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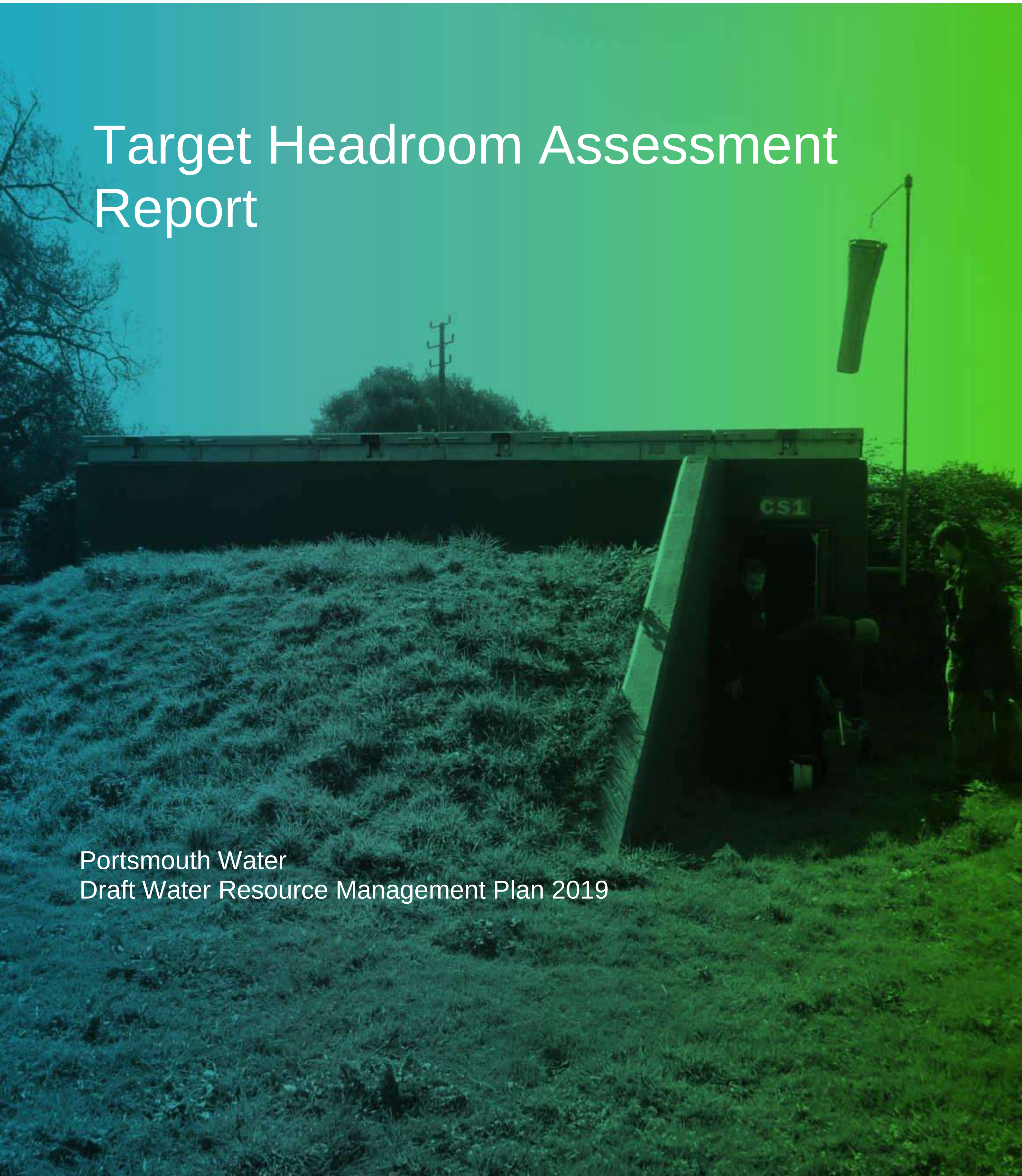


# Target Headroom Assessment Report

Portsmouth Water
Draft Water Resource Management Plan 2019

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# Executive Summary

## Background

As part of the company's 2019 draft Water Resources Management Plan (dWRMP19) submission, Portsmouth Water must calculate the supply-demand balance for its single Water Resource Zone (WRZ) over the 25-year planning period from 2020 to 2045. In accordance with statutory guidelines and industry standard practice, the supply-demand balance includes a margin between supply and demand to allow for uncertainties inherent within the supply and demand forecasts. This margin is known as 'headroom', and Portsmouth Water must calculate appropriate values of headroom for each planning scenario considered in dWRMP19. The headroom value determined for each year across the planning horizon is termed the target headroom allowance.

There are a range of factors leading to uncertainty in the calculations of supply and demand over the 25-year planning horizon. These include: accuracy of meters measuring abstractions and distribution input, variation in the company's future demand forecasts, uncertainty in the future impacts of climate change, risks of future pollution impacts on supply availability, and risks of changes to the company's abstraction licences for sustainability or other reasons. The aim of calculating a target headroom allowance is to provide a reasonable margin to cover the statistically combined impact of all of these factors on the supply-demand balance, at a defined level of risk.

## Purpose of this report

AECOM has undertaken a reassessment of the required target headroom allowance for dWRMP19 on behalf of Portsmouth Water, for both the dry year annual average (DYAA) and dry year critical period (DYCP) planning scenarios. The target headroom allowance for each of these scenarios is presented in the units of millions of litres per day (megalitres/day or Ml/d), and varies over the 25-year planning period of the dWRMP19. The calculations were carried out in accordance with the Environment Agency's *Water Resource Planning Guideline* (WRPG) (April 2017).

## Methodology

The target headroom assessment is based on the latest methodology as outlined in *An Improved Methodology for Assessing Headroom* (UKWIR, 2002) and referred to by the Environment Agency in their *WRPG* (April, 2017). The method involves defining suitable probability distributions for each relevant uncertainty factor, based on available data and assumptions as agreed in discussion with Portsmouth Water staff. These individual probability distributions are then statistically combined, using a standard technique called Monte Carlo simulation, into an overall company headroom distribution from which a target headroom allowance can be determined at the required level of risk (e.g. for a 5% risk, the 95% headroom value would be taken).

The outputs of the Monte Carlo simulation are used to determine profiles of target headroom at selected probabilities. However, in accordance with the *WRPG* (Environment Agency, April 2017), Portsmouth Water have adopted a variable profile of probability across the planning period. An initial risk of 10% is selected for the period to 2025, and then the risk level is increased by 1% at every 5-year interval, to a risk level of 14% in 2045. This is a slightly increased level of risk compared with the risk profile adopted for the WRMP14 assessment.

## Results

The results of the assessment are summarised below. Portsmouth Water's target headroom allowance, for each of the two planning scenarios assessed, is presented for the 25-year planning period and based on the selected risk profile as outlined above.

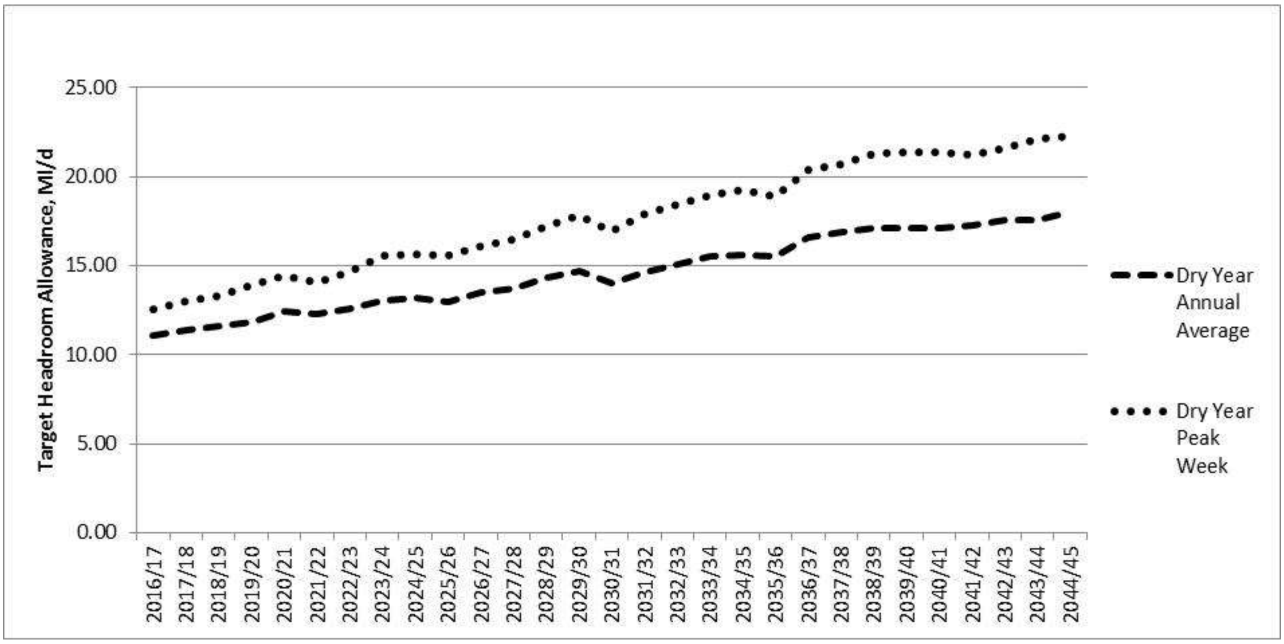
The target headroom allowance values are higher than those calculated for WRMP14; the main drivers behind this increase are changes in the uncertainty assumptions, as follows:

- Oil pollution risks: probability of occurrence per source/per year increased from 0.83% to 1.39% (DYAA) and from 0.71% to 1.11% (DYCP);

- Demand forecast variation (based on September 2017 forecasts): wider uncertainty ranges (with increases from 4 to 26 Ml/d (DYAA) and from 6 to 31 Ml/d (DYCP) by the end of the planning period; and

- Impacts of climate change on supply: wider ranges of uncertainty (with increases of between 5 – 8 Ml/d (DYAA), and between 1 – 9 Ml/d (DYCP)).

| Year | Combined Company Target Headroom Allowance, Ml/d | |
|---|---|---|
| | Dry Year Annual Average | Dry Year Critical Period (Peak Week) |
| **2017/18** | 11.4 | 13.0 |
| **2019/20** | 11.8 | 13.9 |
| **2024/25** | 13.2 | 15.7 |
| **2029/30** | 14.7 | 17.8 |
| **2034/35** | 15.6 | 19.3 |
| **2039/40** | 17.1 | 21.4 |
| **2044/45** | 18.0 | 22.3 |



# 1 Introduction

## 1.1 Background

Portsmouth Water is required to submit an assessment of its target headroom allowance every five years as part of its Water Resources Management Plan (WRMP) submission. The purpose of including a headroom allowance within the supply/demand balance is to include a margin between supply and demand to allow for the risk of variations in the forecast supply/demand balance due to uncertainty in the various components.

Portsmouth Water calculated a target headroom allowance to incorporate within the supply/demand balance, for their Final WRMP submissions of 2004, 2009 and 2014. A summary of the previous results is given in Table 1-1.

**Table 1-1 Portsmouth Water Headroom Allowance – Water Resources Management Plans from 2004 to 2014**

| Year | Headroom Allowance (Ml/d) | | | | | |
|---|---|---|---|---|---|---|
| | Dry Year Annual Average | | | Dry Year Critical Period | | |
| | WRMP 2004 | WRMP 2009 | WRMP 2014 | WRMP 2004 | WRMP 2009 | WRMP 2014 |
| **2008/09** | 7.7 | 7.7 | N/A | 9.2 | 9.2 | N/A |
| **2009/10** | 23.5 | 7.7 | N/A | 4.5 | 9.5 | N/A |
| **2014/15** | 24.3 | 8.4 | 10.0 | 8.5 | 10.9 | 13.8 |
| **2019/20** | 25.1 | 10.7 | 10.3 | 12.3 | 12.4 | 13.8 |
| **2024/25** | 25.8 | 9.6 | 9.5 | 16.1 | 8.9 | 13.4 |

The figures in Table 1-1 for WRMP 2009 and WRMP 2014 were derived from Monte Carlo simulations to combine probability distributions representing the range of uncertainty, in megalitres per day (Ml/d), for each of the factors at risk of causing future variations in the forecast supply-demand balance and for each of the company's sources as applicable. This resulted in combined headroom probability distributions for each of the two planning scenarios. Company headroom allowance values were selected from the combined probability distributions at specified percentile values for each period across the planning horizon, to give a reducing risk profile.

Note that the figures for WRMP 2004 were derived with a different methodology, using a simple scoring system as set out in UKWIR's 1998 report, 'A Practical Method for Converting Uncertainty into Headroom'. Since WRMP 2009 the company has based all headroom assessments on the more detailed, analytical approach to the determination of uncertainty through probabilistic simulation as outlined in 'An Improved Methodology for Assessing Headroom' (UKWIR, 2002).

AECOM (incorporating URS) undertook the previous assessment of the headroom allowance in February 2013 for Portsmouth Water's WRMP 2014, and Portsmouth Water commissioned the company to carry out an update of the assessment for their draft Water Resources Management Plan 2019 (dWRMP 2019) submission. The updated analysis, based on a review of risk and uncertainty factors and updated supply and demand forecast values for 2020-2045, is the subject of this report.

The assessment was completed in accordance with the Environment Agency's *Water Resources Planning Guideline* (April 2017).

## 1.2 Objectives

The aim of the headroom assessment is to determine probability distributions to represent the range of uncertainty within the supply-demand balance for each relevant factor. These are then combined into overall probability distributions of company target headroom for each planning scenario and for each year across the

25 year planning horizon from 2020 to 2045. A time-varying profile of headroom can then be determined from the distribution for each period at an appropriate probability or level of risk.

The key objectives of this analysis can be summarised as follows:

- Assess the risks and uncertainties which apply to the components of Portsmouth Water's supply/demand balance, through consideration of operational data and other relevant information;
- Develop suitable probability distributions to represent each relevant uncertainty factor, which may differ according to planning scenario if appropriate;
- Combine the individual probability distributions into a single distribution representing Portsmouth Water's headroom uncertainty for each year in the planning horizon; and
- Determine headroom allowance profiles, by selecting values from the combined headroom uncertainty distributions at appropriate levels of risk across the planning horizon.

In the current report, Section 2 provides an overview of the methodology used to undertake the headroom assessment. Section 3 presents a review of the relevant uncertainty factors in Portsmouth Water's supply-demand balance and the assumptions adopted for each of the individual probability distributions, whilst Section 4 summarises the results of the assessment. Section 5 provides the report conclusions.

# 2 Methodology

Portsmouth Water has adopted the industry standard method for the calculation of target headroom allowance; the method is outlined in *An Improved Methodology for Assessing Headroom* (UKWIR, 2002) and referred to by the Environment Agency in their *WRPG* (April, 2017).

In this approach, a probability distribution is assigned to each individual risk or uncertainty factor within the supply/demand balance, based on known data and other relevant information. These probability distributions are then combined using the statistical technique of Monte Carlo simulation, which iteratively takes random samples from each distribution and sums them according to specified rules. The summed result of each iteration then forms a point on the curve of the combined distribution; by sampling the distributions over a large number of iterations it is then possible to build up a probability distribution to represent the overall risk or uncertainty of all factors taken together.

The Monte Carlo simulation software @RISK was used for the analysis, which operates in conjunction with the Microsoft Excel spreadsheet package.

Due to the random nature of the Monte Carlo simulation technique, it is not possible to guarantee that identical results will be generated each time the same simulation is run. However, by selecting a suitably large number of iterations for the simulation, to give an acceptable mean standard error for the simulation results, it should be possible to obtain repeatable results to an acceptable level of accuracy. The 2002 UKWIR methodology suggests using 5,000 as a typical number of iterations. However, in practice it was found that more consistent results were obtained using 10,000 iterations. All Monte Carlo simulations undertaken for this headroom assessment have therefore been run for 10,000 iterations.

