

# Section 5

## Allowing for risk and uncertainty





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Section 5.

## Allowing for risk and uncertainty

- In this section we describe how we have assessed risk and uncertainty relating to our supply demand balance to calculate an allowance called target headroom.
- The components of target headroom are explained and baseline values are presented for each water resource zone (WRZ) for both average and peak scenarios.

### A. Introduction

5.1 Uncertainties are inevitable in the planning process and how uncertainty is handled is important in the formulation of a supply demand programme. In water resources planning, uncertainty is handled through the calculation of ‘target headroom’, defined as:

*“The minimum buffer that water companies are required to maintain between supply and demand in order to account for current and future uncertainties in supply and demand.”<sup>1</sup>*

5.2 Thus, target headroom is the minimum buffer that a prudent company should allow between supply and demand to cater for uncertainties in the overall supply demand balance and to meet its agreed level of service.

5.3 We use a statistical technique called Monte Carlo analysis to examine the uncertainty in specific elements of our supply and demand forecast.

5.4 In this process we examine the possible range of values (termed distribution) that elements of our forecast could take. We examine the uncertainty around both the supply and demand side forecasts and bring these values together to understand the range of uncertainty in our plan. We then choose a single allowance (target headroom) to allow for a proportion of this uncertainty.

5.5 This allows for the fact that we have more time to adapt to risks further into the future as they begin to become evident. Therefore we are able to accommodate more risk in our future plans. Our allowance for uncertainty is not fixed over time. We take less risk in the short term (5%) over the current AMP period and more risk in the long term (29%)<sup>2</sup>. The level of risk is

<sup>1</sup> UKWIR, WRMP19 - Risk Based Methods Guidance, 2015

<sup>2</sup> We make the choice about the level of risk we are prepared to accept as a business. The choice we believe is the best balance between the risks of supply failure and investing in assets before they are needed. Section G of this document and of Appendix V: Risk and uncertainty provides an explanation of our decision making process surrounding setting the level of target headroom risk.

fixed at 29% from 2044 as target headroom starts to decrease with an increase in the level of risk from this point onwards.

5.6 The remainder of this section is structured as follows:

- Introduction
- How the supply side uncertainty components are included in headroom
- How the uncertainty components of demand forecasting are included in headroom
- The baseline target headroom is presented for each WRZ

## B. Methodology and approach

5.7 Target headroom is the minimum buffer that a prudent company should allow between supply and demand to cater for uncertainties in the overall supply demand balance and meet its agreed level of service.

### *Methodology*

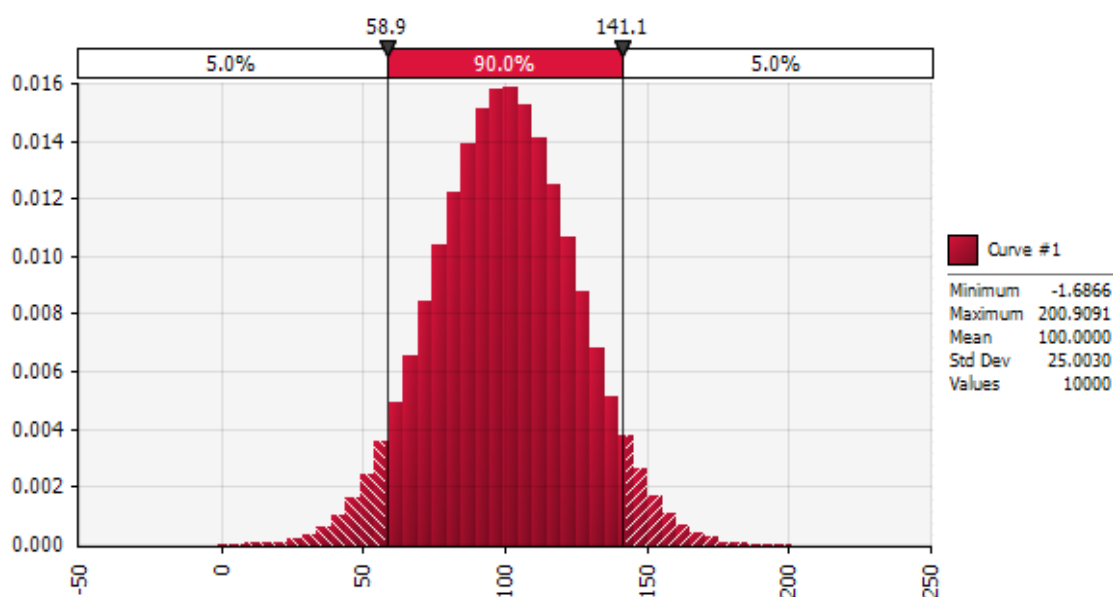
5.8 We use the ‘improved methodology’<sup>3</sup> in our assessment for all WRZs. We adopt this improved method to ensure we have an accurate estimate of uncertainty in our plan, given the importance of our plan to customer supply security and the number of customers we serve. The improved method uses a risk-based technique, full details of which are available in Appendix V: Risk and uncertainty. We are also addressing the vulnerability of our system to more extreme drought events through sensitivity analysis of the current Thames Water resource system and water resource options to different drought types than those in the historical record, as well as providing the basis for a more varied and robust assessment of climate change impacts through the modelling of stochastic weather patterns. This is explained in Appendix I: Deployable output and will be tested using various scenarios and development programmes.

5.9 The calculation of target headroom uses Monte Carlo simulation, a computerised mathematical technique that allows us to account for risk in quantitative analysis and decision making. Effectively it enables any chosen uncertain parameter, which up to this point would have had a deterministic (or specific chosen or calculated value), to be replaced with a range of potential values, defined by a statistical distribution. An example of a probability distribution is shown in Figure 5-1; it shows a probability density function (pdf). A pdf tells you the probability (value on the y-axis) that a random sample from the probability distribution will equal the corresponding value on the x-axis. The data in Figure 5-1 is purely illustrative, but you could suppose the x-axis represents the volume of water produced by a single borehole in MI/yr. The bar along the top (from left to right) shows there is a 5% chance that the borehole produces less than 58.9 MI/yr, a 90% chance it produces between 58.9 and 141.1 MI/yr and a 5% chance it produces more than 141.1 MI/yr.

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<sup>3</sup> UKWIR (2002) An Improved Methodology for Assessing Headroom

**Figure 5-1: An example distribution used in headroom modelling**



- 5.10 Once it has been decided which parameters are particularly uncertain and would better be defined by a probability distribution, models are used to run calculations thousands of times, taking a random sample from within the defined probability distributions.
- 5.11 This enables a probabilistic output to be produced (i.e. how likely is it that supply would be less than demand) and enables us to take an informed view on the level of risk we should allow for in our future planning. Should we take no risk and thus plan for sufficient headroom that even in an extreme case we will achieve our levels of service? Or is it more reasonable, particularly when looking decades into the future that we take more risk, confident that all the risk will not materialise, or that there will be time for us to act before the risk is realised?
- 5.12 Once calculated and a risk profile agreed, target headroom is added to the forecast of demand and compared with the water available for use (WAFU) to establish the available headroom or the gap in the baseline supply demand balance.

### ***Approach***

- 5.13 There are two stages at which target headroom is calculated. We assess uncertainty on both the supply side and the demand-side in separate models, and then draw them together using a Monte Carlo process to produce a combined uncertainty.
- 5.14 The initial assessment of headroom for the baseline supply demand balance does not include two of the headroom categories: S9 “Uncertain output from new resource developments”; and “Uncertain outcome from demand management measures”. The uncertainty associated with new resource developments and demand management measures is incorporated along with baseline uncertainty through the programme appraisal in the development of the preferred plan. This is described in Section 10: Programme appraisal.

- 5.15 The total volume of target headroom for a given WRZ in a given year may then be disaggregated into its component parts.
- 5.16 Below we discuss how we have accounted for the various supply side and demand side uncertainties acting on our plan.

## C. Supply side uncertainty

### *Components of supply side uncertainty*

- 5.17 The headroom components identified in the methodology that are supply-related are as follows:
- S1 - Vulnerable surface water licences
  - S2 - Vulnerable groundwater licences
  - S3 - Time-limited licences
  - S4 - Bulk imports/exports
  - S5 - Gradual pollution of sources (causing a reduction in abstraction)
  - S6 - Accuracy of supply side data
  - S8 - Uncertainty of impact of climate change on source yields
  - S9 - Uncertain output from new resource developments
- 5.18 S1, S2 and S3 components are not included in the analysis following guidance from the Environment Agency, as set out on page 26 of the 2017 Water Resources Planning Guidelines (WRPG)<sup>4</sup>. With regard to S1 and S2 the guidance states ‘You should not include any allowance for uncertainty related to sustainability changes to permanent licences’. With regard to S3 the guidance states ‘You may include an allowance for uncertainty related to non-replacement of time-limited licences on current terms’ however, following a review of our time-limited licences we have made a presumption of renewal with the exception of Bexley within our London WRZ where a risk of non-renewal has been identified and this has been included as an unconfirmed sustainability reduction (Section 4: Current and future water supply) and addressed through scenario testing during programme appraisal (Section 10: Programme appraisal).
- 5.19 Bulk imports/exports (S4): Our bulk supply imports and exports are subject to contractual agreements and as such we consider that the uncertainty around them is minimal. We do not include this component in our headroom assessment.
- 5.20 Gradual pollution (S5): With regard to gradual pollution we have reviewed the risk of our groundwater sources to gradual pollution and confirmed that there are no issues to include at this stage. This is due to the installation (or programmed installation) of suitable treatment processes for nitrates and cryptosporidium. In addition, we are working with the Environment Agency to develop suitable Catchment Management Plans that mitigate recognised issues.

<sup>4</sup>Environment Agency and Natural Resources Wales and also produced in collaboration with Defra, the Welsh Government, and Ofwat, Final Water Resources Planning Guideline, April 2017



We also have a specific risk of bromate pollution in London which we deal with separately; this is discussed below under new resource development (S9).

