that whichever risk profile was chosen the supply-demand balance would remain in surplus (as shown in Figure 9). On this basis the same risk profile was chosen as for the Strategic Resource Zone).

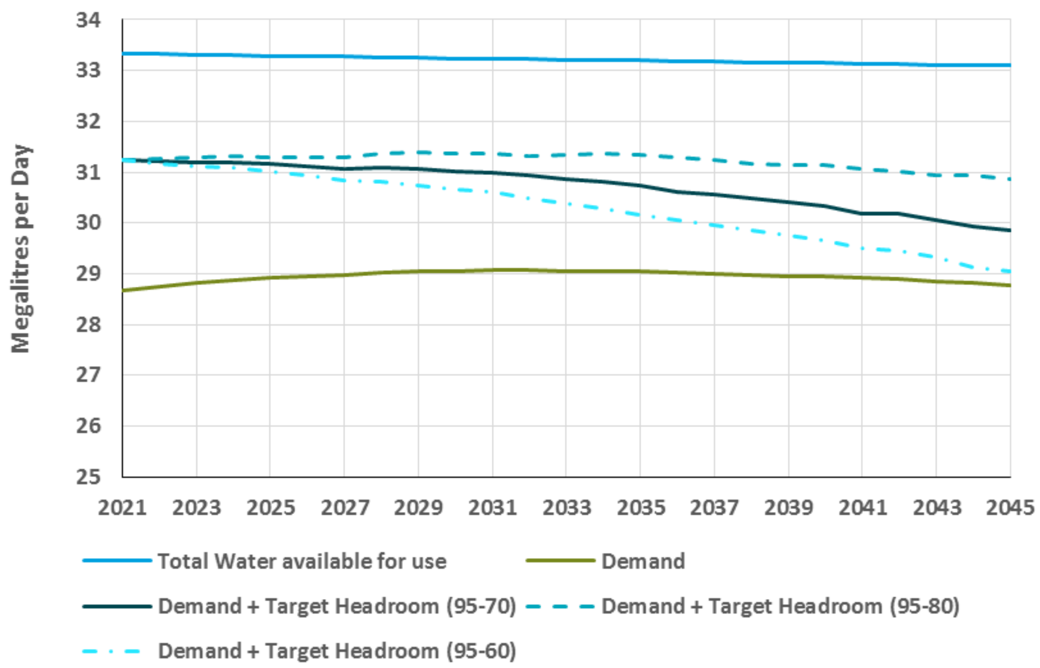



*Figure 9 Carlisle Resource Zone supply-demand balance with different risk profiles for target headroom*

## 6. Target headroom values

The calculated target headroom values required in the supply demand balance for each resource zone are summarised in Table 6.

*Table 6 Target headroom values*

| | 2020/21 | 2030/31 | 2040/41 | 2044/45 |
|---|---|---|---|---|
| **Strategic Resource Zone (Dry Year)** | | | | |
| Target Headroom (Ml/d) | 105.8 | 98.2 | 97.9 | 95.5 |
| % of water for available use | 5.8 | 5.5 | 5.5 | 5.4 |
| **Carlisle Resource Zone (Critical Period)** | | | | |
| Target Headroom (Ml/d) | 2.55 | 1.93 | 1.25 | 1.07 |
| % of water for available use | 7.7 | 5.8 | 3.8 | 3.2 |
| **Barepot Resource Zone (Dry Year)** | | | | |
| Target Headroom (Ml/d) | 1.41 | 1.41 | 1.41 | 1.41 |
| % of water for available use | 4.1 | 4.1 | 4.1 | 4.1 |
| **North Eden Resource Zone (Dry Year)** | | | | |
| Target Headroom (Ml/d) | 0.28 | 0.28 | 0.31 | 0.33 |
| % of water for available use | 2.8 | 2.8 | 3.2 | 3.3 |

## 7. Comparison with previous plan

Table 7 summarises the target headroom values derived for our WRMP15 which were published in the WRMP15 document. For Regulatory Reporting 2016, a revision was made to the supply-demand balance data due to the Met Office updating their weather-demand model, the updated headroom values are shown in Table 7. This has change been reported through the Annual WRMP process. Table 8 summarises the target headroom values calculated for this WRMP.

The main change as seen between Table 7 and Table 8 in the target headroom calculation is due to climate change; this can be seen in the graphs in section 4.1. There is minimal change in the North Eden Resource Zone figures which is mainly due to there being no impact from climate change applied. The other notable difference between the two tables is the resource zones. The West Cumbria and Integrated Resource Zones have been combined to make the Strategic Resource Zone for WRMP19 following the completion of the Thirlmere transfer.

*Table 7 Target headroom values in Ml/d derived for WRMP15 RR16 update - dry year uplift method, with risk profiles of continuous 50th percentile for climate change and 95th to 70th percentile for all other components*

| | 2015/16 | 2019/20 | 2024/25 | 2029/30 | 2039/40 |
|---|---|---|---|---|---|
| **Integrated Resource Zone** | 82.5 | 74.7 | 72.0 | 74.4 | 87.1 |
| **Carlisle Resource Zone** | 2.7 | 2.3 | 1.9 | 1.9 | 2.0 |
| **North Eden Resource Zone** | 0.3 | 0.2 | 0.2 | 0.2 | 0.3 |
| **West Cumbria resource zone** | 3.3 | 2.7 | 2.3 | 2.2 | 2.4 |

*Table 8 Target headroom values in Ml/d derived for WRMP19, with a risk profile for all components of 95th to 70th percentile for the Strategic and Carlisle Resource Zones and 95th percentile continuous risk profile for the North Eden and Barepot Resource Zones*

| | 2015/16 | 2019/20 | 2024/25 | 2029/30 | 2039/40 |
|---|---|---|---|---|---|
| **Strategic Resource Zone** | 84.8 | 101.5 | 98.7 | 99.2 | 99.0 |
| **Carlisle Resource Zone** | 2.4 | 2.6 | 2.3 | 2.0 | 1.4 |
| **Barepot Resource Zone** | 1.4 | 1.4 | 1.4 | 1.4 | 1.4 |
| **North Eden Resource Zone** | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |

## References

Department for the Envrionment, Food and Rural Affairs, 2004. Principle Guidance.

Department of the Environment, Transport and the Regions, 1999. Maintaining Public Water Supplies.

Environment Agency and Natural Resources Wales, 2016. *Final Water Resources Planning Guideline.* [Online].

Environment Agency and Natural Resources Wales, 2017. *Water Resources Planning Guideline: Interim update.* [Online].

UK Water Industry Report, 2002. *An Improved Methodology for Assessing Headroom, Report Ref. No.02/WR/13/2.* [Online].

UK Water Industry Research Limited, 2012. *Water Resources Planning Tools 2012, Report Ref. No.12/WR/27/6, Evaluation of New Methods for 2019 and Beyond.* [Online].

UK Water Industry Research, 1998. A Practical Method for Converting Uncertainty into Headroom.

UK Water Industry Research, 2016. *WRMP 2019 Methods - Risk Based Planning, Report Ref. No. 16/WR/02/11.* [Online].