Cambridge WRZ Headroom Analysis

Water Resource Management Plan 2024

August 2023

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Executive summary

This document summarises the target headroom assessment carried out for Cambridge Water Resource Zone, forming part of the South Staffs Water WRMP24 planning process.

Target Headroom is defined as the minimum buffer that a prudent water utility should introduce into the annual supply-demand balance to ensure that the Water Utility's chosen level of service can be achieved. Target Headroom is calculated according to a standard methodology developed and published by UKWIR (An Improved Methodology for Assessing Headroom, UKWIR, 2002). All components of target headroom uncertainty have been assessed and reviewed by South Staffs Water, with time series of uncertainty distributions defined from 2022 to 2100 for each component, reflective of dry year annual average (DYAA) and dry year critical period (DYCP) conditions.

The distributions were uploaded into a tailor-made spreadsheet headroom model using @Risk Monte Carlo analysis. 10,000 iterations of the model were run to determine a comprehensive percentile distribution of headroom time series for both DYAA and DYCP conditions. A risk profile was selected in line with the WRMP guidelines and used to output target headroom values for supply demand balance modelling of the Water Resource Zone.

DYAA target headroom starts at 3 Ml/d in 2025, increasing steadily along the 80th percentile profile to 4.3 Ml/d in 2050, and remaining fairly constant thereafter to 4 Ml/d by 2100. DYCP Target headroom starts at 4.6 Ml/d in 2025, increasing steadily along the 80th percentile profile to 5.6 Ml/d in 2050 and 6.4 Ml/d by 2100.

1 Introduction and background

Water Companies in England and Wales have a statutory duty to prepare and submit Water Resources Management Plans (WRMP), including Supply Demand Balance (SDB), to the Environment Agency (EA) and Ofwat. A key component of these WRMPs is Target Headroom.

Target Headroom is defined as the minimum buffer that a prudent water utility should introduce into the annual supply-demand balance to ensure that the Water Utility's chosen level of service can be achieved. Target Headroom is calculated according to a standard methodology developed and published by UKWIR (An Improved Methodology for Assessing Headroom, UKWIR, 2002).

Mott MacDonald (MM) has been engaged by South Staffordshire Water to assess Target Headroom for WRMP24, for the Cambridge region.

1.1 Objectives and scope of work

The objectives of the project are:

- to review and analyse data provided by South Staffs Water, to evaluate uncertainty in headroom components and produce appropriate probability distributions for each component; and
- to assess Target Headroom for the Cambridge Water Resource Zone (WRZ) under average and peak conditions.

The scope of work was set out in “SSW WRMP24 Headroom & Outage Proposal 4 May 2021”, issued under separate cover.

1.2 Background to Target Headroom

1.2.1 Why assess Target Headroom

A variety of components of the supply/demand balance are subject to uncertainty, both their present values and forecast future trends.

It is therefore important that water companies make sufficient allowance in their water resource planning for such uncertainty to ensure that, for each resource zone, the risk of a supply-demand deficit in critical periods is eliminated or reduced to an acceptable level. This is done by calculating and incorporating in the supply-demand balance a target headroom allowance.

Water companies must show evidence that they have taken this into account when they submit their WRMPs as part of the periodic review process. The last WRMPs were submitted to the Environment Agency in 2019 and these also formed the companies’ supply-demand balance submissions to the Office of Water Services (Ofwat) as part of PR19. These plans take a long-term view and demonstrate how the company intends to maintain an acceptable balance of supply and demand into the future. The last plans considered the planning period 2020 to 2045 whilst the PR19 planning period will cover the years 2025 to 2100.

1.2.2 Headroom in the Supply Demand Balance and Accepted Definitions

The Supply Demand Balance is calculated as the difference between Water Available for Use (including imported water if applicable) and demand at any given point in time by comparing deployable output (DO) with water demand, after allowing for outage and target headroom.

In assessing the supply demand balance, the following equations are normally adopted:

1. Water Available for Use (WAFU) = Deployable Output (DO) – Outage
2. Available Headroom = WAFU – demand
3. Available Headroom ≥ Target Headroom needed to satisfy given standards of service

Definitions for the terms used in the equations are given in Box 1 below. These are taken from the Environment Agency Water Resources Planning Guidelines (2012), and may vary slightly from other references. No change to definition is presented in the 2016 or 2021 guidelines.

Table 1.1: Definitions

Quantity	Definition
Water Available for Use	The value calculated by deducting allowable outages and planning allowances from deployable output in a resource zone
Available Headroom	The difference (in Ml/d or percent) between water available for use (including imported water) and demand at any given point in time
Target Headroom	A buffer between supply and demand designed to cater for specified uncertainties.

Source: EA Water Resource Planning Guidelines, June 2012

Deployable Output is generally considered to be the output of a source allowing for all constraints, whether physical, licence or environmental, for a given level of service. As such it is the volume of water that can be deployed into supply. Outage is defined at its simplest as a temporary loss of deployable output.

Target headroom is defined as the minimum buffer that a prudent water utility should introduce into the annual supply-demand balance to ensure that the Water Utility's chosen level of service can be achieved. It is the margin between water available for use (WAFU) and demand required for planning purposes to cater for uncertainties (except for those due to outages) in the overall supply-demand balance.

Available Headroom is defined as the margin between Water Available for Use (WAFU) and demand at a given point in time and in theory is a measurable quantity of water. Target Headroom is a derived value which represents the minimum acceptable Headroom required for planning purposes to cater for uncertainties (excluding outages) in the overall supply-demand balance.

The issue of headroom came to prominence as a result of the 1995/96 Yorkshire drought where the independent commission of inquiry chaired by Professor Uff concluded that the Yorkshire Water supply system had an insufficient margin of resource over demand. This led to the concept of headroom uncertainty being introduced in the Environment Agency (EA) 1997 Water Resources Planning Guideline and the United Kingdom Water Industry Research (UKWIR) project that developed the 1998 Headroom Methodology. In 2002, UKWIR issued an improved risk based methodology for assessing headroom uncertainty (the 2002 UKWIR Headroom Methodology) which has been widely adopted and is considered to be the “best practice” methodology.

1.3 Environment Agency Water Resources Planning Guidance

The Environment Agency issued in February 2021 the Water Resource Planning Guidelines for the 2024 Water Resource Plans. The report states the following.

You should include an allowance for uncertainty relating to your supply and demand forecasts depending on your chosen methods.

You should analyse the sources of uncertainty around the components of your supply-demand balance and the range of uncertainty around these variables. The following documents set out different approaches to assessing uncertainty:

- *UKWIR (2016) Risk Based Planning*
- *UKWIR (2016) Decision Making Process Guidance*
- *UKWIR (2002) An Improved Methodology for Assessing Headroom*

If you use risk-based planning tools or a decision-making tool to assess uncertainty and variability you may not need to calculate target headroom. Alternatively you may need to exclude some target headroom components. If so, you will need to explain the methods and assumptions you have used and demonstrate that you have not double counted or omitted uncertainties. It is recommended however, that you provide a headroom value which represents uncertainty. This is so that the uncertainties in your plan are explicit, even if you are using more advanced methodologies.

You should consider the appropriate level of risk for your plan. If target headroom is too large it may drive unnecessary expenditure. If it is too small, you may not be able to meet your planned level of service. You should accept a higher level of risk further into the future. This is because as time progresses the uncertainties will reduce and you have time to adapt to any changes.

