# Thames Water

# Final Water Resources Management Plan 2019

## Technical Appendices

## Appendix V: Risk and uncertainty

# Table of contents

# Figures



# Tables

Appendix V.

# Risk and uncertainty

- This section of our Water Resources Management Plan 2019 (WRMP19) describes how the uncertainty in determining the supply demand balance, known as Target Headroom, is accounted for in the development of the plan.
- We explain the areas of uncertainty and present how the components of baseline and final plan Target Headroom are derived.
- Target Headroom is defined and its calculation for each of our water resource zones (WRZs) is explained.
- The methodology for both baseline and final plan Target Headroom is described. However outcomes, including Target Headroom over the planning period and component graphs, are presented for baseline only. Final plan Target Headroom outcomes are presented in Section 10: Programme appraisal and scenario testing.

## A. Report structure

V.1 This appendix is structured as follows:

- Definition of Target Headroom
- The methodology is explained
- The components of both the demand side and supply side uncertainty are described
- The calculation of the demand side uncertainty allowance is explained
- The calculation of supply side uncertainty allowance is explained
- How the level of risk has been decided is explained
- The Target Headroom analysis is presented
- The baseline Target Headroom is presented together with the component analysis

## B. Headroom

### *Definition of Target Headroom*

V.2 Uncertainties are inevitable in the planning process and how uncertainty is handled is critical to the formulation of the eventual supply demand programme. Headroom is 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.'*[1]

V.3 Target Headroom is the threshold of minimum acceptable headroom, which would trigger the need for water management options to increase water available for use or decrease demand.

# C. Target Headroom methodology

## *Introduction*

V.4 The industry, through UKWIR, has developed methodologies for assessing the supply demand balance and the planning of water resources. These are based on assessing the risks and uncertainties around the information used in the planning process. These are:

- UKWIR (2016) WRMP19 Methods – Risk Based Planning
- UKWIR (2016) WRMP19 Methods – Decision Making Process
- UKWIR (2002) An Improved Methodology for Assessing Headroom
- UKWIR (2002) Uncertainty and Risk in Supply/Demand Forecasting
- UKWIR (1998) A Practical Method for Converting Uncertainty into Headroom

V.5 We decided to use the same approach for estimating Headroom for the draft 2019 Water Resources Management Plan (WRMP19) as we did for Water Resources Management Plan 2014 (WRMP14), which uses the process as outlined in:

- 'An Improved Methodology for Converting Uncertainty into Headroom', UKWIR 2002[2]
- 'Uncertainty and Risk in Supply/Demand Forecasting', UKWIR 2002[3]

V.6 The former was used to estimate supply side headroom uncertainty and the latter demand side headroom uncertainty. In both cases the authors of the UKWIR reports were commissioned to assist the company in developing the methodology and producing the software. Both methodologies use commercially available risk analysis software (@Risk) built into models developed in Excel spreadsheets.

V.7 The Target Headroom concept to address uncertainty, which utilises the above UKWIR methods from 2002, is a best practice method which links to Risk Composition 3 (the risk composition we are following for our WRMP19 as detailed in Section 4: Current and Future Water Supply) as described within the UKWIR (2016) guidance[4] and as referred to in the 2018 Water Resources Planning Guidelines (WRPG)[5].

V.8 There are two stages at which Target Headroom is calculated:

[1] UKWIR, WRMP19 Methods - Risk Based Planning, 2016
[2] Methodology developed for UKWIR by Mott MacDonald
[3] Methodology developed for UKWIR by Atkins
[4] UKWIR, WRMP19 - Risk Based Planning Methods Guidance, 2016
[5] Environment Agency and Natural Resources Wales and also produced in collaboration with Defra, the Welsh Government, and Ofwat, Final Water Resources Planning Guideline, July 2018.

1) An initial assessment of headroom for the baseline supply demand balance, which does not include two of the headroom categories:
   - S9 "Uncertain output from new resource developments"
   - D4 "Uncertain outcome from demand management measures from AMP6 and beyond"
2) The uncertainty associated with new resource developments and demand management measures is incorporated in the development of the least cost plan, which also includes the baseline uncertainty

## *Supply side components*

V.9 The supply-related headroom components in the methodology use the same naming conventions as previously used; these are as follows:

- S1 Vulnerable surface water licences
- S2 Vulnerable groundwater licences
- S3 Time-limited licences
- S4 Bulk imports
- S5 Gradual pollution of sources (causing a reduction in abstraction)
- S6 Accuracy of supply-side data
- S8 Uncertainty of impact of climate change on source yields
- S9 Uncertain output from new resource developments

V.10 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 WRPG. 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).

V.11 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.

V.12 S5 Gradual Pollution – 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. We have Drinking Water Safety Plans (DWSP) in place for all our supply sources, which include the assessment of their source catchments and the hazards to raw water quality. The DWSP drive the implementation of measures to ensure no deterioration in raw water quality due to anthropogenic sources of pollution, and help to reduce the level of water treatment required while meeting drinking water standards. This includes working with the Environment Agency to develop suitable Catchment Management Plans that mitigate recognised raw water quality issues. In addition, the risk from gradual pollution is managed, where necessary, by the installation (or programmed installation) of suitable treatment processes for nitrates and cryptosporidium. We also have a specific risk of bromate pollution in London which we deal with separately; this is discussed below, and in Section K, under new resource development (S9).

V.13 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

V.14 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.

V.15 The timing of the introduction of restrictions is subjective, however 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.

V.16 These uncertainties around the Accuracy of Supply Side Data (S6) are discussed further in Section I.

V.17 Single Source Dominance (S7) - in the original methodology is now considered as an outage issue and is not included.

V.18 Climate Change (S8) – the uncertainty around climate change is discussed in Section J.

V.19 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 section K below. A brief discussion of the process is provided in Section 5: Allowing for risk and uncertainty and the application of final plan Target Headroom is discussed in Section 10: Programme appraisal.

V.20 Northern New River Wells (NNRW) - an additional uncertainty has been included within the Target Headroom modelling which relates to the risk of 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 Ml/d with an average Source Deployable Output (SDO) of 98.8 Ml/d.

V.21 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 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 our Water Resources Management System (WARMS2) and comparing with the value of DO before the change; here the AR17 Baseline London DO of 2,305 Ml/d derived using the optimised LTCD is used as the base run. The results from which is a reduction in DO of 12 Ml/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.

V.22 North London Artificial Recharge Scheme (NLARS) - One of our strategic water resource schemes is 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 Annual Return 2016 (AR16); named NLARS Scenario 3. However, there remains a risk around what the scheme may actually be capable of during a drought. Therefore 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 AR17 Baseline London DO of 2,305 Ml/d derived using the optimised LTCD is used as the base run. The risk is now in the range 15 Ml/d to 17 Ml/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.

V.23 These uncertainties around New Resource Developments (S9) are discussed further in Section K.

## *Demand side components*

V.24 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 impact of climate change on demand
- D4 – Uncertain outcome from demand management measures

V.25 The exception to this is the uncertainty associated with leakage reductions. We have traditionally employed methods to assess leakage uncertainty and we use these as part of internal planning and performance reporting but excluded them from Target Headroom. For the revised draft WRMP19 we have included a larger number of enhanced leakage activities and significantly increased our ambition on leakage. To manage the uncertainties related to this we have split leakage into two components:

- The first "base" leakage component includes standard activities and we continue to exclude uncertainties around these activities from our Target Headroom assessment.; and
- The second component is new enhanced leakage activities and we have chosen to include these uncertainties in our final planning headroom.

## *Methodologies for assessing uncertainty*

V.26 The methodologies require the uncertainty for each headroom component (listed above) to be defined as a probability distribution. *Headroom uncertainty* can then be calculated, using Monte Carlo simulation, as the sum of the component profiles:

V.27 Supply side headroom uncertainty = S5+S6+S8+S9 (a1)

V.28 Baseline headroom demand side headroom uncertainty is given by

$$D_{Average}^{Total} = D_{HH} + D_{NH} + D_{L} + \Delta D_{BaseYr} \quad \text{(a2)}$$

where

($D_{HH}$) = Household consumption

($D_{NH}$) = Non-household consumption

($\Delta D_{BaseYr}$) = Base year uncertainty

($D_{L}$) = Loss due to "base" leakage (this has no stochastic element)

V.29 There are assumptions inherent in these equations:

- The headroom components are independent. An inspection of the list of components confirms that this is generally the case, but some can be inter-related. One headroom component may be dependent on another, components may be mutually exclusive or components may be correlated. The Monte Carlo analysis can be modified to allow for these inter-relationships. A study of the potential for correlation between demand side components and how correlation is accounted for can be found in section D.
- All sources of headroom uncertainty occur simultaneously, gradual pollution, data inaccuracy and climate change effects can all occur at the same time. This does

represent the true situation, namely that the uncertainties are omnipresent and cumulative. Some uncertainties may be greater than expected and some may be less or zero. Some may not materialise. What is of interest is their effect on the combined uncertainty to the supply demand balance. Monte Carlo simulation allows the combined uncertainty to be estimated.

V.30 This provides a probability distribution of headroom uncertainty. There are a number of other steps before Target Headroom can be calculated for inclusion in the WRMP. The UKWIR WR27 Water Resources Planning Tools Project[6] sought to update and develop a common understanding for water resources practitioners. As part of this work a schedule of definitions was produced and it is the nomenclature used in this report that will be used to describe the conversion of headroom uncertainty into Target Headroom.

V.31 The deterministic value of available headroom is:

$$\text{Available headroom} = \text{WAFU} - D_{DYA} \quad \text{(a3)}$$

Where WAFU is the water available for use and $D_{DYA}$ is the dry year annual average demand. WAFU is defined as the DO less the allowable outage (O) less the "best estimate" of the impact of climate change (CC) for the given year. Equation (a3) can therefore be expanded to

$$\text{Available headroom} = \text{DO} – \text{O} – \text{CC} – D_{DYA} \quad \text{(a4)}$$

V.32 To avoid confusion and in recognition of the fact that the result of equation (a4) can be negative as well as positive, i.e. the DO of a WRZ may not always be greater than the demand, we have substituted the term 'balance of supply' for 'available headroom' in equation (a4)

V.33 If the uncertainty associated with supply (Su) and demand ($D^{Total}_{Average}$) is introduced into equation (a4) then a probabilistic expression (indicated by pdf[…]) can be written as

$$\text{pdf[Balance of Supply]} = (\text{DO} – \text{O} – \text{CC} – \text{pdf[Su]}) – (D_{DYA} - \text{pdf}[D^{Total}_{Average}]) \quad \text{(a5)}$$

pdf[Su] is the summation of the supply side uncertainties S1 to S9 and pdf[$D^{Total}_{Average}$] is the summation of the demand side uncertainties. Equation (a5) can be rearranged to

$$\text{pdf[Balance of Supply]} = (\text{DO} – \text{O} – \text{CC} – \text{DDYA}) - \text{pdf}[\text{Su} + D^{Total}_{Average}] \quad \text{(a6)}$$

$$\text{pdf[Balance of Supply]} = (\text{DO} – \text{O} – \text{CC} – \text{DDYA}) - \text{pdf[Headroom Uncertainty]} \quad \text{(a7)}$$

V.34 Once equation (a7) has been evaluated, Target Headroom at a defined level of risk (sampled from the probability distributions) can be back calculated using

$$\text{Target Headroom (x\% Risk)} = \text{DO} – \text{O} – \text{CC} – \text{DDYA} - \text{Balance of Supply (x\% Risk)} \quad \text{(a8)}$$

V.35 This forms the basis of the methodology that we have adopted for the estimation of Target Headroom.

[6] 'UKWIR, WR27 Water Resources Planning Tools - Definitions, 2012

V.36 The decision on the level of risk to be adopted is obviously key to the process and this will be discussed later.

# D. Demand side uncertainty

V.37 This section provides additional supporting information to supplement the description of demand side uncertainty contained in Section 5.D: Allowing for risk and uncertainty, Demand side uncertainty. As such beyond an initial high level description for each sub-section this section of the appendix does not duplicate information presented elsewhere in the WRMP.

