Thames Water

Final Water Resources Management Plan 2015 - 2040

Main Report

Section 5 - Allowing for Risk and Uncertainty – ‘Headroom’

Contents

Figures

Tables

Section 5 Allowing for Risk and Uncertainty – 'Headroom'

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 for both average and peak scenarios.

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:

"A buffer between supply and demand designed to cater for specified uncertainties."[1]

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 meet its agreed level of service.

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

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 (termed target headroom) to allow for a proportion of this uncertainty.

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%) and more risk in the long term (30%).

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 Water Resource Zone.

[1] WRPG, section 5.1

5.1 Introduction

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.

5.1.1 Methodology

The WRPG sets out two suitable methodologies for calculating target headroom. We use the 'improved methodology'[2] 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.

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 distribution is shown in Figure 5-1.

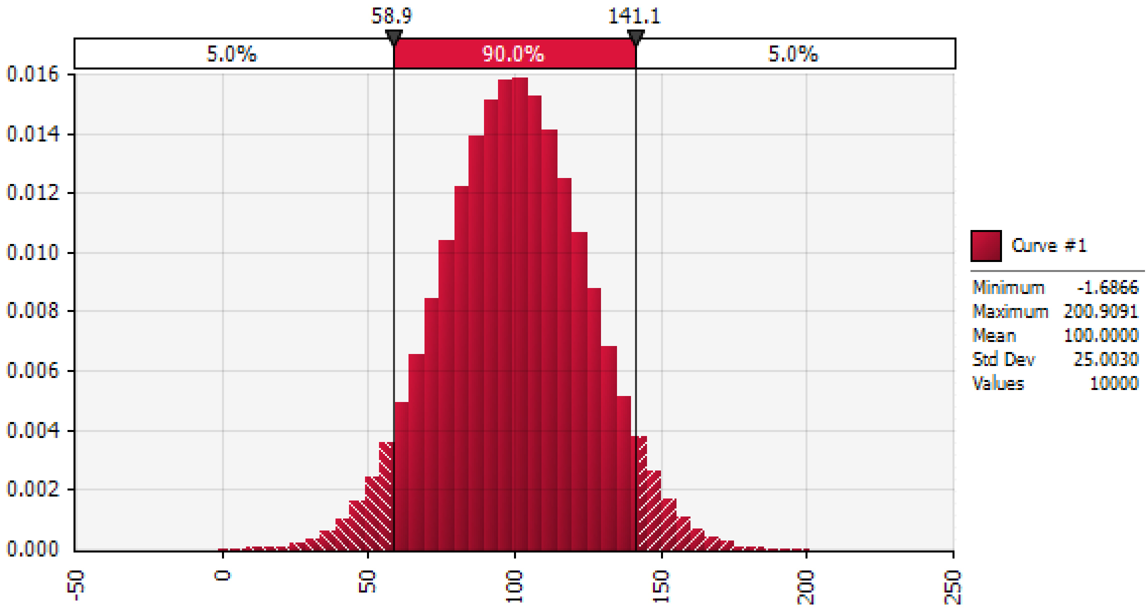

Figure 5-1: An example distribution used in headroom modelling

Once it has been decided which parameters are particularly uncertain and would better be defined by a distribution, models are used to run calculations thousands of times, taking a random sample from within the defined distributions.

[2] UKWIR (2002) An Improved Methodology for Assessing Headroom

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 take 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?

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.

5.1.2 Approach

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, then draw them together using a Monte Carlo process to produce a combined uncertainty.
- 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 throughout the programme appraisal in the development of the preferred plan. This is described in Section 8.
- The total volume of target headroom for a given WRZ in a given year may then be disaggregated into its component parts.

Below we discuss how we have accounted for the various supply-side and demand-side uncertainties acting on our Plan.

5.2 Supply side uncertainty

5.2.1 Components of supply side uncertainty

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.

S1, S2 & S3 components are not included in the analysis following guidance from the Environment Agency, as set out in the WRPG.

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.

Gradual Pollution (S5) – The risk around gradual pollution is included, where identified. There is a risk for some sources in the Guildford and SWOX WRZs. However, the resultant headroom is very small < 0.1 Ml/d and invariably through Monte Carlo sampling is zero and is thus not considered of significance. 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).

Accuracy of supply side data (S6) – Data inaccuracy and scarcity of information may render estimates of Deployable Output 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 deployable output. 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

These issues are discussed in detail in Appendix V.

As part of the methodology for our Drought Plan (DP) we will, in future, be required to introduce restrictions upon customers earlier than has historically been the case, based on the Lower Thames Control Diagram. 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.

The timing of the introduction of restrictions is subjective however and the benefit will not necessarily always be there. By introducing 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.

Climate Change (S8) – The uncertainty around climate change is discussed in sub-section 5.2.2, with further detail contained in Appendix V.

New Resource Developments (S9) – The uncertainty around new schemes has been assessed as part of the development of the final planning programme. The risk around each scheme relates to changes to the timing of schemes or changes in the scheme outputs and cost, leading to a consequential change in uncertainty. Details are provided in Appendix W.

In addition, a further uncertainty has been included within the Target Headroom modelling which relates to the risk of the Northern New River Well (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 at Coppermills and Chingford water treatment works (WTW) cannot deal with the concentration of bromate in the water, which is also exacerbated by the ozonation process at the two works. At Hornsey WTW, the bromate treatability issues are partially mitigated by additional treatment installed.

In 2005, a scavenging remediation scheme was implemented in conjunction with Veolia Water Central (now 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 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. It has been represented as a triangular distribution with a minimum and most likely impact of zero but with a potential maximum impact of 23 Ml/d. Although showing significant seasonality and variability in response to groundwater recharge, the level of bromate concentrations was believed to have stabilized since Affinity Water commenced scavenge pumping. However, following the end of the 2011/12 drought, bromate concentrations rose significantly, approaching and exceeding the highest concentrations seen since 2005. As a result, there is concern that there could be a greater impact from bromate than that already included within target headroom. The risk of a yield reduction from the NNRW and other sources is being considered further, as outlined in Appendix I, particularly the reassessment of relationships for predictive purposes under drought scenarios.