You should provide a clear justification of the assumptions and the information you use to assess your uncertainties. You should assess the relative contributions of uncertainty, showing which uncertainties have the biggest impact in each water resource zone. You should communicate this clearly so that regulators, customers and interested parties can understand it easily. You should also consider whether there are any steps you could take to reduce uncertainty during the planning period.

You should ensure your plans can adequately adapt to over- or under-achievement of demand management activity. You should use scenario testing to examine the potential uncertainty of any future demand forecasts.

You should not include uncertainty related to non-replacement of time-limited licences on current terms. If there are risks to supply because your licences may not be renewed, you should address this uncertainty directly in your plan through investigations and planning alternative supplies as necessary.

You should work with the Environment Agency or Natural Resources Wales, and regional groups (where applicable) to discuss how to consider possible future sustainability changes. Longer term potential sustainability changes can be explored through the environment destination work carried out locally and at a regional level. You should not include any allowance for uncertainty related to sustainability changes to permanent licences, as the Environment Agency or Natural Resources Wales will work with you to ensure that these do not impact your security of supply.

Your final plan headroom should reflect the preferred options in your final plan. If you have significant uncertainty you should consider whether an adaptive planning approach would be beneficial. For further details see Section 10 of this guideline and the Supplementary Guidance: Adaptive planning. If you do use adaptive planning, you should consider what implications this will have for your management of uncertainty, for example target headroom.

South Staffs Water has opted to use the 2002 UKWIR Headroom Methodology for target headroom to assess uncertainty in the Cambridge WRZ, rather than using risk-based planning or decision-making tools, so there is no risk of double counting uncertainties.

2 Methodology

The methodology for this headroom analysis follows the best practice guidance set out in the 2002 UKWIR "Improved Methodology for Assessing Headroom". It builds on the headroom analysis models used by South Staffs Water to calculate their target headroom for previous WRMPs.

2.1 Overview

In 2002, UKWIR published its improved methodology for the calculation of headroom allowances. This advocates the use of a probabilistic approach, based on Monte Carlo analysis. The analysis involves defining probability distributions for magnitude of headroom components and combining these to give an overall probability distribution for the target headroom allowance.

2.2 Components of Headroom Uncertainty

The 2002 UKWIR methodology Headroom is divided into the following supply side and demand side components:

Table 2.1:Supply and Demand Side Headroom Categories

Supply Side Headroom Categories	Demand Side Headroom Categories
S1 – Vulnerable surface water licences	D1 – Accuracy of sub-component data
S2 – Vulnerable groundwater licences	D2 – Demand forecast variation
S3 – Time limited licences	D3 – Uncertainty of climate change on demand
S4 – Bulk transfers	D4 – Uncertainty of demand management solutions
S5 – Gradual pollution causing a reduction in abstraction	
S6 – Accuracy of supply side data	
S8 – Uncertainty of climate change on yield	
S9 – Uncertain output of new resource developments	

Source: UKWIR

The 2002 UKWIR methodology removed issue S7 (single source dominance and critical periods) as it was considered to be an outage issue and already included in the supply demand balance. The following two headroom components were added:

- S9 Uncertain output of new resource developments
- D4 Uncertain outcome of demand management measures

Each of the above components has been considered by South Staffs Water for the Cambridge water resource zone and the headroom uncertainty issues associated with each component have been identified. For some of the components listed above, more than one issue has been included.

2.2.1 Supply Side Components

S1-S3 (vulnerable licences): Uncertainty over future reductions in abstraction licensing have been updated to include the latest deployable output and abstraction licence values (S1-S3 are only used for sensitivity analysis and are not included in target headroom).

No allowance is made for S4, bulk transfers, because these are insignificant in the baseline supply demand balance for Cambridge WRZ.

S5, gradual pollution of groundwater sources, is applied to allow for uncertainty associated with future long-term trends in nitrate pollution. No allowance is specified for borehole deterioration, which is not considered to present a significant risk to deployable output for Cambridge Water, and there are no mine water pollution risks. *Temporary* losses of DO relating to nitrate are quantified and accounted for in the Outage allowance.

S6 comprises uncertainty in the accuracy of supply-side data. For every groundwater source, the constraining factor for DO is identified: abstraction licence, infrastructure, pumping water level (potential yield), treatment capacity or water quality. For abstraction licences, the uncertainty relates to meter reading reliability. To avoid double-counting, only meters measuring abstraction separately to distribution input are included here. Infrastructure constraints carry uncertainty in pump outputs, yield constraints are subject to a number of uncertainties in the "source reliable output" method. There are uncertainties in a number of treatment processes, and water quality can limit deployable output subject to uncertainty in existing conditions (not relevant to Cambridge Water). Trend uncertainty is covered under S5. No surface water sources exist in Cambridge WRZ.

Uncertainty of climate change on groundwater source yield (S8), is quantified using the results of regional groundwater modelling with monthly climate change perturbation for the 2030s, 2060s and 2080s.

CWC are reinstating a number of sources. Where there is uncertainty associated with these in DO benefit, due to water quality or yield uncertainty, this is accounted for in component S9. Preferred options identified in WRMP should not feature in baseline target headroom, but uncertainty in their output could be determined as necessary for any options selected in the final preferred balance.

Supply side components have been updated to include the latest deployable output values reviewed for the draft WRMP.

Sign convention for supply-side headroom follows that of UKWIR 2002, that is:

- Data uncertainty that leads to a loss of *Deployable Output* = negative Headroom
- Data uncertainty that leads to an increase in *Demand* = positive Headroom

2.2.2 Demand Side Components

D1 accounts for uncertainty in the accuracy of sub-component data. As for S6, this reflects the reliability of meter readings, which could impact the accuracy of the demand forecast.

D2 comprises uncertainty in the demand forecast. This is made up of uncertainty in population growth, change in size of households, measured and unmeasured consumption, non-household consumption, dry-year correction, and peak period adjustment. These are input as time series of % uncertainty to the model.

D3, uncertainty of impact of climate change on demand has been determined according to the UKWIR methodology, Impact of Climate Change on Water Demand (2013), with time series of % uncertainty applied to household consumption.

D4, uncertainty of demand management solutions, has not been included in baseline target headroom. Should demand management solutions be required to maintain the supply demand balance to 2100, an allowance could be made in final preferred target headroom for D4.

Sign convention for demand-side headroom follows that of UKWIR 2002, that is:

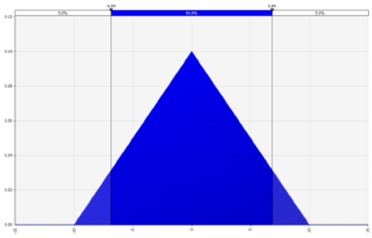
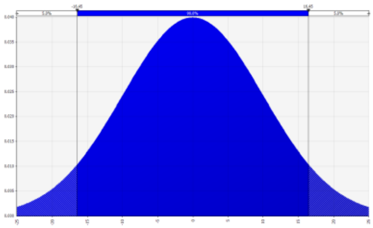
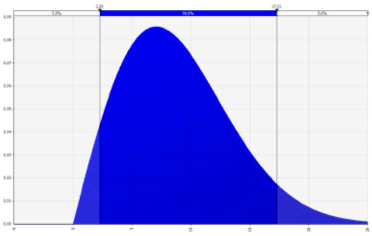
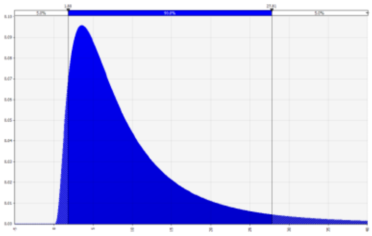
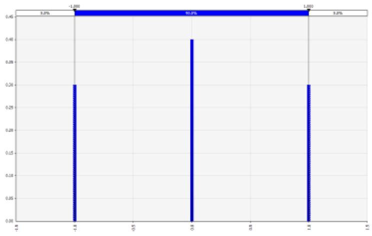
- Data uncertainty that leads to a decrease in De*mand* = -ve Headroom
- Data uncertainty that leads to an increase in *Demand* = +ve Headroom