## *Uncertainty in the base year*

V.38 Uncertainty is included around both the recorded value of Distribution Input (DI) in the base year and also the uplift required to re-express base year DI in the planning scenario being used, i.e. dry year annual average (DYAA) or dry year critical period (DYCP) as appropriate.

## *Household per capita consumption (PCC) uncertainty*

V.39 Uncertainty around PCC used in Target Headroom analysis is consistent with the uncertainty around PCC forecasts which output from the household demand forecasting model produced by Artesia Consulting. This model is also used in the production of the deterministic demand forecasts.

## *Household population uncertainty*

V.40 Uncertainty around household population is estimated using the methodology provided in the UKWIR report on population, household property and occupancy forecasting project[7].

V.41 Not only are the forecast values of population used in the production of our plan but the actual population served at current is also uncertain. Uncertainty around the current population we are serving tends to be lowest immediately after we have completed analysis of new Census results[8]. Currently a Census is undertaken every ten years, with the most recent occurring in 2011.

V.42 The population we serve changes by only a few core mechanisms (discussed below) but the underlying drivers for these mechanisms are many, varied and virtually impossible to track in totality. The biggest mechanisms by which the population we serve are birth rates, death rates and net migration, i.e. people becoming resident or leaving our supply area. The population forecast being discussed here is for household (resident) population. We are not considering

[7] UKWIR, WRMP19 Methods – Population, Household Property and Occupancy Forecasting, (15/WR/02/8), 2015

[8] The UKWIR report estimates uncertainty around Census forecasts to be +/- 0.15% nationally and around +/- 0.7% for an individual Local Authority area. Current estimates for Local Authority area level population are +/- 1.4% suggesting uncertainty has doubled in the 4-5 years (report was published in 2015/16) since the Census.

non-resident population[9] here as this is largely considered as part of non-household demand. It is feasible for the population we serve to change as a result of the operating area we cover being changed, but this requires a change to our licence and this is not considered in this analysis.

V.43 The methodology proposed in the UKWIR report is to use one of three time series of normal distributions for population forecasts. The distributions are summarised in Figures 5-8 and 5-9 in Section 5.D: Allowing for risk and uncertainty, Demand-side uncertainty. The choice from amongst the three series is made on the basis of the geographical scale of the population being forecast. The smaller the population being forecast the larger the spread of uncertainty will be. This reflects the fact that in larger areas there is a lesser impact from individual local impacts due to the greater opportunity for offsetting impacts in other parts of the area.

V.44 The distributions produced by UKWIR are based on analysis of forecasts provided by the Office for National Statistics (ONS). These forecasts have been compared to the actual value of populations reported in the 2011 Census, as discussed above the Census reflects the most accurate reporting of population that is likely able to be produced. ONS forecasts produced in 2004, 2006, 2008 and 2010 are compared against the 2011 Census to explore how the accuracy of forecasting changes the further in to the future forecasts are made.

V.45 A final important note is that the authors of the UKWIR report considered that their approach was not suitable for London based on the fact that "*growth of population in some London Boroughs defied all expectations in the period 2001-2011*". We consider that, whilst this impact has the potential to be true at the individual London Borough level, we do believe that it remains true at the WRZ level to which the results are applied. The London WRZ covers the majority of London Boroughs and some Local Authorities outside the Greater London Authority. We consider that this is sufficient scale such that even if forecasts are more volatile in an individual Borough there is greater potential for offsets in other parts of the WRZ.

### *Measured non-household demand*

V.46 Uncertainty around measured household demand is estimated by Servelec Technologies who also produced the deterministic forecast.

### *Impacts of climate change on demand*

V.47 Uncertainty around the impact of climate change on demand forecasts was estimated by HR Wallingford.

### *Metering savings*

V.48 Metering saving estimates both for use in preparing the deterministic demand forecast and for use in characterising uncertainty for Target Headroom analysis is primarily derived from a

[9] Non-resident population are people who use our services but do not live within our operating area. The most material segments amongst these are people who work in our region but live elsewhere and use water whilst at work and visitors to our region who use water in hotels or other commercial premises.

study of nearly 10,000 households performed by our Innovation team. Estimates are triangulated with data from the results achieved by other companies in our region in their own compulsory metering programmes.

V.49 We have not directly considered uncertainty over the volume of meters delivered as part of Target Headroom analysis as we consider the delivery of this target to be largely within our management control and hence not appropriate to include in the analysis.

### *Water efficiency savings*

V.50 Uncertainty around water efficiency savings has been estimated from the results of a study by our Water Efficiency team of actual water efficiency savings in our AMP6 programme. The same assumptions are used for water efficiency in AMP7 and beyond for final planning headroom.

### *Enhanced leakage activities*

V.51 As outlined in V.25 we now include uncertainties around the benefits of:

(i) DMA Enhanced activities, which include Active Leakage Control (ALC) and other measures to improve water accounting ;and

(ii) enhanced mains replacements, pressure management and customer supply leakage.

V.52 The uncertainties in “base” or more standard leakage activities are still excluded from headroom. The approach adopted was to review previous assessments of the uncertainty in these activities and then to hold an internal workshop, which resulted in the introduction of two sub-components uncertainty distributions into D4. For ALC it was assumed that it was ‘most likely’ that we achieved 100% of the planned benefits but introduced a triangular distribution with a minimum value of 70% and maximum value of 105% of the planned benefits. For other measures there was greater confidence in meeting ambitious targets. We assumed that it was ‘most likely’ that we achieved 100% of the planned benefits but introduced a triangular distribution with a minimum value of 80% and maximum value of 105% of the planned benefits.

## *Changes between the Draft and Revised Draft Water Resources Management Plans 2019*

V.53 A summary of demand uncertainty components and changes between the draft revised draft WRMP19 is set out below:

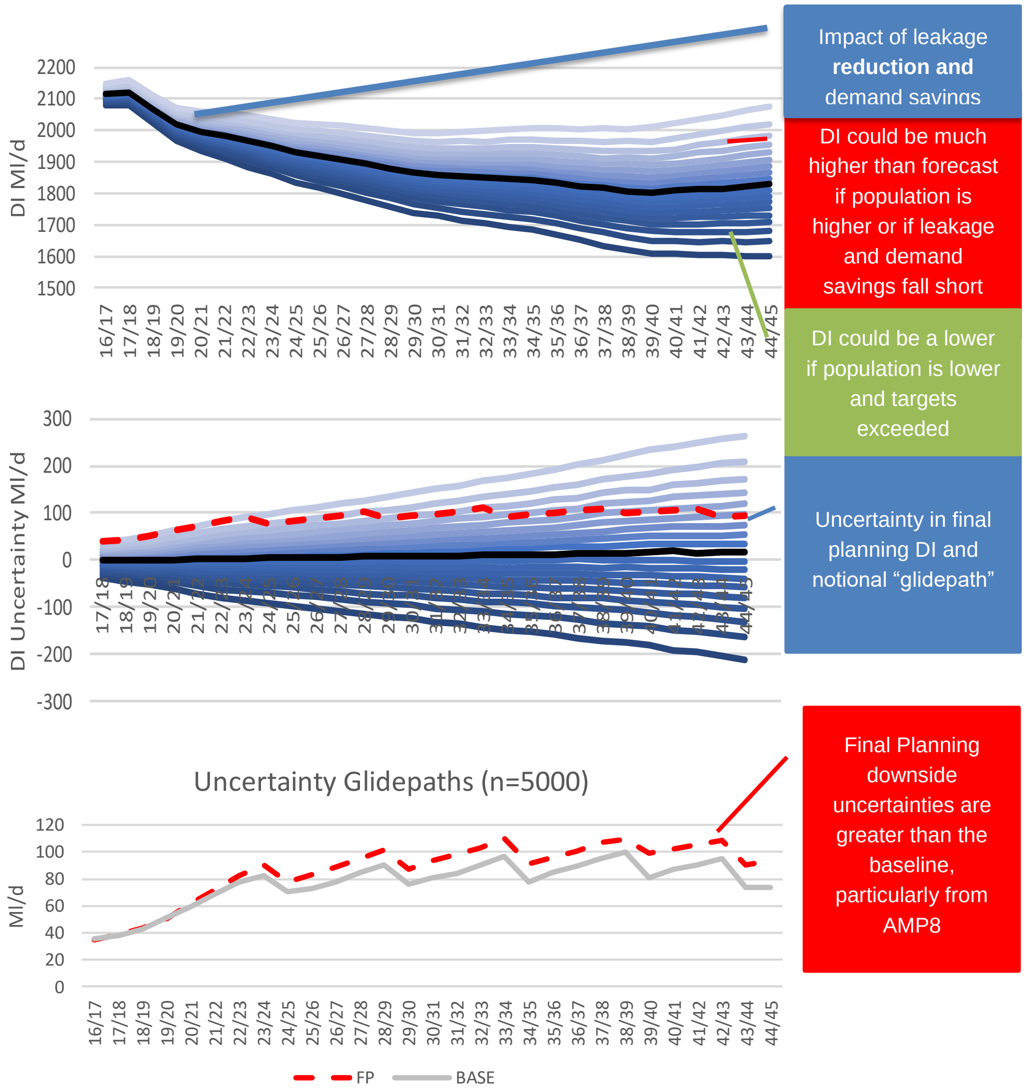
**Table V-1: A summary of demand uncertainty components and changes between the draft and revised draft WRMP19**

| Demand Uncertainty Component | Comments | Change | Cross-ref. or source |
|---|---|---|---|
| **Baseline Target Headroom** | | | |
| D1 – Uncertainty in base year data | Base year DI (+/- 2%) and uplift to DYAA planning scenario (+/- 5%, expert view)<br>Leakage traditionally excluded.<br>Operational usage and water taken unbilled excluded. | No change in D1.<br>Enhanced leakage activities will include some uncertainty *to be included in D4.* | Main report Section 5.D Demand Side Uncertainty |
| D2 – Demand forecast variation | **i. Base PCC** based on Artesia model (3-4% in 2025 and +/-10-11% by 2044 in London for 80% C.I.) (includes PCC trend scenarios, model coefficients, property classification and base year occupancy).<br>**ii. Population Uncertainty** using UKWIR methodology – significant impact (+/- 14% over 30 years).<br>**iii. Non-household demand** Based on Servelec Tech modelling (Fig 5.9 presents wider uncertainties than included in the Sprint spreadsheet) | No change<br>No change<br>No change | Main report Section 5.D Demand Side Uncertainty |
| D3 – Uncertainty of climate change on demand | Minor impact for Dry Year (up to 1% for DYAA) but significant for ADPW (up to 5.5%) | No change | Main report Section 5.D Demand Side Uncertainty<br>Fig. 5.10 |
| D4 – Uncertainty of demand management | Metering savings (Assumed normal ~17% +/- 2%)<br>Water efficiency savings from visits (expected to be 5-6%). Distribution mean 94% s.d. 3% linked to target saving. | No change | Main report Section 5.D Demand Side Uncertainty |
| **New sub-components** | | | |
| D4 –AMP7 water efficiency savings | Not included in draft WRMP<br>We used same distribution as for AMP6 Household Water Efficiency savings from visits (5-6%). Therefore, there is a correlation with AMP6 WEFF assumptions = 1. | Addition to revised draft WRMP | Main report Section 5.D Demand Side Uncertainty |
| D4 - DMA Enhanced Uncertainty of new | Not included in draft WRMP<br>Triangular -30%, planned, +5% over performance. | Addition to revised draft WRMP | Internal workshop with leakage teams |

| Demand Uncertainty Component | Comments | Change | Cross-ref. or source |
|---|---|---|---|
| Active Leakage Control and associated measures | Previous PR14 assessments have assumed +/-10% on demand savings and +/- 20% on the Natural Rate of Rise (NRR) of leakage or around +/- 12.5% overall. In the revised draft WRMP19 improvements has increased, hence a higher likelihood of not meeting targets. Potential underperformance of planned demand savings – 30% | Assuming demand savings of 30 Ml/d and 20 Ml/d in AMP7 and AMP8. Split across London, SWOX and Guildford. | |
| D4 - Pressure Management<br>Uncertainty of new leakage/demand measures | Not included in draft WRMP<br>Triangular -20%, planned, +5% over performance.<br>PR14 previously assumed +/- 16% in AMP5 and -25% plus 10% in AMP6. | Addition to revised draft WRMP19 | Internal workshop with leakage teams |
| D4 - Mains replacement<br>Uncertainty of new leakage/demand measures | As above | Addition to revised draft WRMP19 | Internal workshop with leakage teams |
| D4 - CSL (Customer Side Leakage)<br>Uncertainty of new leakage/demand measures | As above | Addition to revised draft WRMP19 | Internal workshop with leakage teams |
| **Correlations between assumptions** | | | |
| All components | The draft WRMP demand side Headroom analysis included a large correlation matrix between all variables, which has now been removed to simplify the analysis. | Removal of correlations between baseline variables.<br>Addition of moderate positive correlations between water efficiency and leakage reductions for final planning runs only. | ~ |

V.54 The overall impact of these changes can only be seen through comparison on the EBSD+ results as uncertainties are dealt within this model. However, to illustrate the potential impacts the baseline risk profile for Target Headroom can be compared with the equivalent risk profile for Final Planning Headroom (Figure V-1). This shows that “downside” uncertainties for London, SWOX and SWA have increased by around 8 Ml/d, 13 Ml/d and 21 Ml/d for the end of AMP7, end of AMP8 and at the end of 2044/45 respectively.