5.2.2 S8 – Climate Change

Climate change is expected to lead to variations in patterns and frequencies of droughts, and other extreme weather events. UKCP09 report that by the 2080's with medium emissions, *"The biggest changes in precipitation in summer, down to about –40% (–65 to –6%), are seen in parts of the far south of England"*[3].

The impacts of climate change will be felt throughout our business, as shown in Figure 5-2 below. 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 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

[3] UK Climate Projections Online Briefing Report on UKCP09 data 2013

The UK Climate Projections 2009 (UKCP09) provide 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 (HRW) 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.

The updated climate change scenarios were launched by UKCIP in June 2009 and provide 10,000 equally possible outcomes of future temperature and precipitation (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.

It is not possible to individually model 10,000 equally possible future scenario's therefore a tiered approach to climate change analysis was followed as outlined in the WRPG.

Basic Vulnerability Assessment

The first stage of this analysis conducted by HRW was to undertake a basic vulnerability assessment (BVA) of all our WRZs[4]. This assesses whether a WRZ is vulnerable given the full range of equally possible future scenarios. All of our WRZs were identified as having a low vulnerability with the exception of Swindon and Oxfordshire (SWOX) and London, which therefore required further assessment.

Intermediate Assessment

The intermediate assessment involves the identification of current system vulnerability through the analysis of the causes and mechanisms of historic droughts in the vulnerable WRZs. To help define the conditions which lead to the onset of historic droughts in our catchments an Aridity Index (AI) was used. This describes the ratio of precipitation (rainfall) and potential evapotranspiration (PET) (the process of transferring moisture from the earth to the atmosphere by evaporation of water and transpiration from plants). This was found to be the best indicator of drought in our supply area. It has shown that Thames Water's system is particularly sensitive to the climate over the preceding twelve month period. For the London WRZ the critical aridity period in the year is from October to September, whereas for SWOX it is from December to July.

Using the Aridity Index as an indicator of the vulnerability in WRZ's we could then reduce the number of scenarios assessed from the 10,000 in total whilst still ensuring that specific scenarios under which our WRZ's would be vulnerable would be adequately represented. This two stage sampling process was called "split sampling". This split sample covers the spread of

[4] HR Wallingford (2012) 'Thames Water climate change impacts on supply for the 2030s'

UKCP09 data and targets specific drought conditions to provide a better estimate of both the impact on DO and Headroom uncertainty.

A method called Latin Hypercube sampling (LHS) was used to select 100 representative samples from the 10,000. The AI was then applied to select an even spread of 10 samples across the full range plus 10 further samples from the driest part of the distribution. The distribution of these samples is shown in Figure 5.3.

It was found that the same drought indicator could be used to represent both London and SWOX WRZ, which provided very similar sub-samples of 20. As a result we are able to use the same sub-sample of UKCP09 for both London and SWOX. These defined the climate change factors that have been run for the Teddington Catchmod model to derive river flow factors for the 2030 period, which was historically our most sensitive drought period. Further details are provided in Appendix V.

Emissions scenarios

The UKCP09 projections are available for three greenhouse gas emissions scenarios; Low, Medium and High. Comparison of the UKCP09 temperature and rainfall changes for the Thames catchment by HRW[4] show that for the 2030s either Medium or High emission scenarios can be selected without having a substantial influence on the projected impacts. The Medium emissions scenario was therefore chosen to provide the basis of the impact assessment.

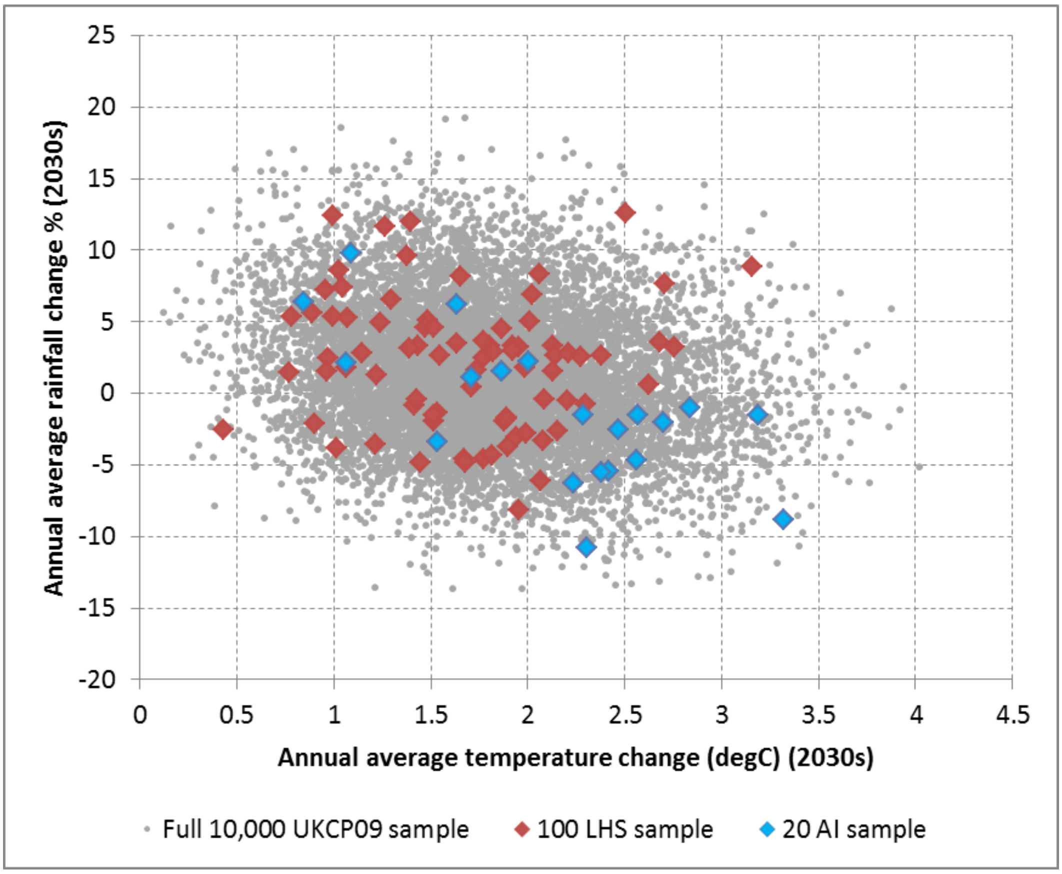

Figure 5-3: Temperature & Precipitation Spread of Sub-samples

Prior to the publication of the WRPG we had undertaken analysis of our groundwater sources based on the UKCP09 data for the 2020s. 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 & 10. The rainfall and temperature climate change factors for each of the five scenarios were used to generate recharge scenarios for input to Thames Water regional groundwater models within the Thames Valley. These models were then used to undertake hydrogeological analysis of the climate change impacts on the aquifers.