For both WRMP 2009 and WRMP 2014, Portsmouth Water based all its supply/demand balance analysis on a single company-wide Water Resource Zone (WRZ). This approach has been continued for the dWRMP 2019, and therefore the analysis of headroom allowance has also been carried out at the company-wide or single WRZ level. Two planning scenarios have been considered in this headroom assessment, as follows:

- Dry Year Annual Average (DYAA) – based on Average Demand Deployable Output (ADO). The assessment of ADO is linked to the DYAA planning scenario. The UKWIR WR27 DO report (2012) defines the ADO as *'the deployable output of a source for the average annual period'* and goes on to state that *'the average demand is literally the average over the year computed as average over a normal year or average over a dry year'*.

- Dry Year Critical Period (DYCP) – based on dry year Average Demand in the Peak Week (ADPW) and Peak Deployable Output (PDO). Water companies *"may also choose to explain how you will deal with a period of peak strain known as the critical period"* (Environment Agency, April 2017). The assessment of PDO is associated with the 'dry year critical period' (DYCP) planning scenario, where the resource zone supply-demand balance is sensitive to peak demand. PDO is the "*deployable output for the period in which there is highest demand*" (UKWIR, 2014).

Key areas of future risk and uncertainty in Portsmouth Water's future supply-demand balance were identified through discussion and correspondence with the relevant water resources planning and operational staff at Portsmouth Water. These were categorised with reference to the uncertainty factors specified in the 2002 UKWIR methodology, as listed in Table 2-1 below. The assumptions adopted for Portsmouth Water's headroom calculation, for each of these factors, are listed in Section 3.

**Table 2-1 Supply-demand balance uncertainty factors**

| Factor | Name | Description |
|---|---|---|
| S1 | Vulnerable Surface water licences | Risk of future loss of deployable output due to sustainability changes to surface water abstraction licences for environmental reasons |
| S2 | Vulnerable Groundwater licences | Risk of future loss of deployable output due to sustainability changes to groundwater abstraction licences for environmental reasons |
| S3 | Time Limited Licences | Risk of future loss of deployable output due to non-renewal of time limited abstraction licences |
| S4 | Bulk Imports | Risk of future loss of deployable output due to changes in bulk supply agreements (imports only) |
| S5 | Gradual Pollution | Risk of future loss of deployable output due to pollution and/or water quality issues which cannot be mitigated or recovered |
| S6 | Accuracy of Supply-Side Data | Uncertainty surrounding the accuracy of supply side data e.g. percentage accuracy of abstraction meters |
| S7 | Single Source Dominance | (This factor is no longer used in the headroom methodology) |
| S8 | Impact of Climate Change on Deployable Output | Uncertainty surrounding the future impact of climate change on deployable output (varying estimates of loss depending on scenario) |
| S9 | New Sources | Uncertainty surrounding the available yield of major new resource developments included in the final planning supply-demand balance |
| D1 | Accuracy of Sub-component Demand Data | Uncertainty surrounding the accuracy of demand side data i.e. percentage accuracy of distribution input meters (generally located at service reservoirs) |
| D2 | Demand Forecast Variation | Uncertainty surrounding future demand forecasts which may be higher or lower than assumed in the baseline supply-demand balance |
| D3 | Impact of Climate Change on Demand | Risk of future increases in demand due to climate change impacts (varying estimates of demand effects depending on scenario) |
| D4 | Demand Management Measures | Uncertainty surrounding the impact on future demand of demand management measures including leakage reduction, metering strategy and water efficiency activities. |

# 3 Review of Uncertainty Factors

## 3.1 Overview of headroom assumptions

A review of the methodology, key data used in the previous analysis, key changes to guidelines, water resources system parameters and identified risks since the publication of WRMP 2014 was carried out. The aim was to agree a set of assumptions, including appropriate probability distributions, relating to each factor for inclusion within the target headroom Monte Carlo simulation model.

The key assumptions and relevant probability distributions adopted for the dWRMP 2019 assessment are summarised and compared with those adopted for WRMP14 in Table 3-1 and are discussed further in the following sections. The deployable output values for the 1 in 20 year event (stochastic runs) were used for both scenarios in the supply side headroom assessment.

It should be noted that the Source U has an ongoing water quality issue that is unlikely to be resolved in the current WRMP cycle (and the source is also used for river augmentation purposes). The deployable output (DO) assessment for the source has therefore determined a DO value of zero. As this source effectively does not contribute to the supply-demand balance assumed for dWRMP 2019, there is no uncertainty surrounding its future contribution and therefore no headroom allowance is attributed to the source.

**Table 3-1 Comparison of uncertainty factor assumptions with previous (WRMP 2014) assessment**

| Factor | WRMP 2014 | dWRMP 2019 |
|---|---|---|
| S1 - Vulnerable surface water licences | No allowance included. | No change. |
| S2 - Vulnerable groundwater licences | No allowance included. | No change. |
| S3 - Time limited licences | No allowance included. | No change. |
| S4 – Bulk imports | No allowance included. | No change. |
| S5 – Gradual pollution | Nitrates: No allowance included.<br>Pesticides: No allowance included.<br>Turbidity: No allowance included.<br>Cryptosporidium: No allowance included.<br>Oil spill risks: for annual average, 0.83% probability of occurrence per source/ per year; for critical period, 0.71% probability of occurrence per source/ per year. | Nitrates: No change.<br>Pesticides: No change.<br>Turbidity: No change.<br>Cryptosporidium: No change.<br>Oil spill risks: Same approach used to determine a discrete distribution, but with an increased probability of occurrence per source/per year (1.39% DYAA and 1.11% DYCP). This is due to the inclusion of a number of recent recorded events in the updated calculation. |
| S6 - Accuracy of supply-side data | Allowance of between ±5 to 10% used to represent the uncertainty in the accuracy of abstraction meters and/or source yield assessments. | No change to approach; constraint types updated for several sources following the 2017 review of deployable output values. |
| S7 - Single source dominance | No allowance included. | No change. |

| Factor | WRMP 2014 | dWRMP 2019 |
|---|---|---|
| S8 - Impact of climate change on deployable output | Calculated from 100 UKCP09 sampled scenarios and scaled back from the 2030s; range of uncertainty calculated based on maximum and minimum predicted DO's. | Calculated from 100 UKCP09 sampled scenarios, but scaled back from the 2080s; also range of uncertainty calculated based on 90% and 10% predicted DO's owing to a larger range than at WRMP 2014. |
| S9 - New sources | No allowance included. | No change. |
| D1 - Accuracy of sub-component demand data | Allowance of ±5% used to represent the uncertainty in the accuracy of distribution input meters. | No change to approach, but demand-side meter accuracy assumed to be improved from 5% to 2%. |
| D2 - Demand forecast variation | Low, Medium and High company demand forecasts, produced by Portsmouth Water, used to determine probability distribution. | A similar approach to determining the probability distribution has been used, but with differing levels of growth assumed in the high and low forecast scenarios (based on 10% and 90% confidence bands around population/property forecasts). The magnitudes of the uncertainty ranges are significantly higher: e.g. increased from 4 Ml/d to 26 Ml/d (DYAA) and from 6 Ml/d to 31 Ml/d (DYCP) by the end of the planning period. |
| D3 - Impact of climate change on demand | Micro-component analysis of Per Capita Consumption (PCC). | Impacts assessed using new methodology as outlined in UKWIR 2013 study. Generally the magnitudes of uncertainty ranges are somewhat smaller than for WRMP 2014. |
| D4 - Demand management measures | No allowance included. | Triangular distributions representing uncertainty in annual meter optant rates and leakage reduction have been incorporated. |

In summary, there is a significantly wider range of uncertainty assumed for both demand forecast variation and climate change impacts on deployable output than for the WRMP 2014, and the risks of source closure due to potential oil pollution are higher based on actual recorded events. The effect of these changes on the resulting target headroom allowance calculations can be observed in the results presented in Section 4.

Further detail on how the assumptions were determined for each of the specified uncertainty factors is given in the sections below.

## 3.2 S1 Vulnerable surface water licences

Portsmouth Water has one surface water abstraction, from the River Itchen at Source A. A hands-off flow condition to protect the river in low flow conditions was agreed with the Environment Agency and implemented in 2011.

No further sustainability changes are expected to be implemented at the River Itchen abstraction, so no uncertainty allowance has been included for this factor.

## 3.3 S2 Vulnerable groundwater licences

The Environment Agency's *Water Resources Planning Guideline* (April 2017) states that the headroom component should not include any allowance for sustainability changes to abstraction licences, as they would work with water companies to ensure that any such changes would not impact on security of supply. Furthermore Portsmouth Water believe that their licences are all sustainable and so would not expect any further changes. On this basis no allowance has been included in the headroom calculation for this factor.

## 3.4 S3 Time limited licences

The Environment Agency's Water Resources Planning Guideline (April 2017) states that companies may include an uncertainty allowance for the non-replacement of time-limited licences based on an assessment of environmental risks. Most of Portsmouth Water's licences have been renewed in the last few years with only a small number of time limited licence conditions, expiring in 2028. Portsmouth Water see this as sufficiently long to not cause any concern, particularly in the light of future abstraction reform which is likely to occur in a shorter timescale and may have more significant implications. It is not practical to include any allowance for abstraction reform in this headroom assessment as there are insufficient details to evaluate a range of uncertainty at this stage.

## 3.5 S4 Bulk imports

Currently there are no plans being considered for any bulk imports into Portsmouth Water's supply area, so there is no need to include any uncertainty allowance for this factor.

## 3.6 S5 Gradual Pollution

In this assessment we have considered five key sources of pollution which could potentially place some or all of Portsmouth Water's sources of water at risk of loss of deployable output for medium to long periods of time. Short term pollution events in which deployable output reduction can be recovered within 90 days or less have been assessed as part of the company's outage allowance (AECOM, 2017). An allowance has therefore been made in the headroom assessment for the loss of deployable output as a result of events lasting more than 90 days.

### 3.6.1 Oil Spillage

In recent years Portsmouth Water has experienced some long-term outages due to spillages of domestic heating oil or transformer cooling oil in the proximity of groundwater sources. These have resulted in the closure of the affected source as a precautionary measure, although no pollution of the source has occurred in practice.

In an effort to reduce the risks of future occurrences of this type, Portsmouth Water is targeting water safety planning initiatives at rural areas within sensitive zones in proximity to their groundwater sources. As part of this initiative, Portsmouth Water is offering subsidised replacement of domestic oil tanks in such areas and also working proactively with insurance companies to encourage preventative measures i.e. maintenance or replacement of oil tanks. However, since the last headroom assessment (WRMP 2014) there have been several further instances of these longer term source closures, and this remains a future risk to the company's supply availability.

The methodology and probability distribution type is consistent with the previous assessment however the parameters have been updated to reflect additional events.

The recorded events can be summarised as follows, with the first three of these having been taken account of in the previous (WRMP 2014) assessment:

- Source C: source closure for 328 days during the period 2005-2006;
- Source J: source closure from 11/11/2011 – 26/3/2012 (136 days);
- Source K: source closure for over 1 year from 8/12/2011;
- Source K: source closure from 1/4/2013 – 31/3/2014 (365 days);
- Source R: source closure from 17/11/2014 – 31/3/2015 (134 days); and
- Source H: source closure from 6/1/2017 – 1/4/2017 (1 year and 3 months).

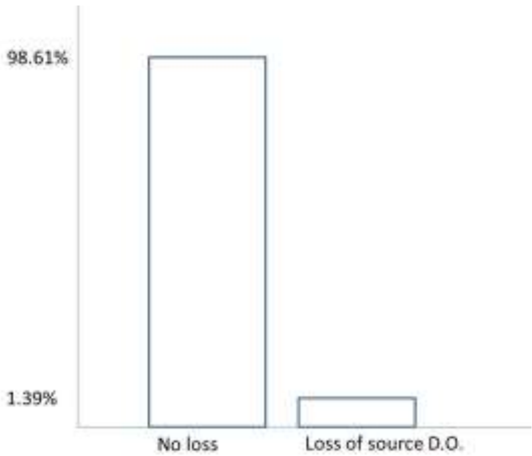
The development of a probability distribution from the above information is summarised as follows.

Portsmouth Water has 19 groundwater and spring sources at risk of oil contamination due to their location in or close to the unconfined chalk aquifer (reduced from 20 in the previous assessment, as Source U is no longer in use). In a record of company outage events covering the period 1998/99 – 2016/17, there are approximately 5 occurrences of losing 1 source for 1 year (treating the Source C and both Source K events as 1 year each, and summing the number of days in the Source H, Source J and Source R events as approximately 2 years), out of a possible 361 occurrences (19 sourceworks x 19 years). The probability of losing any given source for any given future planning year in the dry year annual average planning scenario can therefore be expressed as 5/361 = 1.39%. Based on the first three recorded events, the previous (WRMP 2014) assessment expressed this probability as 0.83%.

For each of the 19 sources at risk of oil pollution, a discrete distribution has been adopted, in each planning year, with a large probability of no loss of deployable output, and a small probability (1.39%) that the whole source deployable output is lost due to oil pollution. An example is shown in Figure 3-1. This approach is in line with the 2002 UKWIR methodology shown in example S5B. However, a correlation between successive years has not been assumed, as the recorded data has not indicated that any of these events are permanent losses.

Note that the calculation was adjusted for the DYCP scenario, as the Source J and Source R events did not occur during the company's critical period. The probability of losing a source due to oil pollution during the critical period was calculated based on 4 occurrences during 19 years, i.e. 4/361 = 1.11%.

**Figure 3-1 Discrete distribution to represent the risk of source loss due to oil pollution in one planning year (Dry Year Annual Average Scenario)**




### 3.6.2 Nitrates

Portsmouth Water have identified rising trends in nitrate levels at a number of their sources. However, water quality schemes to address the problem through blending solutions have been identified and in many cases already implemented over the last few years. The company is also actively engaged in catchment management initiatives in partnership with the Environment Agency and Natural England, to reduce the impact of agricultural diffuse pollution on water quality. On the basis that blending solutions and catchment management activities will be sufficient to mitigate future risks, it is not felt necessary to include this factor as a future risk in the headroom calculation.

### 3.6.3 Pesticides

Recently pesticides have been detected in one sample at Source B, however there is no indication of any trend and water quality investigations have been initiated to address this problem via the installation of granular activated carbon filters at Works A if required. As this is an isolated occurrence, and could be mitigated by adapting treatment processes, this factor has not been included as a future risk within the headroom calculation.

### 3.6.4 Turbidity

Two of Portsmouth Water's sources, Source C and Source O, have been affected by turbidity issues resulting in the reduction of the reported deployable output for each source. In both cases, investigations have been initiated and potential solutions to recover the reduction in deployable output have been identified (involving adaptation to the treatment process at Source C, and borehole lining and/or sealing of an adit at Source O). As these mitigation schemes are likely to be included in Portsmouth Water's final planning supply-demand balance, there are no further risks which need to be taken account of within the headroom component and so this factor has not been included within the calculation.

### 3.6.5 Cryptosporidium

The risks of source deployable output loss due to contamination from cryptosporidium can generally be mitigated by membranes or UV plant treatment facilities. Cryptosporidium has recently been detected at Portsmouth Water's Source I; this is a standby source but the company does wish to retain the available deployable output within their supply-demand balance and have therefore initiated water quality investigations into the cost and feasibility of treatment options. Again, this factor has been excluded from the headroom uncertainty assessment as mitigation schemes to address the risks have been initiated.

As mentioned earlier, Portsmouth Water's Source U has been discontinued from supply as it is uneconomic to provide cryptosporidium treatment due to the small size of the site. This source now has a zero deployable output value in Portsmouth Water's supply-demand appraisal and so will not contribute any uncertainty to the headroom component.

## 3.7 S6 Accuracy of supply side data

As for the previous (WRMP 2014) headroom assessment, a small allowance has been included to represent the uncertainty in the accuracy of abstraction meters and/or source yield assessments. The maximum and minimum values are based on ± 5% of deployable output for sources constrained by licence or infrastructure, or ± 10% of deployable output for sources constrained by yield (resource).