**Figure V-1: Final planning Headroom demand-side uncertainty (London)**




## *Characterising uncertainty distributions*

V.55 Section 5: Allowing for risk and uncertainty discusses in several places the practice of characterising an uncertainty distribution from a confidence interval or a summary statistics. This sub-section explains how this works in practice.

V.56 Many common types of distribution are characterised (meaning to be completely described by) only a small number of parameters. For example, a normal distribution requires only the mean and the variance or the standard deviation[10] to be defined for any other output or parameter of the distribution to be calculated. The formula below is the probability density function (pdf) of a normal distribution. The pdf describes the probability that the distribution

[10] Standard deviation is the square root of variance

will take any value *x*. Only constants Pi (π) and e (base of the natural logarithm) and the mean (μ) and standard deviation (σ) are used in the pdf to estimate the probability that the distribution = *x*.

$$pdf = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

V.57 In other circumstances we can use known properties of distributions to calculate the parameters used to characterise the distribution.

V.58 A confidence interval can be used to characterise some distributions. A confidence interval describes the range between which there is an associated probability that a random sample from the distribution will fall. For example, if we say that the range 20 to 50 is 95% confidence interval for a distribution there is then a 95% chance a random sample from that distribution will be greater than or equal to 20 and less than or equal to 50.

V.59 If the distribution is assumed to be normal then a confidence interval can be used to derive both the mean and standard deviation of the distribution. Because a normal distribution is symmetric about its mean we can calculate the mean to be the mid-point of the confidence interval. So from the example in the paragraph above, if the distribution is normal, then the mean is 35. For any normal distribution the width of a confidence interval of any given percentage is the same number of standard deviations. A 95% confidence interval for any normal distribution is 3.92 * standard deviation wide. Therefore, for the example in the paragraph above the standard deviation is 7.65.

V.60 The Target Headroom analysis has also used PERT distributions to describe distributions which are believed not to be symmetrical. In the same way that a normal distribution is characterised by its mean and standard deviation a PERT distribution is typically characterised by the minimum, most likely and maximum value. However, you can use any percentile value above the most likely value to find the maximum and any percentile value below the most likely value to find the minimum. Therefore, the specialist Monte Carlo modelling software[11] used to perform Target Headroom analysis will accept inputs of this type to define a PERT distribution.

# E. Supply side uncertainty

V.61 Data and information have been assembled for each headroom component in each WRZ. This information came from a variety of sources within the business, including expert judgement. Data, whenever possible, makes use of standard practice.

V.62 Each of the components is expressed as a probability distribution. The type of probability distribution selected is that which is best suited to the type of available data or information. Guidance on distribution selection is provided in the model documentation.

[11] Pallisade @Risk.

## Combining supply and demand side uncertainties

V.63 Supply-side and demand-side uncertainties are combined to produce an initial headroom uncertainty which does not include the uncertainty around output from new resource developments and the uncertainty around demand management measures. In practice, this is achieved by inputting the total demand side probability distribution output from the demand-side model using the baseline demand forecasts into the supply-side model.

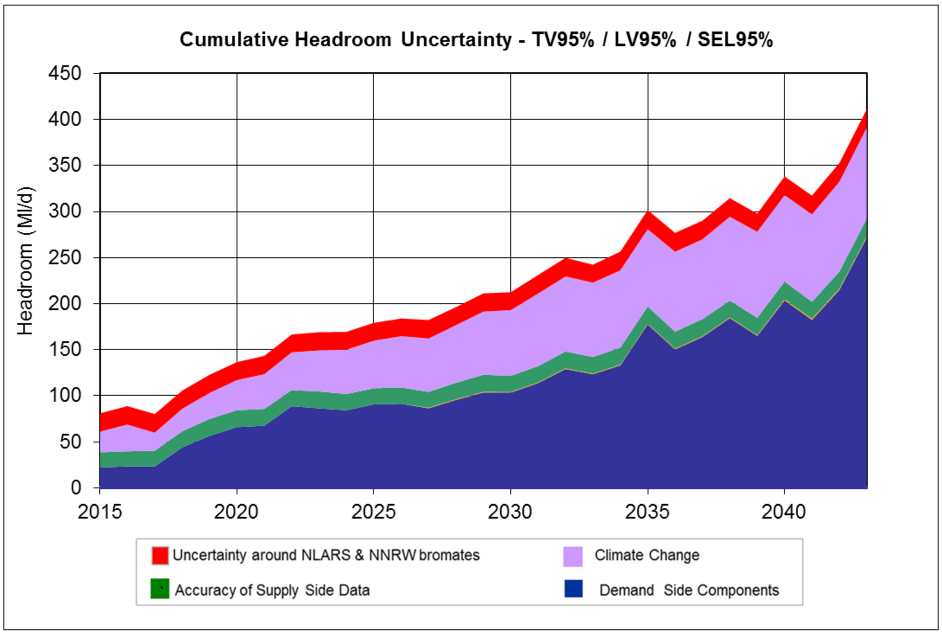
V.64 The resultant initial Target Headroom data is then input to the modelling to develop the least cost plan, which introduces the uncertainty associated with new resource developments and demand management measures. The Programme Appraisal methodology is outlined in Appendix W: Programme appraisal methods.

## Reviewing the headroom components

V.65 One of the strengths of the methodology is that it enables the components of headroom uncertainty to be displayed in a way that promotes discussion and decision about how the individual components should be incorporated in the analysis. In particular, it facilitates a comparison between the various components that contribute most to the uncertainty. This facility applies to the supply-side and combination model.

V.66 A typical example of the component analysis is shown in Figure V-2. It is clear that, for London, the largest contributions are made by demand side uncertainty and supply side climate change and the way that this should be incorporated has been subject to detailed analysis. Climate change analysis is detailed in Appendix U: Climate change.

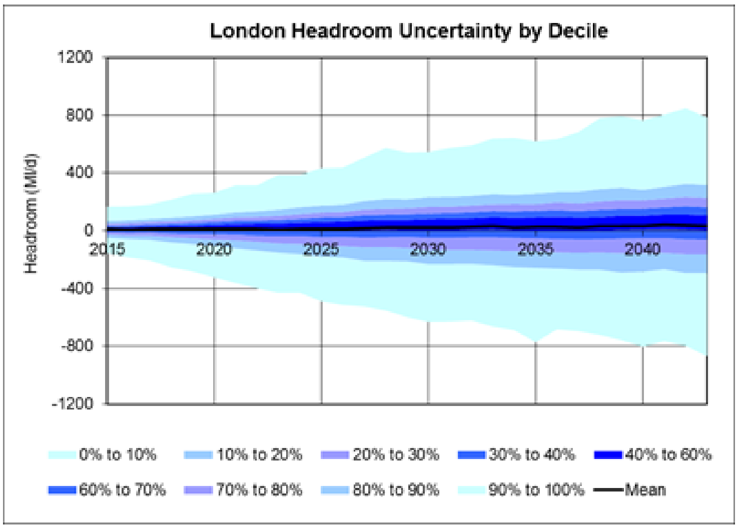
**Figure V-2: London – components of headroom uncertainty (95%ile)**



# F. Calculating Target Headroom

V.67 An example of the combined headroom uncertainty for London over time during the planning horizon is given in Figure V-3. This discussion is based on the base line assessment so the uncertainties around new schemes and the demand management uncertainties are not present in this sample analysis.

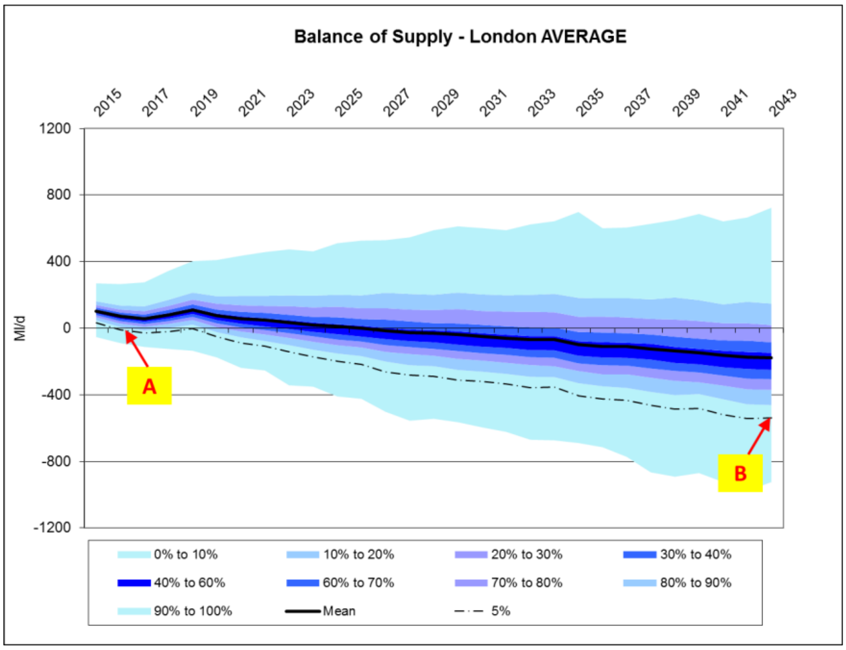
**Figure V-3: Headroom uncertainty – London**




V.68 Demand forecasts, DO[12] and outage values for each year in the planning period are also input to the model and a probability distribution of the balance of supply is produced using the headroom uncertainty equation (a7) in paragraph V.33. The resulting balance of supply for London is shown in Figure V-4.

[12] Calculated using Thames Water's WARMS2

**Figure V-4: Headroom: balance of supply – London**




V.69 From the balance of supply, Target Headroom at a defined level of risk can then be back calculated using equation (a8) in paragraph V.34. This is probably best illustrated by means of a worked example[13].

- For 2016: $D_{DYA}$ = 2105.27 Ml/d

  DO = 2288.70 Ml/d (i.e. base DO 2305 Ml/d less bulk supply and insets of 16.3 Ml/d and zero sustainability reductions)

  Outage = 84.55 Ml/d

  Climate change impact = 19.46 Ml/d

- If a risk of 5% is selected the balance of supply is -10.49 Ml/d (Point A on Figure V-4) and Target Headroom can be back calculated using equation (a8) in paragraph V.34.
- Target Headroom 2016 (5% Risk) = DO – O – CC – $D_{DYA}$ – Balance of Supply (5% Risk)

  = 2288.70 – 84.55 – 19.46 – 2105.27 – (-10.49)

  = 89.91Ml/d

V.70 This process is repeated for each year in the planning period applying the appropriate risk until 2043/44 where the Target Headroom remains the same value for the remainder of the planning period 2043-2100:

- For 2043: $D_{DYA}$ = 2193.87 Ml/d

  DO = 2248.48 Ml/d (i.e. base DO 2305 Ml/d plus 5 Ml/d from AMP6 schemes less bulk supply and insets of 18.52 Ml/d and net

[13] It should be noted that these numbers are for illustration purposes only and are not reported information

reductions from licence changes and Npower Trading Agreement expiring of -12 Ml/d less 8 Ml/d impact of Bray abstraction less 23 Ml/d Essex and Suffolk bulk supply adjustment.)