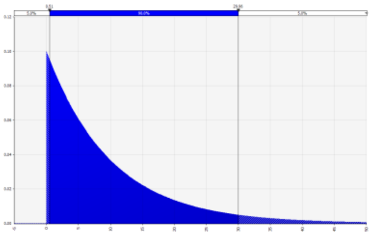
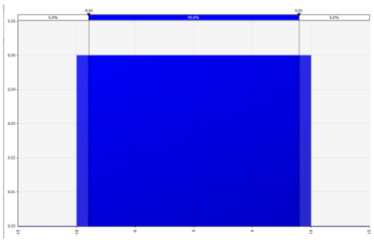
Each of the components of headroom is described in more detail in the following sections.

2.3 Probability Distributions and Monte Carlo Simulation

For each issue, a probability distribution has been developed that quantifies the extent of the uncertainty. A variety of distributions is available within the methodology, with triangular distribution being the most commonly used. Distributions have been used depending upon the individual circumstances with examples presented in Table 2.2.

Table 2.2: The Types of Probability Distribution that can be used for Headroom Analysis

Type	Shape	Description	Application
Triangular		Most easily defined continuous distribution. Defined by a least likely, most likely & maximum likely value. Can be skewed either way.	Situations where the value can be any value within a range and the most likely value can be estimated. Widely applicable, though may not be appropriate if highly skewed.
Normal		Symmetrical continuous distribution defined by a mean and standard deviation.	Most commonly applied situations where the probability of the extreme values of the distribution would artificially increase if using a triangular distribution.
Weibull		Continuous distribution.	Difficult to define but could be fitted to a data set within the software.
Log-normal		Skewed continuous distribution defined by a mean and standard deviation.	Situations where there is a large difference between the maximum and the most likely values such that a triangular distribution is considered unsuitable.
Discrete		Non-continuous distribution defined by values and probabilities.	Situations where specific values apply and values in between do not.

Type	Shape	Description	Application
Exponential		Continuous distribution.	Suitable for extreme events but with the introduction of cut-offs. Difficult to define but could be fitted to a data set within the software.
Fixed		Continuous distribution defined by a single value.	Situations where only one value applies. Essentially not a distribution but given as an option within the software.

The Monte Carlo simulation combines each of the individual component distributions to produce an overall distribution of headroom uncertainty. This is achieved by running a large number of trials (or iterations). In each trial values are randomly selected from within the component distributions and summed to give an overall headroom value for the trial. After a large number of trials (ten thousand has been used in this analysis) a distribution of headroom values results. To take account of changing uncertainty throughout the planning period the analysis has been repeated on an annual basis between 2012/23 to 2099/100. Key issues identified during the analysis, together with the results are presented below for each resource zone.

2.3.1 Software and simulations

Various software packages are available for performing Monte Carlo analysis. This methodology has been tested using @RISK, an add-in software package which operates within a spreadsheet environment. When a Monte Carlo simulation is run, the software randomly selects numbers from the probability distribution assigned to each component of target headroom. Each set of random numbers effectively simulates a single 'what-if' scenario for the spreadsheet model. As the simulation runs, the model is recalculated for each scenario and the results are presented as a series of forecast charts for Headroom Uncertainty.

The simulation stops according to criteria set by the user, which is normally a number of iterations or trials. The number of trials must be set to give an acceptable mean standard error for the simulation results, whilst controlling the processing time to workable limits. A typical number of trials might be 1,000 to 10,000.

3 Headroom Components

The Cambridge Water headroom model has been developed following the best-practice UKWIR methodology, and builds on previous iterations used for WRMP14 and WRMP09.

3.1 Supply Components

3.1.1 S1.1 Vulnerable Surface Water Licences

Not applicable to Cambridge WRZ.

3.1.2 S2.1 Vulnerable Groundwater Licences

Any likely or certain reductions to licences will be provided by the Environment Agency as Sustainability Changes, and these will be explicitly included in the Supply Demand balance as reductions to Deployable Output. Vulnerable groundwater licences in addition to these reductions would be as a result of Water Framework Directive assessments and, in particular, no deterioration requirements. The impact on volume from these is uncertain and quantitative numbers are not yet available, pending WINEP investigations planned for AMP7. There is some potential impact to deployable output on all groundwater licences, and this has been considered under scenario modelling for the draft plan.

There is some uncertainty surrounding Horseheath, which has been subject to investigation regarding impacts on the River Granta. The proposed licence reduction Is 0.3 Ml/d to 1.4 Ml/d, but this is yet to be confirmed. 1.4 Ml/d will be included in the baseline supply demand balance and no allowance is made under headroom.

3.1.3 S3.1 Time-limited Licences

The Company has three time-limited licences:

Table 3.1: Time-limited licence quantities and dates

Licence	Time Limited Quantity (Annual Average Ml/d)	Time Limited Quantity (Peak Week Ml/d)	Time Limit Date
Euston	2.0	2.5	31st March 2024
Brettenham	7.34	10	31st March 2024
Fowlmere	3.6	5.4	31st March 2027

The Euston and Brettenham licences have a draft agreed volume for renewal from 2018 until 2024. Thereafter, the risk of renewal at lower volumes is a consideration. We test the potential impact on target headroom accordingly. A discrete distribution is used for peak and average conditions, with the minimum and most likely losses both set to 0 Ml/d and the maximum losses as shown in Table 3.2.

Table 3.2: Time-limited licences: discrete headroom distribution for renewal volume uncertainty

	Annual Average	Peak Week	Probability
Minimum Loss (gain in DO)	0 Ml/d	0 Ml/d	96%

Maximum Loss (loss in DO)	6.25 Ml/d	12.5 Ml/d	4%

The results show that including this time-limited licence uncertainty would increase target headroom by 0.36 Ml/d on average between 2025 and 2030, and by 0.25 Ml/d between 2045 and 2050.

The Fowlmere uncertainty is for the licence to be increased to a higher flow limit, should it be possible to prove the source has no environmental impact; however this is considered very unlikely by 2024 and therefore no headroom allowance is made.

Time limited licences have not been included in the final headroom model run as it is now likely that the time limited licences will be capped on renewal.

3.1.4 Bulk Supplies

The very low level of bulk imports in the plan (<0.1Ml/d) received by the Company, means that the significance of any uncertainty over their availability is minimal and therefore this is not included in the assessment of the headroom component for the Company. The same applies to exports, (<0.7Ml/d) which are explicitly included as deployable output reductions.

There is some risk of this changing in the future subject to renewal of agreements. This has not been quantified for target headroom.

3.1.5 S5 Gradual Groundwater Pollution

The effects of a gradual or sudden pollution events can have a significant impact on deployable output. Where this results in a permanent loss of deployable output, then this should be included in headroom. Three areas of uncertainty have been identified by South Staffs Water under this category, only one of which is relevant to Cambridge Water.