The groundwater level changes derived from this analysis were then used to assess the impact on groundwater Source Deployable Outputs (SDOs). The SDOs for the remainder of the twenty climate change scenarios were derived by interpolation; this used a linear relationship between SDO and AI defined for successive pairs of the five discretely defined SDOs. These data based on the UKCP09 data for the 2020s were used in our assessment of climate change impacts in the draft WRMP. The impact on groundwater sources has since been updated for the final WRMP14 to reflect the UKCP09 data following publication of the WRPG. The results of this work show a further decrease in the central impact of climate change on DO, in London from 82.2 Ml/d to 72.7 Ml/d.

The amended groundwater SDOs together with the rainfall, PET and flow factors were input to the Water Resources Management System (WARMS) to assess the impact on the DO for London and SWOX of 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 flow factors derived from the HRW work for the 2030s 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.

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.

Using the sub-sample of 20 climate change scenarios to assess the impact on the London DO gives a range of change by 2035/36 from −408 Ml/d (Dry scenario) to +169 Ml/d (Very Wet scenario) with a 'best estimate' of the impact of −72.7 Ml/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 -72.7 Ml/d has been calculated as the 'best estimate' by 2035.

As set out in the WRPG, 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. The target headroom methodology shows climate change to be the most significant uncertainty on the supply side. In London the direct impact on DO is around 11 Ml/d by the start of AMP6 increasing to around 78 Ml/d by the end of the period. When the uncertainty on this is taken into account the impact is around 31 Ml/d increasing to 140 Ml/d by the end of the period; a reduction of around 10 Ml/d since the draft plan. The range of potential uncertainty around DO is shown in Figure 5-4.

On 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 DO – DYAA

Reduction in DYAA DO due to Climate Change (Ml/d)							
WRZ	**2012/13**	**2015/16**	**2020/21**	**2025/26**	**2030/31**	**2035/36**	**2039/40**
London	0.0	11.5	30.6	49.8	66.7	72.7	77.6
SWOX	0.0	1.34	3.5	5.8	7.7	8.49	9.06
Kennet Valley	0.0	0.09	0.2	0.4	0.5	0.58	0.62
Henley	0.0	0.00	0.0	0.0	0.0	0.00	0.00
SWA	0.0	0.18	0.4	0.7	1.0	1.13	1.21
Guildford	0.0	0.00	0.0	0.0	0.0	0.00	0.00

Table 5-2: Climate Change Impact on DO – DYCP

Reduction in DYCP DO due to Climate Change (Ml/d)							
WRZ	**2012/13**	**2015/16**	**2020/21**	**2025/26**	**2030/31**	**2035/36**	**2039/40**
London	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SWOX	0.0	1.56	4.17	6.77	9.07	9.90	10.56
Kennet Valley	0.0	0.79	2.11	3.42	4.59	5.00	5.34
Henley	0.0	0.00	0.00	0.00	0.00	0.00	0.00
SWA	0.0	0.39	1.05	1.71	2.29	2.50	2.66
Guildford	0.0	0.08	0.21	0.35	0.47	0.51	0.54

Since the publication of the UKCP09 climate change data we have actively engaged with our regulators and stakeholders. This has been in the form of meetings and workshops since the appointment of HRW in 2009. The objective was to keep them informed of progress and give the opportunity to provide feedback on HRW's programme of work for assessing the impact of climate change on our water resources. At the same time 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) and Professor Jim Hall (Professor of Climate and Environmental Risks, University of Oxford). The approach to liaison that was adopted has proved very useful in ensuring that there is a common understanding of the issues and has informed judgements on making the best use of the large amount of data that is available through UKCP09.