Outage = 84.55 Ml/d

Climate change impact = 114.30 Ml/d

- If a risk of 5% is selected the balance of supply is – 537.58 Ml/d (Point B on Figure V-4) and Target Headroom can be back calculated using equation (a8) in paragraph V.34.
- Target Headroom 2043 (5% Risk) = DO – O – CC – $D_{DYA}$ – Balance of Supply (5% Risk)

= 2248.48 – 84.55 – 114.30 – 2193.87 – (-537.58)

= 393.34 Ml/d

V.71 Clearly this would change if the level of associated risk applied varies over the planning period.

V.72 By building these equations into the model, Target Headroom can be determined for a range of risk for the planning period. An example of the Target Headroom for London at 5% risk is shown in Figure V-5. Note that there is variation in the Target Headroom values due to the use of Monte Carlo sampling techniques.

**Figure V-5: Target Headroom at 5% risk – London**

# G. Target Headroom risk

### *Setting the level of risk*

V.73 Target Headroom can be calculated for the full range of risk over the planning period as shown in Figure V-3 which is the result of 4,000 Monte Carlo simulations at each level of risk.

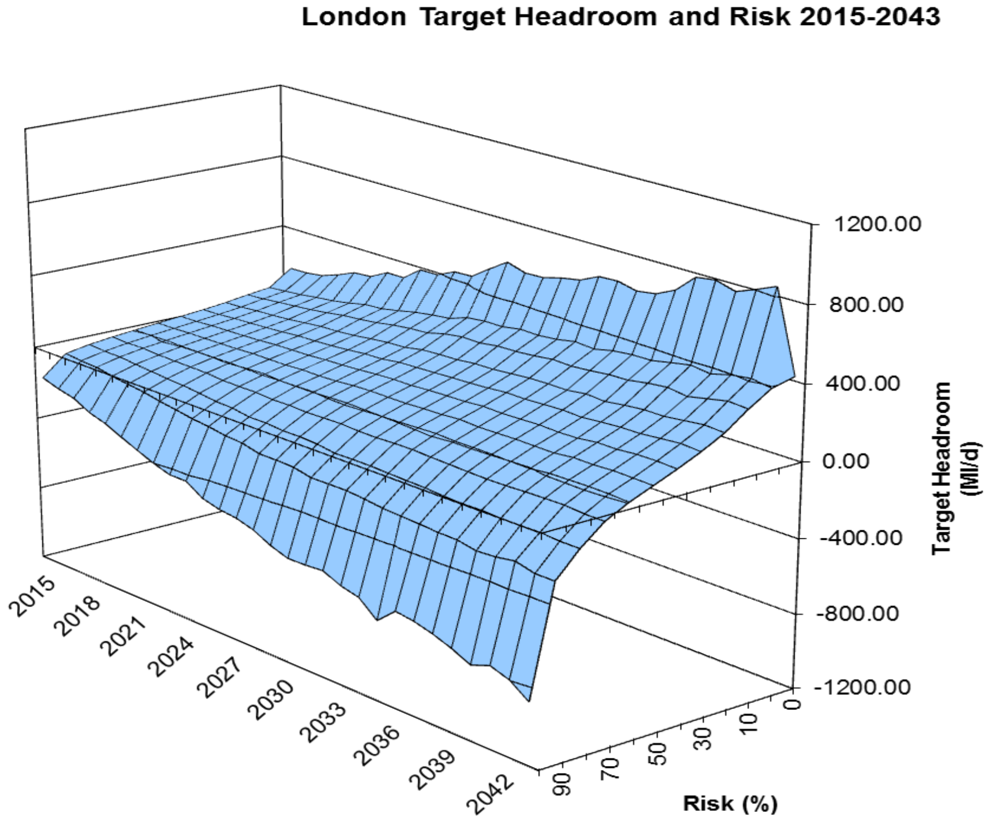
V.74 As can be seen from Figure V-6, it is possible for Target Headroom to be negative. In other words under certain circumstances a headroom allowance is not necessary and at the extreme there may be an over provision of DO at the defined Level of Service. In the short term, this may be because the uncertainties around both supply and demand side data are based upon metered figures and meters can both under and over register. In the longer term, this may be related to the increased range of uncertainty around the population forecasts. There is around a 60% chance that headroom will be required in 2022, in other words for four years in ten there may be no requirement for the supply demand balance to cover uncertainty. This however excludes the risk around the provision of new resources or demand management measures and would increase markedly if this were to be included, probably to around 70% to 80% by 2022. After 2022, this risk continues to increase but much more slowly. It is clear therefore, that to underestimate the requirement for headroom would be a high-risk strategy and one that no prudent company would accept.

V.75 The Environment Agency recognise the need for companies to make informed decisions about an appropriate level of planning risk and to choose to accept a level of risk (or uncertainty) according to company policy. The Environment Agency[14] recognises that:

- It is neither practical nor affordable to plan for 100% certainty and the Environment Agency and Ofwat will not expect to see water companies producing headroom calculations that allow such a level of certainty.
- Water companies should not take unnecessary risks by applying too low Target Headroom.
- Water companies need to assess individual components of uncertainty and variability using risk-based planning techniques, through the decision making tool or assess uncertainty separately from individual components using the Target Headroom approach.
- Water companies should accept a higher level of risk in future than at present. This is because, over time, the uncertainties for which headroom allows will become smaller.

[14] They note that in most cases a comparison with the previous level of Target Headroom will be appropriate

**Figure V-6: London Target Headroom and risk 2015–2043**




V.76 The Environment Agency also requires that assumptions of risk must be documented and justified. Further, once the level of headroom risk is defined, evidence is required on how the choice of Target Headroom is linked to the target Level of Service, which may be considered as the risk that there will be insufficient supply in the WRZ in a repeat of the worst drought in the historic record.

V.77 One of the strengths of the methodology is that it provides information on which to base a decision on risk and it has fuelled considerable discussion inside the company. A key issue was the degree to which a decision on risk would potentially impact on customers. For example, if 10% were seen as an acceptable level of risk it means that there is, by definition, a 10% risk (1:10 on average) that there would be insufficient headroom to cover the full range of uncertainty. Additional resources (or demand savings) would be needed therefore to maintain the Level of Service in the critical drought period. The discussions were centred on how this shortfall might be managed.

V.78 An overall planning risk throughout the plan period of 5% was considered to best reflect the level of risk the business should accept. However, for investment planning purposes it is not sensible to have a single level of risk for the entire planning period and the level of risk later in the period should reflect the lead-time for development to return the system to the planning risk, should this prove to be needed.

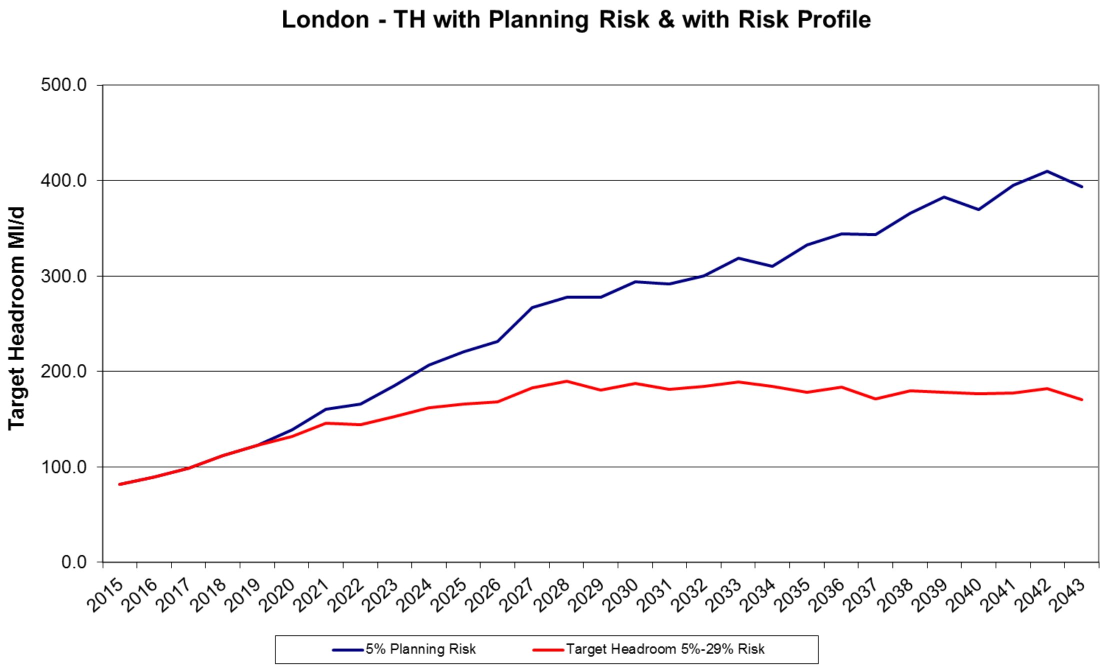
V.79 It was decided that the risk for Target Headroom should be 5% for AMP6 (the same as the planning risk) but should have the profile given in Table V-2 for the subsequent AMP periods. Note the profile increases at 1% per annum until 2043/44 then is held at this level over the remainder of the planning period to 2100. This was based on our judgement of a reasonable balance using the strength of customer research on reliability of supply, the future risks and uncertainties and the ability to be flexible for the future.

**Table V-2: Risk profile for Target Headroom assessment**

| | Headroom risk profile (%) | | | | | | |
|---|---|---|---|---|---|---|---|
| | **2016/17** | **2019/20** | **2024/25** | **2029/30** | **2034/35** | **2039/40** | **2043/44** |
| Planning risk | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| WRMP19 | 5 | 5 | 10 | 15 | 20 | 25 | 29 |

V.80 Adopting this risk profile will result in deficits against the planning risk and an example is shown for the London area between the blue and the red lines in Figure V-7.

**Figure V-7: London – deficits against planning risk with Target Headroom risk profile**




V.81 It is considered that there is sufficient lead-time to cover the additional risk. For example, a list of contingency options has been identified in Appendix P: Options list tables.

# H. Target Headroom analysis

V.82 A review of the components of headroom uncertainty within the Target Headroom modelling has been undertaken and updated where appropriate. The sources of uncertainty not included in the analysis are S1, S2, S3, S4 and S5. For those components that are sources of uncertainty in our planning process the relevant changes in assumptions are outlined below.

# I. Accuracy of supply side data

## *General*

V.83 Data inaccuracy and scarcity of information may render estimates of 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 WRZs:

- Pump or infrastructure capacity
- Abstraction licence limits
- Aquifer characteristics for groundwater
- Climate and catchment characteristics affecting surface waters

V.84 These four issues are discussed in detail below.

### ***Infrastructure constrained sources***

V.85 The output from some sources is constrained by the capacity of the infrastructure, in particular borehole pumps. Given that pumps and infrastructure degrade with time, it is more likely that the capacity is less than previously thought. Thus, a skewed triangular probability distribution may be appropriate for uncertain infrastructure capacity. With the information available, a linear relationship between the estimates is sufficient, and therefore a triangular distribution is most adequate. Based on engineering judgement and experience, parameters of -2% and +1% have been selected for this component in each of the WRZs.

### ***Licence constrained sources***

V.86 Licence constrained sources may be subject to meter error. If a source is believed to be operating at its licensed output, but the meter is under-registering, then the output of the source will have to be reduced when the meter is checked and corrected. Similarly, if the meter is over-registering, then the output of the source could increase before exceeding its licence. An allowance for meter inaccuracy is included in headroom uncertainty where the source meter is different to the meter(s) used to measure DI. Where the same meter is used to measure source output and distribution, there can be no uncertainty between supply and demand. The assessment of the meter calibration data shows that there is no bias towards either a + or - meter inaccuracy. On this basis a symmetrical distribution is selected. The normal distribution allows extreme values to be included without disproportionally increasing the probability of values above 95% occurring. Analysis of our meter calibration data suggests that there is an average variation in meter results of +1.5%, but some meters can have errors in excess of ±10%. For this component a 95%ile value equal to the average error has been selected and the standard deviation selected accordingly. This allows the extremities of the distribution to exceed the expected maximum variations.