3.1.5.1 Physical Deterioration of Boreholes

A comprehensive re-evaluation of the asset condition and performance of boreholes was undertaken in AMP6 and this assessment has identified no gradual pollution risks to sources that have no mitigation in place for known quality parameters. The Company would not discontinue maintaining any sources due to them becoming uneconomic. The risk of any asset maintenance impacting deployable output is considered to be negligible.

3.1.5.2 S5/2 Nitrate, Pesticide and Solvent contamination

From the point of view of headroom, uncertainty in future long-term trends in nitrate and other groundwater contaminants has the potential to impact DO through a need for additional treatment and associated losses. Any output failures due to short term or seasonal peaks in nitrate are captured in company outage allowance.

Using nitrate trending the Company has identified nitrate risks to water quality at a number of sources in the WRMP planning horizon, as follows.

Table 3.3: Sources at risk from gradual pollution: treatment status, nature of risk and DYAA D.O

Source	Treatment	risk type	Annual Average DO
Fleam Dyke	Existing IEX	baseline trend	14.3Ml/d
Babraham	Existing IEX	baseline trend	6.42Mld
Fowlmere	IEX delivered in 2020	baseline trend	3.6Ml/d

Morden Grange	none	seasonal peak	1.2Ml/d
Melbourn	none	baseline trend and seasonal peak	7.2Ml/d
Brettenham	none – blended at Euston	baseline trend	8.25Ml/d
Euston	Existing IEX	baseline trend	8Ml/d
Fulbourn	blended in supply	baseline trend	1.25M/d

At sources with existing treatment, there is sufficient spare capacity in the treatment works that any uncertainty in nitrate trends could be mitigated with an increase in treated component, blended back with untreated water without incurring any additional losses.

Sources at risk through seasonal peaks in nitrate only have this risk included in Outage, through modelling of recent events.

A headroom allowance for uncertainty in nitrate is therefore only required where there is a risk of baseline trends increasing more rapidly than in the baseline planning forecast at sources with no existing treatment. The most significant of these are Melbourn and Fulbourn. No ion exchange (IEX) is expected to be required at either of these within the planning period. However, if treatment were to become necessary, there is a risk of up to 1% losses in the treatment process. The Company has assessed the losses from operational IEX nitrate removal treatment plants, and actual losses range from 0.19-0.27% of the works output, but 1% losses are considered feasible. This is equivalent to <0.1 Ml/d across both sources combined. To be conservative, a value of 0.1 Ml/d is included with a probability of 40%. The earliest treatment is forecast to be required is 2030.

Fowlmere is forecast to require ion-exchange treatment by 2020. Potential losses due to treatment are included in baseline DO. The remaining uncertainties in these treatment losses are too small to warrant inclusion in headroom.

A discrete distribution has been applied to both annual average and peak week headroom, as the treatment plant would treat the same amount of water under both scenarios.

Table 3.4: Nitrate treatment uncertainty: triangular headroom distribution values in 2030

	Magnitude	Probability
Minimum Loss	0 Ml/d	60%
Maximum Loss	0.1 Ml/d	40%

The uncertainty around nitrate treatment has been added with a starting point of 2030 in the headroom model.

3.1.5.3 S5/3 Mine waters

No risk from mine water is identified.

3.1.6 S6 Accuracy of Supply-side Data: Groundwater

Data inaccuracy or lack of information can be a significant source of uncertainty around the calculation of deployable output. We have examined the constraining factors which define the Company's deployable output figures and assessed the range of uncertainty around each of these.

3.1.6.1 Abstraction Licence Constraints

The table below summarises the groundwater source deployable outputs that are constrained by abstraction licence, and whether the source has separate abstraction and distribution input meters. Where there are separate meters then the potential metering error has been estimated and is used as a measure of the uncertainty in the deployable output figures.

A figure of +/-2% is assumed for metering uncertainty. Where the abstraction meter and the distribution input meter are one and the same, then no uncertainty is attributed to the deployable output as this uncertainty would be double counted in the demand components of headroom. The table confirms that only dry year annual average deployable output is constrained by abstraction licence. Critical period deployable output is not constrained by abstraction licence.

Table 3.5: Abstraction licence-constrained sources: DO and meter uncertainty status

Source	Dry Year Deployable Output affected Ml/d	Peak Week Deployable Output affected Ml/d	Separate abstraction and distribution input meter	Include meter uncertainty here?
Abington	1	0	Yes	Ave only
Babraham	6.42	9.09	Yes	Yes
Brettenham	8.25	15	Yes	Yes
Croydon	1.4	1.4	No	Ave only
Dullingham	0	0	Yes	No
Duxford	4.45	5.68	No	Ave only
Euston	8	10	Yes	Yes
Fleam Dyke	0	0	Yes	No
Fowlmere	3.6	5.4	Yes	Yes
Fulbourn	1.25	0	Yes	Ave only
Gt Chishill	0	0	Yes	No
Gt Wilbraham	5.19	9.09	Yes	Yes
Heydon	1.13	0	Yes	Ave only
Hinxton	5.77	6.82	Yes	Yes
Horseheath	1.7	1.7	No	No
Kingston	0.92	0.92	No	
Linton	0	2.73	No	No
Lowerfield	3.41	4.27	Yes	Yes
Melbourn	0	0	Yes	Ave only
Rivey	1	2.75	Yes	Yes
Sawston	1.49	0	No	Ave only
St Ives	1.62	1.62	No	
Westley	7.92	0	Yes	Ave only
Weston Colville	0	0	Yes	No
Morden Grange	0	0	Yes	No
Volume included	52.94	62.42		

*Takes account of RSA licence changes

This uncertainty has been applied using a triangular distribution

Table 3.6: Abstraction licence-constrained sources: headroom distribution for metering inaccuracy

	Annual Average	Peak Week
Minimum Loss (gain in DO)	-1.06 Ml/d	-1.25 Ml/d
Best Estimate	0 Ml/d	0 Ml/d
Maximum Loss (loss in DO)	1.06 Ml/d	1.25 Ml/d

3.1.6.2 Infrastructure (Pump Capacity) Constraints

The table below summarises the groundwater source deployable outputs that are constrained by pumping capacity.

Table 3.7: Infrastructure (pump capacity)-constrained sources DO

Source	Average Deployable Output affected Ml/d	Peak Week Deployable Output affected Ml/d
Abington Park	Licence-constrained	4.0
Dullingham	3.24	3.6
Fulbourn	Licence-constrained	1.49
Morden Grange	0	1.5
Sawston	Licence-constrained	2.16
Total	3.24	12.75

An overall uncertainty around pumping capacity has been derived from the detailed breakdown. This is +/- 5%. This uncertainty has been applied using a triangular distribution

Table 3.8: Infrastructure (pump capacity)-constrained sources: headroom distribution

	Annual Average	Peak Week
Minimum Loss (gain in DO)	-0.16 Ml/d	-0.64 Ml/d
Best Estimate	0 Ml/d	0 Ml/d
Maximum Loss (loss in DO)	0.16 Ml/d	+0.64 Ml/d

3.1.6.3 Pumping Water Level

A comprehensive review of SROS was undertaken in 2012 and this was reviewed in 2017. There have been no changes since then. A number of sources are constrained by pumping water level, in relation to a deepest advisable Pumping level (DAPWL). These sources are listed below.