- 5.21 Accuracy of supply side data (S6): Data inaccuracy and scarcity of information may render estimates of deployable output (DO) unreliable and this uncertainty needs to be included in headroom uncertainty. The impact of data inaccuracy affects all sources but depends on the factors that are constraining DO. The following issues have been assessed for impact on each of the resource zones:
- Pump or infrastructure capacity
  - Abstraction licence limits
  - Aquifer characteristics for groundwater
  - Climate and catchment characteristics affecting surface waters
- 5.22 These issues are discussed in detail in Appendix V: Risk and uncertainty.
- 5.23 As part of the methodology for our Drought Plan we are required to introduce Temporary Use Ban (TUB) restrictions upon customers earlier than has historically been the case, based on the Lower Thames Control Diagram (LTCD). This is to allow time for the process of securing “regulatory permissions” such as Drought Orders and Drought Permits. As a result of imposing Level 3 restrictions (temporary use or hosepipe bans) in London at an earlier stage in a drought event, and earlier than in the defined methodology for determining DO, there will be a potential DO benefit.
- 5.24 However, the timing of the introduction of restrictions is subjective and the benefit will not necessarily always be there. By imposing restrictions upon customers earlier than in the methodology for determining the DO, a potential bias in favour of an increased DO is being introduced. To address this potential bias in the DO calculation and the supply demand balance, the “risk” can be included within the target headroom modelling with a negative skew, i.e. a reduction. The details are explained in Appendix V: Risk and uncertainty.
- 5.25 Climate change (S8): The uncertainty around climate change is discussed in the climate change sub-section below, with further detail contained in Appendix V: Risk and uncertainty.
- 5.26 New resource developments (S9): The uncertainty around new schemes has been assessed as part of the development of the final planning programme. Since no new resources are considered as part of the baseline this component has no impact on baseline target headroom. The risk around each scheme relates to changes in the DO of the scheme. Uncertainty is also estimated around the cost to deliver a new resource, but this does not contribute to target headroom and is discussed further in Appendix V: Risk and Uncertainty. A brief discussion of the process is provided in paragraphs 5.51 to 5.54 and the application of final plan target headroom is discussed in Section 10: Programme appraisal.
- 5.27 Northern New River Wells (NNRW): An additional uncertainty has been included within the target headroom modelling which relates to the risk to the NNRW sources from bromate pollution. The source of the bromate pollution is a former bromine chemicals factory at Sandridge, now redeveloped as a housing estate. The presence of bromate in the water pumped from the NNRW has meant that abstraction from these wells has had to be reduced in recent years to meet water quality standards. This is because current treatment facilities in north London cannot deal with the concentration of bromate in the water, which is also





exacerbated by the ozonation process at two works. The combined licensed output from the sources average 100.5 MI/d with an average Source Deployable Output (SDO) of 98.8 MI/d.

- 5.28 In 2005, a scavenging remediation scheme was implemented in conjunction with Affinity Water from one of their groundwater sources. This was done to assist remediation of the bromate plume in the chalk aquifer and also to manage the concentration of bromate reaching the NNRW sources. There is however a risk that the NNRW would not be able to deliver its output should there be a problem, for whatever reason, with the scavenging remediation scheme. As this is not an outage issue but represents a real risk to our resources and with no recognized way within the methodology of including the risk, it has been included as a risk to our resources within target headroom. The impact of the reduced output from the NNRW was evaluated by inputting this data into the Water Resources Management System (WARMS2) and comparing it with the value of DO before the change; here the London DO of 2,305 MI/d, derived using the optimised LTCD, is used as the base run. The results from which is a reduction in DO of 12 MI/d and for modelling expedience this is applied as the most likely impact in a triangular distribution within the target headroom analysis under the S9 functionality.
- 5.29 North London Artificial Recharge Scheme (NLARS): One of our strategic water resource schemes is the NLARS. This scheme abstracts water from a number of boreholes in the Lee Valley and discharges to the raw water system including from some boreholes to the New River and in some cases directly to reservoir. The nature of the scheme is to abstract water from the confined aquifer where output will decrease over time. Improved information on borehole performance, together with better information about the aquifer state of storage allowed an updated view of NLARS output at AR16; named NLARS Scenario 3. There remains a risk around what the scheme may actually be capable of during a drought thus two further scenarios of the output from NLARS have been evaluated (named 1 and 2) to aid the evaluation of the risk around NLARS. The impact of the modified output from NLARS for the two alternative scenarios was evaluated by inputting this data into WARMS2 and comparing with the value of DO before the change; here the London DO of 2,305 MI/d derived using the optimised LTCD is used as the base run. The risk is now in the range 15 MI/d to 17 MI/d and for modelling expedience these values are applied as the most likely and maximum impact in a triangular distribution within the target headroom analysis under the S9 functionality.

### ***Climate change***

- 5.30 Climate change is expected to lead to variations in patterns and frequencies of droughts, and other extreme weather events. The UK Climate Projections 2009 (UKCP09) reports that by the 2080s with medium emissions, "The biggest changes in precipitation in summer, are possibly down to about –50% by the 2080s, are seen in parts of the far south of England"<sup>5</sup>.
- 5.31 The impacts of climate change will be felt throughout our business, as shown in Figure 5-2. The potential impact on water usage and abstraction is of concern. Reduced or extreme variation in annual rainfall rates may mean that the yields from river or groundwater sources

<sup>5</sup> UK Climate Projections Online UKCP09 data

could be reduced and household water use could increase through increased garden watering and increased frequency of bathing and showering.

**Figure 5-2: The impacts of climate change on our business**



5.32 UKCP09 provides a large amount of information on how the UK climate may change over the next 100 years in response to different levels of greenhouse gas emissions. To understand the impact of the new scenarios on our assessments of supply and demand, HR Wallingford was engaged to develop a methodology to make the most use of the UKCP09 output data as practically possible. An outline of our climate change impact assessment is presented here and a detailed account of the methodology and how it has been applied is given in Appendix U: Climate change.

5.33 The updated climate change scenarios were launched by UK Climate Impacts Programme in June 2009 and provide 10,000 equally possible outcomes of future temperature and rainfall. The new projections are 'probabilistic' in that they encompass a wide range of possible changes in climate based upon the strength of evidence from observations, climate change models and expert opinion.

#### ***Basic vulnerability assessment***

5.34 The first stage of the analysis by HR Wallingford was to undertake a basic vulnerability assessment (BVA) of all our WRZs (HR Wallingford 2017)<sup>6</sup>. This is the first phase of analysis

<sup>6</sup> HR Wallingford, Thames Water climate change assessment and impacts on supply, March 2017



in a tiered approach to climate change analysis as outlined in the Environment Agency/UKWIR (2013) report<sup>7</sup>. Guildford and Henley WRZs have been identified as low vulnerability, Kennet and the Slough, Wycombe and Aylesbury (SWA) WRZs as medium vulnerability with the Swindon and Oxfordshire (SWOX) and London WRZs classified as high vulnerability, which required further “intermediate assessment”. Note the magnitude-sensitivity for SWOX was classified initially as medium vulnerability. However, given the interactions between London and SWOX, and SWOX’s vulnerability to short, intense droughts, it has been upgraded to high vulnerability.

#### ***Intermediate assessment***

- 5.35 The intermediate assessment involves the identification of current system vulnerability through the analysis of the causes and mechanisms of historic droughts.
- 5.36 The Water Resources Management Plan 2014 (WRMP14) approach to assessing climate change impacts was based around using climatological drought indicators to identify a sub-sample of 20 climate change scenarios. When a similar approach was applied for the 2080s, the detailed analysis presented in the HR Wallingford report suggests that the resulting sub-sample may not be as adequate for identifying an appropriate sub-sample to take forward to the DO assessment.
- 5.37 In order to identify a more robust sample of climate change scenarios, simplified London and SWOX water supply system models were used to simulate the full 10,000 member UKCP09 ensemble for the 2080s, Medium Emission scenario. This allows the impacts of each climate change scenario on water supply system performance to be calculated using a system-based metric, as opposed to relying on the drought indicator methods which were shown to be less reliable for the 2080s. The climate change impacts simulated using the simplified water supply system model are considered to much better reflect what their relative impacts would be when used in WARMS2 and therefore provide a better basis for identifying a sub-sample to take forward into the draft Water Resources Management Plan 2019 (draft WRMP19).
- 5.38 WARMS2 currently applies the Teddington flow factors to the Teddington and Days Weir natural inflows. It also uses a number of rainfall run-off models to simulate flows in various sub-catchments of the Thames. Thus when climate change factors of rainfall, evaporation and flows are input to the model, perturbed flows are generated and then used to calculate the flows of the various gauged and ungauged catchments throughout the model. It should be noted that in WARMS2, the greater proportion of flows are generated by rainfall-runoff models for gauged locations, where climate change impacts are simulated with the use of climate factors, and not through the use of flow factors. The simplified water supply system model demonstrates that by using only a single set of flow factors, as opposed to location specific hydrometric factors, the impacts of climate change on DO may be under-estimated by ~50 MI/day for London. This is because WARMS2 is more detailed and generates and accumulates flows from various points throughout the Thames catchment rather than from a limited number of locations.

<sup>7</sup> Environment Agency/UKWIR, Climate change approaches in water resources planning – Overview of new methods, 2013

- 5.39 The output from the HR Wallingford study is a sub-sample of 20 UKCP09 climate change scenarios that are considered to provide the most appropriate representation as to the range and likelihood of the projected climate change impacts in the London WRZ. The sub-sample has also been shown to be valid for the SWOX WRZ and is therefore considered to represent the most robust sample of scenarios to use.

#### ***Emissions scenarios***

- 5.40 The UKCP09 projections are available for three emissions scenarios; low medium and high, where for WRMP14 we used the medium emissions scenario to quantify the impact of climate change on our water resources. The Environment Agency's 2017 WRP Supplemental Guidance<sup>8</sup>, states that when using the Spatially Coherent Projections (SCPs) that a medium emission should be used as a minimum. This is also relevant when using the UKCP09 probabilistic scenarios that we have used for draft WRMP19, thus to be consistent with previous analysis at WRMP14 and be compliant with the guidance, the medium emission scenario has been used to assess climate change impacts for the 2080s. It should also be noted that we understand that the UKCP18 data will include a medium emission scenario but not a high scenario.

#### ***Assessment of climate change on groundwater***

- 5.41 We have undertaken the analysis of our groundwater source drought performance based on the UKCP09 data for the 2080s. Five scenarios from the 20 were selected to assess the groundwater system sensitivity to each of the potential futures. The scenarios were selected, based on their percentiles, to focus on drier potential futures, but also to consider wetter scenarios. The percentiles used are 99, 95, 90, 50 and 10. The rainfall and temperature climate change factors for each of the five scenarios were used to generate recharge scenarios for input into Environment Agency regional groundwater models covering the major aquifers of London and the Thames Valley. These models were then used to undertake hydrogeological analysis of the climate change impacts on the aquifers, specifically the impact on groundwater levels.
- 5.42 The groundwater level changes derived from this regional analysis of five scenarios for each of the groundwater sources were then used to assess the impact on groundwater SDOs. The SDO for the remainder of the twenty climate change scenarios was derived by interpolation. This interpolation was based on a relationship between SDO and modelled baseflow change in the River Thames at Teddington for each of the five successive pairs of discretely defined SDOs. This data based on the UKCP09 data for the 2080s is used to assess the central or "best estimate" impact of climate change on DO.