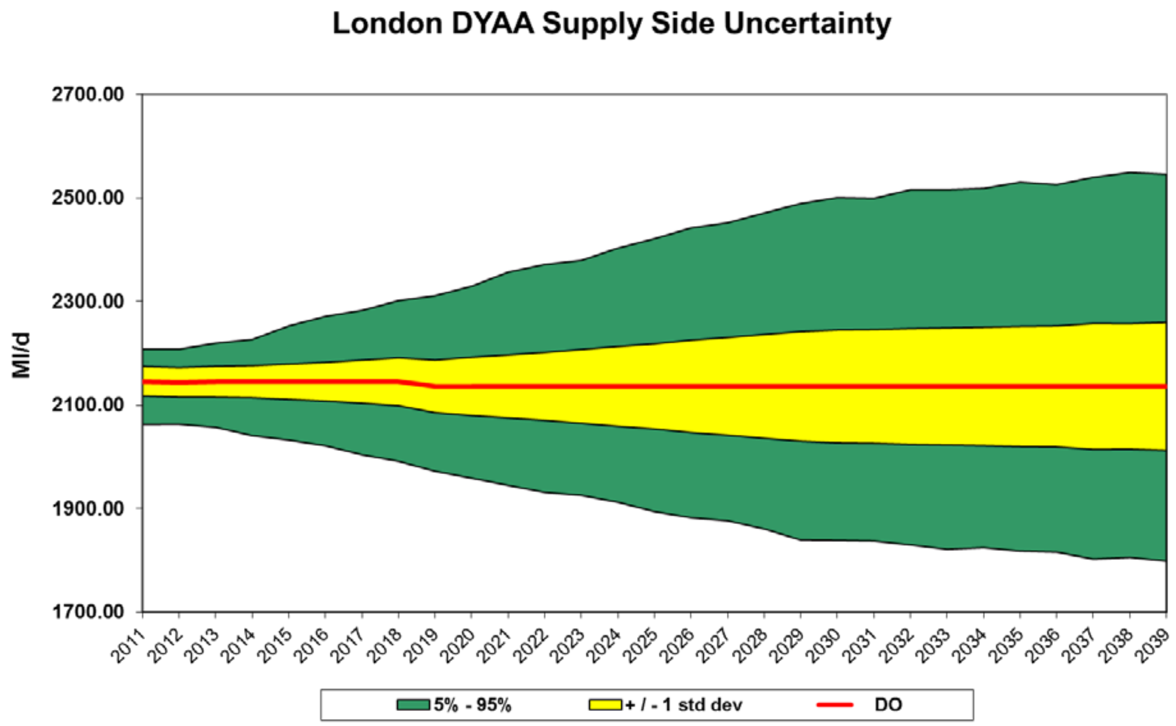

Figure 5-4: London DYAA Supply Side Baseline Headroom Uncertainty.

5.2.3 Summary

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 WRPG does not allow the uncertainties of future 'unknown' sustainability reductions to be included in our plan. As explained in Section 4 these could be significant. As such we have tested our plan against this in scenario analysis as detailed in Section 10.

5.3 Demand-side Uncertainty

5.3.1 Components of demand side uncertainty

The demand-related headroom components identified in the methodology are as follows:

- D1 – Accuracy of sub-component data.
- D2 – Demand forecast variation.
- D3 – Uncertainty of climate change on demand.

- D4 – Uncertainty of demand management measures.

We have developed a Demand Uncertainty (DUN) model that uses Monte Carlo analysis to understand the uncertainty around the deterministic demand forecast. We describe this briefly in paragraph 5.3.2 before examining the individual components D1 to D4. For further detail see Appendix V.

5.3.2 Model Overview

The DUN model is used to calculate the uncertainty associated with the demand forecasts that are described in Section 3. The demand forecasts produce a single value for demand for each year of the forecast period. Underpinning the demand forecast are a series of values which are considered the best estimate. Like any estimate, there is scope for uncertainty and the DUN model is used to understand this uncertainty. The DUN model uses Monte Carlo simulation to understand how the uncertainties from the input variables translate into uncertainty in the overall demand forecast. An overview of the model is shown in Figure 5-5.

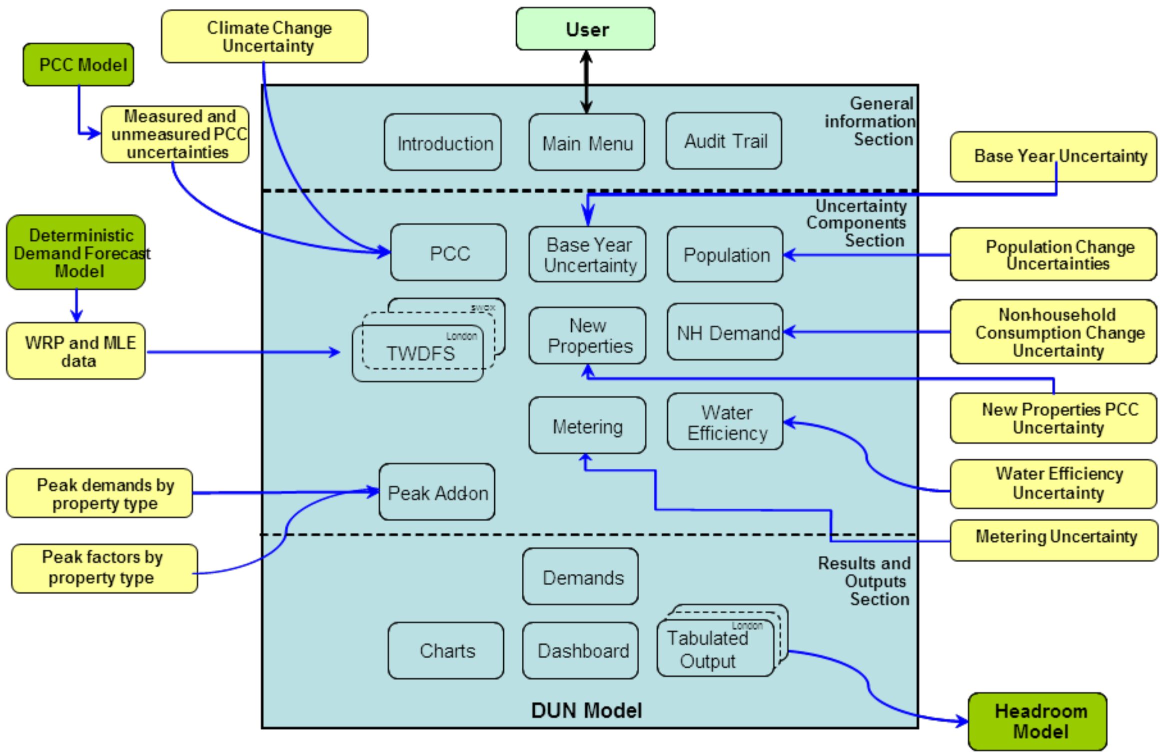

Figure 5-5: Representation of the Demand Uncertainty (DUN) model

5.3.3 D1 – Uncertainty in the Base Year data

The base year uncertainty is applied only to Distribution Input (DI) with the uncertainty taken from the water balance maximum likelihood estimation (MLE) confidence levels. This is only possible for the base year as DI is a measured volume whereas in future years DI is calculated as the sum of demand components.

5.3.4 D2 – Demand forecast variation

.The sources of demand forecast variation considered in the DUN model are as follows:

- PCC (Measured and Unmeasured)
- Population
- Measured Non Household Demand
- New Property Consumption
- Peaking Factors for peak household consumption

Each demand component 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.