Table 3.9: Pumping water level (yield)-constrained sources DO

Source	Average Deployable Output affected Ml/d	Peak Week Deployable Output affected Ml/d
Duxford Grange	2.88	2.88
Fleam Dyke	14.3	14.3
Gr Chishill	1.15	1.06
Heydon	N/A (Licence Constraint)	2.13

Morden Grange	1.2	0
Melbourn	7.2	9.15
Westley	N/A (Licence Constraint)	10.6
Weston Colville	2.92	2.92
Total	29.65	43.04

A composite value (+- Ml/d) has been calculated based on a +-10% uncertainty at borehole sources affected by low water levels.

Table 3.10: Pumping water level-constrained sources: headroom distribution

	Annual Average	Peak Week
Minimum Loss (gain in DO)	-2.97 Ml/d	-4.30 Ml/d
Best Estimate	0 Ml/d	0 Ml/d
Maximum Loss (loss in DO)	2.97 Ml/d	+4.30 Ml/d

3.1.6.4 Treatment Capacity

Disinfection treatment at all source works is designed for peak outputs, with no risk of impacting DO, and therefore does not require headroom allowance.

3.1.6.5 Water Quality

The only water quality parameters of relevance to CWC are turbidity and nitrates. Nitrates are assessed in Section S5 and turbidity failures are included in the Outage allowance.

We aim to have recommissioned lower greensand and gravel sources into supply by 2025. These will have a different water quality challenge to chalk boreholes: iron/manganese/ammonia/sulphates at greensand and pesticides/cryptosporidium at gravels sources. Treatment is expected to cope with historical loading and there is no clear trend in these potential raw water quality issues visible in historical data. For greensand sources, more frequent backwashing may be needed to address water quality worse than expected, which could impact DO through extended regeneration cycles. An allowance for backwashing will be made under treatment losses, but making any uncertainty allowance for this is very difficult without data. We identify a further risk relating to borehole potential yield as a result of potential iron encrustation of borehole screens, but this is also too uncertain to quantify at present. Elevated suspended solids is one other risk when running filters, but the treatment has been designed to cope with maximum anticipated levels.

We propose not to make any headroom allowance for these issues at WRMP24, but instead to review again after 5 years operation for WRMP29.

For the reinstated source in the shallow gravels (St Ives), there is further uncertainty associated with potential yield during drought, which we account for under S9, “Uncertain output of new resource developments”.

3.1.7 Accuracy of data for surface water yields

Not applicable.

3.1.8 S8 Uncertainty of Climate Change on Deployable Output

Cambridge Water's climate change analysis (2013) identified eight sources at risk of loss of yield due to climate change, with combined DO of 20.6 Ml/d (average) and 38.7 Ml/d (peak). The Cambridge WRZ is determined as being low vulnerability to climate change overall, with only 2% of DO at risk.

Nonetheless a Tier 3 assessment was carried out for the zone, providing yield impact values for three time-snapshots: 2030, 2060 and 2080. 10th, 50th and 90th percentile impacts were determined for each of low, medium and high emission scenario model runs. Comparing the dry and wet scenarios to the mid-range scenario, there is limited time-trend in yield uncertainty apparent, with considerable scatter in the data. However, the uncertainty in impacts on DO is very small.

For simplicity, a value of +/- 0.5 Ml/d climate change DO uncertainty is specified for 2045 for both peak week and dry year average. The wet and dry uncertainty has been interpolated back from 2045, using the scale factors set down in Section 3.3.6 of the Environment Agency's water resources planning guidelines (2012).

Table 3.11: Climate Change Uncertainty in Deployable Output

Scenarios at 2045	Base DO (Ml/d)	Range of Uncertainty by 2045 (Wet) (Ml/d)	Range of Uncertainty by 2045 (Dry) (Ml/d)
Dry Year	99.98	+0.5	-0.5
Peak Week	116.64	+0.5	-0.5

This uncertainty range has been incorporated into both dry year annual average and peak week headroom by assuming a triangular distribution with the upper and lower limits defined by the wet and dry scenario results. The mid-range estimate is incorporated within the baseline forecast. As the wet year case produces an increase in DO, it is treated as negative headroom and the dry year case vice versa.

3.1.9 S9 Uncertain output of new resource developments

CWC are reinstating a number of sources. The deployable output of two of these sources, Croydon and Kingston, is known with good accuracy, being constrained by WFD "no deterioration" caps to licence. St. Ives is a source abstracting from shallow gravels, with notable uncertainty associated with water quality and drought. We account for this uncertainty under S9 as follows.

Source	DEPLOYABLE OUTPUT	Year of implementation	Distribution Type	Min	Source	DEPLOYABLE OUTPUT	Year of implementation	Distribution Type
New Resource Average	1.6	0.0	2022	Triangular	0.00	0.00	0.80	St Ives reinstatement
New Resource Peak	0.0	1.6	2022	Triangular	0.00	0.00	0.80	St Ives reinstatement

3.2 Demand Components

3.2.1 D1/1 Accuracy of sub-component data

Potential errors in the measurement of distribution input are an important component of headroom and are accounted for here. Only errors on meters which measure distribution input separately to abstraction are accounted for: otherwise there would be a double count because abstraction (metering) error is identified under S6/1.errors in the

The Company has assumed constant meter accuracy value of +/- 2% over the planning period. This will not be altered by subsequent meter replacements. Those distribution input meters that are separate from the source meters are listed in the following table.

Table 3.12: Source Deployable Output and Distribution Input Meter Status

Source	Dry Year Deployable Output licence constrained Ml/d	Peak Week Deployable Output licence constrained Ml/d	distribution input meter	Include uncertainty
Abington	1.00	4.00	Yes	Ave only
Babraham	6.42	9.09	Yes	Yes
Brettenham	8.25	15.00	Yes	Yes
Croydon	1.40	2.50	Yes	Yes-
Dullingham	3.24	3.60	Yes	No
Duxford	4.45	0.00	No	Ave only
Duxford Grange	2.88	0.00	Yes	Ave only
Euston	8.00	10.00	Yes	Yes
Fleam Dyke	14.30	14.30	Yes	No
Fowlmere	3.60	5.40	Yes	Yes
Fulbourn	1.25	0.00	Yes	Ave only
Gt Chishill	1.15	1.06	Yes	No
Gt Wilbraham	5.19	9.09	Yes	Yes
Heydon	1.13	0.00	Yes	Ave only
Hinxton	5.77	6.82	Yes	Yes
Horseheath	1.40	1.70	No	No
Kingston	0.92	1.10	Yes	Yes
Linton	0.00	0.00	No	No
Lowerfield	3.39	4.27	Yes	Yes
Melbourn	7.20	0.00	Yes	Ave only
Morden Grange	1.20	1.50	Yes	No
Rivey	1.00	2.75	Yes	Yes
Sawston	1.49	0.00	No	Ave only
St Ives	1.62	0.00	Yes	Ave only
Westley	7.92	0.00	Yes	Ave only
Weston Colville	2.92	2.92	Yes	No
Volume included	89.75	93.40		

The total DO with separate DI meters is less than the demand forecast at DYAA and DYCP across the planning period; therefore, headroom uncertainty is constant. A triangular distribution based an uncertainty of +/- 2% is applied as follows:

Table 3.13: Distribution Input Meter Accuracy: Headroom Distribution

	Annual Average	Peak Week
Minimum Headroom (decrease in demand)	-1.80 Ml/d	-1.89 Ml/d
Best Estimate	0 Ml/d	0 Ml/d
Maximum Headroom (increase in demand)	+1.80 Ml/d	+1.89 Ml/d

3.2.2 D2/1 Demand Forecasting Uncertainty

This element of headroom accounts for the uncertainty around the forecasts of individual demand components. Uncertainty must be estimated on the normal year forecasts as the dry-year adjustment is added on to the normal year demand as an aggregate figure at the end. In order to account for any additional uncertainty resulting from the dry year adjustment this is included as well.