#### ***Climate change impacts on deployable output***

- 5.43 The amended groundwater SDOs together with the rainfall, potential evapotranspiration (PET) and flow factors were input to the WARMS2 to assess the impact on the DO for London and SWOX from the 20 climate change scenarios. The results of the groundwater analysis also provided the basis for the impact assessments for the other non-conjunctive use WRZs. The

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<sup>8</sup>Environment Agency, Estimating the impacts of climate change on water supply, April 2017



flow factors derived from the HR Wallingford work for the 2080s is the basis for the impact assessment on the Fobney DO in the Kennet Valley WRZ and Shalford DO in the Guildford WRZ, which are both river abstraction sources.

- 5.44 The methodologies developed have then allowed us to derive uncertainties around these possible outcomes such that target headroom can be calculated for London and the other WRZs. The uncertainty around the “best estimate” value is included in target headroom. We sought advice and peer review from notable experts in climate change including Professor Nigel Arnell (Director of the Walker Institute and Professor of Climate Science), Professor Jim Hall (Director of the Environmental Change Institute and Professor of Climate and Environmental Risk, University of Oxford) and Dr Steven Wade (Head of the Met Office’s Scientific Consultancy). It was decided that consideration of a discrete distribution of the climate change impacts was most appropriate as it takes into account the full variability of the calculated impacts. A discrete distribution was built into the target headroom models to be able to determine the uncertainty around the “best estimate” of the impact on DO.
- 5.45 Using the sub-sample of 20 climate change scenarios to assess the impact on the London DO gives a range of change by 2080s from –485 MI/d (dry scenario) to +204 MI/d (very wet scenario) with a ‘best estimate’ of the impact of –184.9 MI/d. This indicates that the more extreme changes could be highly significant for supply/demand long term planning. The ‘best estimate’ of the climate change impact has been calculated by modelling a discrete probability distribution function (pdf) using the variation in DO data and probability weightings. The target headroom model applies Monte Carlo techniques to determine the statistics from the discrete distribution and the mean impact value of -184.9 MI/d has been calculated as the ‘best estimate’ by 2085.

***Climate change uncertainty in target headroom***

- 5.46 The Environment Agency specifies that the ‘best estimate’ of the modelled climate projection is applied as a reduction in DO and the uncertainty around this projection is handled in headroom. The impact of the ‘best estimate’ scenario for each of the WRZs average DO is shown in Table 5-1 and for peak DO in Table 5-2.
- 5.47 In our current forecast the impact of climate change is greatest in London. This is also the zone where we have most customers.



**Table 5-1: Climate change impact on DYAA<sup>9</sup> DO**

WRZ	Reduction in DYAA DO due to climate change (MI/d)						
	2016/17	2019/20	2024/25	2029/30	2034/35	2039/40	2044/45
London	19.5	34.1	58.4	82.7	99.2	107.6	116.0
SWOX	1.11	1.95	3.34	4.74	5.68	6.16	6.64
Kennet Valley	0.42	0.74	1.26	1.79	2.15	2.33	2.51
Henley	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SWA	0.19	0.33	0.57	0.80	0.96	1.04	1.12
Guildford	0.00	0.00	0.00	0.00	0.00	0.00	0.00

WRZ	Reduction in DYAA DO due to climate change (MI/d)					
	2049/50	2059/60	2069/70	2079/80	2089/90	2099/00
London	124.4	141.2	158.0	174.8	191.6	208.4
SWOX	7.12	8.09	9.05	10.01	10.98	11.94
Kennet Valley	2.69	3.06	3.42	3.78	4.15	4.51
Henley	0.00	0.00	0.00	0.00	0.00	0.00
SWA	1.21	1.37	1.53	1.70	1.86	2.02
Guildford	0.00	0.00	0.00	0.00	0.00	0.00

<sup>9</sup> DYAA – Dry Year Annual Average



**Table 5-2: Climate change impact on DYCP<sup>10</sup> DO**

WRZ	Reduction in DYCP DO due to climate change (MI/d)						
	2016/17	2019/20	2024/25	2029/30	2034/35	2039/40	2044/45
London	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SWOX	1.27	2.22	3.81	5.40	6.48	7.02	7.57
Kennet Valley	1.21	2.12	3.64	5.15	6.18	6.70	7.22
Henley	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SWA	0.12	0.22	0.37	0.53	0.64	0.69	0.74
Guildford	0.00	0.00	0.00	0.00	0.00	0.00	0.00

WRZ	Reduction in DYCP DO due to climate change (MI/d)					
	2049/50	2059/60	2069/70	2079/80	2089/90	2099/00
London	N/A	N/A	N/A	N/A	N/A	N/A
SWOX	8.12	9.22	10.32	11.41	12.51	13.61
Kennet Valley	7.75	8.79	9.84	10.89	11.93	12.98
Henley	0.00	0.00	0.00	0.00	0.00	0.00
SWA	0.80	0.90	1.01	1.12	1.23	1.34
Guildford	0.00	0.00	0.00	0.00	0.00	0.00

<sup>10</sup> DYCP - Dry Year Critical Peak



5.48 The difference around this “best estimate” value is used to create discrete distributions for both groundwater and surface water climate change impacts for each year of the planning period within each WRZ. The uncertainty around the “best estimate” value is derived from the target headroom model and the results shown in Table 5-3 and Table 5-4.

**Table 5-3: Uncertainty around climate change in target headroom for DYAA**

WRZ	Climate change uncertainty for DYAA target headroom (MI/d)						
	2016/17	2019/20	2024/25	2029/30	2034/35	2039/40	2044/45
London	29.7	51.6	78.2	95.3	95.1	83.0	76.8
SWOX	2.27	4.00	5.22	6.03	5.69	5.20	4.57
Kennet Valley	0.59	1.11	1.92	2.65	2.59	2.41	2.17
Henley	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SWA	0.36	0.66	0.97	1.18	1.15	1.09	0.95
Guildford	0.00	0.00	0.00	0.00	0.00	0.00	0.00

WRZ	Climate change uncertainty for DYAA target headroom (MI/d)					
	2049/50	2059/60	2069/70	2079/80	2089/90	2099/00
London	76.8	76.8	76.8	76.8	76.8	76.8
SWOX	4.57	4.57	4.57	4.57	4.57	4.57
Kennet Valley	2.17	2.17	2.17	2.17	2.17	2.17
Henley	0.00	0.00	0.00	0.00	0.00	0.00
SWA	0.95	0.95	0.95	0.95	0.95	0.95
Guildford	0.00	0.00	0.00	0.00	0.00	0.00





**Table 5-4: Uncertainty around climate change in target headroom for DYCP**

WRZ	Climate change uncertainty for DYCP target headroom (Ml/d)						
	2016/17	2019/20	2024/25	2029/30	2034/35	2039/40	2044/45
London	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SWOX	2.69	4.85	6.53	7.56	7.48	7.00	6.25
Kennet Valley	0.72	1.33	2.10	2.90	2.84	2.42	2.06
Henley	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SWA	0.39	0.69	1.06	1.34	1.31	1.25	1.15
Guildford	0.00	0.00	0.00	0.00	0.00	0.00	0.00

WRZ	Climate change uncertainty for DYCP target headroom (Ml/d)					
	2049/50	2059/60	2069/70	2079/80	2089/90	2099/00
London	N/A	N/A	N/A	N/A	N/A	N/A
SWOX	6.25	6.25	6.25	6.25	6.25	6.25
Kennet Valley	2.06	2.06	2.06	2.06	2.06	2.06
Henley	0.00	0.00	0.00	0.00	0.00	0.00
SWA	1.15	1.15	1.15	1.15	1.15	1.15
Guildford	0.00	0.00	0.00	0.00	0.00	0.00



5.49 Therefore it can be seen that the total impact of climate change on the supply demand balance for the DYAA conditions is as presented in Table 5-5 and for the DYCP conditions in Table 5-6.

**Table 5-5: Total impact of climate change for DYAA**

WRZ	Climate change impact for DYAA target headroom (MI/d)						
	2016/17	2019/20	2024/25	2029/30	2034/35	2039/40	2044/45
London	49.2	85.7	136.6	178.0	194.3	190.6	192.8
SWOX	3.38	5.95	8.56	10.77	11.37	11.36	11.21
Kennet Valley	1.01	1.85	3.18	4.44	4.74	4.74	4.68
Henley	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SWA	0.55	0.99	1.54	1.98	2.11	2.13	2.07
Guildford	0.00	0.00	0.00	0.00	0.00	0.00	0.00

WRZ	Climate change impact for DYAA target headroom (MI/d)					
	2049/50	2059/60	2069/70	2079/80	2089/90	2099/00
London	201.2	218.0	234.8	251.6	268.4	285.2
SWOX	11.69	12.66	13.62	14.58	15.55	16.51
Kennet Valley	4.86	5.23	5.59	5.95	6.32	6.68
Henley	0.00	0.00	0.00	0.00	0.00	0.00
SWA	2.16	2.32	2.48	2.65	2.81	2.97
Guildford	0.00	0.00	0.00	0.00	0.00	0.00



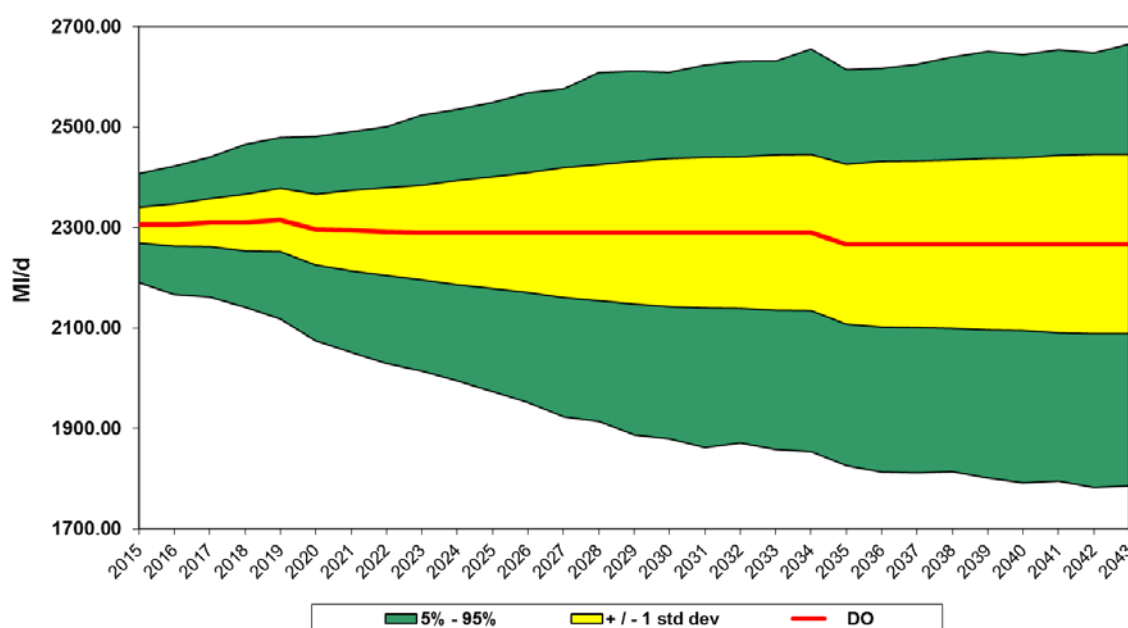
**Table 5-6: Total impact of climate change for DYCP**

