APPENDIX G1a – TARGET HEADROOM REPORT

Contents

Executive summary

This document summarises the target headroom assessment carried out for South Staffs 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) 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 DYAA 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 10.04 Ml/d in 2025, increasing steadily along the 80th percentile profile to a maximum of 14.4 Ml/d in 2050 and 20.1 Ml/d by 2100.

1 Introduction

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).

1.1 Objectives and scope of work

The objectives of the project are:

- to review and analyse data provided by South Staffs Water (SSW), to evaluate uncertainty in headroom components and produce appropriate probability distributions for each component; and
- to assess SSW's Target Headroom under average conditions.

2 Background to Target Headroom

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 we make sufficient allowance in our 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.

We must show evidence that they have taken this into account when we submit our WRMP. 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 PR24 planning period will cover the years 2025 to 2100.

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:

Water Available for Use (WAFU) = Deployable Output (DO) – Outage

Available Headroom = WAFU – demand

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: 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 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.

2.3 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.

We have opted to use the 2002 UKWIR Headroom Methodology for target headroom to assess uncertainty in our area, rather than using risk-based planning or decision-making tools, so there is no risk of double counting uncertainties.

3 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 we have used to calculate our target headroom for previous WRMPs.

3.1 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.

3.2 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

We have considered each of the above components 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.

3.3 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).

An allowance for S4, bulk transfers, has been introduced at PR19, after better understanding of the uncertainty in company bulk exports.

S5, gradual pollution of groundwater sources, is applied to allow for uncertainty associated with deterioration, rehabilitation and replacement of boreholes, uncertainty in future long-term trends in nitrate pollution, and uncertainty over coalfield mine water pollution at Moors Gorse. Temporary losses of DO relating to these factors 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, but no such sources exist for South Staffs. There are uncertainties in a number of treatment processes, and water quality can limit deployable output subject to uncertainty in existing conditions (primarily sand ingress here). Trend uncertainty is covered under S5. Surface water yield uncertainty is due to imperfect climate and hydrological historical data records and variability in surface water yield models.

Uncertainty of climate change on source yield (S8), is quantified using Aquator modelling of climate change scenarios on the DO of surface water sources. No groundwater sources are constrained by potential yield, such that there is no risk of climate change impacting groundwater DO.

No new options are planned for completion in the near future, such that in S9, only final preferred options need be considered. These 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

3.4 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 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 been included in baseline target headroom as part of an update to the target headroom undertaken for the revised draft WRMP. This is because the preferred plan is based on demand management solutions to maintain the supply demand balance to 2050, and so it is important that an allowance will be made in final preferred target headroom for D4.

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

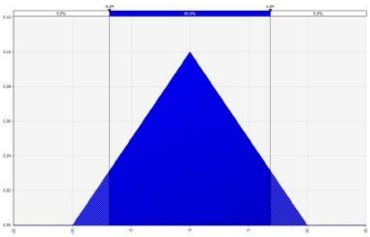
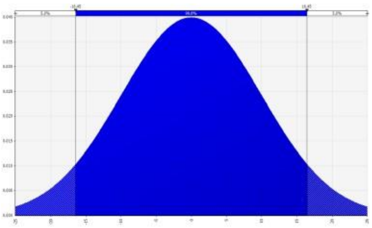
- Data uncertainty that leads to a decrease in Demand = negative Headroom
- Data uncertainty that leads to an increase in Demand = positive Headroom

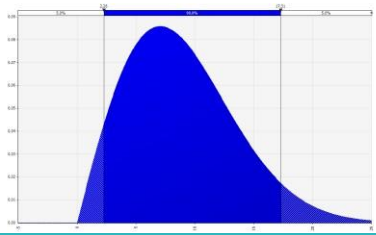
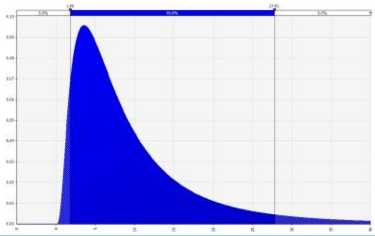
Each of the components of headroom is described in more detail in the following sections.

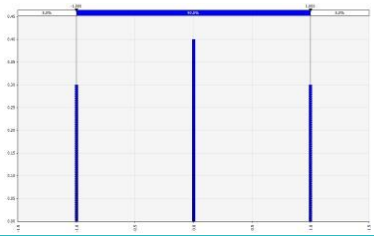
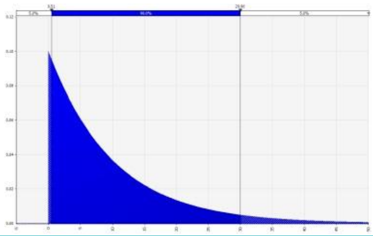
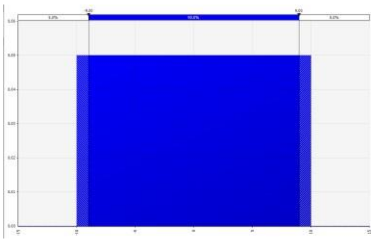
3.5 Probability Distributions and Monte Carlo Simulation

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.