Per Capita Consumption Uncertainty

Per Capita Consumption (PCC) uncertainty is calculated within the PCC model using the stochastic micro-component model. This model considers uncertainties around individual micro-components for their frequency of use, volume per use and how use is forecast to change in the future. The micro-components to which uncertainty is applied are as follows:

- Toilet
- Bath
- Showers
- Washing machines
- Dishwasher
- Internal taps
- Garden watering

The outputs from the PCC model are imported into the DUN Model.

Population Uncertainty

Population uncertainty has been estimated using the scenario analysis undertaken by Experian as part of the population forecasting exercise. As no probability is attached to the scenarios, values have been taken that fall within the ranges produced by Experian and are shown in Table 5-3. Full details of the uncertainty ranges produced by Experian can be found in Appendix E.

Table 5-3: Population Uncertainty Parameters

Final Year	Unit	Min	Mean	Max
London	%	-10.7	4.0	18.7
Thames Valley	%	-12.6	1.8	16.2

Measured Non-Household Demand

The uncertainty for measured non-household demand is based on the upper and lower forecasts Experian produced as part of their non-household demand forecasting work for us. The upper and lower forecasts are based on future economic performance and how matters within the Eurozone banking sector are resolved. For unmeasured non-households the uncertainty is based on the confidence interval used for the annual report. The values used for both measured and unmeasured non-households are shown in Table 5-4.

Table 5-4: Non-household Demand Uncertainty

	Unit	Final Year		
		Min	Mean	Max
Unmeasured non-household uncertainty profile	%	-25	0	25
Measured non-household uncertainty profile	%	-6	0	7

New Property Consumption

New property consumption has been given a variable uncertainty profile over the forecast year. This is initially skewed towards higher consumption to reflect uncertainty in the effectiveness of the Building Regulations, or the policing of them, before becoming skewed towards lower consumption in the latter part of the forecast, when there is a higher likelihood that greater progress will have been made. The profile used for new property consumption in the base year is shown in Figure 5-6.

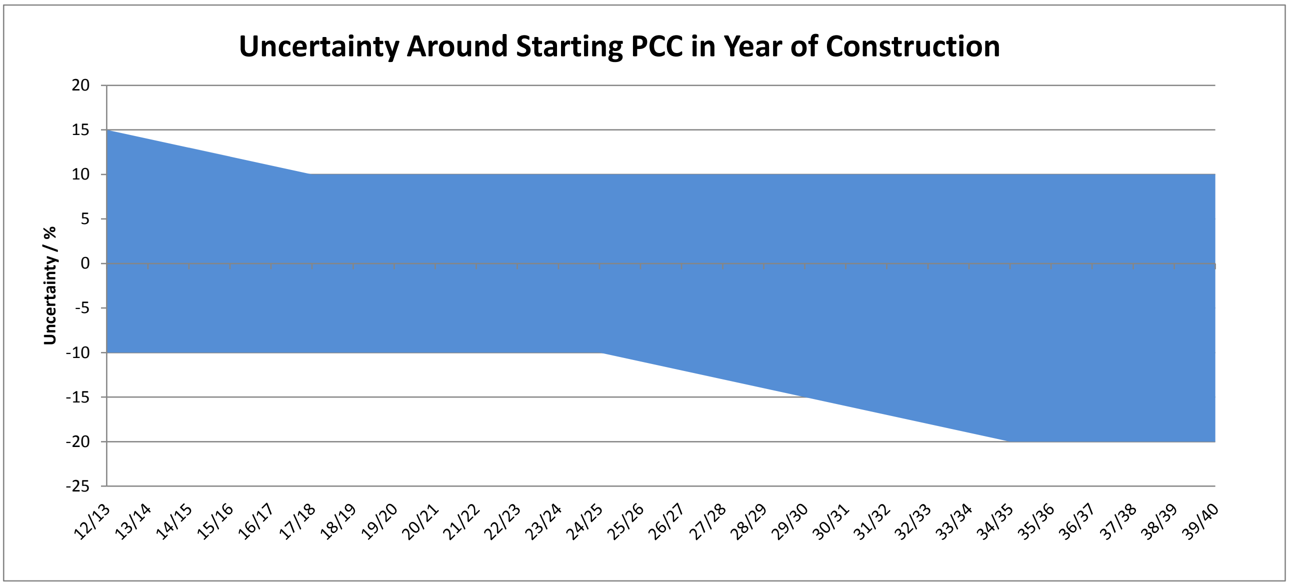

Figure 5-6: New household PCC uncertainty in year of construction

Peaking Factors for peak household consumption

Peaking factors[5] are based on ten years of historic consumption data from the Domestic Water Use Study. Peaking factors observed are averaged over the period and then a standard deviation is calculated which is used to estimate uncertainty. The peaking factors used in the DUN model are shown in Table 5-5 and Table 5-6.

5 A peaking factor is an uplift between the observed values in a particular year to the value that would be observed in planning scenario, such as a dry year

Table 5-5: Measured household peak additional consumption uncertainty

Household Type	Min	M. Likely	Max
Detached	1.26	1.43	1.59
Semi-detached	1.28	1.40	1.51
Terraced	1.05	1.12	1.20
Other flats	1.06	1.13	1.20
Purpose-built flats	1.06	1.13	1.20

Table 5-6: Unmeasured household peak additional consumption uncertainty

Household Type	Min	M. Likely	Max
Detached	1.40	1.59	1.77
Semi-detached	1.42	1.55	1.68
Terraced	1.17	1.25	1.33
Other flats	1.13	1.20	1.28
Purpose-built flats	1.06	1.13	1.20
Non-household	1.06	1.13	1.20

5.3.5 D3 – Impact of climate change on demand

HR Wallingford carried out a study[6] 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 3.3.6. The climate change ranges are summarised in Figure 5-7 for DYAA and Figure 5-8 for DYCP.