The uncertainty range for each source and constraint type is shown in Table 3-2. Constraint types have been reviewed and updated with reference to the updated assessment of deployable output values (AECOM, 2017).

**Table 3-2 Source deployable output values, constraint types and uncertainty range values**

| Source | Deployable Output (Ml/d) | | Constraint | | Assumed range of uncertainty in headroom simulation (Ml/d) | | | |
|---|---|---|---|---|---|---|---|---|
| | Average | Peak | Average | Peak | Average | | Peak | |
| | | | | | Min | Max | Min | Max |
| Source C | 17.30 | 22.50 | Licence | Infrastructure | -0.865 | 0.865 | -1.125 | 1.125 |
| Source D | 1.10 | 2.40 | Infrastructure | Infrastructure | -0.055 | 0.055 | -0.12 | 0.12 |
| Source E | 0.40 | 0.50 | Licence | Licence | -0.02 | 0.02 | -0.025 | 0.025 |
| Source F | 7.20 | 11.70 | Licence | Infrastructure | -0.36 | 0.36 | -0.585 | 0.585 |
| Source G | 1.50 | 3.30 | Licence | Licence | -0.075 | 0.075 | -0.165 | 0.165 |
| Source H | 7.70 | 9.10 | Licence | Licence | -0.385 | 0.385 | -0.455 | 0.455 |
| Source I | 1.50 | 2.10 | Licence | Licence | -0.075 | 0.075 | -0.105 | 0.105 |
| Source A | 36.90 | 40.60 | Licence | Licence | -1.845 | 1.845 | -2.03 | 2.03 |
| Source J | 9.10 | 10.20 | Infrastructure | Licence | -0.455 | 0.455 | -0.51 | 0.51 |
| Source K | 9.60 | 12.30 | Licence | Infrastructure | -0.48 | 0.48 | -0.615 | 0.615 |
| Source B | 53.00 | 57.80 | Resource | Resource | -5.3 | 5.3 | -5.78 | 5.78 |
| Source U | 0.00 | 0.00 | N/A | N/A | 0 | 0 | 0 | 0 |
| Source L | 13.70 | 15.50 | Infrastructure | Infrastructure | -0.685 | 0.685 | -0.775 | 0.775 |
| Source M | 4.50 | 6.00 | Infrastructure | Infrastructure | -0.225 | 0.225 | -0.3 | 0.3 |
| Source N | 22.20 | 35.20 | Licence | Licence | -1.11 | 1.11 | -1.76 | 1.76 |
| Source O | 4.10 | 4.20 | Infrastructure | Infrastructure | -0.205 | 0.205 | -0.21 | 0.21 |
| Source P | 8.40 | 10.00 | Infrastructure | Infrastructure | -0.42 | 0.42 | -0.5 | 0.5 |

| Source | Deployable Output (Ml/d) | | Constraint | | Assumed range of uncertainty in headroom simulation (Ml/d) | | | |
|---|---|---|---|---|---|---|---|---|
| | Average | Peak | Average | Peak | Average | | Peak | |
| | | | | | Min | Max | Min | Max |
| Source Q | 9.70 | 12.40 | Infrastructure | Infrastructure | -0.485 | 0.485 | -0.62 | 0.62 |
| Source R | 10.30 | 13.50 | Infrastructure | Infrastructure | -0.515 | 0.515 | -0.675 | 0.675 |
| Source S | 1.90 | 2.50 | Licence | Licence | -0.095 | 0.095 | -0.125 | 0.125 |
| Source T | 6.40 | 8.50 | Infrastructure | Infrastructure | -0.32 | 0.32 | -0.425 | 0.425 |

A normal probability distribution has been adopted to represent the range of uncertainty for each source or group of sources; in each case the parameters are given by:

Mean = 0

Standard Deviation (σ) = Maximum value (Ml/d)/4

Equating the minimum and maximum values with ±4σ ensures that the probability of the meter error lying within this range is approximately 99.99%. Selecting a normal distribution for meter/source yield accuracy reflects the random nature of the error and is in line with the recommendations in the 2002 UKWIR methodology.

## 3.8 S7 Single source dominance

This factor is no longer included in the headroom assessment methodology.

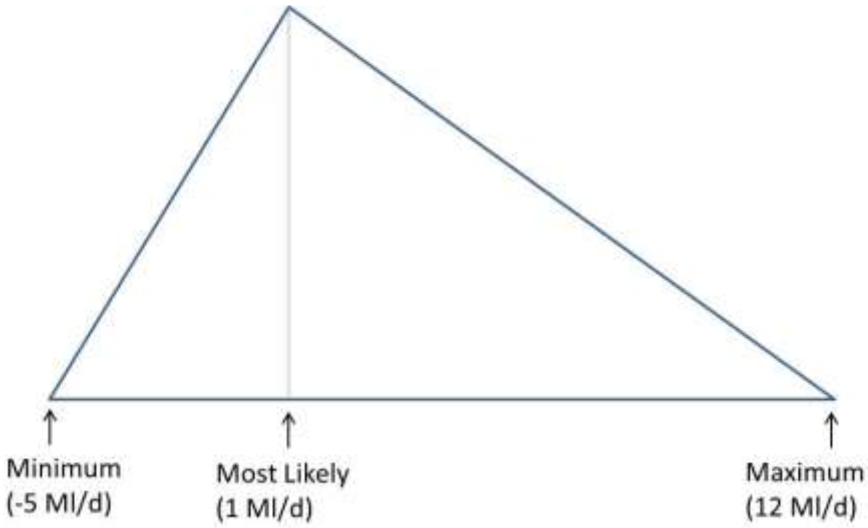
## 3.9 S8 Impact of climate change on deployable output

A climate change vulnerability assessment was completed for the Portsmouth Water company area in September 2016 by HR Wallingford. This assessment identified Portsmouth Water's single WRZ as being of 'Low Vulnerability' to climate change. This is a change from the WRMP 2014 assessment, which considered the zone to be of 'Medium Vulnerability'. Despite this, a similar level and complexity of climate change impact assessment has been undertaken for dWRMP 2019 as for WRMP 2014.

The assessment of climate change impacts on Portsmouth Water's deployable output has involved identifying a representative sample of 100 climate change scenarios from the UKCP09 10,000 member ensemble for the 2080s under a Medium Emission Scenario; this sampling was undertaken by HR Wallingford. AECOM then applied rainfall and potential evapotranspiration monthly scaling factors to the stochastic climate data to assess climate change impacts on groundwater levels at Well 'X' and on surface water flows in the River Itchen during a 'dry year'. This enabled climate change impacts on deployable output to be estimated for the 2080s for each of the 100 sampled scenarios, and then scaled back across the planning horizon by interpolation.

From the 100 sampled scenarios, a profile of 'most likely' climate change impacts was determined, as well as the 'lower range' and 'upper range' profiles. The lower and upper range profiles were based on the 10% and 90% quantiles of the impacts across all 100 scenarios. These were used to define triangular probability distributions to represent the uncertainty range in climate change impacts on deployable output in each year across the planning horizon, as illustrated in Figure 3-2.

**Figure 3-2 Typical headroom uncertainty distribution function for climate change impacts on deployable output (Dry Year Annual Average Scenario, 2044/45)**




Note that in these distributions a positive value indicates a loss of deployable output (contributing to an increase in overall headroom) whilst a negative value indicates a gain in deployable output (which would contribute to a decrease in headroom).

## 3.10 S9 New sources

This factor is designed to allow for any uncertainty surrounding estimated future yields of specific new resource developments included in a company's future supply-demand balance. Currently Portsmouth Water do not anticipate including any significant new sources in their final plan and so this factor will not be included as an uncertainty component in the headroom calculation.

## 3.11 D1 Accuracy of sub-component demand data

The uncertainty surrounding demand (or distribution input, DI) data is based on the accuracy of distribution input meters located at service reservoirs; for the previous (WRMP 2014) assessment a variation of +/- 5% was assumed. However, Portsmouth Water have recently replaced many of these meters with new magflow meters of better accuracy and which enable an improved electronic methodology for calibrating the meters on a regular basis. The current assessment is therefore based on a narrower range of variation, of +/- 2%.

As for factor S6 (Accuracy of supply-side data), a normal distribution is adopted for this factor, to reflect the random nature of errors associated with meter accuracy, and in line with the guidelines in the 2002 UKWIR methodology. The parameters of the normal distribution, for each year in the planning horizon and for each planning scenario, are defined as follows:

Mean = 0

Standard Deviation (σ) = 2% of Company Distribution Input / 4

This ensures that the probability of the variation from DI due to meter error lying within the range ± 2% of DI is 99.99%. The variation lies almost entirely between a minimum value of -2% of DI and a maximum value of +2% of DI. The range for each planning year and planning scenario are shown in Table 3-3.

**Table 3-3 Sub-component demand data uncertainty ranges**

| Year | Dry Year Annual Average | | | Dry Year Critical Period | | |
|---|---|---|---|---|---|---|
| | Minimum | Mean | Maximum | Minimum | Mean | Maximum |
| 2016/17 | -3.42 | 0.00 | 3.42 | -4.26 | 0.00 | 4.26 |
| 2017/18 | -3.42 | 0.00 | 3.42 | -4.25 | 0.00 | 4.25 |
| 2018/19 | -3.41 | 0.00 | 3.41 | -4.24 | 0.00 | 4.24 |
| 2019/20 | -3.31 | 0.00 | 3.31 | -4.12 | 0.00 | 4.12 |
| 2020/21 | -3.30 | 0.00 | 3.30 | -4.11 | 0.00 | 4.11 |
| 2021/22 | -3.30 | 0.00 | 3.30 | -4.10 | 0.00 | 4.10 |
| 2022/23 | -3.30 | 0.00 | 3.30 | -4.09 | 0.00 | 4.09 |
| 2023/24 | -3.29 | 0.00 | 3.29 | -4.08 | 0.00 | 4.08 |
| 2024/25 | -3.29 | 0.00 | 3.29 | -4.07 | 0.00 | 4.07 |
| 2025/26 | -3.29 | 0.00 | 3.29 | -4.06 | 0.00 | 4.06 |
| 2026/27 | -3.29 | 0.00 | 3.29 | -4.05 | 0.00 | 4.05 |
| 2027/28 | -3.29 | 0.00 | 3.29 | -4.04 | 0.00 | 4.04 |
| 2028/29 | -3.29 | 0.00 | 3.29 | -4.03 | 0.00 | 4.03 |
| 2029/30 | -3.29 | 0.00 | 3.29 | -4.03 | 0.00 | 4.03 |
| 2030/31 | -3.29 | 0.00 | 3.29 | -4.03 | 0.00 | 4.03 |
| 2031/32 | -3.30 | 0.00 | 3.30 | -4.03 | 0.00 | 4.03 |
| 2032/33 | -3.30 | 0.00 | 3.30 | -4.03 | 0.00 | 4.03 |
| 2033/34 | -3.31 | 0.00 | 3.31 | -4.03 | 0.00 | 4.03 |
| 2034/35 | -3.31 | 0.00 | 3.31 | -4.03 | 0.00 | 4.03 |
| 2035/36 | -3.32 | 0.00 | 3.32 | -4.04 | 0.00 | 4.04 |
| 2036/37 | -3.32 | 0.00 | 3.32 | -4.04 | 0.00 | 4.04 |
| 2037/38 | -3.33 | 0.00 | 3.33 | -4.04 | 0.00 | 4.04 |
| 2038/39 | -3.34 | 0.00 | 3.34 | -4.05 | 0.00 | 4.05 |
| 2039/40 | -3.34 | 0.00 | 3.34 | -4.05 | 0.00 | 4.05 |
| 2040/41 | -3.35 | 0.00 | 3.35 | -4.06 | 0.00 | 4.06 |
| 2041/42 | -3.36 | 0.00 | 3.36 | -4.07 | 0.00 | 4.07 |
| 2042/43 | -3.37 | 0.00 | 3.37 | -4.07 | 0.00 | 4.07 |
| 2043/44 | -3.38 | 0.00 | 3.38 | -4.08 | 0.00 | 4.08 |
| 2044/45 | -3.39 | 0.00 | 3.39 | -4.09 | 0.00 | 4.09 |

## 3.12 D2 Demand forecast variation

Portsmouth Water have prepared their company demand forecasts for the dWRMP 2019 submission based on population and property estimates provided by Experian. Experian have also provided 10% and 90% confidence bands around their central estimates, so these have been used to derive ‘low’ and ‘high’ forecast profiles to estimate the band of uncertainty around the ‘medium’ or ‘central’ forecast adopted for the dWRMP

2019 baseline supply-demand balance. The high and low forecast profiles represent the upper and lower bounds in the demand forecasts due to uncertainty in population and property growth.

The baseline demand forecast (central profile) incorporates the company's strategy on metering, leakage reduction and water efficiency savings; uncertainty surrounding these factors is discussed further in Section 3.14. It also includes a median allowance for the impacts of climate change; this is discussed further in Section 3.13 below.

A summary of Portsmouth Water's demand forecasts to the end of the WRMP planning horizon (2045), for each of the key planning scenarios considered in the headroom assessment, is given in Table 3-4 along with the range of potential variation, and illustrated in Figure 3-3 and Figure 3-4.

Note that the demand forecasts were prepared in September 2017 and may be subject to slight adjustment in the future. This assessment of target headroom is based on these latest forecasts from September 2017.

**Table 3-4 Summary of Portsmouth Water's demand forecasts for WRMP 2019**

| Year | Dry Year Annual Average (Ml/d) | | | Dry Year Critical Period (Ml/d) | | |
|---|---|---|---|---|---|---|
| | Low | Central | High | Low | Central | High |
| 2016/17 | 171.29 | 171.29 | 171.29 | 213.48 | 213.48 | 213.48 |
| 2017/18 | 169.29 | 171.15 | 173.39 | 210.76 | 213.05 | 215.78 |
| 2018/19 | 168.56 | 170.93 | 174.19 | 209.52 | 212.44 | 216.4 |
| 2019/20 | 167.86 | 170.72 | 174.87 | 208.31 | 211.83 | 216.88 |
| 2020/21 | 162.07 | 165.42 | 170.59 | 202 | 206.12 | 212.4 |
| 2021/22 | 161.63 | 165.21 | 171.06 | 201.1 | 205.51 | 212.59 |
| 2022/23 | 160.83 | 165.01 | 171.1 | 199.75 | 204.9 | 212.26 |
| 2023/24 | 160.4 | 164.85 | 171.47 | 198.86 | 204.34 | 212.34 |
| 2024/25 | 159.99 | 164.72 | 172.3 | 198.01 | 203.83 | 212.96 |
| 2025/26 | 159.31 | 164.61 | 172.84 | 196.82 | 203.32 | 213.25 |
| 2026/27 | 159.28 | 164.51 | 173.26 | 196.42 | 202.85 | 213.38 |
| 2027/28 | 158.96 | 164.43 | 173.97 | 195.66 | 202.37 | 213.85 |
| 2028/29 | 158.74 | 164.36 | 174.45 | 195.03 | 201.92 | 214.04 |
| 2029/30 | 158.63 | 164.41 | 175.38 | 194.59 | 201.66 | 214.85 |
| 2030/31 | 158.62 | 164.56 | 176.1 | 194.34 | 201.59 | 215.45 |
| 2031/32 | 158.63 | 164.71 | 175.95 | 194.11 | 201.54 | 215.03 |
| 2032/33 | 158.64 | 164.91 | 177.47 | 193.9 | 201.55 | 216.61 |
| 2033/34 | 158.68 | 165.13 | 178.27 | 193.73 | 201.58 | 217.33 |
| 2034/35 | 158.73 | 165.35 | 179.22 | 193.56 | 201.62 | 218.24 |
| 2035/36 | 158.78 | 165.58 | 179.69 | 193.4 | 201.67 | 218.57 |
| 2036/37 | 158.38 | 165.84 | 180.51 | 192.71 | 201.76 | 219.33 |
| 2037/38 | 158.88 | 166.14 | 182.59 | 193.12 | 201.92 | 221.62 |
| 2038/39 | 158.95 | 166.48 | 183.39 | 193.04 | 202.15 | 222.4 |
| 2039/40 | 159.43 | 166.84 | 184.02 | 193.44 | 202.4 | 222.97 |
| 2040/41 | 159.7 | 167.22 | 184.58 | 193.6 | 202.7 | 223.46 |

| Year | Dry Year Annual Average (Ml/d) | | | Dry Year Critical Period (Ml/d) | | |
|---|---|---|---|---|---|---|
| | Low | Central | High | Low | Central | High |
| 2041/42 | 160.22 | 167.61 | 185.27 | 194.06 | 202.99 | 224.11 |
| 2042/43 | 160.54 | 168.02 | 185.88 | 194.29 | 203.32 | 224.66 |
| 2043/44 | 161.07 | 168.45 | 186.58 | 194.78 | 203.67 | 225.33 |
| 2044/45 | 161.41 | 168.89 | 187.22 | 195.03 | 204.04 | 225.92 |