WRZ	Climate change impact for DYCP target headroom (MI/d)						
	2016/17	2019/20	2024/25	2029/30	2034/35	2039/40	2044/45
London	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SWOX	3.96	7.07	10.34	12.96	13.96	14.02	13.82
Kennet Valley	1.93	3.45	5.74	8.05	9.02	9.12	9.28
Henley	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SWA	0.51	0.91	1.43	1.87	1.95	1.94	1.89
Guildford	0.00	0.00	0.00	0.00	0.00	0.00	0.00

WRZ	Climate change impact for DYCP target headroom (MI/d)					
	2049/50	2059/60	2069/70	2079/80	2089/90	2099/00
London	N/A	N/A	N/A	N/A	N/A	N/A
SWOX	14.37	15.47	16.57	17.66	18.76	19.86
Kennet Valley	9.81	10.85	11.90	12.95	13.99	15.04
Henley	0.00	0.00	0.00	0.00	0.00	0.00
SWA	1.95	2.05	2.16	2.27	2.38	2.49
Guildford	0.00	0.00	0.00	0.00	0.00	0.00

5.50 The target headroom methodology shows climate change to be the most significant uncertainty on the supply side. In London the direct impact on average DO is around 19.5 MI/d at the start of the planning period increasing to around 116.0 MI/d by 2044 and climbing to 208.4 MI/d by 2099. When the uncertainty on this is taken into account the combined impact is ~49 MI/d at the start increasing to ~193 MI/d by 2044 increasing to ~285 MI/d by 2099. The range of potential uncertainty around DO is shown in Figure 5-3.

**Figure 5-3: London DYAA supply side baseline headroom uncertainty**



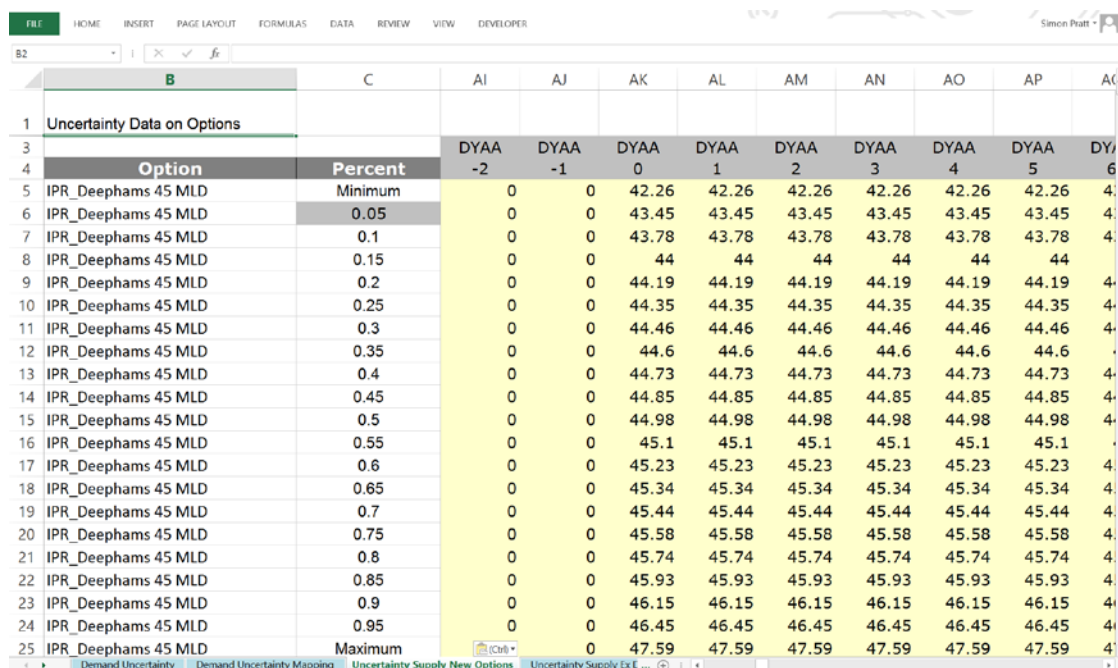
***New resource development uncertainty***

5.51 The inclusion of new resource schemes within the preferred programme, or any other considered as part of programme appraisal, will include elements of uncertainty over the actual DO produced by that scheme under the planning scenario delivered and also the cost of delivering the scheme. In essence the scope of the scheme, the assets constructed, are considered to be fixed and equal to that identified in Appendix R: Scheme dossiers. Note that cost uncertainty is not considered as part of the target headroom calculation and is discussed further in Section R: Scheme dossiers.

5.52 The uncertainty around scheme yield has been assessed using the judgement of expert hydrologists and hydrogeologists supported by assessments made by our engineering partner Mott MacDonald in Appendix R: Scheme dossiers. The judgement is made initially at generic option type level. That assumption is then applied, challenged and reviewed for each option of that type. For example, DO under the DYAA planning scenario for all aquifer storage and recovery (ASR) schemes will be normally distributed with a mean of the deterministic scheme yield and a standard deviation of 15% of the deterministic scheme yield. That assumption is then scrutinised for each individual ASR scheme and amended if justified. All estimates and associated justification are captured in Appendix R: Scheme dossiers.

- 5.53 Our Economics of Balancing Supply and Demand (EBS+D) system accepts information about scheme uncertainty in a time series for DO produced by the scheme starting from the first year of scheme delivery (i.e. planning or construction) through to 80 years after delivery. Data is presented in years relative to planned scheme delivery, i.e. year = 0 is the year in which the scheme is planned to first produce new resource. In this way the time series is able to reflect uncertainty about both timing and yield. We have not included uncertainty around scheme timing in our target headroom analysis. For schemes which are time limited (e.g. the extension of the Didcot bulk supply agreement from 2020 to 2030) the uncertainty around DO ceases in the same year the scheme is expected to cease providing water.
- 5.54 For each year an uncertainty distribution is characterised by percentile outputs in 5% increments as shown in Figure 5-4, a screen shot of the data upload file. EBS+D then interpolates the value of the distribution between these points and samples from the interpolated distribution when calculating required target headroom.

**Figure 5-4: Screenshot of EBS+D data import file, new resource uncertainty data**



Option	Percent	DYAA -2	DYAA -1	DYAA 0	DYAA 1	DYAA 2	DYAA 3	DYAA 4	DYAA 5	DYAA 6
IPR_Deephams 45 MLD	Minimum	0	0	42.26	42.26	42.26	42.26	42.26	42.26	42.26
IPR_Deephams 45 MLD	0.05	0	0	43.45	43.45	43.45	43.45	43.45	43.45	43.45
IPR_Deephams 45 MLD	0.1	0	0	43.78	43.78	43.78	43.78	43.78	43.78	43.78
IPR_Deephams 45 MLD	0.15	0	0	44	44	44	44	44	44	44
IPR_Deephams 45 MLD	0.2	0	0	44.19	44.19	44.19	44.19	44.19	44.19	44.19
IPR_Deephams 45 MLD	0.25	0	0	44.35	44.35	44.35	44.35	44.35	44.35	44.35
IPR_Deephams 45 MLD	0.3	0	0	44.46	44.46	44.46	44.46	44.46	44.46	44.46
IPR_Deephams 45 MLD	0.35	0	0	44.6	44.6	44.6	44.6	44.6	44.6	44.6
IPR_Deephams 45 MLD	0.4	0	0	44.73	44.73	44.73	44.73	44.73	44.73	44.73
IPR_Deephams 45 MLD	0.45	0	0	44.85	44.85	44.85	44.85	44.85	44.85	44.85
IPR_Deephams 45 MLD	0.5	0	0	44.98	44.98	44.98	44.98	44.98	44.98	44.98
IPR_Deephams 45 MLD	0.55	0	0	45.1	45.1	45.1	45.1	45.1	45.1	45.1
IPR_Deephams 45 MLD	0.6	0	0	45.23	45.23	45.23	45.23	45.23	45.23	45.23
IPR_Deephams 45 MLD	0.65	0	0	45.34	45.34	45.34	45.34	45.34	45.34	45.34
IPR_Deephams 45 MLD	0.7	0	0	45.44	45.44	45.44	45.44	45.44	45.44	45.44
IPR_Deephams 45 MLD	0.75	0	0	45.58	45.58	45.58	45.58	45.58	45.58	45.58
IPR_Deephams 45 MLD	0.8	0	0	45.74	45.74	45.74	45.74	45.74	45.74	45.74
IPR_Deephams 45 MLD	0.85	0	0	45.93	45.93	45.93	45.93	45.93	45.93	45.93
IPR_Deephams 45 MLD	0.9	0	0	46.15	46.15	46.15	46.15	46.15	46.15	46.15
IPR_Deephams 45 MLD	0.95	0	0	46.45	46.45	46.45	46.45	46.45	46.45	46.45
IPR_Deephams 45 MLD	Maximum	0	0	47.59	47.59	47.59	47.59	47.59	47.59	47.59

## Summary

- 5.55 We have used the improved methodology for calculating the impact of uncertainty on the supply side of our supply demand balance. The work shows that the impact of climate change is the most significant uncertainty on the supply side. We have undertaken considerable work to understand the impact. The Environment Agency guidance does not allow the uncertainties of future ‘unknown’ sustainability reductions to be included in our plan. As explained in Section 4: Current and future water supply, these could be significant. As such we have tested our plan against this using scenario analysis as detailed in Section 10: Programme appraisal and scenario testing.

## D. Demand side uncertainty

### ***Components of demand side uncertainty***

- 5.56 The demand-related headroom components identified in the methodology are as follows:
- D1 – Uncertainty in base year data
  - D2 – Demand forecast variation
  - D3 – Uncertainty of climate change on demand
  - D4 – Uncertainty of demand management measures
- 5.57 We have undertaken analysis of demand uncertainty using Monte Carlo simulation to understand the uncertainty around the deterministic demand forecast. We describe this briefly in the “Demand uncertainty overview” section below, before examining the individual components D1 to D4. For further detail see Appendix V: Risk and uncertainty.
- 5.58 The approach we have used is consistent with the current UKWIR guidance<sup>11</sup> which is recommended by the Environment Agency’s 2017 WRPG.