[6] HR Wallingford (2012) EX6828 Thames Water Climate Change Impacts and Water Resource Planning. Thames Water Climate Change Impacts on Demand for the 2030s

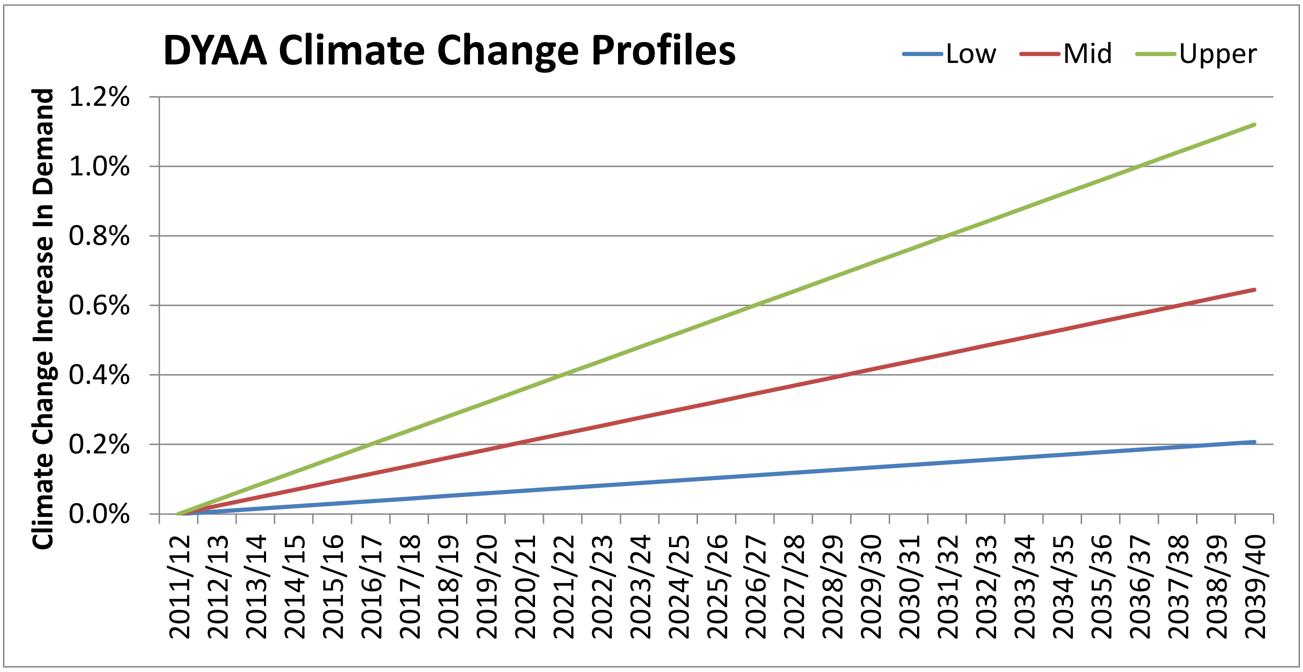

Figure 5-7: The impacts of climate change for the DYAA scenario

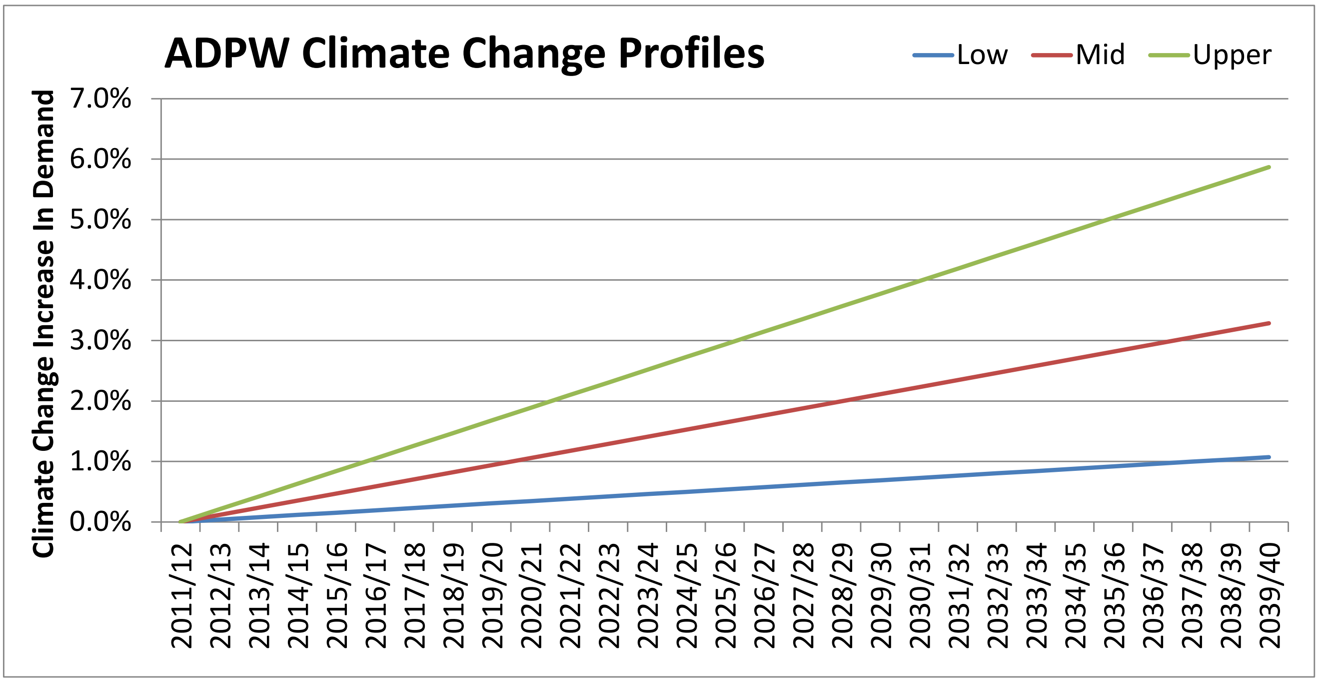

Figure 5-8: The impacts of climate change for the DYCP scenario

5.3.6 D4 – Uncertainty of demand management measures

The sources of uncertainty in demand management measures considered in the DUN model are as follows:

- Metering savings
- Metering delivery
- Water efficiency savings

Leakage uncertainty is not included within the DUN model. While the methodologies used for leakage uncertainty are the same as the other demand components the magnitude of uncertainty and the control Thames Water has on reducing this risk has led us to evaluate leakage uncertainty outside the standard headroom assessment. This has the benefit of allowing a number of measures of risk to be evaluated and allows the leakage control strategy to be refined in order to reduce risk.