Components have been included for population, housing growth, measured and unmeasured demand and leakage as well as the switching forecast. Uncertainty in the peak demand forecast and in the dry year factor used in the annual average demand forecast have also been considered. The headroom approach for each component of the demand forecast is described below.

- Household Consumption: Uncertainty in population, growth in number of properties, measured and unmeasured per capita consumption, household growth, and number of meter optants has been assessed and compiled into a single set of values for upper and lower bounds, input to the model as a triangular distribution centred on the baseline forecast. The overall Household Consumption uncertainty is between -9.25 Ml/d and +10.0 Ml/d by 2050 for DYAA conditions, and -10.1 to +10.0 Ml/d by 2050 for DYCP conditions, based on 95th and 5th percentiles.
- Non-Household Consumption: Uncertainty around non-household consumption is estimated to be between -5.25 Ml/d and +4.31 Ml/d by 2050. This range was determined from the NHHCF scenario-based outputs' upper, central, and lower estimates.
- Leakage: Uncertainty around leakage has been included in headroom based on the historic range of reported leakage. A triangular distribution between +7.5% and -5% has been applied. This is consistent with work on SELL for the business plan.
- The dry year adjustment has been calculated as 4.5% of household demand. It is assumed that this could be as high as 5.5% or as low as 4%.
- There are also uncertainties surrounding predicted peak consumption volumes used in the supply demand balance. This is because dry years do not occur regularly and the predicted demands do not always coincide with supply shortfalls. The baseline difference between critical period and annual average household demand is 22.4%. Review of historic data shows P90 and P10 values for this uplift to be 36% and 13% of average household demand respectively. Hence a triangular distribution between +12% and -10% of household demand has been applied for headroom.

For each year the uncertainties for each consumption category are added together within the headroom model to give an overall uncertainty for the demand forecasts. The percentages are calculated from demand excluding SPL and MUR. The table below demonstrates the size of the demand component for key years in the forecast.

Table 3.14: Total Demand Headroom Annual Average 5 yearly intervals

Annual Average	2024/25	2029/30	2034/35	2039/40	2044/45	2049/50	2099/100
Minimum Headroom (decrease in demand)	-10.29	-11.31	-12.36	-13.72	-14.58	-15.16	-25.17
Best Estimate	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Maximum Headroom (increase in demand)	9.61	10.82	12.29	13.54	14.41	15.46	19.50

The approach to assessing the demand component for peak week headroom uncertainty is the same as that for annual average except that the dry year adjustment component is replaced with that for since peak week volume uncertainty.

Table 3.15: Total Demand Headroom Peak Week 5 yearly intervals

Peak Week	2024/25	2029/30	2034/35	2039/40	2044/45	2049/50	2099/100
Minimum Headroom (decrease in demand)	-14.64	-16.37	-17.75	-19.19	-20.16	-20.93	-31.61
Best Estimate	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Maximum Headroom (increase in demand)	16.05	16.99	18.45	19.64	20.46	21.57	29.02

3.2.3 D3 Uncertainty of impact of Climate Change on Demand

The impact of climate change on demand was previously assessed using the techniques developed in the UKWIR study, Impact of Climate Change on Demand. This has used statistical analyses performed on PCC data from Thames Water and Severn Trent Water to generate regression models relating demand to climatic data. These models have been used in combination with UKCP09 climate projections to derive algorithms and look-up tables for each UK region.

The Company has selected the Severn Trent water model as it better simulates the water using behaviour of the Cambridge customer base. It has used probability data on increase in demand in the Anglian region as this geographically matches the majority of its supply area. The data tables contain forecast values for the percentage increase in household consumption and these have been directly applied using Company average PCC values on an annual basis.

The table below shows the range of uncertainty associated with the forecast annual average impact of climate change on demand. P50 impacts have been included in the baseline demand forecast. Hence the P10 and P90 values below are relative to this baseline.

Table 3.16: Climate Change Demand Uncertainty Annual Average: 5 yearly Headroom

Annual Average	2024/25	2029/30	2034/35	2039/40	2044/45	2049/50	2099/100
P10 Headroom Ml/d	-0.04	-0.09	-0.14	-0.19	-0.24	-0.29	-0.63
P50 Adjustment (baseline) Ml/d	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P90 Headroom Ml/d	0.05	0.11	0.17	0.23	0.29	0.35	1.02

Table 3.17: Climate Change Demand Uncertainty Peak Week: 5 yearly Headroom

Peak Week	2024/25	2029/30	2034/35	2039/40	2044/45	2049/50	2099/100
P10 Headroom Ml/d	-0.15	-0.32	-0.49	-0.67	-0.85	-1.06	-3.56
P50 Adjustment (baseline) Ml/d	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P90 Headroom Ml/d	0.18	0.38	0.59	0.80	1.02	1.22	3.34

3.2.4 D4 Uncertainty in demand management options

For final WRMP24, an allowance was made for uncertainty in the benefits delivered by demand management options, “D4”. An uncertainty distribution in demand management benefits was determined for every year in the planning period (data provided by Artesia for South Staffs Water). For target headroom, this uncertainty was modelled as triangular distributions as shown below, with the same values used for both annual average and peak week conditions.

Table 3.18: Demand Management Uncertainty: 5 yearly Headroom

Year	2024/25	2029/30	2034/35	2039/40	2044/45	2049/50	2099/100
Maximum decrease in forecast	-0.09	-0.19	-0.23	-0.32	-0.41	-0.38	-0.51
Best estimate	0.00	0.00	0.00	0.00	0.00	0.00	
Maximum increase in forecast	0.09	0.20	0.27	0.41	0.55	0.50	0.69

3.3 Analysing the data

Once the distributions are selected, they are built into the @Risk model. The model is then run for 10,000 iterations to produce the combined headroom. The in-built sensitivity functions are used to analyse which inputs have the greatest impact on the result.

4 Results and conclusions

4.1 Target Headroom Results

4.1.1 DYAA

The results of the target headroom modelling under dry year average conditions are shown in Figure 4.1**Error! Reference source not found.** below. A full table of results by percentile is presented in Appendix A. The chosen risk profile is also shown. Target headroom starts at 3.04 Ml/d in 2025, increasing steadily along the 80th percentile profile to 4.55 Ml/d in 2050, and remaining fairly constant thereafter to 4.51 Ml/d by 2100.