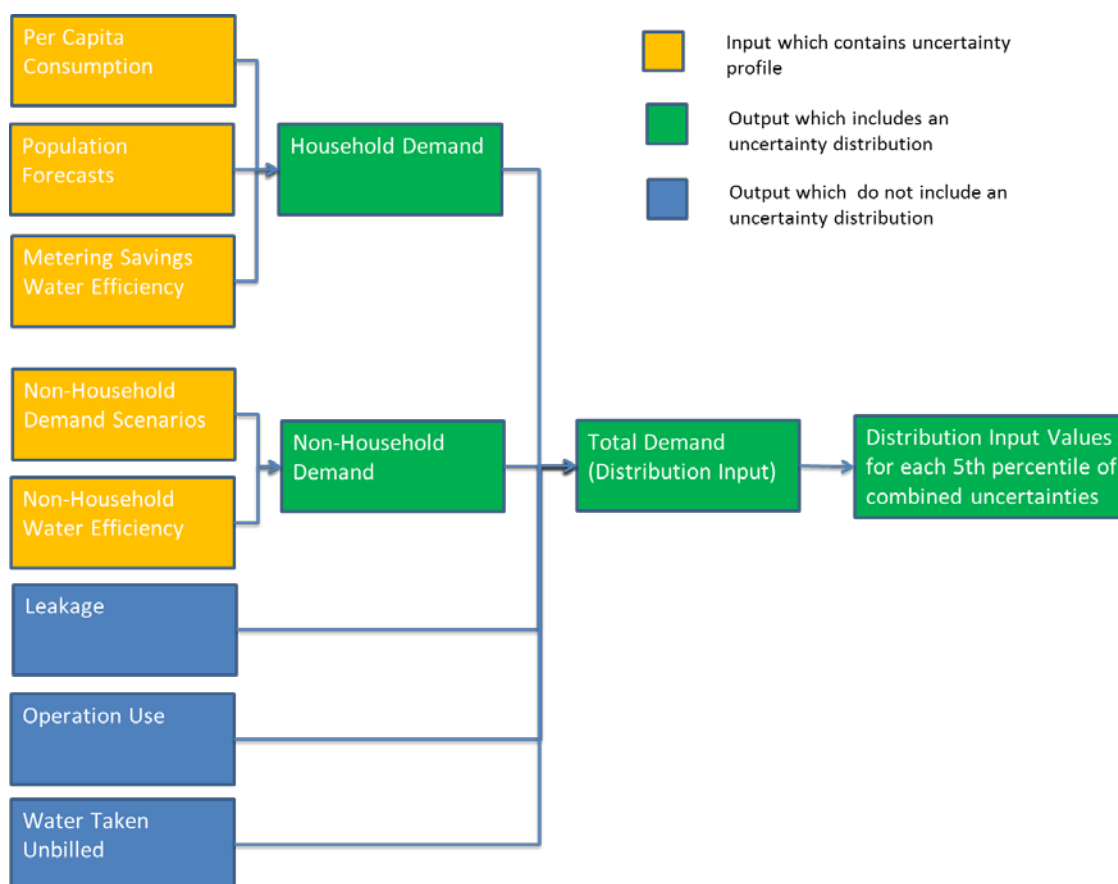
### ***Demand uncertainty overview***

- 5.59 Specialist software is used to calculate the uncertainty associated with the demand forecasts that are described in Section 3: Current and future demand for water. The demand forecasts produce a single value for demand for each year of the forecast period. Underpinning the demand forecast is a series of values which are considered the best estimate. Like any estimate, there is scope for uncertainty and analysis of these uncertainties is used to produce the demand uncertainty, that is then used in the calculation of target headroom. Monte Carlo simulation is used to understand how the uncertainties from input variables translate into uncertainty in the overall demand forecast. An overview of this is shown in Figure 5-5.

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<sup>11</sup> UKWIR, WRMP 2019 Methods – Risk Based Planning, Appendix D7, (16/WR/02/11), 2016.

**Figure 5-5: Overview of analysis of uncertainty in demand forecasts**



5.60 Each demand component shown in orange is assigned a probability distribution according to the information available. Most of the uncertainty ranges around these components have been estimated based on studies where possible, and expert judgment or opinion where little information is available. Where judgment/opinion has been used output values have been examined to ensure that the uncertainty range is reasonable.

5.61 Uncertainty distributions for the following outputs are not included for demand components shown in blue in Figure 5-5:

- Leakage – The outturn value for leakage is, to a degree, within our management control to deliver. This does not mean there is no uncertainty. Weather and in particular cold winters can cause metal pipes to contract and fracture increasing leakage. Furthermore we have more than 30,000km of buried water network and whilst we invest considerable effort in understanding and modelling how it deteriorates over time, it is not an exact science. As such predictions for future leakage can be difficult. However, on balance we consider it is inappropriate to consider uncertainty around leakage in our target headroom estimate. Instead we consider the uncertainty in terms of the cost it will take for us to meet or out-perform our leakage target in each year through a mix of activities including finding and fixing leaks as they break out and replacing our old iron pipes with new plastic pipes.

- Operational use and demand from our properties – This component reflects the water we use in operational activity such as flushing mains for water quality reasons or water used at out sites or offices for sanitation purposes. Similarly to leakage the outturn value for this component is, to a large degree, within our management control to deliver. Therefore the same logic applies around the inclusion of uncertainty in future forecasts. Note that these values are not actually forecast and are assumed to be constant at base year values over the planning period. As such the uncertainty around this output is part of the base year measurement uncertainty described in paragraphs 5.62 to 5.67. Additionally the total volume of this category is approximately 1% of total distribution input (DI) and therefore any reasonable uncertainty estimates around forecast values would be unlikely to have a material impact on the results of this analysis.
- Water taken illegally or unbilled – These values are not actually forecast and are assumed to be constant at base year values over the planning period. As such the uncertainty around this output is part of the base year measurement uncertainty described in paragraphs 5.62 to 5.67. Additionally the total volume of this category is approximately 1% of total DI and therefore any reasonable uncertainty estimates around forecast values would be unlikely to have a material impact on the results of this analysis.

### ***D1 – Uncertainty in the base year data***

- 5.62 The actual DI supplied in the base year is used as base data to support the forecast of demand for the 80 year planning period. DI is measured by meters, typically located at the outlet of a water treatment works. These meters are subject to a statutory verification programme, but there is still uncertainty about the results they record. This uncertainty is reflected in the calculation of the water balance as part of the annual performance report to Ofwat.
- 5.63 Here we have used the same uncertainty distribution for base year DI used as part of the water balance calculation. Base year DI is a random variable with a normal distribution where the mean is equal to the deterministic estimate of base year DI and the standard deviation is equal to 1.02%<sup>12</sup> of deterministic DI.
- 5.64 Uncertainty is also estimated around the uplift from the base year recorded value of DI to reflect the planning scenario in use<sup>13</sup>. This uplift reflects the weather and operational circumstance of the base year may have been more (or less) favourable than would be expected to be the case in a year typical of the planning scenario i.e. a dry year. For example, in London the recorded DI in the base year was 2,080.7 Ml/d. The weather in the base year was assessed to have suppressed demand below what it would have been in dry year conditions. An uplift of 24.6 Ml/d is applied to convert DI to the value expected if conditions in the base year had been equal to dry year conditions.
- 5.65 There is uncertainty about the accuracy of the recording of conditions in the base year, the assessment of conditions in the dry year and the impact of those conditions on DI. Therefore we apply an uncertainty to the value of the uplift used. Because it is impossible to validate the

<sup>12</sup> This is based on a 95% confidence interval for reported DI being +/- 2% and 95% confidence interval for a normal distribution being +/- 1.96 standard deviations.

<sup>13</sup> E.g. Dry Year Annual Average basis for London.



accuracy of the uplift directly<sup>14</sup> we use expert judgement to set the uncertainty distribution used to reflect uncertainty around the uplift.

- 5.66 The value of the uplift in deterministic forecast is our best estimate and therefore we believe is also the most likely value. We do not have any reason to believe that the distribution is likely to be skewed and therefore we have used a normal distribution to characterise the uncertainty around the uplift. We chose to set standard deviation for the distribution at 5% of the value of the deterministic uplift value. This resulted in a distribution which best matched the expectation of a number of experts.
- 5.67 The impact of the uncertainty around base year estimates is then set the sum of both uncertainty distributions less the deterministic value of the base year DI in dry year conditions<sup>15</sup>.

## ***D2 – Demand forecast variation***

- 5.68 The sources of demand forecast variation considered in the Demand Uncertainty Model are as shown in the list below. Each is discussed in a separate section which follows below:
- Household per capita consumption (PCC)
  - Household population
  - Non-household demand

### ***Household PCC uncertainty***

- 5.69 Household PCC is the average volume of water used by each person in a household. Typically it is reported in units of litres per head per day (l/h/d). PCC is a measure of customers' water use behaviour. In this section the PCC discussed is the baseline<sup>16</sup> value, meaning that it is the value prior to any demand management activity we might deliver to influence the value.
- 5.70 PCC uncertainty is calculated by using high and low scenarios within the household demand forecasting model produced by Artesia Consulting. The demand forecasting model uses a multiple linear regression approach. This approach and the function of the model are explained further in Section 3.C: Current and future demand for water, Household water use and Appendix F: Household water demand modelling.
- 5.71 An 80% confidence interval for forecasts of household PCC produced by applying the demand forecasting model are a standard output of the process. The limits of this confidence interval along with the expected value used in the deterministic demand forecast are used to

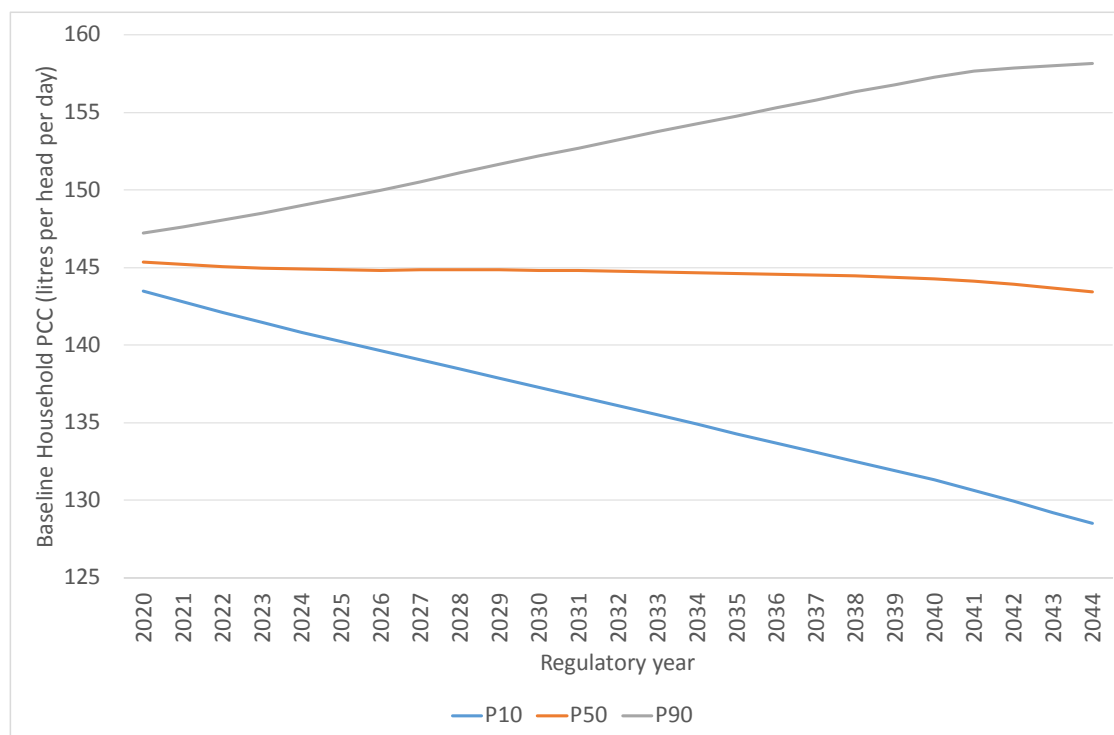
<sup>14</sup> There is no opportunity to actually replicate the base year circumstances (population, customer water use behaviour, etc...) in dry year weather conditions.