Metering Savings

Metering savings have been based on judgement and have an uncertainty range of ±5% to their deterministic value. The ranges this ±5% uncertainty results in are shown in Table 5-7 for progressive metering and in Table 5-8 for optant metering.

Table 5-7: Progressive metering saving uncertainty parameters

WRZ	Unit	Min	Most Likely	Max
London	%	85	87.19	95
Thames Valley	%	80	82.26	95

Table 5-8: Optant metering saving uncertainty parameters

WRZ	Unit	Min	Most Likely	Max
London	%	90	95	100
Thames Valley	%	90	95	100

Metering Delivery

Metering delivery uncertainty is based on professional judgement and reflects the uncertainty of the stated level of metering for both optants and progressive meters being met. A wide range of uncertainty is associated with both components, these ranges are shown in Table 5-9 and Table 5-10. For optants this is due to this being a voluntary process reliant on customers asking for a meter to be installed and is therefore inherently uncertain. For progressive metering the uncertainty reflects that at the time of writing no progressive metering programme has been rolled out within our water supply area previously and therefore uncertainty around delivery is high.

Table 5-9: Progressive metering delivery uncertainty parameters

WRZ	Unit	Min	Most Likely	Max
London	%	95	100	110
Thames Valley	%	95	100	110

Table 5-10: Optant metering delivery uncertainty

WRZ	Unit	Min	Most Likely	Max
London	%	70	100	110
Thames Valley	%	70	100	110

Water Efficiency Uncertainty

The uncertainty for water efficiency is based on a study carried out by Artesia Consulting[7]. The range of uncertainty around savings are shown in Table 5-11. In the demand forecasts the full saving is assumed to be delivered. Based on the results of the Artesia study the uncertainty ranges shown in Figure 5-9 were used in the DUN model.

Table 5-11: Water efficiency savings uncertainty parameters for Households and Non-household

WRZ	Unit	Min	Most Likely	Max
London	%	7	40	100
Thames Valley	%	7	40	100

[7] Artesia (2013) Domestic water use micro-component input values for PCC model for WRMP14. Ref: AR1067

5.4 Model Outputs

The output from the model, which is then used in the headroom model, is a table with a demand value for each 5th percentile. A graphical representation of the output can be seen in Figure 5-9.

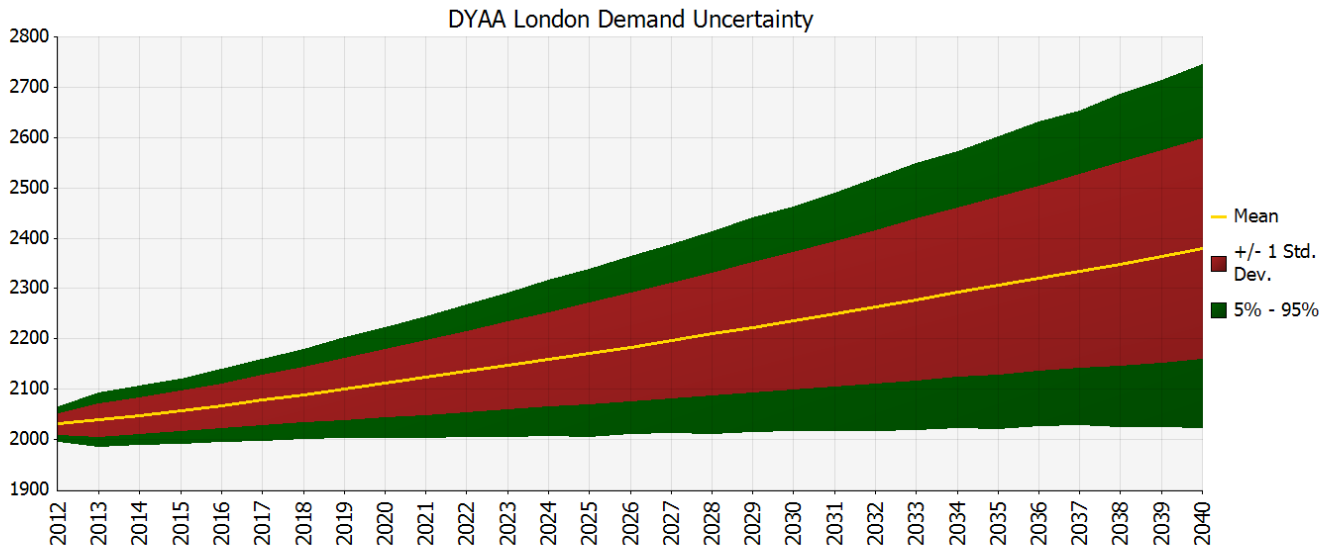

Figure 5-9: Baseline demand forecast uncertainty spread – London WRZ

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.

5.5 Baseline target headroom & risk profile

Our baseline forecast has used a stepped risk profile as shown in Table 5-12. A smaller allowance for uncertainty is made in the future as we consider the opportunity to review plans and adapt to changes. A linear profile of 5% per AMP period has been applied. 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[8].

Table 5-12: Target Headroom Risk Profile

	Headroom Risk Profile (%)					
Plan	**2010-15**	**2015-20**	**2020-25**	**2025-30**	**2030-35**	**2035-40**
WRMP09	10	15	20	25	30	N/A
WRMP14	5	10	15	20	25	30

5.5.1 Target Headroom Components

An example of the typical components of a target headroom profile is provided in Figure 5-10 below, illustrating the relative importance of each of the parameters.