Figure 4.1: DYAA Target Headroom Results and chosen risk profile

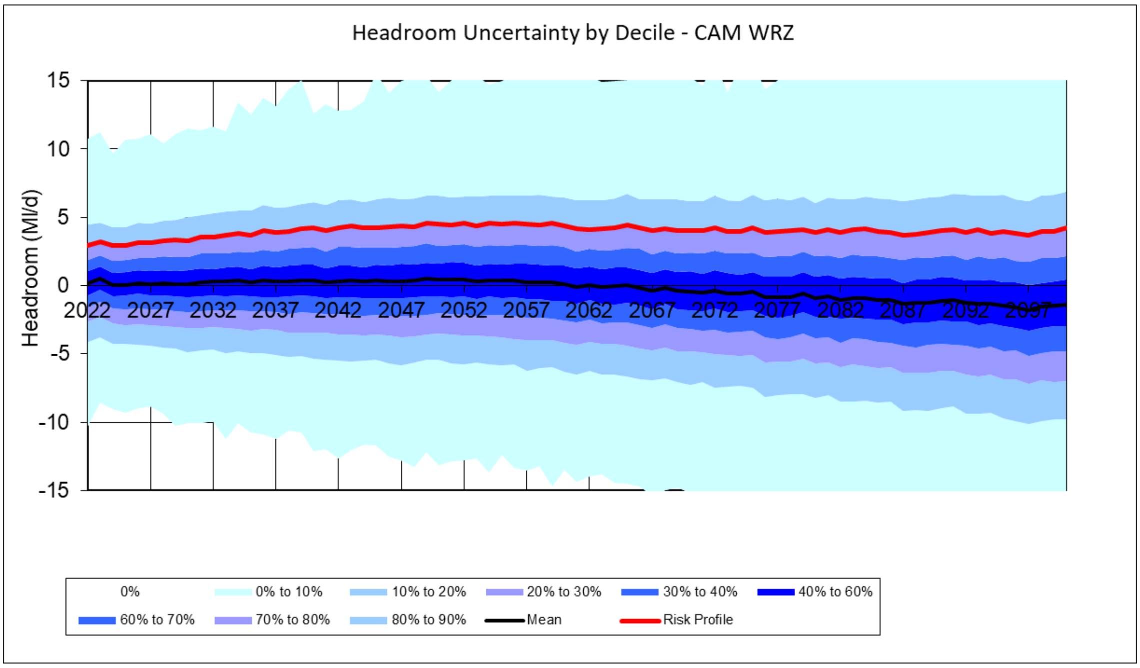
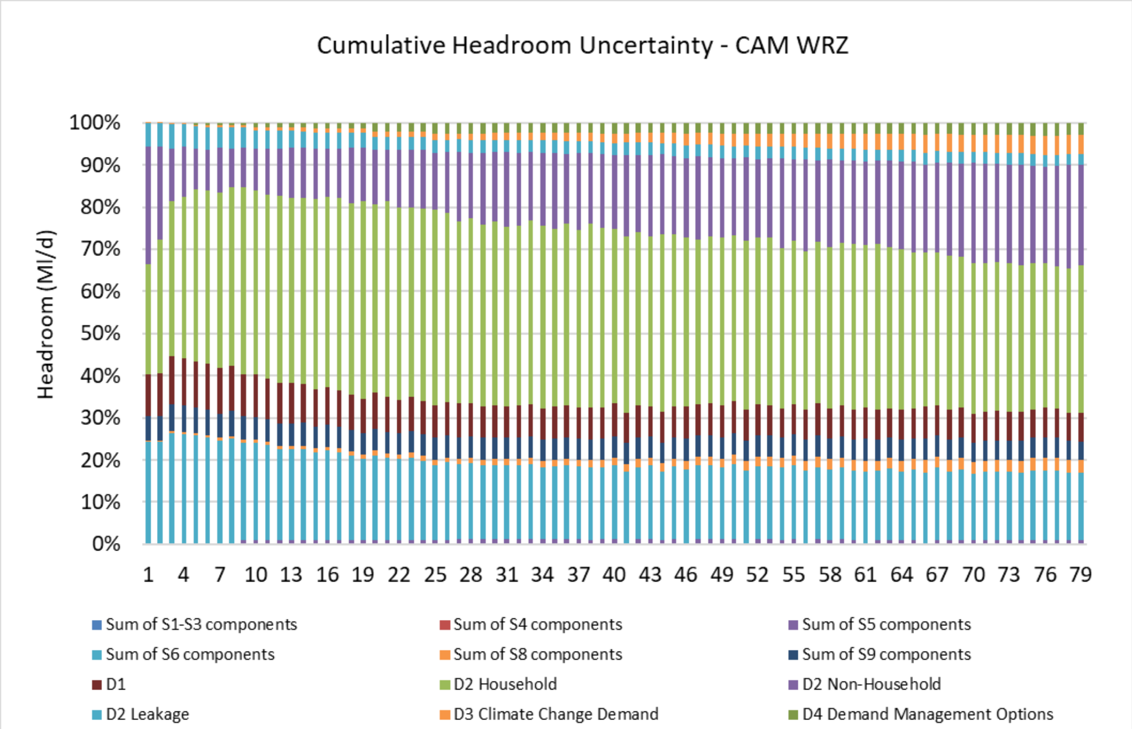


Figure 4.2 shows the proportional breakdown of target headroom by component for the selected risk profile.

Figure 4.2: Breakdown of DYAA Target Headroom by sub-component



4.1.2 DYCP

The results of the target headroom modelling under dry year critical period conditions are shown in Figure 4.3 below. A full table of results by percentile is presented in Appendix A. The chosen risk profile is also shown. Target headroom starts at 4.96 Ml/d in 2025, increasing steadily along the 80th percentile profile to 6.14 Ml/d in 2050 and 7.22 Ml/d by 2100.