**Figure 3-3 Portsmouth Water's Dry Year Annual Average low, central and high demand forecasts from 2017 to 2045**

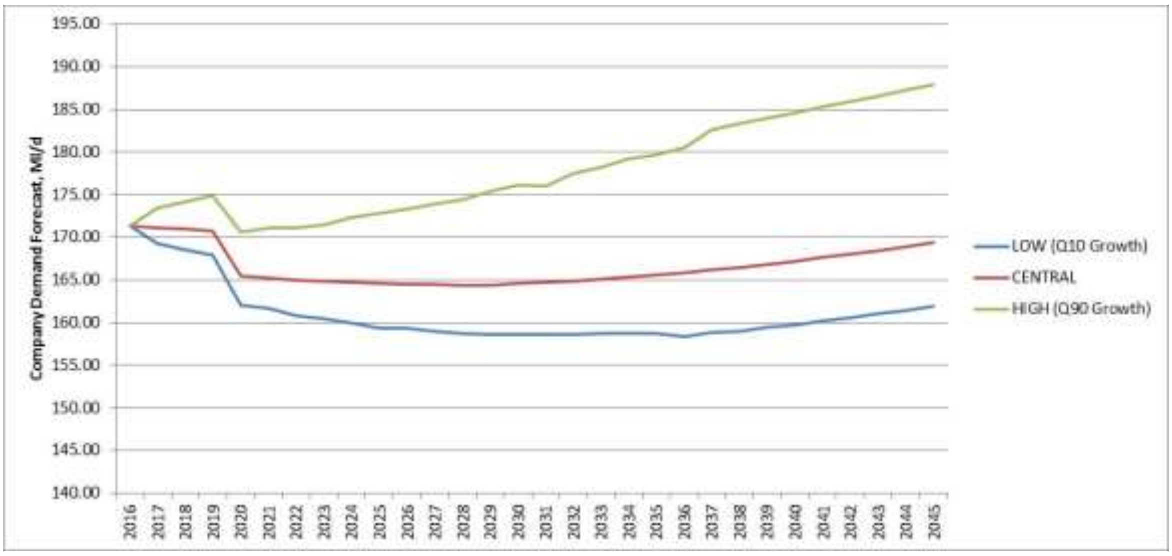
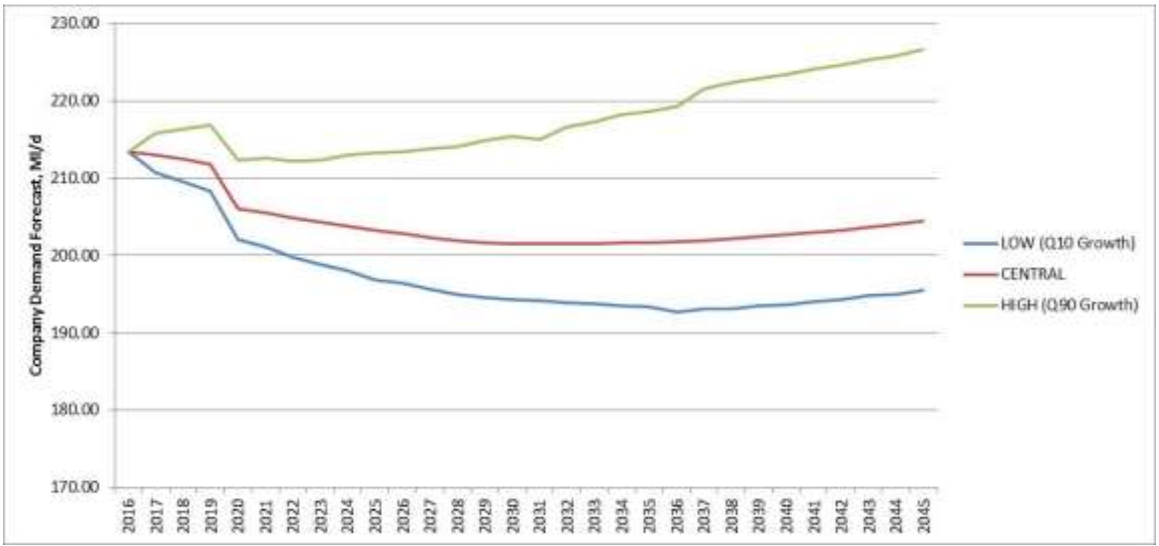



**Figure 3-4 Portsmouth Water's Dry Year Critical Period low, central and high demand forecasts from 2017 to 2045**




For each planning year and planning scenario, a triangular distribution has been adopted to represent the potential variation from the medium demand forecast if either the Low or High forecast were to apply. The parameters of each triangular distribution were therefore calculated as follows:

Minimum = Low – Central forecast in Ml/d (a negative value)

Most Likely = 0 (as the central forecast is adopted in the baseline supply-demand balance)

Maximum = High – Central forecast in Ml/d (a positive value)

An example of this type of distribution is shown in Figure 3-5, and the triangular distribution parameters for both scenarios considered in this analysis across the planning horizon to 2045 are shown in Table 3-5.

**Figure 3-5 Typical headroom uncertainty distribution function for demand forecast variation (Dry Year Annual Average Scenario, 2044/45)**

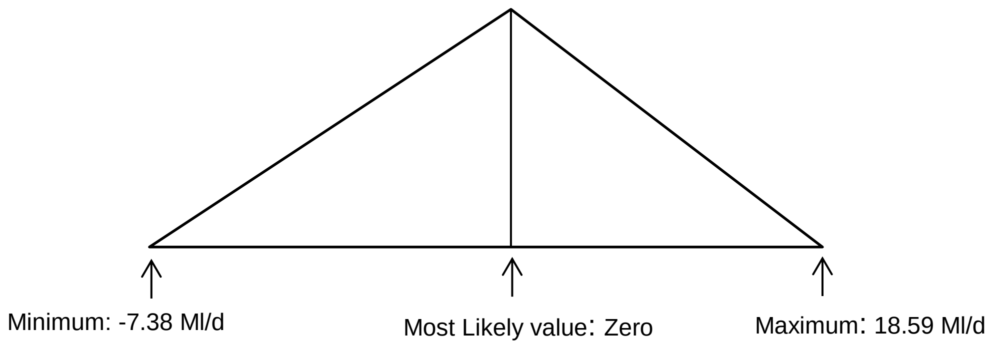



**Table 3-5 Triangular distribution parameters for demand forecast variation uncertainty**

| Year | Dry Year Annual Average (Ml/d) | | | Dry Year Critical Period (Ml/d) | | |
|---|---|---|---|---|---|---|
| | Minimum | Most Likely | Maximum | Minimum | Most Likely | Maximum |
| 2016/17 | -1.86 | 0.00 | 2.24 | -2.29 | 0.00 | 2.73 |
| 2017/18 | -2.37 | 0.00 | 3.26 | -2.92 | 0.00 | 3.96 |
| 2018/19 | -2.86 | 0.00 | 4.15 | -3.52 | 0.00 | 5.05 |
| 2019/20 | -3.35 | 0.00 | 5.17 | -4.12 | 0.00 | 6.28 |
| 2020/21 | -3.58 | 0.00 | 5.85 | -4.41 | 0.00 | 7.08 |
| 2021/22 | -4.18 | 0.00 | 6.09 | -5.15 | 0.00 | 7.36 |
| 2022/23 | -4.45 | 0.00 | 6.62 | -5.48 | 0.00 | 8.00 |
| 2023/24 | -4.73 | 0.00 | 7.58 | -5.82 | 0.00 | 9.13 |
| 2024/25 | -5.30 | 0.00 | 8.23 | -6.50 | 0.00 | 9.93 |
| 2025/26 | -5.23 | 0.00 | 8.75 | -6.43 | 0.00 | 10.53 |
| 2026/27 | -5.47 | 0.00 | 9.54 | -6.71 | 0.00 | 11.48 |
| 2027/28 | -5.62 | 0.00 | 10.09 | -6.89 | 0.00 | 12.12 |
| 2028/29 | -5.78 | 0.00 | 10.97 | -7.07 | 0.00 | 13.19 |
| 2029/30 | -5.94 | 0.00 | 11.54 | -7.25 | 0.00 | 13.86 |
| 2030/31 | -6.08 | 0.00 | 11.24 | -7.43 | 0.00 | 13.49 |
| 2031/32 | -6.27 | 0.00 | 12.56 | -7.65 | 0.00 | 15.06 |
| 2032/33 | -6.45 | 0.00 | 13.14 | -7.85 | 0.00 | 15.75 |
| 2033/34 | -6.62 | 0.00 | 13.87 | -8.06 | 0.00 | 16.62 |
| 2034/35 | -6.80 | 0.00 | 14.11 | -8.27 | 0.00 | 16.90 |
| 2035/36 | -7.46 | 0.00 | 14.67 | -9.05 | 0.00 | 17.57 |
| 2036/37 | -7.26 | 0.00 | 16.45 | -8.80 | 0.00 | 19.70 |
| 2037/38 | -7.53 | 0.00 | 16.91 | -9.11 | 0.00 | 20.25 |
| 2038/39 | -7.41 | 0.00 | 17.18 | -8.96 | 0.00 | 20.57 |
| 2039/40 | -7.52 | 0.00 | 17.36 | -9.10 | 0.00 | 20.76 |

| Year | Dry Year Annual Average (Ml/d) | | | Dry Year Critical Period (Ml/d) | | |
|---|---|---|---|---|---|---|
| | Minimum | Most Likely | Maximum | Minimum | Most Likely | Maximum |
| 2040/41 | -7.39 | 0.00 | 17.66 | -8.93 | 0.00 | 21.12 |
| 2041/42 | -7.48 | 0.00 | 17.86 | -9.03 | 0.00 | 21.34 |
| 2042/43 | -7.38 | 0.00 | 18.13 | -8.89 | 0.00 | 21.66 |
| 2043/44 | -7.48 | 0.00 | 18.33 | -9.01 | 0.00 | 21.88 |
| 2044/45 | -7.38 | 0.00 | 18.59 | -8.88 | 0.00 | 22.19 |

## 3.13 D3 Impact of climate change on demand

Portsmouth Water has assessed the impacts of climate change on their company demand forecasts, using the methodology and data from the study 'Impact of climate change on water demand' (UKWIR, 2013). This presents the impacts of climate change as percentage changes in household demand, for five quantiles (10%, 25%, 50%, 75% and 90%). Portsmouth Water has adopted the median (50%) quantile to calculate the percentage increase in household demand to incorporate in their baseline central demand forecast. The company has used the 10% and 90% quantile impacts to calculate 'high' and 'low' ranges of household demand around this baseline profile; the resulting demand forecast profiles are shown in Table 3-6 below. These values have been used to determine the parameters for the statistical probability distribution representing the uncertainty in climate change impacts on demand, using a triangular distribution type, as follows:

Minimum = 10% - Median profile in Ml/d (a negative value)

Most Likely = 0 (as the median impacts are incorporated in the baseline supply-demand balance)

Maximum = 90% – Median profile in Ml/d (a positive value)

**Table 3-6 Range of impacts of climate change on Portsmouth Water's demand forecast**

| Year | Dry Year Annual Average (Ml/d) | | | Dry Year Critical Period (Ml/d) | | |
|---|---|---|---|---|---|---|
| | 10% | Median | 90% | 10% | Median | 90% |
| 2016/17 | 171.14 | 171.15 | 171.18 | 212.99 | 213.05 | 213.13 |
| 2017/18 | 170.9 | 170.93 | 170.98 | 212.31 | 212.44 | 212.59 |
| 2018/19 | 170.67 | 170.72 | 170.79 | 211.64 | 211.83 | 212.07 |
| 2019/20 | 165.35 | 165.42 | 165.5 | 205.87 | 206.12 | 206.43 |
| 2020/21 | 165.13 | 165.21 | 165.32 | 205.19 | 205.51 | 205.88 |
| 2021/22 | 164.91 | 165.01 | 165.14 | 204.53 | 204.9 | 205.33 |
| 2022/23 | 164.74 | 164.85 | 165 | 203.92 | 204.34 | 204.85 |
| 2023/24 | 164.59 | 164.72 | 164.89 | 203.34 | 203.83 | 204.38 |
| 2024/25 | 164.47 | 164.61 | 164.8 | 202.79 | 203.32 | 203.94 |
| 2025/26 | 164.36 | 164.51 | 164.73 | 202.27 | 202.85 | 203.53 |
| 2026/27 | 164.26 | 164.43 | 164.67 | 201.76 | 202.37 | 203.1 |
| 2027/28 | 164.18 | 164.36 | 164.62 | 201.25 | 201.92 | 202.7 |
| 2028/29 | 164.21 | 164.41 | 164.7 | 200.96 | 201.66 | 202.5 |
| 2029/30 | 164.34 | 164.56 | 164.87 | 200.85 | 201.59 | 202.48 |
| 2030/31 | 164.48 | 164.71 | 165.04 | 200.75 | 201.54 | 202.48 |

| Year | Dry Year Annual Average (Ml/d) | | | Dry Year Critical Period (Ml/d) | | |
|---|---|---|---|---|---|---|
| | 10% | Median | 90% | 10% | Median | 90% |
| 2031/32 | 164.66 | 164.91 | 165.26 | 200.71 | 201.55 | 202.54 |
| 2032/33 | 164.87 | 165.13 | 165.51 | 200.7 | 201.58 | 202.63 |
| 2033/34 | 165.08 | 165.35 | 165.75 | 200.7 | 201.62 | 202.73 |
| 2034/35 | 165.29 | 165.58 | 166.01 | 200.7 | 201.67 | 202.83 |
| 2035/36 | 165.53 | 165.84 | 166.28 | 200.74 | 201.76 | 202.97 |
| 2036/37 | 165.81 | 166.14 | 166.61 | 200.86 | 201.92 | 203.18 |
| 2037/38 | 166.13 | 166.48 | 166.97 | 201.05 | 202.15 | 203.47 |
| 2038/39 | 166.47 | 166.84 | 167.36 | 201.27 | 202.4 | 203.78 |
| 2039/40 | 166.84 | 167.22 | 167.76 | 201.51 | 202.7 | 204.13 |
| 2040/41 | 167.21 | 167.61 | 168.18 | 201.76 | 202.99 | 204.47 |
| 2041/42 | 167.61 | 168.02 | 168.61 | 202.05 | 203.32 | 204.86 |
| 2042/43 | 168.02 | 168.45 | 169.07 | 202.36 | 203.67 | 205.25 |
| 2043/44 | 168.44 | 168.89 | 169.54 | 202.68 | 204.04 | 205.68 |
| 2044/45 | 168.88 | 169.35 | 170.02 | 203.04 | 204.43 | 206.12 |

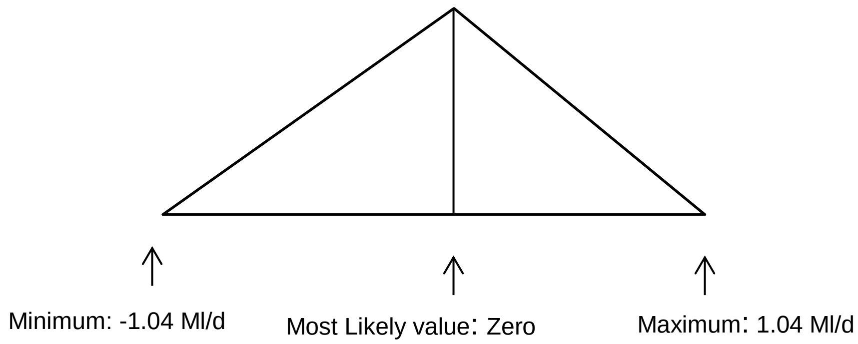
## 3.14 D4 Demand management measures

Portsmouth Water's baseline central demand forecasts include the company's strategic plans and assumptions relating to the average number of meter optants each year and the magnitude of leakage reduction included in the plan. However, there is uncertainty surrounding the demand savings which will be achieved in practice from these demand management measures and these are accounted for within factor D4 of the headroom calculation.