***Aquifer constrained sources***

V.87 Establishing the DO from groundwater sources that are not pump or licence constrained is an uncertain process. The "Methodology for the Determination of Outputs of Groundwater Sources" published by UKWIR[15] and used by Thames Water and most water companies for assessing DO is pragmatic and its accuracy is dependent on the availability of good operational data. The construction of the operational drought curve is a matter of judgement and depends on there being good operational records available to define aquifer behaviour under drought conditions. Where such data is lacking, the positioning of the drought curve is more subject to error. With the information available, a linear relationship between the estimates is sufficient, and therefore a triangular distribution is most adequate. Based on a review of a selection of aquifer constrained source yields within Thames Water, an uncertainty of -2 and +10% has been assumed, with the most likely estimate as zero.

***Surface water constrained sources***

V.88 The modelling of the DO from surface waters is crucially dependent on the accuracy of the hydrological records. The accuracy of these records depends on:

- Measurement errors (river flows, rainfall records etc.)
- The reliance placed on in-filled data
- The quality of the information on spill volumes and compensations releases
- The level of detail available (e.g. monthly or daily data)

V.89 In many cases hydrological records are extended by the use of catchment modelling. Although a widely used technique, it cannot be relied upon to generate river flows which are more accurate than ±10% and on small to medium sized catchments the errors may be greater at ±20%.

V.90 In addition to data accuracy, the models used to simulate river flows or reservoir inflows may not fully represent the catchment. The errors that result will increase uncertainty of DO estimates. Quantifying the potential impacts of data and model inaccuracy on DOs requires judgement by those most familiar with the sources and hydrological analyses. In this instance a global estimate of +/- 2% is assumed to cover the uncertainty of all the issues identified above.

V.91 No change has been made in the percentage error assumptions applied to the DO for each WRZ since WRMP09. Minor sampling changes only are observed from this component of the analysis.

[15] Dr Sarah Beeson, Jan Van Wonderen, Bill Misstear, UKWIR, A Methodology for the Determination of Outputs of Groundwater Sources, 1995

### *Linking the Drought Management Plan with the WRMP19*

V.92 As part of our Drought Plan actions we will be required to introduce restrictions upon customers earlier than has historically been the case, when introduction of restrictions was based on the Lower Thames reservoir storage and the LTCD. The Drought Plan methodology allows time for the process of securing "regulatory permissions" such as drought orders and drought permits. As a result of imposing Level 3 TUBs in London at an early stage in a drought event, and earlier than in the defined methodology for determining DO, there will be a potential DO benefit of 31 Ml/d. The timing of the introduction of restrictions is subjective however and the benefit will not necessarily always arise.

V.93 By introducing restrictions on customers earlier than in the methodology for determining the DO, a bias in favour of an increased DO is being introduced. To account for this uncertainty in the DO calculation and the supply-demand balance, the "risk" can be included within the Target Headroom modelling as a negative skew, i.e. a reduction in Target Headroom. The 31 Ml/d benefit for introducing restrictions early represents 1.34% of the current DO therefore this skewed distribution is included in the Target Headroom modelling through the "accuracy of supply side data" component. By adopting this approach the result is to decrease Target Headroom by around 4 Ml/d to 5 Ml/d over the planning period depending on the level of risk applied.

V.94 In the Swindon and Oxfordshire (SWOX) WRZ the potential benefit from bringing on restrictions earlier is a 2 Ml/d benefit on average and 2.38 Ml/d on peak. These values have been applied as a negative skew around the "accuracy of supply side data" component as an expedient way of reflecting the potential benefit.

## J. Climate change

V.95 The impact of climate change uncertainty is based upon the DO at the time of assessment. The WRPG requires that the "best estimate" of the impact is deducted directly from the DO of each WRZ. This amount is dependent upon the scaling factor used in any year of the planning period. The variation around the "best estimate" value is included in Target Headroom. The methodology for assessing the climate change impact is described in Appendix U: Climate change.

V.96 The climate change analysis has not been updated between the draft and revised draft WRMP19. However the baseline DOs have been updated to align them with AR17+ figures. The change introduced between draft and revised draft WRMP19 by using AR17 climate change analysis with AR17+ DO on climate change impact on DO in 2085/86 is due to variation from the Monte Carlo analysis within the Target Headroom model in combination with the difference between AR17 and AR17+ DOs.

V.97 This process of updating the baseline DOs and not updating the climate change analysis between draft and revised draft is consistent with our process for preparing our Annual Review DO submissions between WRMPs. This is because the climate change analysis is only completed once every five years as part of the WRMP process and has resulted in a marginal change in climate change impact.

V.98 The UK Climate Projections 2009 (UKCP09) data was first used in assessing climate change impacts for the WRMP14. HR Wallingford were employed to develop the WRMP14 approach to assessing climate change impacts, which was based around using climatological drought indicators to identify a sub-sample of 20 climate change scenarios from the 10,000 member UKCP09 ensemble for the 2030s. 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.

V.99 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 WRMP19 and carried forward to the revised draft.

V.100 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.

V.101 The percentiles of the sample extracted for use in the DO impact analysis for London are shown in Table V-3. The probability weighting also shown in Table V-3 is used as input to the discrete distributions to determine the uncertainty around climate change impacts on DO in the Target Headroom analysis.

**Table V-3: Climate change impact on London's DO for the draft WRMP19**

| Scenario | Percentile | Probability weighting | London DO Ml/d | Impact on London DO Ml/d | Difference from base (%) |
|---|---|---|---|---|---|
| No CC | N/A | N/A | 2,305 | Base Position | N/A |
| 1 | 99 | 0.01 | 1,888 | -417 | -18.1% |
| 2 | 98 | 0.01 | 1,823 | -482 | -20.9% |
| 3 | 97 | 0.01 | 1,892 | -413 | -17.9% |
| 4 | 96 | 0.01 | 1,820 | -485 | -21.0% |
| 5 | 95 | 0.01 | 1,866 | -439 | -19.0% |
| 6 | 94 | 0.01 | 2,008 | -297 | -12.9% |
| 7 | 93 | 0.01 | 1,958 | -347 | -15.1% |
| 8 | 92 | 0.01 | 2,052 | -253 | -11.0% |
| 9 | 91 | 0.01 | 1,883 | -422 | -18.3% |
| 10 | 90 | 0.01 | 1,895 | -410 | -17.8% |
| 11 | 89 | 0.05 | 1,958 | -347 | -15.1% |
| 12 | 80 | 0.095 | 1,980 | -325 | -14.1% |
| 13 | 70 | 0.1 | 2,007 | -298 | -12.9% |
| 14 | 60 | 0.1 | 2,083 | -222 | -9.6% |
| 15 | 50 | 0.1 | 2,061 | -244 | -10.6% |
| 16 | 40 | 0.1 | 2,125 | -180 | -7.8% |
| 17 | 30 | 0.1 | 2,124 | -181 | -7.9% |
| 18 | 20 | 0.1 | 2,262 | -43 | -1.9% |
| 19 | 10 | 0.095 | 2,353 | 48 | 2.1% |
| 20 | 1 | 0.06 | 2,509 | 204 | 8.9% |

*Note: Scenarios: 1 – Very Dry; 5 – Dry; 10 – Med-Dry; 15 – Medium; 19 - Med-Wet*

V.102 On running the data for the 20 scenarios through WARMS2, the total impact on London's DO for each of the climate change scenarios is calculated; this is also presented in Table V-3. These data are then input to the Target Headroom model to establish the Target Headroom component of climate change uncertainty for London.

V.103 Similarly the climate change impact was assessed for the SWOX average DO and the results are shown in Table V-4. Again the results are input to the SWOX average Target Headroom model to determine the uncertainty around climate change in Target Headroom.

**Table V-4: Climate change impact on SWOX average DO for the draft WRMP19**

| Scenario | Percentile | Probability weighting | SWOX DO Ml/d | Impact on SWOX DO Ml/d | Difference from base (%) |
|---|---|---|---|---|---|
| No CC | N/A | N/A | 329.2 | Base | N/A |
| 1 | 99 | 0.01 | 295.7 | -33.5 | -10.2% |
| 2 | 98 | 0.01 | 295.6 | -33.5 | -10.2% |
| 3 | 97 | 0.01 | 308.1 | -21.1 | -6.4% |
| 4 | 96 | 0.01 | 297.5 | -31.7 | -9.6% |
| 5 | 95 | 0.01 | 298.1 | -31.1 | -9.5% |
| 6 | 94 | 0.01 | 310.6 | -18.6 | -5.7% |
| 7 | 93 | 0.01 | 304.3 | -24.9 | -7.6% |
| 8 | 92 | 0.01 | 310.1 | -19.1 | -5.8% |
| 9 | 91 | 0.01 | 302.7 | -26.5 | -8.0% |
| 10 | 90 | 0.01 | 309.1 | -20.1 | -6.1% |
| 11 | 89 | 0.05 | 312.2 | -17.0 | -5.2% |
| 12 | 80 | 0.095 | 313.2 | -16.0 | -4.9% |
| 13 | 70 | 0.1 | 312.5 | -16.6 | -5.1% |
| 14 | 60 | 0.1 | 319.5 | -9.7 | -2.9% |
| 15 | 50 | 0.1 | 317.9 | -11.3 | -3.4% |
| 16 | 40 | 0.1 | 320.7 | -8.5 | -2.6% |
| 17 | 30 | 0.1 | 317.2 | -11.9 | -3.6% |
| 18 | 20 | 0.1 | 328.6 | -0.6 | -0.2% |
| 19 | 10 | 0.095 | 330.9 | 1.7 | 0.5% |
| 20 | 1 | 0.06 | 330.9 | 1.7 | 0.5% |

*Note: Scenarios: 1 – Very Dry; 5 – Dry; 10 – Med-Dry; 15 – Medium; 19 - Med-Wet*

V.104 Again the climate change impact was assessed for the SWOX peak DO and the results are shown in Table V-5. Again the results are input to the SWOX peak Target Headroom model to determine the uncertainty around climate change in Target Headroom.

**Table V-5: Climate change impact on SWOX peak DO for the draft WRMP19**

| Scenario | Percentile | Probability weighting | SWOX DO Ml/d | Impact on SWOX DO Ml/d | Difference from base (%) |
|---|---|---|---|---|---|
| No CC | N/A | N/A | 385.4 | Base | N/A |
| 1 | 99 | 0.01 | 346.4 | -39.0 | -10.1% |
| 2 | 98 | 0.01 | 346.3 | -39.1 | -10.1% |
| 3 | 97 | 0.01 | 360.9 | -24.5 | -6.4% |
| 4 | 96 | 0.01 | 348.4 | -37.0 | -9.6% |
| 5 | 95 | 0.01 | 348.9 | -36.4 | -9.5% |
| 6 | 94 | 0.01 | 363.6 | -21.7 | -5.6% |
| 7 | 93 | 0.01 | 356.3 | -29.1 | -7.6% |
| 8 | 92 | 0.01 | 362.9 | -22.5 | -5.8% |
| 9 | 91 | 0.01 | 354.7 | -30.7 | -8.0% |
| 10 | 90 | 0.01 | 362.1 | -23.3 | -6.0% |
| 11 | 89 | 0.05 | 365.8 | -19.6 | -5.1% |
| 12 | 80 | 0.095 | 367.0 | -18.4 | -4.8% |
| 13 | 70 | 0.1 | 366.0 | -19.4 | -5.0% |
| 14 | 60 | 0.1 | 374.4 | -11.0 | -2.8% |
| 15 | 50 | 0.1 | 372.3 | -13.1 | -3.4% |
| 16 | 40 | 0.1 | 375.8 | -9.6 | -2.5% |
| 17 | 30 | 0.1 | 371.8 | -13.6 | -3.5% |
| 18 | 20 | 0.1 | 384.9 | -0.4 | -0.1% |
| 19 | 10 | 0.095 | 387.6 | 2.2 | 0.6% |
| 20 | 1 | 0.06 | 387.6 | 2.2 | 0.6% |

*Note: Scenarios: 1 – Very Dry; 5 – Dry; 10 – Med-Dry; 15 – Medium; 19 - Med-Wet*

V.105 An assessment of the climate change impacts has also been made on the non-conjunctive use WRZs of the Thames Valley. The impacts of climate change on average and peak DO for the WRMP19 is shown from Table V-6 through to Table V-9.