Figure 4.3: DYCP Target Headroom Results and chosen risk profile

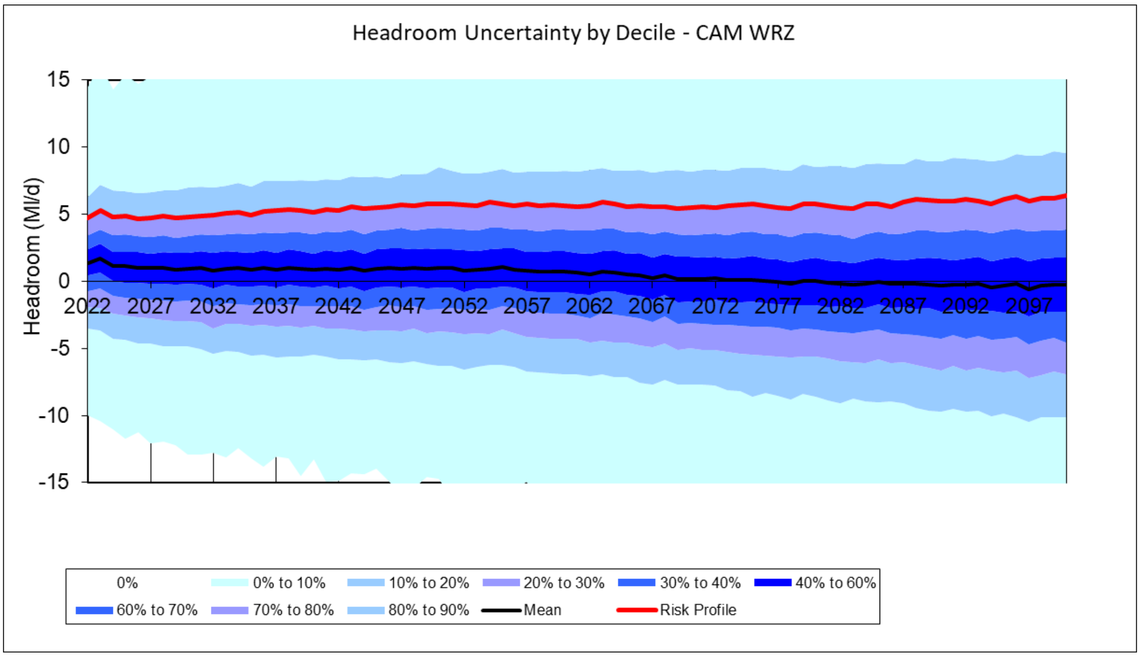
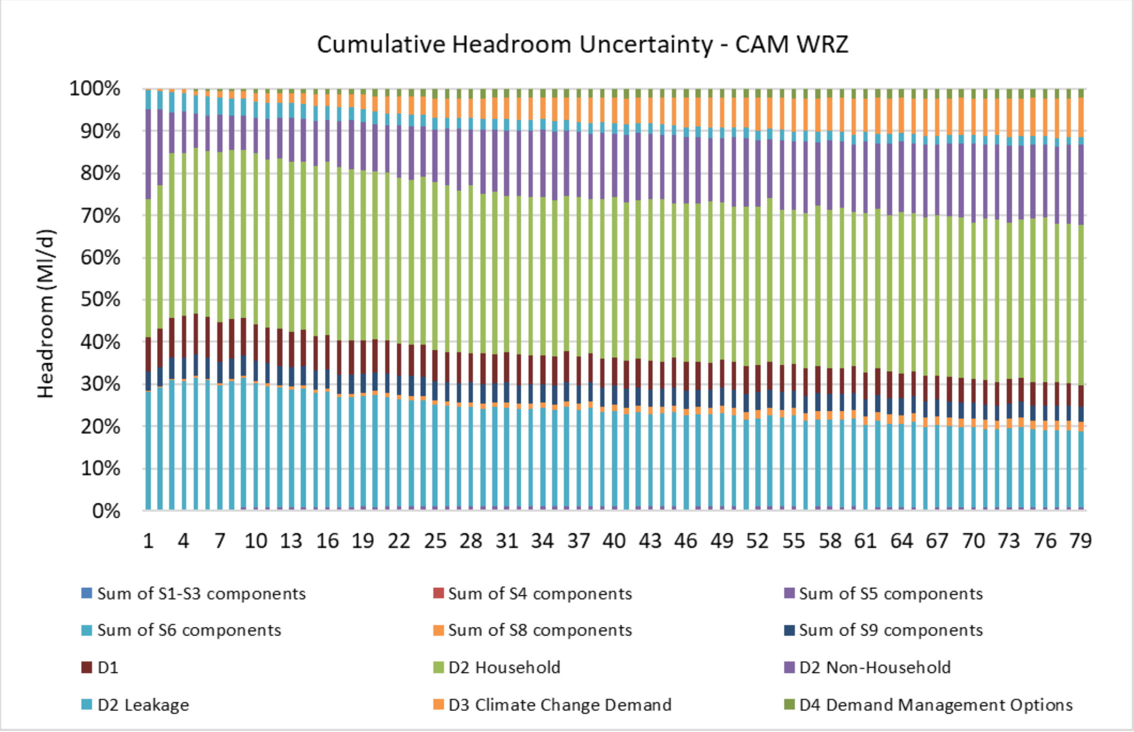


Figure 4.4 shows the proportional breakdown of target headroom by component for the selected risk profile.

Figure 4.4: % Breakdown of DYCP Target Headroom by sub-component



4.2 Chosen Risk Profile

The headroom values for a constant 80th percentile risk profile for each year of the planning period and the corresponding percentiles, both for DYAA and DYCP / Peak are summarised in the tables below.

Table 4.1: Headroom values in Ml/d and corresponding percentiles for the a constant 80th percentile risk profile (DYAA)

Year	DYAA Headroom (climate change components)	DYAA (percentile)	DYAA Headroom (all other components)
2021 / 22	0.01	80%	2.97
2022 / 23	0.02	80%	3.34
2023 / 24	0.02	80%	2.84
2024 / 25	0.02	80%	3.01
2025 / 26	0.03	80%	3.23
2026 / 27	0.03	80%	3.09
2027 / 28	0.04	80%	3.35
2028 / 29	0.04	80%	3.26
2029 / 30	0.04	80%	3.43
2030 / 31	0.05	80%	3.47
2031 / 32	0.05	80%	3.66
2032 / 33	0.06	80%	3.58
2033 / 34	0.06	80%	3.74
2034 / 35	0.07	80%	3.78
2035 / 36	0.07	80%	3.70
2036 / 37	0.08	80%	3.82
2037 / 38	0.08	80%	3.83
2038 / 39	0.08	80%	3.93
2039 / 40	0.09	80%	4.08
2040 / 41	0.09	80%	3.91
2041 / 42	0.10	80%	4.05
2042 / 43	0.11	80%	4.29
2043 / 44	0.11	80%	4.22
2044 / 45	0.11	80%	4.27
2045 / 46	0.12	80%	4.41
2046 / 47	0.12	80%	4.21
2047 / 48	0.13	80%	4.26
2048 / 49	0.13	80%	4.21
2049 / 50	0.14	80%	4.33

Table 4.2: Headroom values in Ml/d and corresponding percentiles for a constant 80th percentile risk profile (DYCP / Peak)

Year	DYCP Headroom (climate change components)	DYCP (percentile)	DYCP Headroom (all other components)
2021 / 22	0.01	80%	4.63
2022 / 23	0.03	80%	5.18
2023 / 24	0.04	80%	4.81
2024 / 25	0.05	80%	4.85
2025 / 26	0.05	80%	4.79
2026 / 27	0.07	80%	4.70
2027 / 28	0.08	80%	4.79
2028 / 29	0.09	80%	4.81
2029 / 30	0.10	80%	4.98
2030 / 31	0.11	80%	4.99
2031 / 32	0.12	80%	5.00
2032 / 33	0.13	80%	4.92
2033 / 34	0.14	80%	4.89
2034 / 35	0.15	80%	4.95
2035 / 36	0.16	80%	5.01
2036 / 37	0.16	80%	4.95
2037 / 38	0.18	80%	5.03
2038 / 39	0.18	80%	5.01
2039 / 40	0.20	80%	5.26
2040 / 41	0.22	80%	5.02
2041 / 42	0.22	80%	5.05
2042 / 43	0.23	80%	5.31
2043 / 44	0.25	80%	5.09
2044 / 45	0.25	80%	5.09
2045 / 46	0.26	80%	5.18
2046 / 47	0.26	80%	5.12
2047 / 48	0.29	80%	5.40
2048 / 49	0.28	80%	5.11
2049 / 50	0.30	80%	5.32

4.3 Risk Profile Sensitivity

The range in target headroom between 20th and 80th percentiles is shown below. Full tables of results for DYAA and DYCP can be provided.

Table 4.3: Difference between 20%ile and 80%iles in 2024/25 and 2049/50

Scenario	20-%ile (2024 / 25)	80-%ile (2024 / 25)	20-%ile (2049 / 50)	80-%ile (2049 / 50)
DYAA	-2.7 Ml/d	3.0 Ml/d	-3.7 Ml/d	4.4 Ml/d
DYCP (Peak)	-2.0 Ml/d	4.9 Ml/d	-3.8 Ml/d	5.7 Ml/d

5 Quality Assurance

Quality Assurance was carried out in detail throughout the headroom assessment, in line with industry best practice. A detailed summary of checks can be provided if required.