Portsmouth Water has calculated a lower and upper band representing the possible impacts on its demand forecast of variations in the assumed rate of meter uptake. The lower band assumes achieving a 10% higher rate of meter optants in each year than in the baseline forecast. The upper band assumes a 20% lower rate of meter optants in each year than in the baseline forecast. The range between the lower band and baseline forecast, and between the upper band and baseline forecast, are taken as the parameters of a triangular distribution representing the uncertainty contribution of this factor to the target headroom allowance in each year across the planning horizon.

With regard to demand savings from leakage reduction, Portsmouth Water's strategy is to install additional District Metering Areas (DMA) by 2018/19, providing a reduction of 5.2 Ml/d. This is incorporated into the company's baseline demand forecasts. High and low scenarios at 20% (1.04 Ml/d) either side of the central estimate have been used to determine triangular distributions to represent the future uncertainty in demand savings which may be achieved from leakage reduction in practice. These distributions, illustrated in Figure 3-6, also contribute to the target headroom allowance in each year across the planning horizon.

**Figure 3-6 Typical headroom uncertainty distribution function for leakage reduction (Dry Year Annual Average Scenario, 2044/45)**




## 3.15 Interdependencies

The @RISK software used for the Monte Carlo probability simulation allows for interdependencies between individual distributions to be incorporated. An interdependency is required if the sampled value of one probability distribution is not completely independent of the value of another, i.e. there is some relationship between the two variables (uncertainty factors). The following interdependencies apply to this analysis of Portsmouth Water's headroom allowance:

- Between S8 (Impact of Climate Change on Deployable Output) and D3 (Impact of Climate Change on Demand)

  A positive interdependency has been assumed between the impacts of climate change on both deployable output and demand. In other words, the greater the increase in demand due to climate change, the greater the reduction in deployable output (both of which impacts have a positive effect on the calculated headroom allowance). This has been modelled by setting a positive correlation (using the @RISK ranked-order correlation functionality) between the probability distribution functions for factor S8 and factor D3 respectively, in each year across the planning horizon.

In the previous (WRMP 2014) assessment, an interdependency between S2 (Vulnerable Groundwater Licences) and S5 (Gradual Pollution) was included (but only for the sensitivity analysis undertaken to assess the impact of including potential groundwater sustainability reductions), however as factor S2 is now excluded from the headroom allowance this interdependency is no longer needed.

# 4 Assessment Results

## 4.1 Company Target Headroom Allowance

The results of the evaluation of Portsmouth Water's company target headroom allowance are shown in Table 4-1 and Table 4-2. A separate simulation for each of the two planning scenarios under consideration (DYAA and DYCP) was carried out in this headroom assessment. Each table shows the overall headroom uncertainty allowance (profiles of target headroom) for each year across the planning horizon, at probabilities of 50%, 75%, 80%, 85%, 90% and 95% respectively. The headroom allowances are expressed as values in Ml/d. Table 4-1 shows the results for the DYAA planning scenario and Table 4-2 shows the results for the DYCP scenario. The profiles of target headroom for the selected probabilities are also illustrated in Figure 4-1 and Figure 4-2.

**Table 4-1 Portsmouth Water Headroom Allowance – Dry Year Annual Average Scenario**

| Year | Company Headroom Allowance (Ml/d) – Dry Year Annual Average | | | | | |
|---|---|---|---|---|---|---|
| | 50% | 75% | 80% | 85% | 90% | 95% |
| 2016/17 | 2.61 | 5.48 | 6.58 | 8.19 | 11.10 | 16.83 |
| 2017/18 | 2.89 | 5.89 | 6.90 | 8.48 | 11.36 | 17.28 |
| 2018/19 | 3.11 | 6.22 | 7.24 | 8.84 | 11.64 | 17.51 |
| 2019/20 | 3.42 | 6.65 | 7.71 | 9.19 | 11.83 | 17.85 |
| 2020/21 | 3.67 | 7.00 | 8.12 | 9.64 | 12.41 | 18.11 |
| 2021/22 | 3.54 | 7.06 | 8.21 | 9.77 | 12.31 | 17.64 |
| 2022/23 | 3.67 | 7.33 | 8.42 | 10.02 | 12.58 | 18.09 |
| 2023/24 | 4.08 | 7.83 | 8.96 | 10.43 | 13.07 | 18.72 |
| 2024/25 | 4.23 | 8.04 | 9.10 | 10.57 | 13.20 | 18.70 |
| 2025/26 | 4.47 | 8.26 | 9.48 | 11.11 | 13.67 | 19.22 |
| 2026/27 | 4.73 | 8.67 | 9.96 | 11.57 | 14.12 | 19.62 |
| 2027/28 | 4.94 | 9.04 | 10.31 | 11.96 | 14.38 | 19.96 |
| 2028/29 | 5.14 | 9.64 | 10.85 | 12.52 | 14.97 | 20.28 |
| 2029/30 | 5.34 | 9.86 | 11.23 | 12.96 | 15.27 | 20.49 |
| 2030/31 | 5.32 | 9.70 | 10.91 | 12.56 | 15.08 | 20.34 |
| 2031/32 | 5.70 | 10.39 | 11.68 | 13.35 | 15.75 | 21.45 |
| 2032/33 | 5.94 | 10.81 | 12.11 | 13.69 | 16.08 | 21.04 |
| 2033/34 | 6.13 | 11.02 | 12.40 | 14.14 | 16.50 | 21.86 |
| 2034/35 | 6.32 | 11.23 | 12.62 | 14.28 | 16.73 | 21.83 |
| 2035/36 | 6.29 | 11.50 | 12.83 | 14.62 | 17.02 | 22.03 |
| 2036/37 | 6.93 | 12.31 | 13.76 | 15.62 | 18.33 | 23.25 |
| 2037/38 | 7.01 | 12.48 | 14.06 | 16.00 | 18.47 | 23.36 |
| 2038/39 | 7.24 | 12.81 | 14.27 | 16.27 | 18.71 | 23.52 |
| 2039/40 | 7.29 | 12.87 | 14.31 | 16.25 | 18.86 | 23.90 |
| 2040/41 | 7.48 | 13.30 | 14.76 | 16.67 | 19.18 | 23.90 |

| Year | Company Headroom Allowance (Ml/d) – Dry Year Annual Average | | | | | |
|---|---|---|---|---|---|---|
| | 50% | 75% | 80% | 85% | 90% | 95% |
| 2041/42 | 7.60 | 13.25 | 14.83 | 16.82 | 19.23 | 24.24 |
| 2042/43 | 7.69 | 13.50 | 15.15 | 17.12 | 19.64 | 24.66 |
| 2043/44 | 7.90 | 13.67 | 15.12 | 17.14 | 19.88 | 24.50 |
| 2044/45 | 7.92 | 13.88 | 15.49 | 17.48 | 20.16 | 24.95 |

**Table 4-2 Portsmouth Water Headroom Allowance – Dry Year Critical Period Scenario**

| Year | Company Headroom Allowance (Ml/d) – Dry Year Critical Period | | | | | |
|---|---|---|---|---|---|---|
| | 50% | 75% | 80% | 85% | 90% | 95% |
| 2016/17 | 3.72 | 6.77 | 7.77 | 9.34 | 12.56 | 18.84 |
| 2017/18 | 4.02 | 7.28 | 8.30 | 9.87 | 13.03 | 19.31 |
| 2018/19 | 4.34 | 7.81 | 8.91 | 10.46 | 13.33 | 19.59 |
| 2019/20 | 4.68 | 8.38 | 9.43 | 11.07 | 13.89 | 20.05 |
| 2020/21 | 4.91 | 8.74 | 9.86 | 11.48 | 14.42 | 20.55 |
| 2021/22 | 4.85 | 8.76 | 9.96 | 11.54 | 14.03 | 20.68 |
| 2022/23 | 5.21 | 9.27 | 10.44 | 11.93 | 14.68 | 20.75 |
| 2023/24 | 5.50 | 9.70 | 11.04 | 12.81 | 15.57 | 21.50 |
| 2024/25 | 5.66 | 10.08 | 11.35 | 12.98 | 15.68 | 21.82 |
| 2025/26 | 5.99 | 10.66 | 12.03 | 13.67 | 16.20 | 21.81 |
| 2026/27 | 6.34 | 10.98 | 12.29 | 14.06 | 16.71 | 22.90 |
| 2027/28 | 6.58 | 11.50 | 12.80 | 14.59 | 17.07 | 22.71 |
| 2028/29 | 7.02 | 12.03 | 13.40 | 15.13 | 17.94 | 23.70 |
| 2029/30 | 7.26 | 12.38 | 13.87 | 15.72 | 18.34 | 23.88 |
| 2030/31 | 7.17 | 12.35 | 13.79 | 15.60 | 18.11 | 24.07 |
| 2031/32 | 7.63 | 13.00 | 14.57 | 16.49 | 19.22 | 25.26 |
| 2032/33 | 7.91 | 13.52 | 14.99 | 16.94 | 19.63 | 25.66 |
| 2033/34 | 8.12 | 13.93 | 15.66 | 17.35 | 20.35 | 26.09 |
| 2034/35 | 8.33 | 14.09 | 15.61 | 17.52 | 20.85 | 26.27 |
| 2035/36 | 8.29 | 14.32 | 15.91 | 17.88 | 20.77 | 26.45 |
| 2036/37 | 9.16 | 15.63 | 17.43 | 19.39 | 22.15 | 27.98 |
| 2037/38 | 9.39 | 15.80 | 17.61 | 19.72 | 22.56 | 28.20 |
| 2038/39 | 9.60 | 16.28 | 18.09 | 20.22 | 23.15 | 28.83 |
| 2039/40 | 9.62 | 16.34 | 18.12 | 20.38 | 23.44 | 28.95 |
| 2040/41 | 9.97 | 16.57 | 18.51 | 20.82 | 23.84 | 29.04 |
| 2041/42 | 10.04 | 16.86 | 18.62 | 20.68 | 23.89 | 29.29 |

| Year | Company Headroom Allowance (Ml/d) – Dry Year Critical Period | | | | | |
|---|---|---|---|---|---|---|
| | 50% | 75% | 80% | 85% | 90% | 95% |
| 2042/43 | 10.29 | 17.09 | 19.08 | 21.10 | 23.90 | 29.60 |
| 2043/44 | 10.37 | 17.35 | 19.23 | 21.53 | 24.57 | 30.22 |
| 2044/45 | 10.50 | 17.63 | 19.57 | 21.89 | 24.97 | 30.81 |

**Figure 4-1 Portsmouth Water's Target Headroom Allowance for Selected Probabilities – Dry Year Annual Average Scenario**

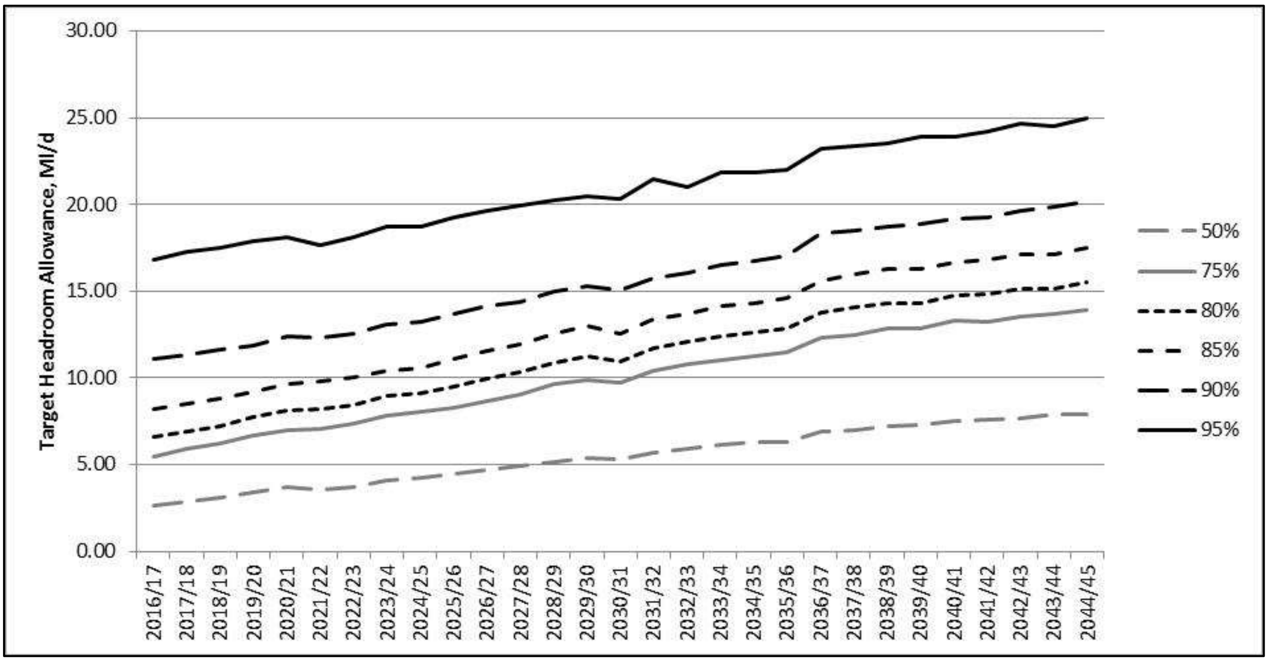
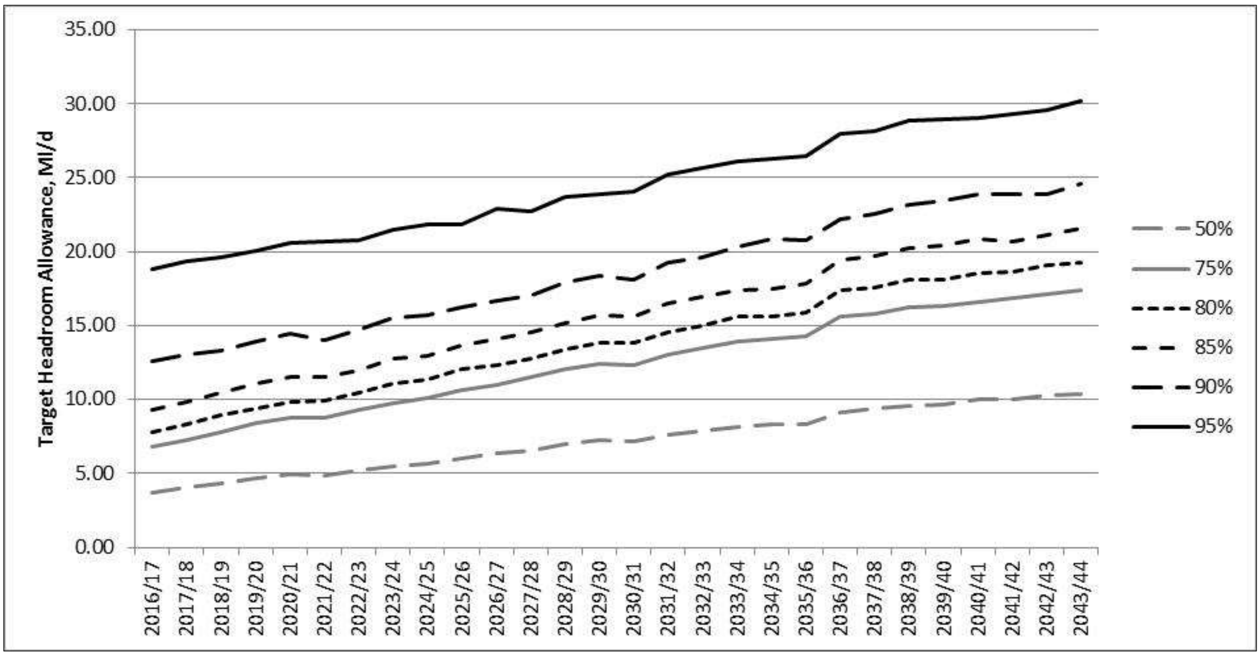



**Figure 4-2 Portsmouth Water's Target Headroom Allowance for Selected Probabilities – Dry Year Critical Period Scenario**




The probability distribution graphs for the total company target headroom allowance are included in Appendices A and B, for each planning scenario.