<sup>15</sup> Because of the properties of normal distributions this results in a normal distribution with a mean of zero and a standard error of the square root of the sum of the squared standard errors of the original distributions. For example, standard error of the distribution of the impact of uncertainty around the base year estimate is equal to the square root of the sum of 1.02% of the measured distribution input squared and 5% of the deterministic uplift value squared.

<sup>16</sup> For example, progressive metering or water efficiency Smarter Home Visits.

characterise a PERT probability density function<sup>17</sup> for household PCC for each year of the planning problem. Figure 5-6 shows the expected value, and the 10<sup>th</sup> percentile and 90<sup>th</sup> percentile values which form the 80% confidence interval for household PCC.

**Figure 5-6: Baseline household PCC results from demand forecasting model**



**Household population uncertainty**

5.72 The household population we serve is a key factor in forecasting demand. Population is the result of a myriad of uncertain components including, birth rates, death rates and net migration. Each of these components is influenced by a range of underlying factors such as macro-economic growth. As such it is easy to see why there is uncertainty in the forecast of population.

5.73 Population uncertainty has been estimated using the methodology suggested in the UKWIR report on population, household property and occupancy forecasting project<sup>18</sup>. The method uses three separate sets of normal uncertainty distributions for population uncertainty which are chosen on the basis of the relative scale of the population being forecast:

- Region (i.e. population of the order of 5 million)
- County (i.e. population of the order of 500,000)
- Local Authority (i.e. population of order of 100,000) or smaller

<sup>17</sup> More detail on how a probability density function is characterised in target headroom analysis can be found in Appendix V: Risk and uncertainty.

<sup>18</sup> UKWIR, WRMP19 Methods – Population, Household Property and Occupancy Forecasting (15/WR/02/8), 2015



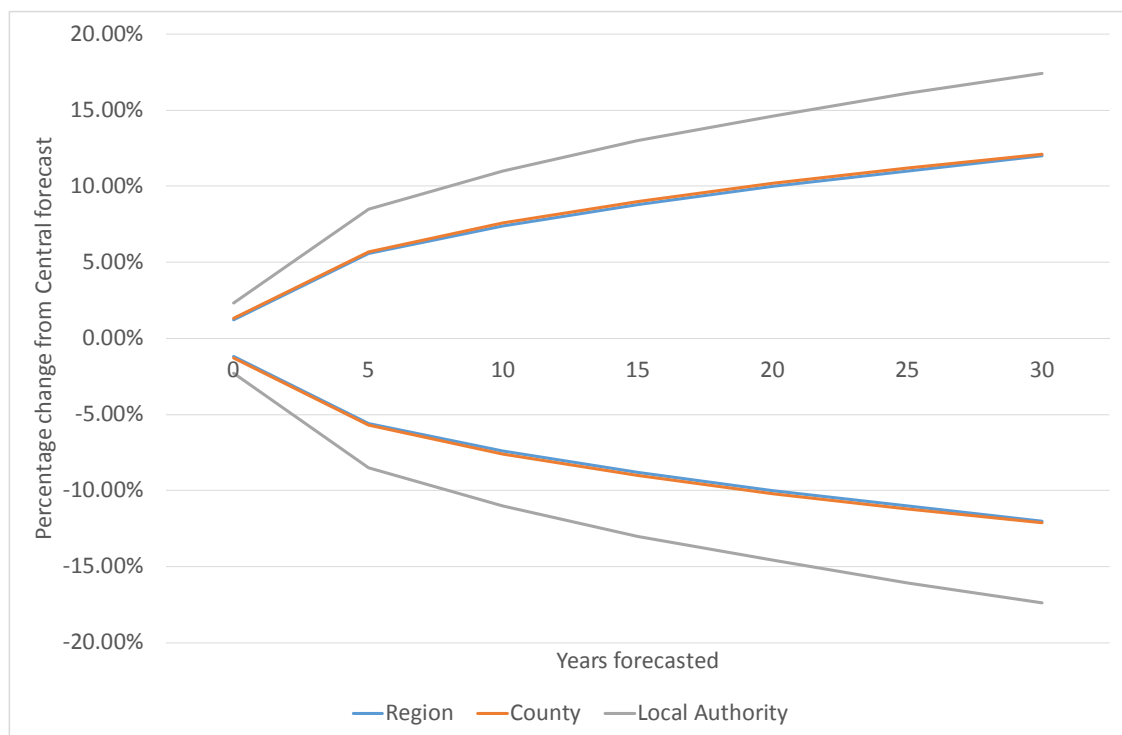
5.74 The report uses data from a number of Office for National Statistics population forecasts compared to the actual outturn population to calibrate the distributions. The results show that generally the smaller the population grouping being forecast the larger the inaccuracy of the forecast in percentage terms tended to be. The apparent logic is that for smaller population groups there is more of a chance for local effects to have a larger impact and less chance to be offset by counteracting effects in other parts of the area. More detail on the approach is provided in Appendix V: Risk and uncertainty.

5.75 We have applied the method at a WRZ level, which results in the following allocation of uncertainty distribution sets:

- Region: London
- County: SWOX, SWA, Kennet Valley
- Local Authority: Guildford, Henley

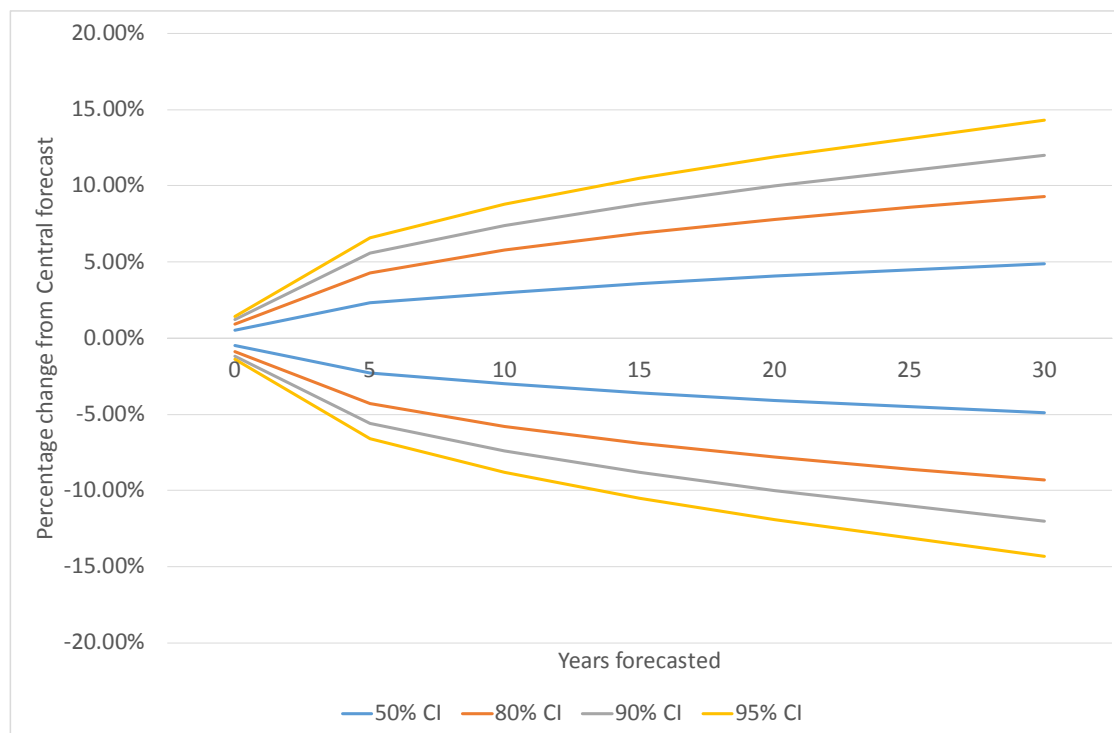
5.76 Figure 5-7 shows the 90% confidence interval over a period of 30 years for each of the three geographic scale types. The confidence interval is expressed in relative terms to the 50<sup>th</sup> percentile population forecast. Note that the region and county level values are highly similar.