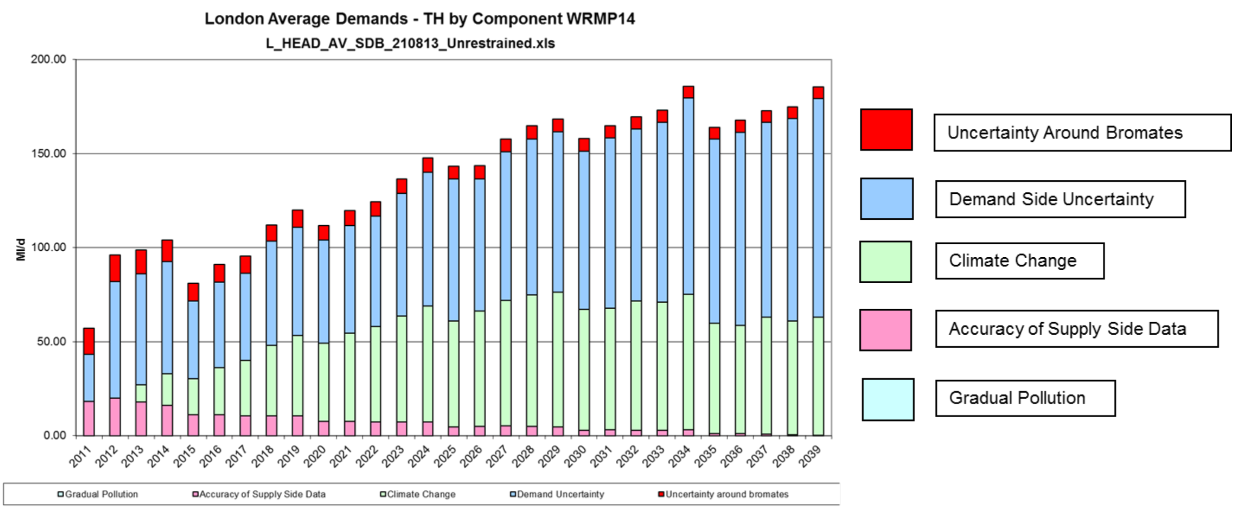

Figure 5-10: Baseline target headroom components

[8] Risk profile based on judgement using the Environment Agency guidelines, the strength of customer research on reliability of supply, the future risks and their characteristics. We tested the plan in Section 10 to changes in the supply-demand balance which can also be used to test how the plan changes with different risk profiles.

Figure 5.10 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 water resource zones 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.

In line with the Water Resource Planning Guidelines our plan does not include any allowance for uncertain sustainability reductions. However studies to date, as detailed in Section 4, 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.

In Section 9 we present our preferred plan. We undertook work to update our target headroom to reflect the uncertainty in the intervention options in the plan. Target headroom has increased between draft and the final WRMP; this is due to:

- Changes in the population forecast
- Resolution of the issue with measured and unmeasured PCC uncertainty;
- Completion of full Monte Carlo analysis of both supply and demand side target headroom; and
- reduction in the error associated with the method used to combine the deterministic demand forecast with the stochastic demand uncertainty forecast.

The method is described in detail in Appendix V.

Table 5-13: Baseline target headroom by WRZ – DYAA

WRZ	Baseline Target Headroom - DYAA (Ml/d)						
	2011/12	2015/16	2020/21	2025/26	2030/31	2035/36	2039/40
Risk Profile →	5%	10%	15%	20%	25%	30%	30%
London	57.2	81.0	111.6	143.2	158.0	163.8	185.3
SWOX	7.1	7.5	10.0	12.6	13.0	13.0	14.5
SWA	7.2	7.2	7.7	8.1	8.6	9.2	9.9
Kennet Valley	4.0	4.9	5.6	6.0	6.2	6.9	7.3
Guildford	3.4	4.1	4.1	4.3	4.6	4.7	4.9
Henley	0.4	0.4	0.5	0.6	0.7	0.7	0.7

Table 5-14: Baseline target headroom by WRZ – DYCP

WRZ	Baseline Target Headroom – DYCP (Ml/d)						
	2011/12	2015/16	2020/21	2025/26	2030/31	2035/36	2039/40
Risk Profile →	5%	10%	15%	20%	25%	30%	30%
London	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SWOX	8.8	9.8	12.3	14.7	14.7	15.0	17.1
SWA	10.6	11.5	12.4	12.8	13.7	13.5	14.5
Kennet Valley	4.2	5.5	5.8	7.8	8.0	8.8	8.6
Guildford	4.3	4.5	4.9	4.9	5.1	5.1	5.5
Henley	0.9	0.7	0.7	0.8	0.8	0.8	0.8

5.6 Errata

5.6.1 SWOX climate change component of Target Headroom

A problem was identified with the SWOX average and peak Target Headroom models, which impacted on how the breakdown of the components of uncertainty were calculated and reported. The overall change in the supply demand balance however has been shown to be negligible given the small values involved and does not impact on the final plan.

The errata identified below refer to the SWOX rows in the "Reference" tables. The current content is shown in the "Reads" row and the amended values are shown in the "Update" row.

Page	Reference	Table 5-1 Climate Change Impact on DO – DYAA							
P10	Reads	SWOX	0.0	1.34	3.58	5.81	7.79	8.49	9.06
	Update	SWOX	0.0	1.33	3.56	5.78	7.74	8.44	9.01

Page	Reference	Table 5-2: Climate Change Impact on DO – DYCP							
P10	Reads	SWOX	0.0	1.56	4.17	6.77	9.07	9.90	10.56
	Update	SWOX	0.0	1.58	4.22	6.85	9.18	10.01	10.68

Page	Reference	Table 5-13: Baseline target headroom by WRZ – DYAA							
P22	Reads	SWOX	7.1	7.5	10.0	12.6	13.0	13.0	14.5
	Update	SWOX	7.1	7.8	10.0	12.7	13.3	13.3	14.8

Page	Reference	Table 5-14: Baseline target headroom by WRZ – DYCP							
P23	Reads	SWOX	8.8	9.8	12.3	14.7	14.7	15.0	17.1
	Update	SWOX	9.0	9.4	12.8	14.5	14.3	14.6	16.6