The target headroom values to be taken forward for the supply-demand balance analysis for dWRMP 2019 have been determined; these are based on selected risk/probability values at each stage of the 25-year planning horizon; further details are given in Section 4.3.

## 4.2 Headroom by Uncertainty Factor

The relative contribution of the various factors to the company's overall headroom values were examined, by collating the results of the Monte Carlo simulations for each factor individually (summed over Portsmouth Water's individual sources where applicable).

The results of the headroom simulation for individual uncertainty factors are shown in Figure 4-3 for both the DYAA and DYCP scenarios, at the 90% probability level, for two selected years in the planning period (2019/20 and 2044/45). An additional sub-total, derived by statistically combining factors S8 and D3 within the Monte Carlo simulation, has been calculated to illustrate the overall contribution of climate change effects to the headroom allowance. Similarly, all other factors have been statistically combined in the same manner, to produce a 'non-climate change effects' sub-total. The relative contributions of the climate change and non-climate change factors are shown in Figure 4-4.

Results at individual source level have not been investigated, as the risks identified are assumed to be similar in percentage terms for all sites, and therefore the magnitude of the contribution of each source to headroom is likely to be in proportion to the relative magnitude of their assessed deployable output values.

Note that the headroom allowance values by factor in Figure 4-3 and Figure 4-4 below do not sum to the company total headroom allowance values in Table 4-1 and Table 4-2 above. This is due to the probabilistic nature of the Monte Carlo simulation, in which simulated supply-demand variations due to the various risk/uncertainty factors do not occur simultaneously in each step of the iteration. However, the results by individual factor, and grouped by climate change / non-climate change effects, do give an indication of their relative contributions to the combined company total values.

**Figure 4-3 Relative Contributions of Uncertainty Factors to Company Headroom Allowance, 90% Probability, Ml/d**

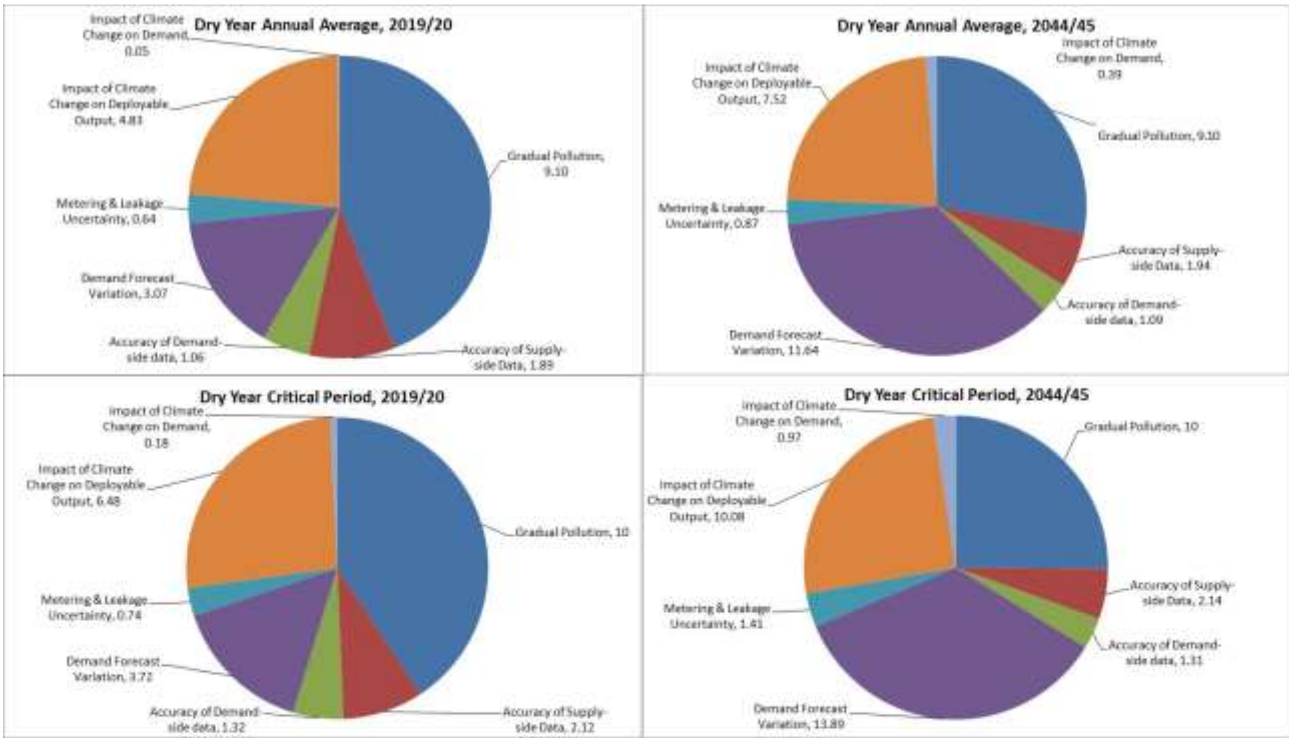
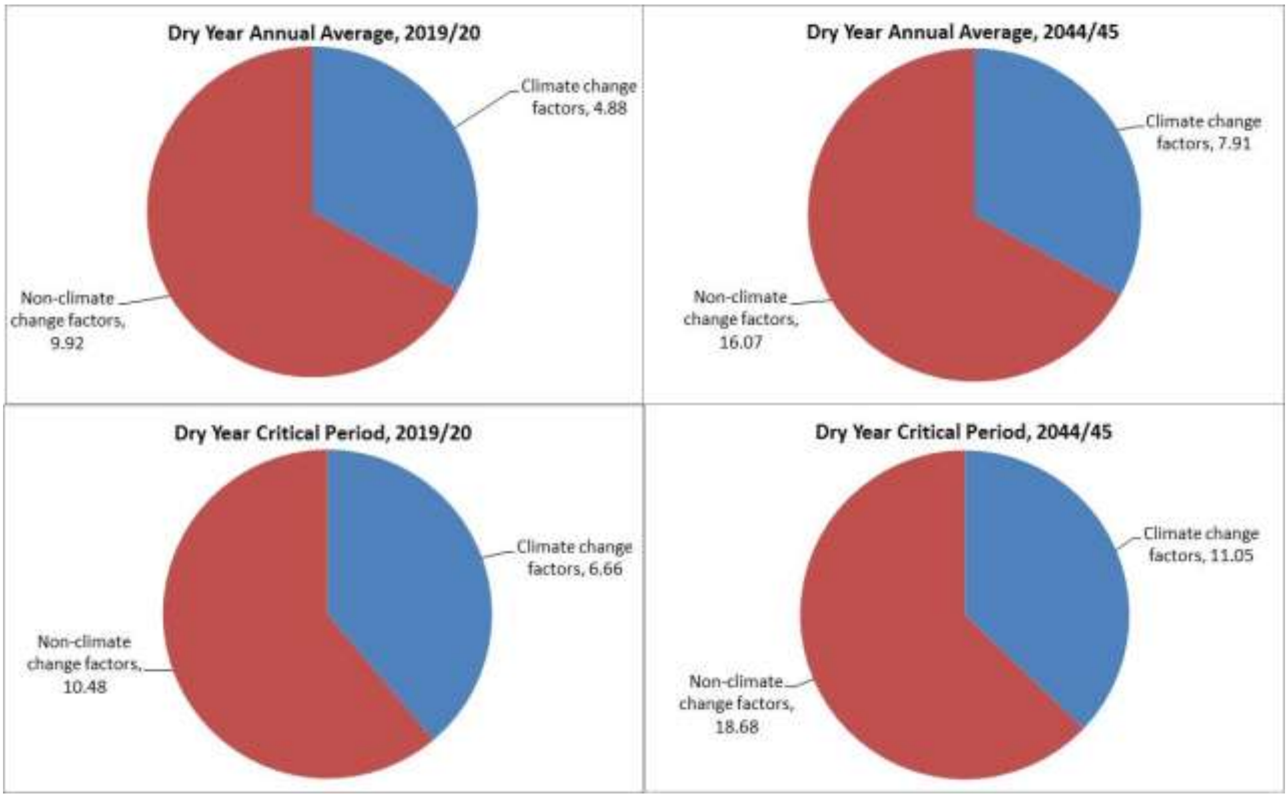


**Figure 4-4 Relative Contributions of Climate Change Factors to Company Headroom Allowance, 90% Probability, Ml/d**




The results indicate that the potential impacts of climate change on Portsmouth Water’s supply-demand balance account for around a third of the headroom uncertainty allowance, at the 90% probability level. The majority of the climate change uncertainty has been assessed as uncertainty regarding the future impacts of climate change on the deployable output of the company’s sources.

The risks of reduced deployable output due to source closure relating to oil pollution risks (shown as ‘gradual pollution’ in the figures and table above) contribute to a significant proportion of the company’s headroom allowance. This is particularly the case in the early years of the planning period, when this factor accounts for nearly half of the headroom uncertainty. Towards the end of the planning period, this proportion is reduced (although the magnitude is similar), as the proportion of the headroom allowance due to demand forecast variation increases steadily over time. The uncertainty in future demand forecasts is the factor which varies most across the 25-year planning period, exhibiting approximately a four-fold increase between 2019/20 and 2044/45.

The remaining factors (supply-side and demand-side data uncertainty, and uncertainty in future demand savings from metering and leakage reduction), make a relatively low contribution to the overall headroom allowance.

Appendices C and D contain tornado graphs showing the regression coefficients of each category (uncertainty factor), in order of their relative contributions to the combined headroom values. (Note that a maximum of 16 factors can be shown on the tornado graph). The graphs in the appendices are all outputs from the @RISK software used to undertake the Monte Carlo simulation.

## 4.3 Risk Profile

The company headroom values presented in Table 4-1 and Table 4-2 vary according to the selected probability point on each combined headroom distribution from which these values are taken. In order to determine a single profile of target headroom allowance across the 25-year planning period, for each planning scenario, it is necessary to select the appropriate level of risk on which to base the target headroom allowance for each year. Portsmouth Water can then incorporate the corresponding headroom value into its supply-demand balance across the planning period.

Table 4-3 illustrates the link between the level of risk adopted in the supply-demand balance for each future planning year, and the percentile point or exceedance probability of the headroom distribution from which the corresponding headroom value is read. The figures in Table 4-3 are based on a similar approach to that selected for the previous (WRMP 2014) target headroom assessment. This was based on a relatively low level of risk of 5% initially, followed by 1% increments in the level of risk adopted at five year intervals going into the future. For this assessment, a slightly higher initial level of risk of 10% was adopted, followed by 1% increments in each five year period as previously.

**Table 4-3 WRMP 2019 Target headroom risk profile, showing link between supply-demand balance risk and headroom**

| | 2020/21 - 2024/25 | 2025/26 - 2029/30 | 2030/31 - 2034/35 | 2035/36 - 2039/40 | 2040/41 – 2044/45 |
|---|---|---|---|---|---|
| Risk of variation (reduced surplus/ increased deficit) in the supply-demand balance | 10% | 11% | 12% | 13% | 14% |
| Headroom distribution probability | 90% | 89% | 88% | 87% | 86% |

Figure 4-5 and Figure 4-6 show the impact of the selected risk levels for each 5-year period across the planning horizon, on the overall glidepath of the final target headroom allowance for the dry year annual average and dry year critical period scenarios respectively.

**Figure 4-5 Target Headroom Risk Profile for WRMP 2019, Dry Year Annual Average Scenario**

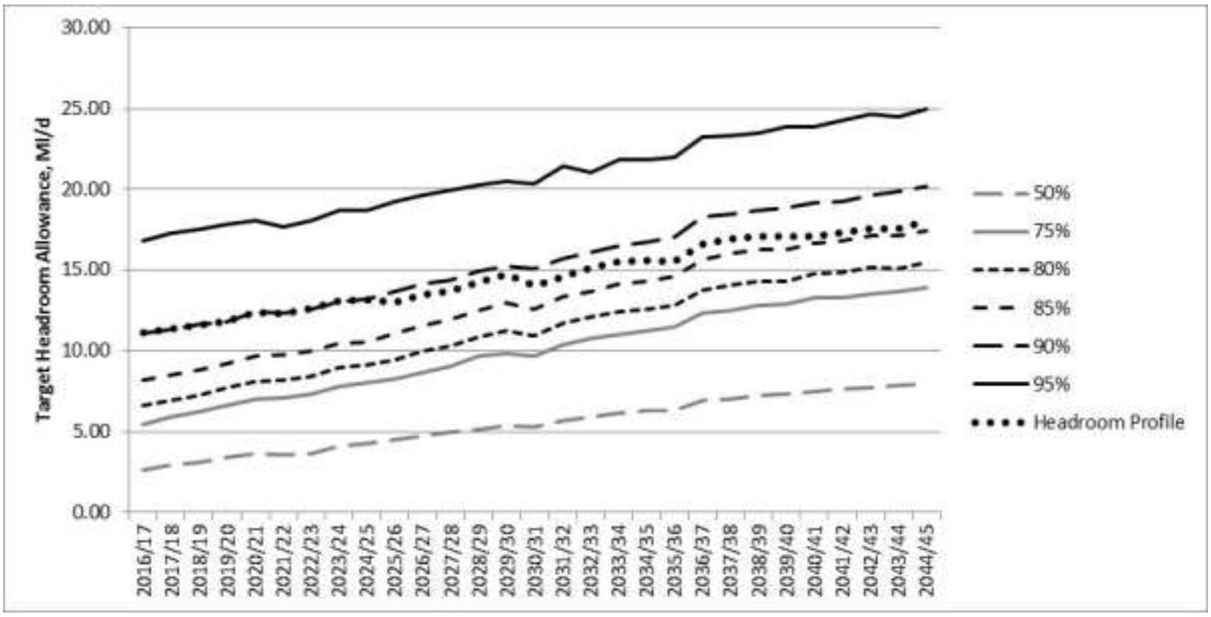
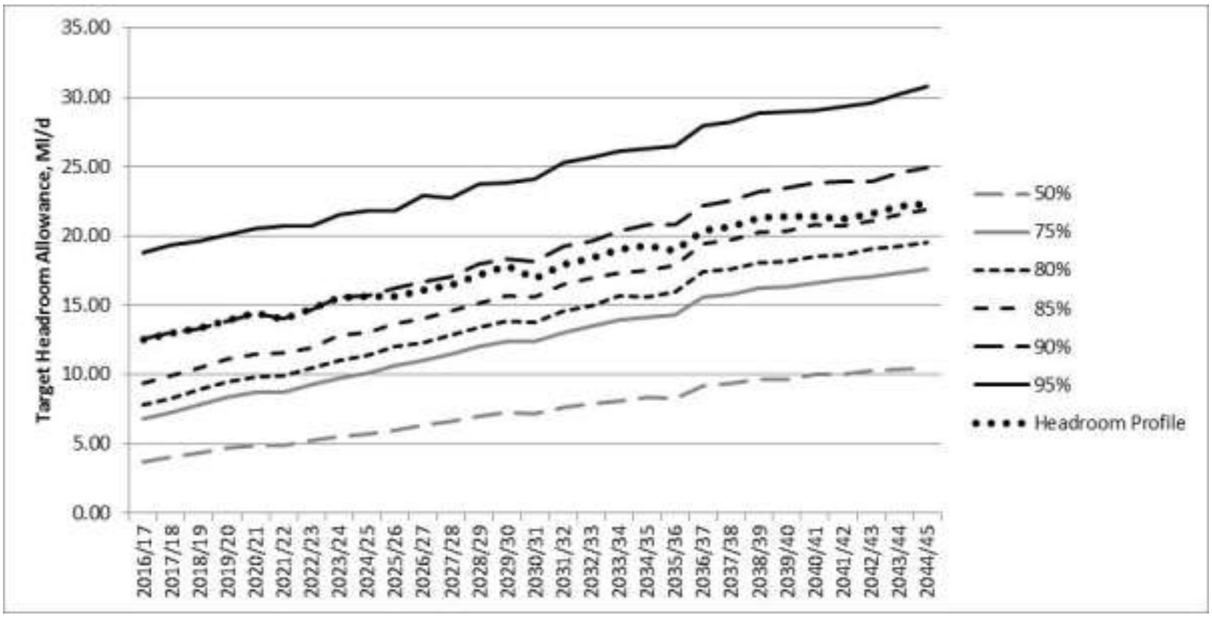



**Figure 4-6 Target Headroom Risk Profile for WRMP 2019, Dry Year Critical Period Scenario**



## 4.4 Comparison with Previous Assessments

The results of this headroom assessment were compared with those calculated for Portsmouth Water's WRMP submissions in 2004, 2009 and 2014. The previous and current results are presented in Table 4-4 for selected years which occur within the 25-year planning period of all of these assessments (albeit that these years were further ahead in time when the earlier assessments were carried out).