**Figure 5-7: Comparison of 90% confidence intervals for UKWIR population uncertainty**



5.77 Figure 5-8 shows 50%, 80%, 90% and 95% confidence intervals for the region geographic scale type over 30 years.

**Figure 5-8: Confidence intervals for region level population forecasts**



**Non-household demand**

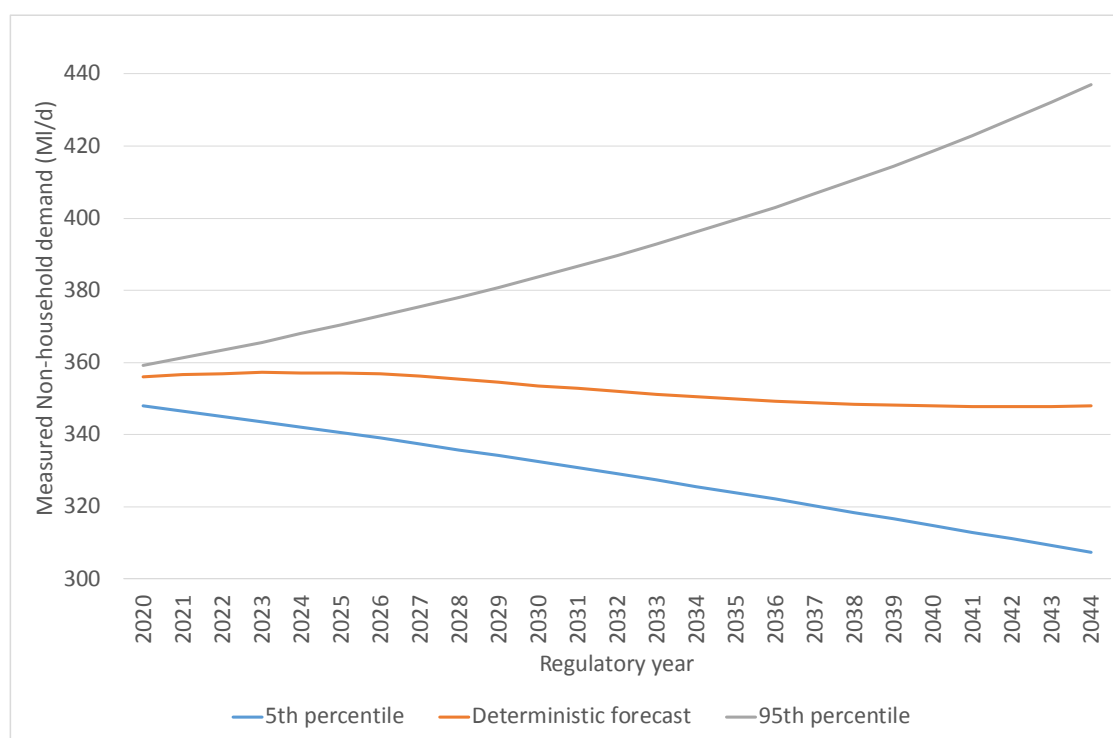
5.78 Unmeasured non-household demand is a comparatively small component of total non-household demand, approximately 4% in London. We believe that measured and unmeasured non-household demand for water will tend to be well correlated as both are primarily driven by regional macro-economic factors. Therefore we have assumed that the uncertainty distribution for measured non-household demand can be applied proportionately to unmeasured non-household demand.

5.79 The deterministic forecast for non-household demand was produced by Servelec Technologies. As part of that work, using the same methodology and varying future macro-economic projections, they also produced lower and upper forecasts for measured non-household demand in each year. These estimates represent a 90% confidence interval for the value of non-household demand in each year.

5.80 We have fitted a PERT probability density function using the deterministic forecast as the 50<sup>th</sup> percentile value and the limits of the 90% confidence interval as 5<sup>th</sup> and 95<sup>th</sup> percentiles. More details on how distributions are fitted can be found in Appendix V: Risk and uncertainty. Figure 5-9 shows the values used to fit uncertainty distributions.



**Figure 5-9: Measured non-household demand forecast uncertainty**



### ***D3 – Impact of climate change on demand***

- 5.81 HR Wallingford carried out a study<sup>19</sup> to estimate the likely impacts of climate change upon household demand. Climate change effects are only considered for domestic water use. More information regarding the effects of climate change on demand can be found in Section 3: Current and future demand for water. The climate change ranges are summarised in Figure 5-10 for DYAA and Figure 5-11 for DYCP.
- 5.82 The low, mid and upper scenarios presented in these figures are 10<sup>th</sup> percentile, 50<sup>th</sup> percentile and 90<sup>th</sup> percentile forecasts for the impact of climate change on demand. We have used these data points to fit a normal probability density function for each year in the planning period.

<sup>19</sup> HR Wallingford, EX6828 Thames Water Climate Change Impacts and Water Resource Planning. Thames Water Climate Change Impacts on Demand for the 2030s, 2012



Figure 5-10: The impacts of climate change for the DYAA scenario

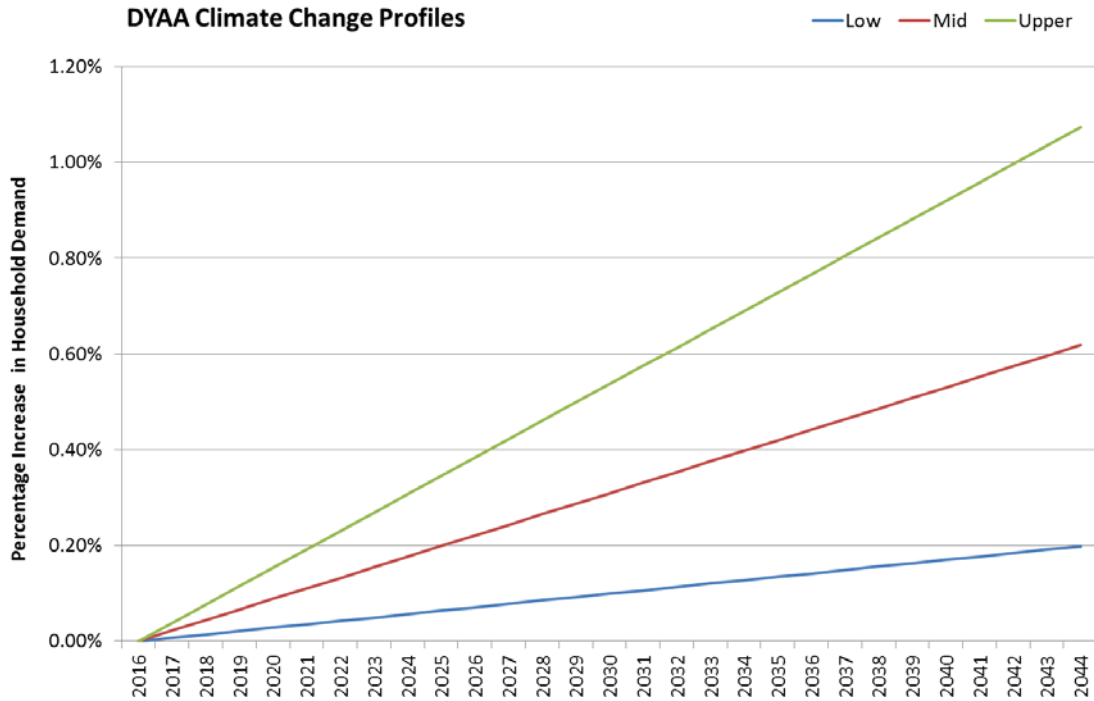
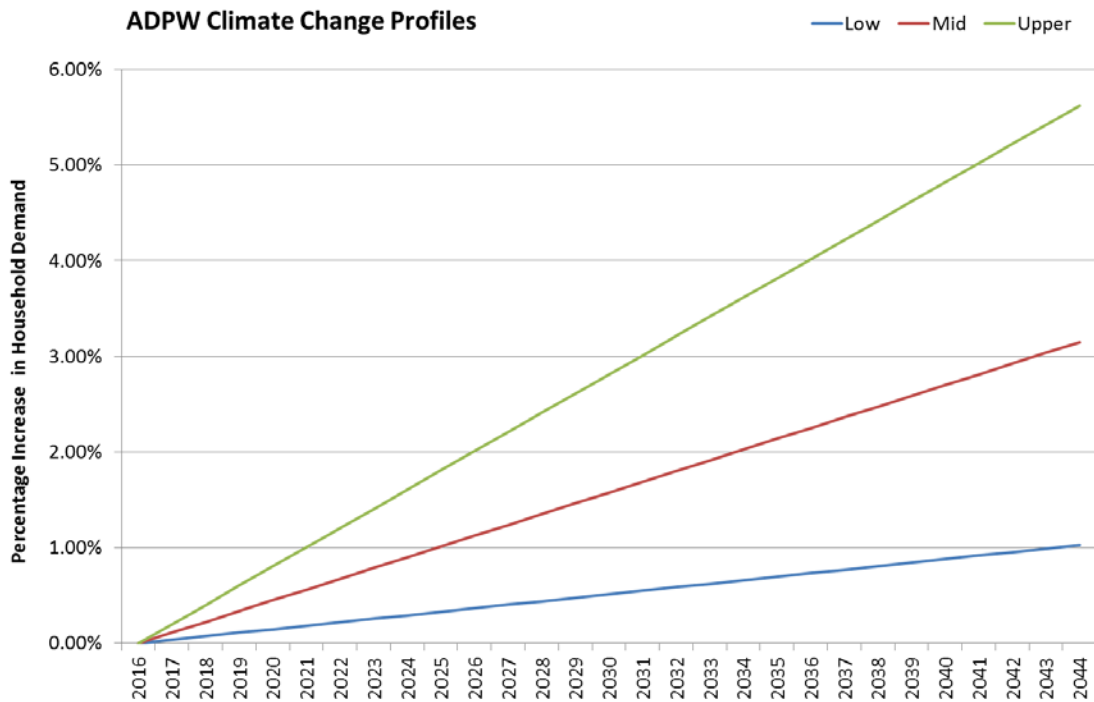


Figure 5-11: The impacts of climate change for the DYCP scenario



## ***D4 – Uncertainty of demand management measures***

- 5.83 These components are not part of the baseline target headroom calculation as the baseline position includes no demand management activity. These components are therefore only used as part of the assessment of target headroom of a candidate final plan as part of the programme appraisal. More detail can be found on the results of applying target headroom analysis on the final plan as part of programme appraisal in Section 10: Programme appraisal.
- 5.84 As stated in paragraph 5.61 uncertainty around leakage is not considered as part of the assessment of target headroom. Uncertainty estimates for the remaining two material components of the demand management programme are produced separately:
- Metering savings from new meter installations.
  - Water efficiency savings from smarter home visits for both household and non-household customers.

### ***Metering savings***

- 5.85 The central estimate for progressive metering savings has been revised since WRMP14 based on the data collected from the delivery and subsequent monitoring of our progressive metering programme (PMP). Data from a sample of 9,567 households<sup>20</sup> were used in a report produced by expert statistical analysts from our Innovation team. The results of the analysis were controlled for the primary influencing factors:
- Housing type
  - Occupancy
  - Ethnicity
- 5.86 The analysis predicts household water use savings of 17.0% if the remaining unmeasured household population were to be metered. However, our experience in the delivery of our AMP6 PMP is showing that the percentage success rates when attempting to meter flats in London is in the low twenties. This is largely due to the complexity of plumbing in many converted flats precluding the ability of economically metering the supply to a single property. Adjusting the analysis to calculate savings for all unmeasured household properties but excluding 80% of flats results in an expected saving of 19.0%.
- 5.87 We have attempted to corroborate these results with data from other sources. We have been informed by Southern Water and Anglian Water that they have observed savings from their progressive metering programmes of 16.5% and 16.0% respectively. Note that the figure for Anglian Water includes a concurrent water efficiency programme.
- 5.88 Triangulation from these sources has led us to use a deterministic forecast of 17.0% for progressive metering savings in draft WRMP19.
- 5.89 Our internal analysis also produced a 95% confidence interval for the estimate of meter savings, shown in the Table 5-7.