**Table V-6: Climate change impact on Kennet Valley (KV) average DO for the draft WRMP19**

| Scenario | Percentile | Probability weighting | KV DO Ml/d | Impact on KV DO Ml/d | Difference from base (%) |
|---|---|---|---|---|---|
| No CC | N/A | N/A | 135.8 | Base | N/A |
| 1 | 99 | 0.01 | 122.1 | -13.7 | -10.1% |
| 2 | 98 | 0.01 | 119.9 | -15.9 | -11.7% |
| 3 | 97 | 0.01 | 118.0 | -17.8 | -13.1% |
| 4 | 96 | 0.01 | 121.9 | -13.9 | -10.2% |
| 5 | 95 | 0.01 | 127.8 | -8.0 | -5.9% |
| 6 | 94 | 0.01 | 125.1 | -10.8 | -7.9% |
| 7 | 93 | 0.01 | 133.6 | -2.2 | -1.6% |
| 8 | 92 | 0.01 | 124.3 | -11.5 | -8.5% |
| 9 | 91 | 0.01 | 124.4 | -11.4 | -8.4% |
| 10 | 90 | 0.01 | 123.0 | -12.9 | -9.5% |
| 11 | 89 | 0.05 | 126.2 | -9.6 | -7.0% |
| 12 | 80 | 0.095 | 127.5 | -8.3 | -6.1% |
| 13 | 70 | 0.1 | 135.4 | -0.4 | -0.3% |
| 14 | 60 | 0.1 | 123.0 | -12.8 | -9.4% |
| 15 | 50 | 0.1 | 135.4 | -0.4 | -0.3% |
| 16 | 40 | 0.1 | 135.4 | -0.4 | -0.3% |
| 17 | 30 | 0.1 | 135.4 | -0.4 | -0.3% |
| 18 | 20 | 0.1 | 134.6 | -1.2 | -0.9% |
| 19 | 10 | 0.095 | 135.8 | 0.0 | 0.0% |
| 20 | 1 | 0.06 | 135.8 | 0.0 | 0.0% |

*Note: Scenarios: 1 – Very Dry; 5 – Dry; 10 – Med-Dry; 15 – Medium; 19 - Med-Wet*

**Table V-7: Climate change impact on Kennet Valley peak DO for the draft WRMP19**

| Scenario | Percentile | Probability weighting | KV DO Ml/d | Impact on KV DO Ml/d | Difference from base (%) |
|---|---|---|---|---|---|
| No CC | N/A | N/A | 157.8 | Base | N/A |
| 1 | 99 | 0.01 | 133.5 | -24.3 | -15.4% |
| 2 | 98 | 0.01 | 131.4 | -26.5 | -19.8% |
| 3 | 97 | 0.01 | 129.6 | -28.2 | -21.5% |
| 4 | 96 | 0.01 | 133.3 | -24.5 | -18.9% |
| 5 | 95 | 0.01 | 139.3 | -18.5 | -13.9% |
| 6 | 94 | 0.01 | 136.7 | -21.1 | -15.1% |
| 7 | 93 | 0.01 | 145.2 | -12.6 | -9.2% |
| 8 | 92 | 0.01 | 136.0 | -21.8 | -15.0% |
| 9 | 91 | 0.01 | 135.9 | -21.9 | -16.1% |
| 10 | 90 | 0.01 | 134.6 | -23.2 | -17.1% |
| 11 | 89 | 0.05 | 137.9 | -19.9 | -14.8% |
| 12 | 80 | 0.095 | 139.2 | -18.6 | -13.5% |
| 13 | 70 | 0.1 | 147.8 | -10.0 | -7.2% |
| 14 | 60 | 0.1 | 134.7 | -23.1 | -15.6% |
| 15 | 50 | 0.1 | 153.6 | -4.2 | -3.1% |
| 16 | 40 | 0.1 | 151.3 | -6.5 | -4.2% |
| 17 | 30 | 0.1 | 150.5 | -7.3 | -4.9% |
| 18 | 20 | 0.1 | 146.4 | -11.4 | -7.6% |
| 19 | 10 | 0.095 | 154.5 | -3.3 | -2.2% |
| 20 | 1 | 0.06 | 157.7 | -0.1 | -0.1% |

*Note: Scenarios: 1 – Very Dry; 5 – Dry; 10 – Med-Dry; 15 – Medium; 19 - Med-Wet*

V.106 The impacts of climate change on the DO of Slough, Wycombe and Aylesbury (SWA) WRZs for the WRMP19 is outlined in Table V-8 and Table V-9. For Guildford WRZ and Henley WRZ there is no associated climate change uncertainty.

**Table V-8: Climate change impact on SWA average DO for the draft WRMP19**

| Scenario | Percentile | Probability weighting | SWA DO Ml/d | Impact on SWA DO Ml/d | Difference from base (%) |
|---|---|---|---|---|---|
| No CC | N/A | N/A | 183.3 | N/A | |
| 1 | 99 | 0.01 | 179.1 | -4.2 | -2.3% |
| 2 | 98 | 0.01 | 178.6 | -4.8 | -2.6% |
| 3 | 97 | 0.01 | 180.1 | -3.3 | -1.8% |
| 4 | 96 | 0.01 | 178.3 | -5.0 | -2.7% |
| 5 | 95 | 0.01 | 179.6 | -3.7 | -2.0% |
| 6 | 94 | 0.01 | 181.1 | -2.3 | -1.2% |
| 7 | 93 | 0.01 | 180.5 | -2.8 | -1.5% |
| 8 | 92 | 0.01 | 181.9 | -1.4 | -0.8% |
| 9 | 91 | 0.01 | 179.4 | -3.9 | -2.1% |
| 10 | 90 | 0.01 | 180.2 | -3.1 | -1.7% |
| 11 | 89 | 0.05 | 180.6 | -2.8 | -1.5% |
| 12 | 80 | 0.095 | 180.6 | -2.7 | -1.5% |
| 13 | 70 | 0.1 | 181.1 | -2.3 | -1.2% |
| 14 | 60 | 0.1 | 181.3 | -2.1 | -1.1% |
| 15 | 50 | 0.1 | 181.5 | -1.8 | -1.0% |
| 16 | 40 | 0.1 | 181.5 | -1.8 | -1.0% |
| 17 | 30 | 0.1 | 181.0 | -2.3 | -1.3% |
| 18 | 20 | 0.1 | 183.0 | -0.4 | -0.2% |
| 19 | 10 | 0.095 | 183.6 | 0.3 | 0.2% |
| 20 | 1 | 0.06 | 183.7 | 0.3 | 0.2% |

*Note: Scenarios: 1 – Very Dry; 5 – Dry; 10 – Med-Dry; 15 – Medium; 19 - Med-Wet*

**Table V-9: Climate change impact on SWA peak DO for the draft WRMP19**

| Scenario | Percentile | Probability weighting | SWA DO Ml/d | Impact on SWA DO Ml/d | Difference from base (%) |
|---|---|---|---|---|---|
| No CC | N/A | N/A | 213.3 | Base | N/A |
| 1 | 99 | 0.01 | 209.4 | -3.9 | -1.8% |
| 2 | 98 | 0.01 | 208.9 | -4.4 | -2.1% |
| 3 | 97 | 0.01 | 210.5 | -2.8 | -1.3% |
| 4 | 96 | 0.01 | 208.6 | -4.7 | -2.2% |
| 5 | 95 | 0.01 | 210.1 | -3.2 | -1.5% |
| 6 | 94 | 0.01 | 211.8 | -1.5 | -0.7% |
| 7 | 93 | 0.01 | 211.1 | -2.2 | -1.0% |
| 8 | 92 | 0.01 | 212.8 | -0.5 | -0.2% |
| 9 | 91 | 0.01 | 209.8 | -3.5 | -1.7% |
| 10 | 90 | 0.01 | 210.7 | -2.6 | -1.2% |
| 11 | 89 | 0.05 | 211.1 | -2.2 | -1.0% |
| 12 | 80 | 0.095 | 211.2 | -2.1 | -1.0% |
| 13 | 70 | 0.1 | 211.7 | -1.6 | -0.7% |
| 14 | 60 | 0.1 | 212.0 | -1.3 | -0.6% |
| 15 | 50 | 0.1 | 212.3 | -1.0 | -0.5% |
| 16 | 40 | 0.1 | 212.3 | -1.0 | -0.5% |
| 17 | 30 | 0.1 | 211.7 | -1.6 | -0.7% |
| 18 | 20 | 0.1 | 213.7 | 0.4 | 0.2% |
| 19 | 10 | 0.095 | 213.5 | 0.2 | 0.1% |
| 20 | 1 | 0.06 | 213.3 | 0.0 | 0.0% |

*Note: Scenarios: 1 – Very Dry; 5 – Dry; 10 – Med-Dry; 15 – Medium; 19 - Med-Wet*

# K. Uncertainty over new resources

## ***Preferred programme***

V.107 The volume of water delivered by new resources can often be uncertain. The uncertainty around existing resources is captured in the supply-side baseline uncertainty. But new resources included as a result of decisions made in this plan are not part of the baseline and must be included as part of a final plan re-assessment of Target Headroom. Section 10: Programme appraisal and scenario testing, presents a discussion of the application of final plan Target Headroom.

V.108 The inclusion of new resource schemes within the preferred programme 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 Appendix R: Scheme dossiers.

V.109 We have considered the impact of climate change on the outputs of our proposed supply options. For the majority of the options, such as Indirect Potable Reuse at Deephams and a reservoir at Abingdon, there is no impact from climate change on their deployable outputs. The only significant exception is for the Severn Thames Transfer options, where the assessed impacts of climate change are accounted for in the deployable outputs used in programme appraisal. Further details regarding the impact of climate change on the Severn Thames Transfer options are included in Appendix R: Scheme dossiers.

V.110 For our smaller groundwater options, including managed aquifer recharge, climate change impact has been assessed as being negligible to minimal. Apart from the Severn Thames Transfer options, both the “best estimate”, or mean, climate change impact on our proposed resource options is considered to be zero. As such, no climate change uncertainty needs to be captured. For all of the options included in our preferred plan, any remaining uncertainty is captured in the uncertainty being considered at a programme level outlined below.

V.111 Between the draft and the revised draft WRMP19 we worked to replicate the approach to final plan Target Headroom followed for the draft WRMP19.

V.112 The draft approach involved assessing uncertainty around scheme yield (using the judgement of expert hydrologists and hydrogeologists supported by estimates and associated justification made by our engineering partner Mott MacDonald in Appendix R: Scheme dossiers) and characterising an uncertainty distribution, by percentile outputs in 5% increments, for each year of the 80 year planning horizon. The EBSD model then interpolated the value of the distribution between these points and sampled from the interpolated distribution. This analysis did not include uncertainty around scheme timing.

V.113 The results from this full appraisal, for the revised draft WRMP19, were counterintuitive as they resulted in reductions to the target headroom allowance. We believe this is due to the surplus generated through our preferred demand management programme shifting the balance of supply probability density function so that equivalent levels of risk result in lower allowances. As an alternative, an allowance of 5% was applied to non-strategic schemes yield being added to baseline target headroom allowance. We consider 5% a pragmatic allowance which would provide a proportionate buffer based on the preferred option size. It was decided to not apply this to strategic schemes (e.g. South East Strategic Reservoir Option, Severn Thames Transfer) as these schemes have had a more rigorous level of investigation which improves the reliability of their DO estimates.

### *Bromate pollution of the Northern New River Wells*

V.114 We have two abstraction licences which allow us to abstract water from the River Lee. One is on the River Lee and a number of groundwater sources known as the NNRW also output to the New River. The presence of bromate in the water pumped from the NNRW has meant that blending of abstracted water has been necessary to ensure water quality standards can be met. Additional treatment for bromate has been installed at one of our treatment works, but our other treatment facilities in north London, where the ozonation treatment process exacerbates bromate risk, rely on blending. The combined licensed output from the sources average 100.5 Ml/d with an average SDO of 98.8 Ml/d.