In summary, Portsmouth Water's company target headroom allowance has increased slightly by around 0.1 – 3.7 Ml/d in this assessment (1% – 39% increase, for the period 2019/20 – 2024/25), compared to the previous values reported at WRMP 2014. At the end of the 25-year planning horizon (comparing 2039/40 from the WRMP 2014 assessment, with 2044/45 in the current assessment), the increase is somewhat greater: around 9.4 Ml/d (109%) for the DYAA scenario, and 8.9 Ml/d (66%) for the DYCP scenario.

The increase in target headroom is mainly due to increased probabilities of source closure due to oil spill risks (based on actual recorded events), increased uncertainty ranges around future demand forecasts and the potential impacts of climate change on supply. The most significant changes in uncertainty assumptions from WRMP 2014 can be summarised as follows:

- Oil spill risks: probability of occurrence per source/per year increased from 0.83% to 1.39% (DYAA) and from 0.71% to 1.11% (DYCP);
- Demand forecast variation: uncertainty range by the end of the planning period increased from 4 to 26 Ml/d (DYAA) and from 6 to 31 Ml/d (DYCP); and
- Impacts of climate change on supply: uncertainty ranges have increased by 5 – 8 Ml/d (DYAA), and by 1 – 9 Ml/d (DYCP), with the differences being greater at the *start* of the planning period.

**Table 4-4 Portsmouth Water Target Headroom Allowance – Comparison with Previous Results**

| | Combined Company Target Headroom Allowance (Ml/d) | | | |
|---|---|---|---|---|
| | Dry Year Annual Average | | Dry Year Critical Period | |
| Submission | 2019/20 | 2024/25 | 2019/20 | 2024/25 |
| **WRMP 2004** | 25.1 | 25.8 | 12.3 | 16.1 |
| **WRMP 2009** | 10.7 | 9.6 | 12.4 | 8.9 |
| **WRMP 2014** | 10.3 | 9.5 | 13.8 | 13.4 |
| **WRMP 2019** | 11.8 | 13.2 | 13.9 | 15.7 |

# 5 Conclusions

Table 5-1 shows a summary of the results of this headroom assessment. The target headroom allowance figures in Ml/d shown in Table 5-1 are the values to be incorporated within Portsmouth Water's supply-demand balance analysis and dWRMP 2019 due for submission in December 2017.

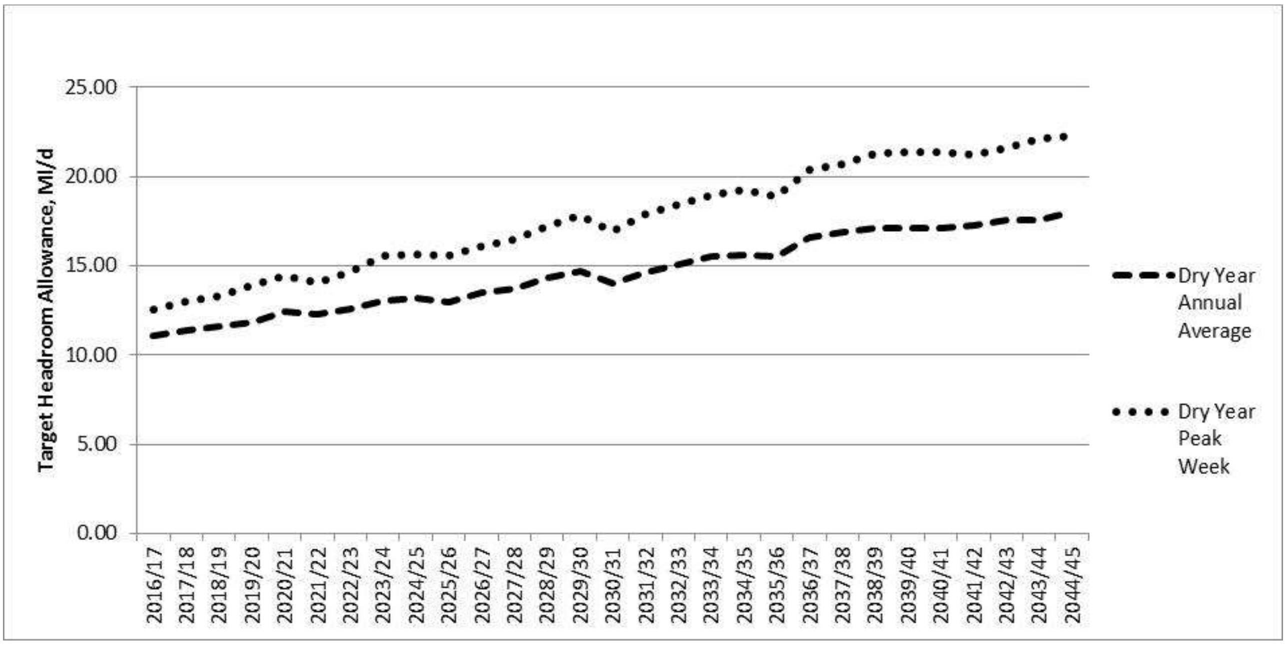
The selected target headroom values are for the selected risk profile at each period as outlined in Section 4.3; the headroom profiles for both planning scenarios are shown in Figure 5-1.

Key areas of uncertainty included in this headroom allowance are: accuracy of data (relating to both supply and demand), risk of pollution due to oil spills, demand forecast variation, metering and leakage uncertainty and impact of climate change on both deployable output and demand.

**Table 5-1 dWRMP 2019 Portsmouth Water Target Headroom Allowance – Summary**

| Year | Combined Company Target Headroom Allowance, Ml/d | |
|---|---|---|
| | Dry Year Annual Average | Dry Year Critical Period (Peak Week) |
| **2017/18** | 11.4 | 13.0 |
| **2019/20** | 11.8 | 13.9 |
| **2024/25** | 13.2 | 15.7 |
| **2029/30** | 14.7 | 17.8 |
| **2034/35** | 15.6 | 19.3 |
| **2039/40** | 17.1 | 21.4 |
| **2044/45** | 18.0 | 22.3 |

**Figure 5-1 Portsmouth Water Target Headroom Profiles, 2016/17 to 2044/45**



# 6 References


AECOM (2017), *Outage Allowance Assessment - Towards Portsmouth Water's WRMP 2019*.

AECOM (2017), *2017 Deployable Output and Climate Change Impact Assessment - Portsmouth Water - Water Resource Management Plan 2019*.

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*UKWIR (2014), Handbook of source yield methodologies.*

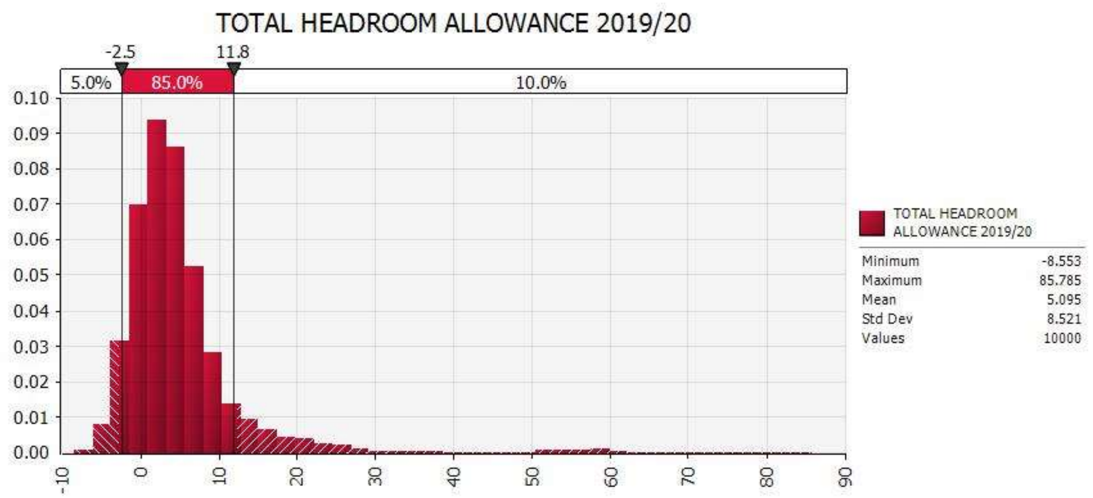
UKWIR (2013), *Impact of climate change on water demand.*

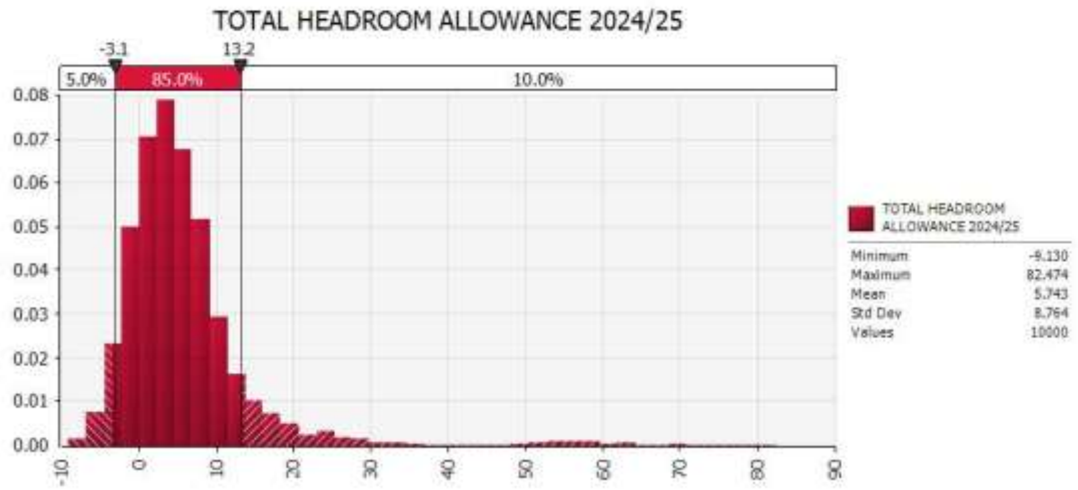
*UKWIR (2012), WR27 DO report.*

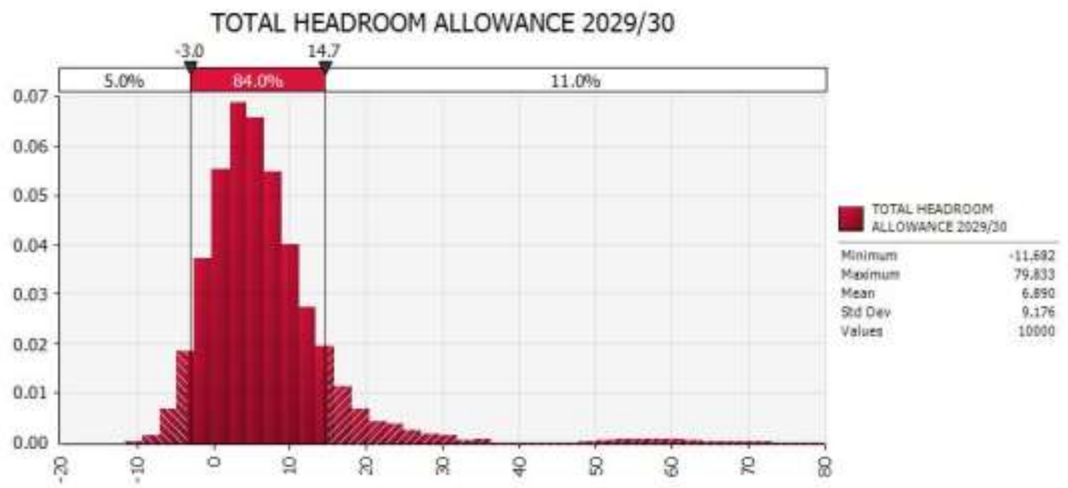
UKWIR (2002), *An Improved Methodology for Assessing Headroom*.

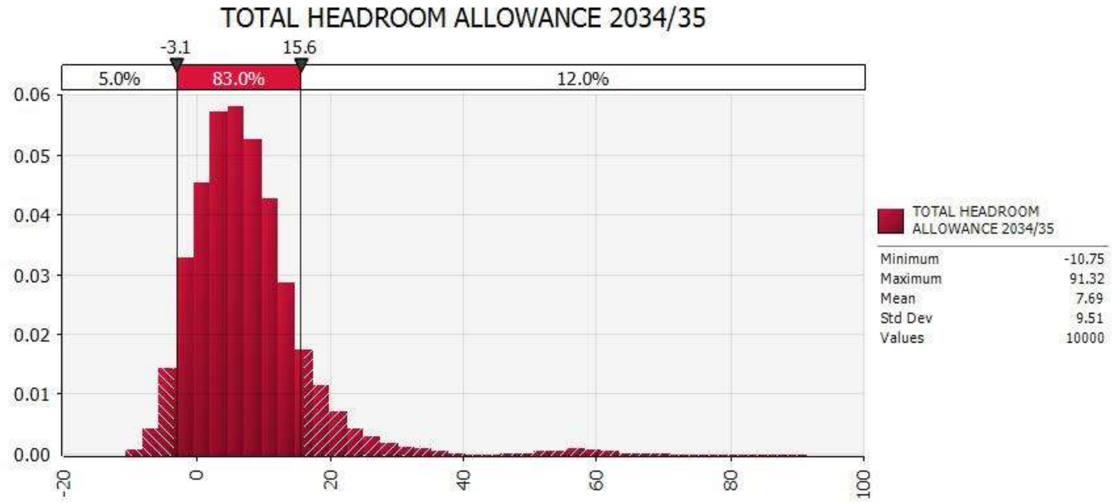
UKWIR (1998), *A Practical Method for Converting Uncertainty into Headroom*.