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<sup>20</sup> 8,567 households which have been measured and a control group of 1,000 properties from the unmeasured domestic water use study



**Table 5-7: Progressive metering saving uncertainty parameters**

WRZ	Unit	Upper estimate	Most likely	Lower estimate
London	%	79	81	83.2
Thames Valley	%	79	81	83.2

5.90 We have used the same width of confidence interval produced by our internal analysis to estimate the uncertainty around the deterministic value of 17.0%. Because the confidence interval is largely symmetrical and actual results will be delivered by many hundreds of thousands of households over likely more than a decade. We have assumed a normal distribution with a mean of the deterministic value and a standard deviation of the width of the 95% confidence interval (4.2%) divided by 3.92<sup>21</sup>.

***Smarter homes visit uncertainty***

5.91 The uncertainty for water efficiency savings is based on a study of the activity carried out in AMP6. The results of this study are presented in Table 5-8. The upper and lower estimates are used as a 95% confidence interval for the most likely saving. This has been used to fit a normal distribution in the same manner as described for metering saving uncertainty in the section above.

**Table 5-8: Water efficiency savings uncertainty parameters for households and non-household**

WRZ	Unit	Lower estimate	Most likely	Upper estimate
London	l/prop/d	9.1	10.6	12.1
Thames Valley	l/prop/d	9.1	10.6	12.1

## **E. Accounting for correlation in demand side uncertainty**

5.92 Some of the sources of uncertainty considered in this analysis will be influenced by similar underlying causes and hence their distributions will be correlated. We have completed a pairwise assessment of each source of uncertainty using expert judgement, the results of which are shown in Appendix V: Risk and uncertainty.

5.93 As a result of this analysis we have used a positive 0.75 correlation factor between the results of uncertainty for metering savings and water efficiency savings. These factors are both heavily influenced by customer attitudes to water use. This means that the model will reflect that if metering savings are higher than expected then water efficiency savings will also tend to be higher than expected. This has the effect of widening the overall uncertainty distribution from which target headroom is produced. Thus this will marginally increase the resulting final plan target headroom over and above what would result from assuming the distributions are independent.

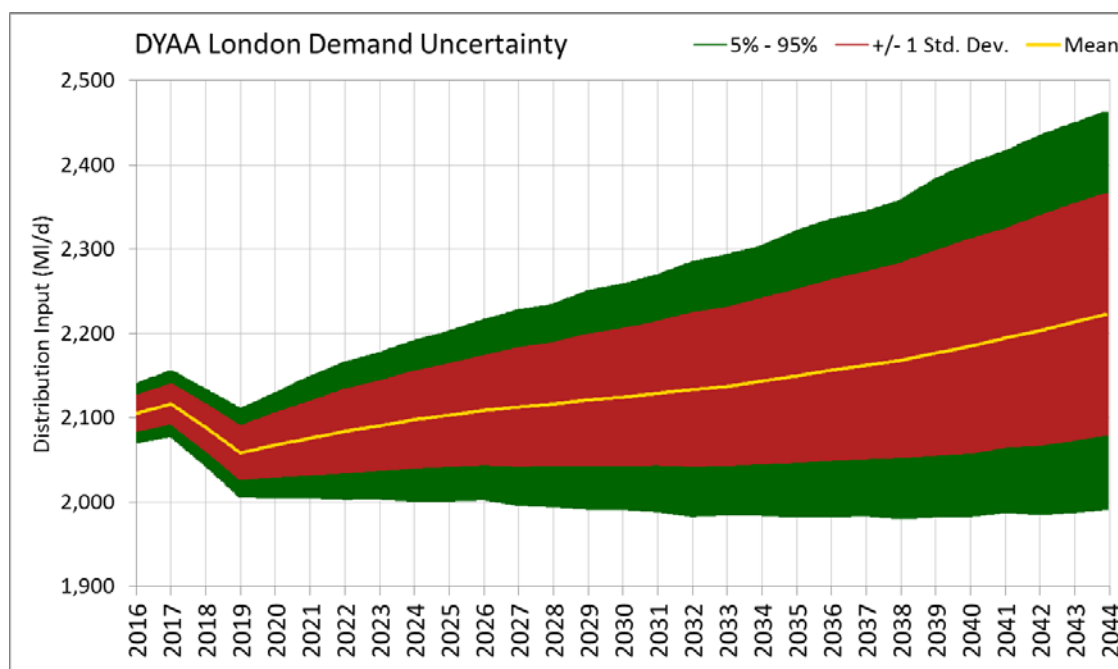
<sup>21</sup> Note the standard normal distribution has a 95% confidence interval bounded by the mean +/- 1.96 times the standard deviation.



## F. Model outputs

5.94 The output from the model, which is then used in the headroom model, is a table with a demand value for each 5<sup>th</sup> percentile. A graphical representation of the output can be seen in Figure 5-12.

**Figure 5-12: Baseline demand forecast uncertainty spread - London WRZ**



5.95 Results from the baseline model run are used as input into the headroom model to form an initial view of target headroom for the baseline forecasts.

## G. Baseline target headroom and risk profile

5.96 Our baseline forecast has used a risk profile as shown in Table 5-9. A smaller allowance for uncertainty is made in the future as we consider the opportunity to review plans and adapt to changes. A profile has been adopted of 5% in AMP6, which then increases at 1% per annum until 2043/44. Thus the risk taken is increased from 5% to 29% by 2043/44 and is then held at this level over the remainder of the planning period till 2100. We have based our risk profile on a range of factors and made a judgement on what we consider is a reasonable balance of risk over the plan period<sup>22</sup>. Appendix V: Risk and uncertainty, Section G provides a detailed explanation of our decision making process surrounding setting the level of target headroom risk.

<sup>22</sup> Risk profile based on judgement (informed by the Environment Agency's 2017 WRPG to ensure an appropriate level of risk has been selected), the strength of customer research on reliability of supply, the future risks and their characteristics. We tested the plan in Section 10: Programme appraisal to changes in the supply demand balance which can also be used to test how the plan changes with different risk profiles.

**Table 5-9: Risk profile for target headroom assessment in WRMP14 and draft WRMP19**

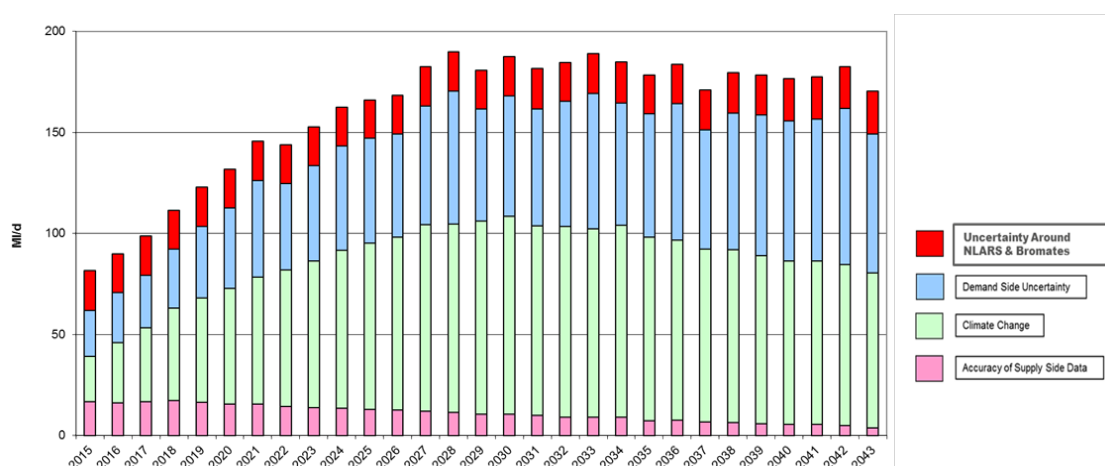
	Headroom Risk Profile (%)						
	2016/17	2019/20	2024/25	2029/30	2034/35	2039/40	2043/44
WRMP14	10	10	15	20	25	30	N/A
WRMP19	5	5	10	15	20	25	29

Note: draft WRMP19 Risk is held at 29% from 2043/44

### Target headroom components

5.97 An example of the typical components of a target headroom profile is provided in Figure 5-13, illustrating the relative importance of each of the parameters.

**Figure 5-13: Baseline target headroom components**



5.98 Figure 5-13 shows that the climate change uncertainty and the demand forecast uncertainty are the most significant components of the headroom forecast for London. The climate change uncertainty continues to increase over the planning period and eventually is greater than the uncertainty around the demand forecast. This is unsurprising given the relative importance of surface water supplies in this zone and the uncertainty around future river flows. The impact of climate change in other WRZs is less marked than in London but the same uncertainty around demand and climate change dominates. Further details of the component breakdown for each WRZ are given in Appendix V: Risk and uncertainty. The baseline DYAA target headroom is shown in Table 5-10 with the DYCP target headroom in Table 5-11. Note the target headroom is maintained at the same level in each WRZ from 2043/44 to 2100.

5.99 In line with the Environment Agency’s 2017 WRPG our plan does not include any allowance for uncertain sustainability reductions. However, studies to date, as detailed in Section 4: Current and future water supply, show that in London these could be significant. As such we have tested our plan against these to assess how robust it is to this uncertainty and details



are outlined in Section 10: Programme appraisal and Appendix W: Programme appraisal methods.

**Table 5-10: Baseline target headroom by WRZ – DYAA**

WRZ	Baseline target headroom – DYAA (MI/d)						
	2016/17	2019/20	2024/25	2029/30	2034/35	2039/40	2043/44
<b>Risk Profile →</b>	5%	5%	10%	15%	20%	25%	29%
London	89.9	122.8	162.4	180.8	184.8	178.5	170.2
SWOX	8.0	12.1	15.5	16.3	16.5	15.1	13.7
Kennet Valley	4.0	5.9	7.1	7.8	7.4	6.1	5.4
Henley	0.3	0.6	0.6	0.6	0.5	0.5	0.5
SWA	3.5	4.5	5.3	5.0	5.0	4.4	4.0
Guildford	1.2	2.0	2.0	1.9	1.4	1.2	1.0

**Table 5-11: Baseline target headroom by WRZ – DYCP**

WRZ	Baseline target headroom – DYCP (MI/d)						
	2016/17	2019/20	2024/25	2029/30	2034/35	2039/40	2043/44
<b>Risk Profile →</b>	5%	5%	10%	15%	20%	25%	29%
London	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SWOX	10.8	16.5	21.4	22.1	24.7	22.5	21.9
Kennet Valley	4.4	7.1	8.8	11.2	10.2	9.7	8.4
Henley	0.5	0.8	0.9	0.9	0.8	0.9	0.7
SWA	4.4	6.8	7.6	8.1	7.9	7.5	7.0
Guildford	1.6	3.0	3.2	2.9	2.9	2.3	2.0