V.115 The source of the bromate pollution is a former bromine chemicals factory at Sandridge. Prior to 2004, concentrations of bromate in the NNRW had showed an alarmingly increasing trend from below 10 ug/l in 2001 to a maximum approaching 70 ug/l in 2003. In 2005, a scavenging remediation scheme was implemented in conjunction with Affinity Water from one of their groundwater sources between Sandridge and the NNRW. 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. This operation continues under a Remediation Notice served by the Environment Agency on the original owners and subsequent developers of the Sandridge chemicals factory site.

V.116 Although this scavenging remediation scheme assists management of bromate and therefore the blending of abstracted water, there remains a risk that the NNRW would not be able to deliver their SDOs should there be a problem, for whatever reason, with the scavenging remediation scheme. The risk around the strategic schemes has previously been assessed and a range of possible impacts has been determined using WARMS2. This has been reviewed using the optimised LTCD in WARMS2 and an update of the estimate of the risk has been calculated. At WRMP14 the maximum risk to these sources was 23 Ml/d when using WARMS. This equated to around 13 Ml/d in the first year of the plan when applied in the Target Headroom model. The current evaluation of risk using WARMS2 is based on the scenario described as Hatfield Off 1[16].

V.117 The impact of the reduced output from the NNRW was evaluated by inputting this data into WARMS2 and comparing with the value of DO before the change. The AR17 baseline London DO of 2,305 Ml/d derived using the optimised LTCD is used as the base run, with the results of the analysis shown in Table V-10. The risk is reduced to 12 Ml/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.

**Table V-10: Estimated risk around the NNRW**

| NNRW | | |
|---|---|---|
| **Scenario** | **London DO (Ml/d)** | **DO difference** |
| Base run | 2305 | -- |
| Hatfield Off 1 | 2293 | -12 |

[16] Hatfield Off 1: assumes a predicted bromate concentration during a drought year based on information prior to the start of the Hatfield remediation scheme

### *Risks around the North London Artificial Recharge Scheme*

V.118 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 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. However, 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:

- **NLARS Scenario 1**: Is the original view of the NLARS output used prior to AR16
- **NLARS Scenario 2:** Following a review of the NLARS sources and with improved information on borehole performance an updated view of the scheme's output was produced

V.119 The impact of the modified output from NLARS for the two alternative scenarios was evaluated by inputting this data into WARMS2 and comparing the results with the value of DO before the change; here the AR17 baseline London DO of 2,305 Ml/d is derived using the optimised LTCD is used as the base run. The risk is now around 16 Ml/d and for modelling expedience these values are applied as the maximum and most likely impact in a triangular distribution within the Target Headroom analysis under the S9 functionality.

**Table V-11: Estimated risk around the NLARS**

| NLARS | | |
|---|---|---|
| **Scenario** | **London DO (Ml/d)** | **DO difference** |
| NLARS Sc3 (base) | 2,305 | -- |
| AR14 profile Sc1 | 2,288 | -17 |
| NLARS Sc2 | 2,290 | -15 |

# L. Target Headroom comparison

V.120 An update of the London Target Headroom has been made since WRMP14 with the planning period extended to 2100 together with the change in the assumed risks over the planning period. The main changes in Target Headroom centre on climate change impacts and demand side uncertainty. The impacts of these changes are shown in Figure V-8 and the reasons for the changes are described below.

V.121 Primarily for London the variation in Target Headroom is because of the changes to the assumptions to climate change uncertainty following resolution of issues around scaling of the impacts over the planning period and use of the UKCP09 data for the 2080s rather than the 2030s. The resolution of the scaling issue has been critical as otherwise there would have been an immediate increase in Target Headroom of around 50 Ml/d for London with smaller increases in SWOX. The details of which are outlined in Appendix U: Climate change. The position is however somewhat balanced later in the planning period with increased uncertainty in demand. In addition for London, the re-development of WARMS and the introduction of an optimised LTCD resulted in a significant increase in DO for the draft WRMP19, carried forward to the revised draft, from WRMP14 (Section 5: Current and future water supply) and therefore Target Headroom has also increased.

V.122 Furthermore, Target Headroom has changed as the risk profile has moved forward by five years from WRP14, therefore the risk profile has been re-based as seen in Table V-12.

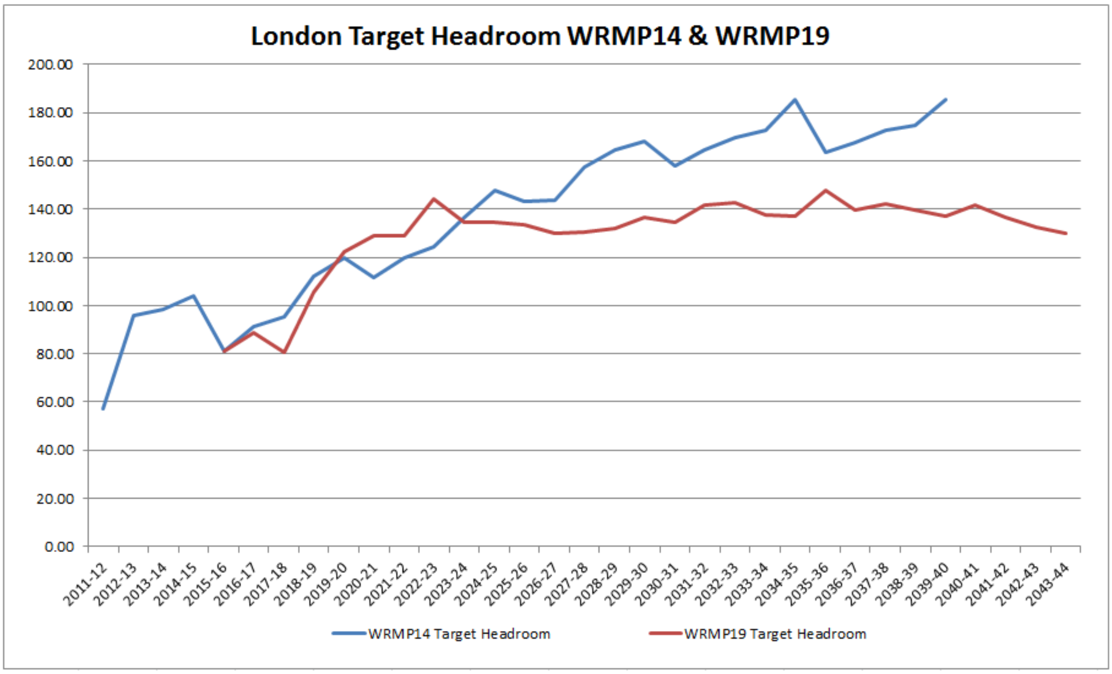
**Table V-12: Risk profile for Target Headroom assessment in WRMP14 and the rdWRMP19**

| | Headroom risk profile (%) | | | | | |
|---|---|---|---|---|---|---|
| | **2016/17** | **2019/20** | **2024/25** | **2029/30** | **2034/35** | **2039/40** |
| WRMP14 | 10 | 10 | 15 | 20 | 25 | 30 |
| WRMP19 | 5 | 5 | 10 | 15 | 20 | 25 |

*Note: The level of risk is increased by 1% per annum from 5% at 2019-20 to 29% at 2043-44 then remains at this level for the remainder of the planning period.*

V.123 In addition, a correction has been made to climate change scaling factors within the Target Headroom model between the draft and revised draft WRMP19 which explains the step in revised draft climate change uncertainty for the 2080s in Figure V-8. For AR17 the Target Headroom model was updated to reflect the updated climate change methodology used to assess climate change impacts for the draft WRMP19. This update was a step change from using climate change UKCP09 medium emissions impacts for the 2030s time slice (2035/36) to using the 2080s time slice (2085/86). The AR18 review has identified and corrected one omission to the Target Headroom model update, namely ensuring that the model is using 2080s as opposed to 2030s scaling factors to scale the climate change impacts through the planning horizon. The impact of this correction is a reduction in the climate change component of Target Headroom uncertainty from 25.2 Ml/d for AR17 (29.2 Ml/d for AR17+) to 19.07 Ml/d for AR18.

**Figure V-8: Target Headroom comparison**




# M. Baseline Target Headroom

V.124 The Target Headroom for DYAA conditions is shown in Table V-13 and for the DYCP in Table V-14. The increase in Target Headroom at the end of the period appears reduced as the level of risk taken by the company is increased from 5% to 29% over the planning period. Note the Target Headroom is maintained at the same level in each WRZ from 2043/44 to 2099/2100.

**Table V-13: Target Headroom by WRZ – baseline average**

| WRZ | Baseline Target Headroom - DYAA (Ml/d) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2016/17 | 2019/20 | 2024/25 | 2029/30 | 2034/35 | 2039/40 | 2043/44 |
| Risk Profile → | 5% | 5% | 10% | 15% | 20% | 25% | 29% |
| London | 88.81 | 122.20 | 134.31 | 136.50 | 137.02 | 136.85 | 130.09 |
| SWOX | 9.00 | 11.82 | 13.89 | 14.12 | 12.52 | 12.26 | 11.77 |
| Kennet Valley | 4.02 | 4.41 | 5.17 | 5.35 | 5.63 | 4.36 | 4.06 |
| Henley | 0.33 | 0.59 | 0.73 | 0.63 | 0.51 | 0.52 | 0.46 |
| SWA | 3.13 | 5.42 | 5.16 | 4.64 | 4.55 | 4.20 | 3.92 |
| Guildford | 1.15 | 1.87 | 2.12 | 2.15 | 1.88 | 1.66 | 1.57 |

*Note: The level of risk is increased by 1% per annum from 5% at 2019-20 to 29% at 2043-44 then remains at this level for the remainder of the planning period.*

**Table V-14: Target Headroom by WRZ – baseline peak**

| WRZ | Baseline Target Headroom – DYCP (Ml/d) | | | | | | |
|---|---|---|---|---|---|---|---|
| | **2016/17** | **2019/20** | **2024/25** | **2029/30** | **2034/35** | **2039/40** | **2043/44** |
| Risk Profile → | 5% | 5% | 10% | 15% | 20% | 25% | 29% |
| London | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| SWOX | 11.17 | 15.91 | 19.39 | 19.04 | 19.91 | 20.02 | 17.82 |
| Kennet Valley | 4.46 | 5.54 | 7.19 | 6.91 | 7.11 | 7.13 | 6.22 |
| Henley | 0.42 | 0.73 | 0.90 | 0.90 | 0.91 | 0.80 | 0.76 |
| SWA | 4.24 | 6.16 | 7.20 | 8.02 | 7.56 | 7.36 | 7.33 |
| Guildford | 1.55 | 2.57 | 3.27 | 3.45 | 3.31 | 3.17 | 2.74 |

*Note: The level of risk is increased by 1% per annum from 5% at 2019-20 to 29% at 2043-44 then remains at this level for the remainder of the planning period.*

# N. Baseline Target Headroom component analysis

V.125 As described in Section C: Target Headroom methodology the following components are considered when calculating baseline Target Headroom:

- S6 – Accuracy of supply side data
  - Additional supply side uncertainty in the London WRZ only around NLARS and bromates included as a separate component
- S8 – Uncertainty of impact of climate change on source yields
- D1 – Uncertainty in base year data
- D2 – Demand forecast variation
- D3 – Uncertainty of climate change on demand

V.126 A breakdown of the baseline Target Headroom components for the London DYAA and SWOX DYCP analyses are shown in Figure V-9 and Figure V-10 respectively. The largest component of uncertainty within Target Headroom is supply side climate change uncertainty (Supply component S8) and demand uncertainty (Demand components D1-D3).