Type	Shape	Description	Application
Discrete		Non-continuous distribution defined by values and probabilities.	Situations where specific values apply and values in between do not.
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 2021/22 to 2099/100. Key issues identified during the analysis, together with the results are presented below for each resource zone.

3.6 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.

4 Headroom Components

The South Staffs Water headroom model has been developed following the best-practice UKWIR methodology, and builds on previous iterations used for WRMP19 and WRMP14.

4.1 Supply Components

S1.1 Vulnerable Surface Water Licences

Headroom uncertainty associated with vulnerable surface water licences arises from concerns over the sustainability of abstractions at the licensed rates and the likelihood that licences may be modified (reduced). Where appropriate, this has been considered under scenario modelling for the draft plan.

S2.1 Vulnerable Groundwater Licences

The EA has an aspiration to reduce groundwater abstraction licences in many catchments as part of their Restoring Sustainable Abstraction Programme. For many catchments the licence clawback is quantified through the Water Industry National Environment Programme process. Uncertainty in future licence reductions is considered under scenario modelling for the draft plan, rather than as part of Target Headroom.

S3.1 Time-limited Licences

The Company has three time-limited licences, as specified in Table 3.1 below. The time limited dates for Nethertown and Broome Lodge were provided by SSW by email (23/06/2021).

Table Error! No text of specified style in document.**.2: Time-limited licence quantities and dates**

Licence	Time Limited Quantity (Annual Average Ml/d)	Time Limit Date
Hampton Loade (18/54/2/584/S)	11	31st March 2034
River Blithe (Nethertown) 3/28/6/84/S and River Blithe (Nethertown) 3/28/6/99/S River Trent (Nethertown)	50	31st March 2027
Broome Lodge (18/54/6/140/G)	2 (0)	31st March 2026

Part of the Hampton Loade licence (No. 584) is time limited to 2034 (11 Ml/d). This abstraction is from the River Severn. The Nethertown (River Blithe) licence was adjusted in 2018, but new licenced volumes will still exceed infrastructure capacity. This means the licence change after 2018 had no impact on peak transfer capacities. However, the deployable output is strongly linked to a clause allowing use of the River Trent (Nethertown) licence to maintain River Blithe flows above the Hands-Off Flow for the River Blithe.

Abstraction from the Broom Lodge borehole is for the purpose of augmenting water levels in the nearby pools and rivers and is neither used for public water supply nor affects the operation of other boreholes

A scenario test was carried out making the following allowance for S3 uncertainty:

S3 Issue	Year	Value 1	Value 2	Prob 1	Prob 2	Distribution
Hampton Loade	2034	0.00	11.00	90%	10%	Discrete
River Blithe (Nethertown) & Broome Lodge	2027	0.00	52.00	90%	10%	Discrete

This scenario would increase P80 DYAA target headroom by 3.4 Mld in 2027 and 4.6 Ml/d in 2034.

S4 Bulk Supplies

We operate around 30 potable water connections at the boundaries of our supply area which together constitute a net export of potable water. The majority of these are small in nature and are known collectively as the Minor Exports. There is a much larger export to Severn Trent Water in the Wolverhampton area which arises from the joint ownership by South Staffs Water and Severn Trent Work of the River Severn abstraction.

The capacity of Minor Exports is up to 5 Ml/d but average usage has been consistently around 1 Ml/d and is largely independent of seasonal demands. Nevertheless, volumes have increased on occasion to 2 Ml/d during the peak demand months. As a consequence, a positive headroom value (increase in demand) of 1 Ml/d is specified.

The contractual entitlement for the Wolverhampton Export is 40.6 Ml/d at average has been adopted for the Company's deployable output calculations with no allowance for uncertainty in headroom.

Table Error! No text of specified style in document.**.3: SSW Bulk Supply Agreements and Uncertainty**

	Annual Average (Ml/d)	Peak Week (Ml/d)		Minimum Uncertainty (Ml/d)	Maximum Uncertainty (Ml/d)
Minor Exports	1.0	1.0	Triangular	0.0	0.0

S5 Gradual Groundwater Pollution

The effects of a gradual or sudden pollution event can have a significant impact on deployable output. Where this results in a long-term loss of deployable output then this should be included in headroom. We have identified three areas of uncertainty under this category.

3.1.5.1 Physical Deterioration of Boreholes

The asset condition and performance of each borehole has been regularly undertaken since PR09. This assessment has underpinned significant increases in investment under asset maintenance in our groundwater sites. The average age of our boreholes is more than 75 years and without this investment, significant borehole failures are likely, resulting in a reduction in deployable output. Whilst it is assumed that sufficient capital maintenance work will be funded and carried out to maintain stable serviceability, experience has shown that losses in deployable output arise in two ways:

- Asset performance, as measured by water quality (sand and turbidity), will decline to such an extent that outputs are cut back. Whilst short term reductions in output are accounted for in our outage allowance, a significant reduction in permanent output may be incurred for a number of years pending site enabling works. Moreover, when re-drilling is required, there may be further delays for the drilling, testing and licencing process; and also, the requirement to construct new pump houses and connecting pipelines to existing treatment and network.
- Where remedial or replacement work is undertaken, there is a risk that yields will be lower or water quality may be different, with a resulting impact on deployable output.