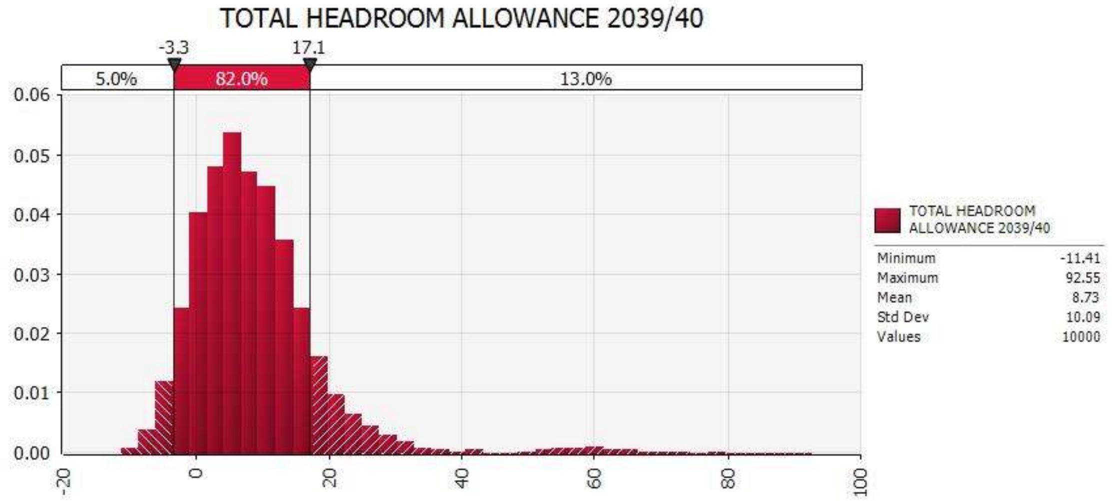
# Appendix A. @RISK Summary Output – Total Company Headroom Allowance – Combined Probability Distributions – Dry Year Annual Average Scenario

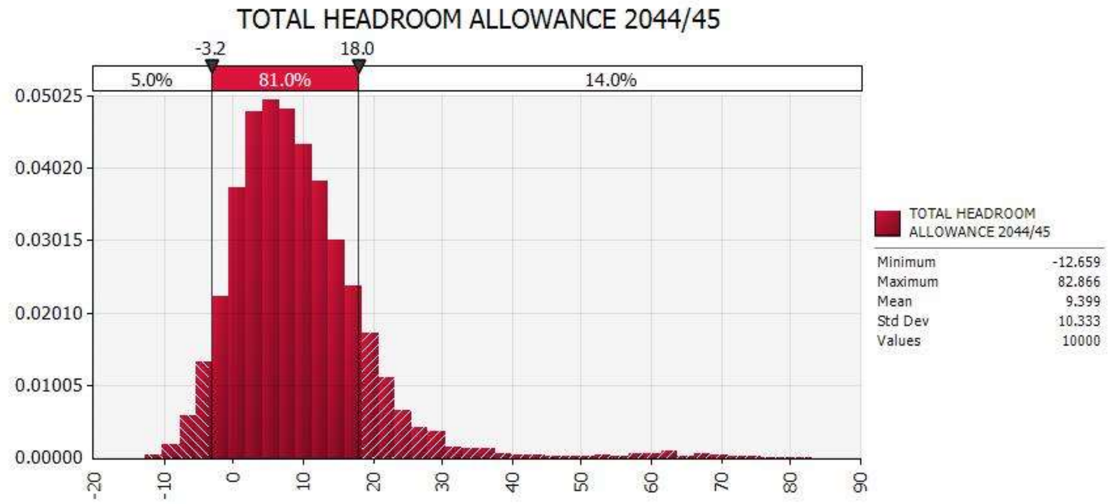


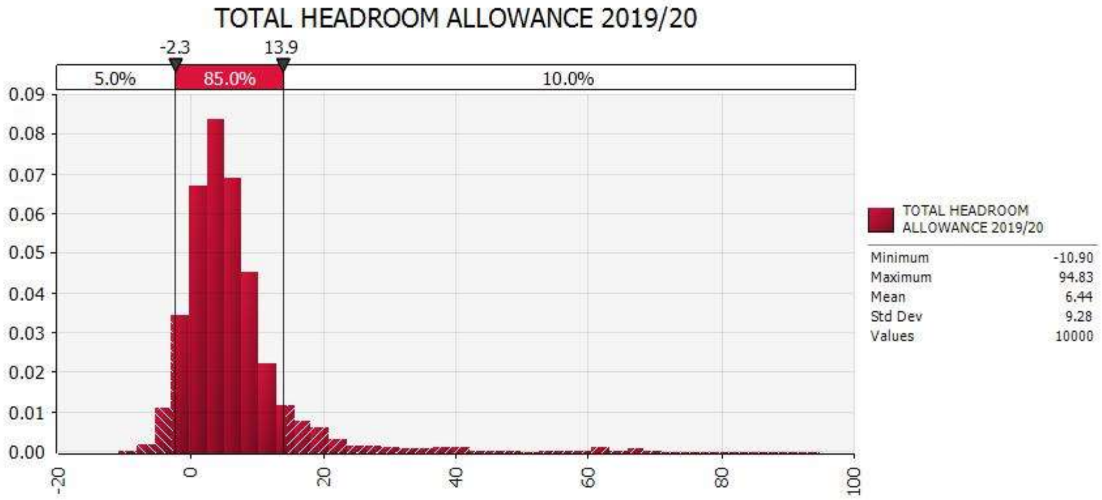



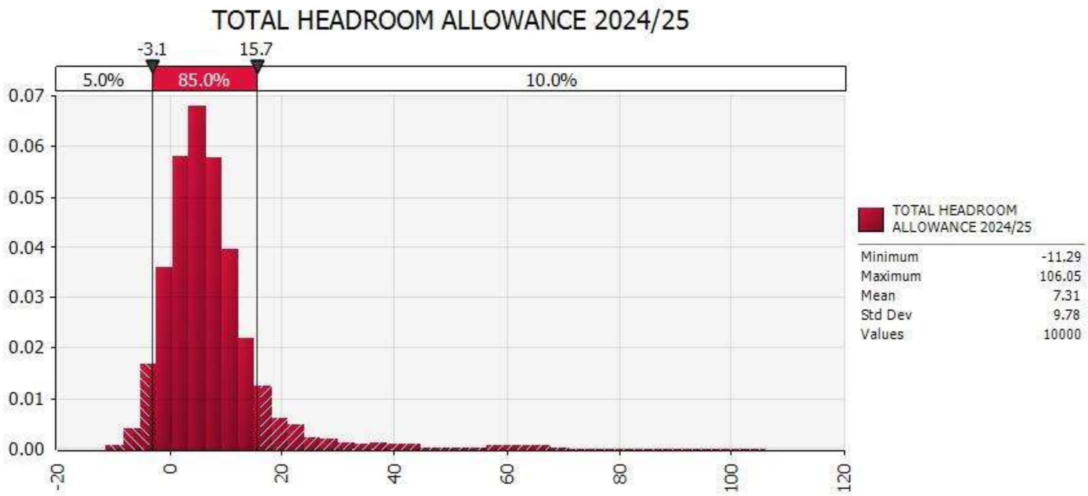

TOTAL HEADROOM ALLOWANCE 2034/35
-3.1
15.6
5.0%
83.0%
12.0%
TOTAL HEADROOM ALLOWANCE 2034/35
Minimum -10.75
Maximum 91.32
Mean 7.69
Std Dev 9.51
Values 10000

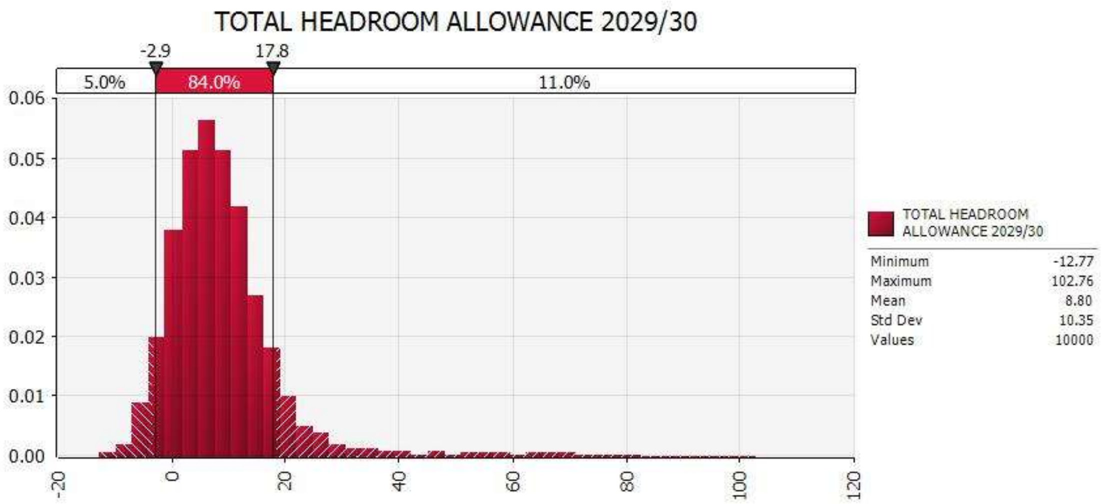

TOTAL HEADROOM ALLOWANCE 2039/40
-3.3
17.1
5.0%
82.0%
13.0%
TOTAL HEADROOM ALLOWANCE 2039/40
Minimum -11.41
Maximum 92.55
Mean 8.73
Std Dev 10.09
Values 10000

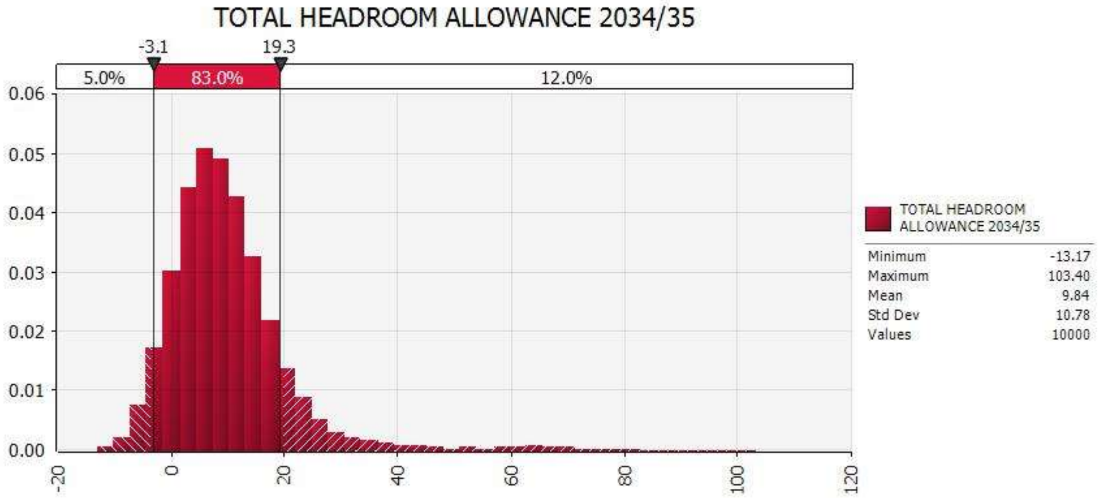

TOTAL HEADROOM ALLOWANCE 2044/45
-3.2
18.0
5.0%
81.0%
14.0%
TOTAL HEADROOM ALLOWANCE 2044/45
Minimum -12.659
Maximum 82.866
Mean 9.399
Std Dev 10.333
Values 10000

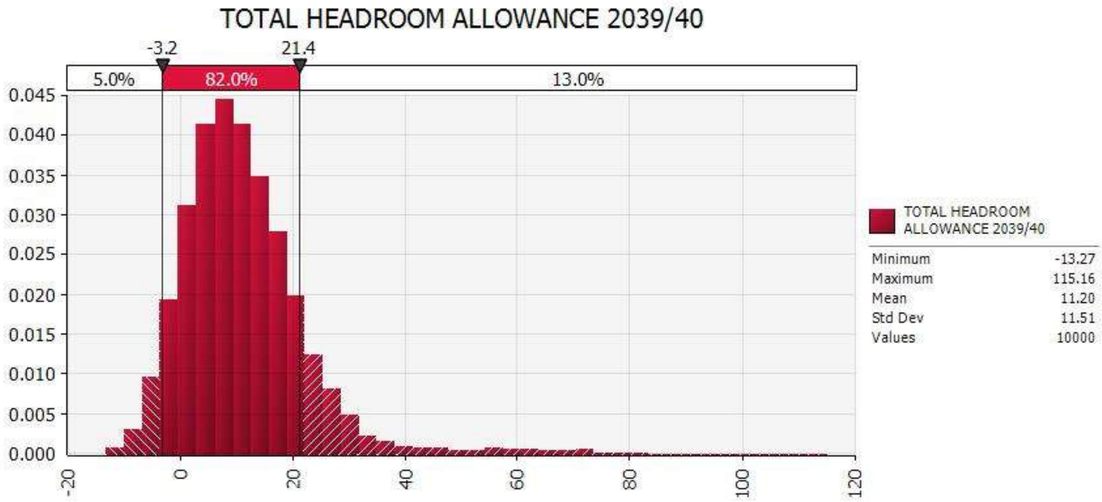
# Appendix B. @RISK Summary Output – Total Company Headroom Allowance – Combined Probability Distributions – Dry Year Critical Period Scenario

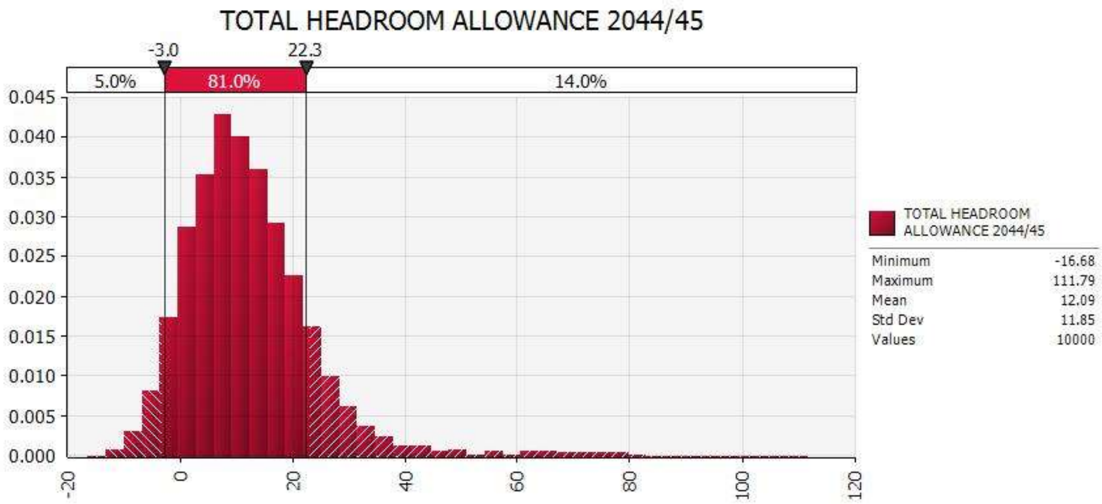



TOTAL HEADROOM ALLOWANCE 2034/35
-3.1
19.3
5.0%
83.0%
12.0%
TOTAL HEADROOM ALLOWANCE 2034/35
Minimum -13.17
Maximum 103.40
Mean 9.84
Std Dev 10.78
Values 10000


TOTAL HEADROOM ALLOWANCE 2039/40
-3.2
21.4
5.0%
82.0%
13.0%
TOTAL HEADROOM ALLOWANCE 2039/40
Minimum -13.27
Maximum 115.16
Mean 11.20
Std Dev 11.51
Values 10000


TOTAL HEADROOM ALLOWANCE 2044/45
-3.0
22.3
5.0%
81.0%
14.0%
TOTAL HEADROOM ALLOWANCE 2044/45
Minimum -16.68
Maximum 111.79
Mean 12.09
Std Dev 11.85
Values 10000

# Appendix C. @RISK Summary Output – Total Company Headroom Allowance – Tornado Graphs of Regression Coefficients – Dry Year Annual Average Scenario

# Appendix D. @RISK Summary Output – Total Company Headroom Allowance – Tornado Graphs of Regression Coefficients – Dry Year Critical Period Scenario

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