**Figure V-9: Target Headroom components – London DYAA**

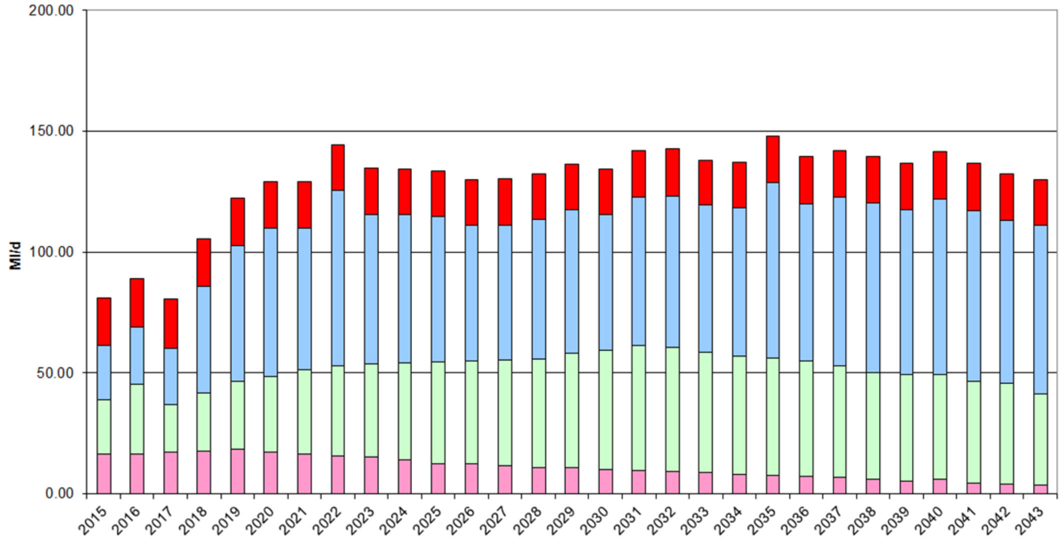
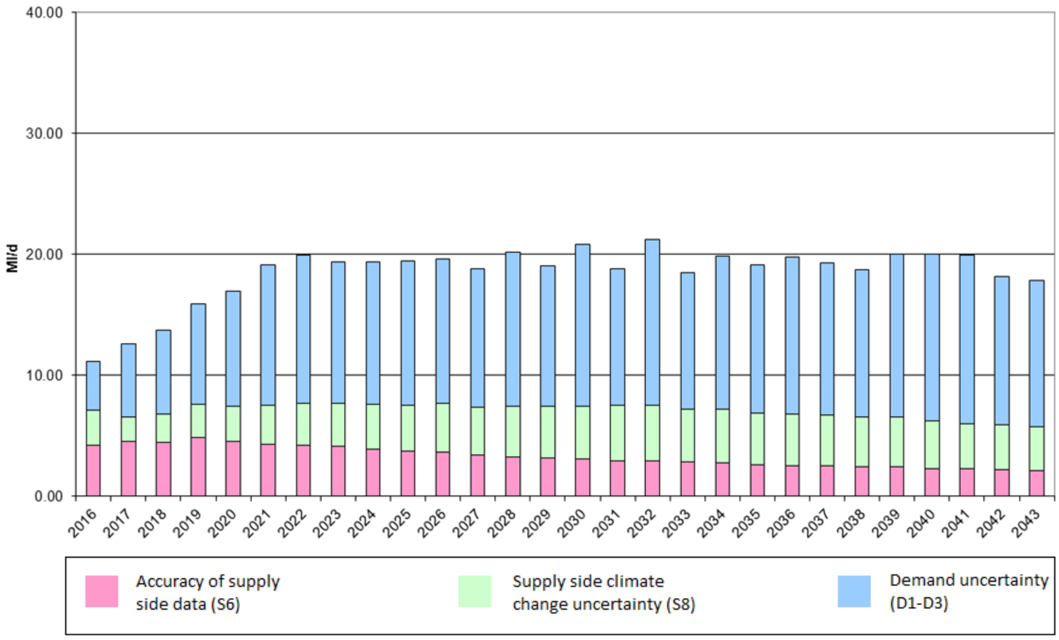
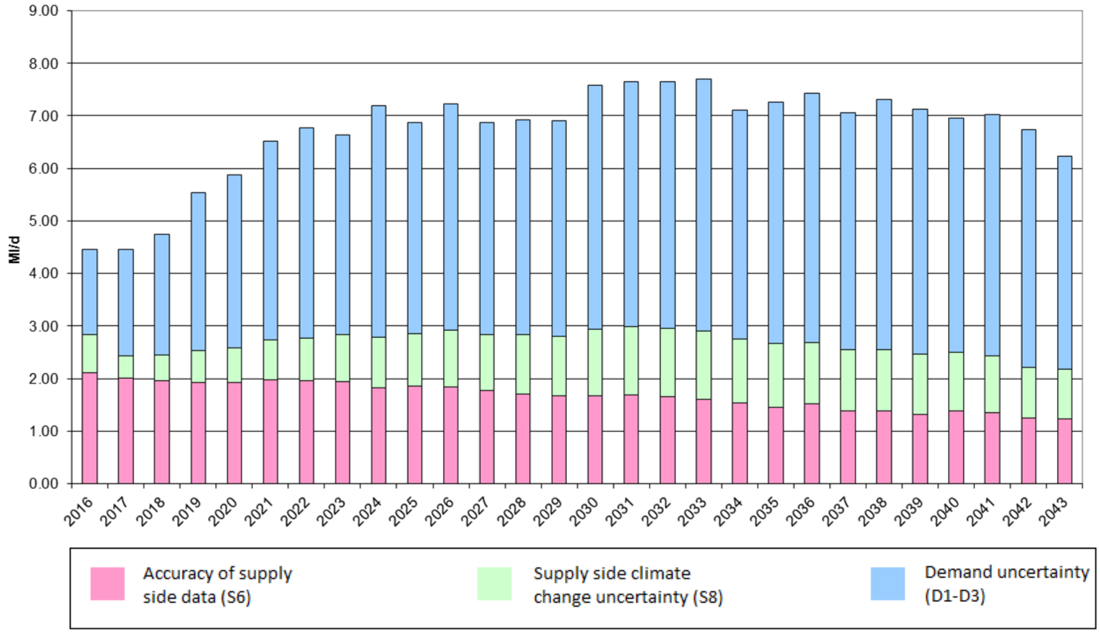



**Figure V-10: Target Headroom components – SWOX DYCP**



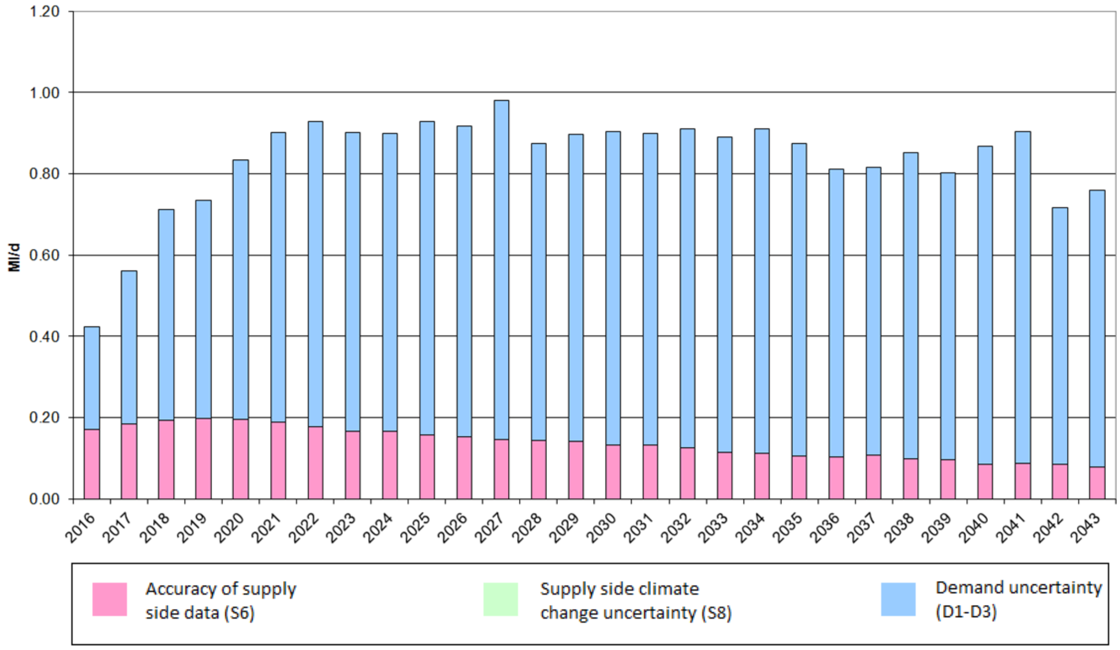

V.127 The WRZs where supply exceeds demand in critical periods in the short term are Guildford, SWA with Kennet Valley by the 2070s and Henley showing a surplus throughout the planning period. For Kennet Valley DYCP it can be seen from Figure V-11 that the main uncertainty is demand uncertainty (Demand components D1-D3) with elements of supply uncertainty around climate change (Supply component S8) and accuracy of supply side data (Supply component S6).

**Figure V-11: Target Headroom components – Kennet Valley DYCP**


Ml/d
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043
Accuracy of supply side data (S6)
Supply side climate change uncertainty (S8)
Demand uncertainty (D1-D3)

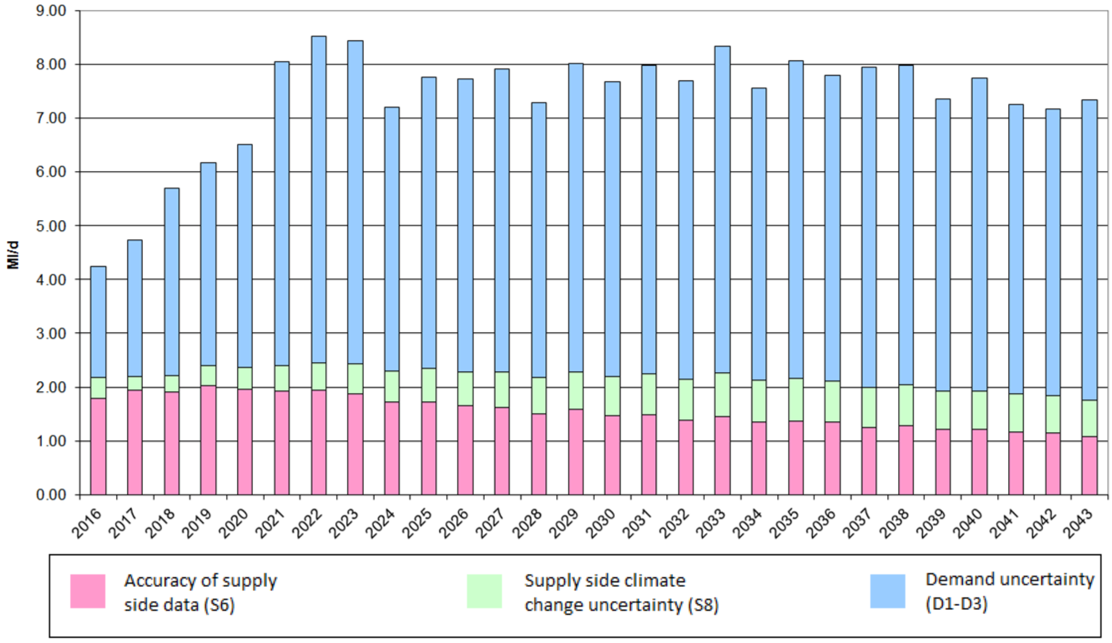
V.128 For Henley DYCP, Figure V-12 shows that the main uncertainty is demand uncertainty forecasts (Demand components D1-D3) with nothing identified for climate change (Supply component S8) (see Appendix U: Climate change) and a small amount for accuracy of supply side data (Supply component S6). The total Target Headroom is however relatively small in Henley, in fact is less than 1.0 Ml/d.

**Figure V-12: Target Headroom components – Henley DYCP**



V.129 Again for SWA DYCP it can be seen from Figure V-13 that the main uncertainty is the demand uncertainty (Demand components D1-D3) with other elements of uncertainty around climate change (Supply component S8) and accuracy of supply side data (Supply component S6).

**Figure V-13: Target Headroom components – SWA DYCP**



V.130 Finally for Guildford DYCP it can be seen from Figure V-14 that the main uncertainty is around is the demand uncertainty (Demand components D1-D3) with nothing identified for climate change (Supply component S8) (see Appendix U: Climate change) and a small amount for accuracy of supply side data (Supply component S6).

**Figure V-14: Target Headroom components – Guildford DYCP**