Factors, Likelihood and Magnitude

The available evidence we have suggests that physical deterioration of boreholes can be divided into three main categories, and each remedial option is associated with some risk.

1. Deterioration of solid casing causing ingress of poor quality water. Subsequent relining can cause additional drawdown and a reduction in yield, or relining may not be practical causing a reduction in source output if the borehole is filled

2. Chemical and/or biological encrustation & clogging of slotted casing and open-hole sections, causing increased drawdown or water quality problems, with potential loss of yield. Chemical or mechanical treatment may cause deterioration in raw water quality.

3. Collapse and/or erosion of sandstone borehole walls, causing turbidity and requiring a drop in pumping rate, with potential loss of yield. Re-drilling or relining can cause additional drawdown and a reduction in yield. Re-drilling can however allow an increase in yield, particularly at peak.

The following assumptions have been used in evaluating the risk from borehole works in headroom:

- The maximum groundwater deployable output that currently could be affected is 140 Ml/d (80% of peak total groundwater DO).
- When each source is relined or replaced, there is a 10% chance that the yield will be reduced by 10%.
- When the borehole is replaced, there is a 5% chance that peak DO is increased by 20%.

- Over the first 20 years this represents a 10% chance of a total loss of 14 Ml/d offset by a 5% chance of a total increase of 28 Ml/d (peak). This level of investment and hence risk is assumed to continue over the remainder of the planning period.

The following discrete distribution was applied for each year for annual average:

Table Error! No text of specified style in document.**.4: Physical Deterioration of Boreholes: Headroom distributions**

	Average
Minimum Loss	-1.4 Ml/d
Median Loss	0 Ml/d
Maximum Loss	0.67 Ml/d
Probability 1	5%
Probability 2	85%
Probability 3	10%

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.

Based on nitrate trends, we have identified a risk that some sources and existing blends (e.g. Ashwood, Churchill and Kinver) may exceed the nitrate limit during and after AMP7. The potential DO loss is based on the following assumptions.

Only a small proportion of the output of each station would be treated to a sufficiently low nitrate level to allow this to blend with the remainder of the source output, to bring the overall nitrate level below the required standard. There will be 2% losses associated with the treated component.

A triangular distribution has been applied to annual average headroom, as the treatment plant would treat the same amount of water under both scenarios. The risk increases incrementally over time.

Table Error! No text of specified style in document.**.5: Nitrate and other groundwater contamination: annual increases in headroom components from 2020**

	Average
Minimum Loss	0 Ml/d
Most Likely	0.05 Ml/d
Maximum Loss	0.15 Ml/d

The uncertainty around nitrate treatment has been added with a starting point of 2020 in the headroom model.

3.1.5.3 S5/3 Mine waters

Available evidence suggests that there is a small risk that the Moors Gorse groundwater source could be contaminated by rising mine water, following the cessation of remedial pumping from the underlying coalfield.

Factors, Likelihood and Magnitude

Following the review of groundwater deployable outputs for the FWRMP, the dry year deployable output of Moors Gorse for the purposes of the headroom model is 2.94 Ml/d at average based on likely NEP outcomes. A discrete distribution has been applied to these values, which assumes a small probability (5%) that the total deployable output from the source will be lost.

Table Error! No text of specified style in document.**.6: Mine water headroom distributions**

	For annual average	
	Volume Ml/d	Probability
Minimum Loss	0	95%
Maximum Loss	2.94	5%

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 our deployable output figures and assessed the range of uncertainty around each of these.

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.

Table Error! No text of specified style in document.**.7: Abstraction licence-constrained sources: DO and meter uncertainty status**

Source	Dry Year Deployable Output affected Ml/d	Separate abstraction and distribution input meter
Slitting Mill	5	No
Moors Gorse	2.94	No

Seedy Mill	5	No
Maple Brook	8.5	No
Ashwood	18	No
Cookley	18	No
Prestwood	20	No
Mayfield	0.5	No
Slade Heath	0.54	Yes
Somerford	0	No
Little Hay	5	Yes
Pipe Hill	11.31	Yes
Trent Valley	12.24	No
Fradley	10	Yes
Chilcote	6.91	yes
Total	123.94	
Total (separate abstraction meters only)	33.8	

This uncertainty has been applied using a triangular distribution.

Table Error! No text of specified style in document.**.8: Abstraction licence-constrained sources: headroom distribution for metering inaccuracy**

	Annual Average
Minimum Loss (gain in DO)	-0.68 Ml/d
Best Estimate	0 Ml/d
Maximum Loss (loss in DO)	+0.68 Ml/d

Infrastructure (Pump Capacity) Constraints

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

Table Error! No text of specified style in document.**.9: Infrastructure (pump capacity)-constrained sources DO**

Source	Average Deployable Output affected Ml/d

Cookley	N/A
Ashwood	N/A
Mayfield	N/A
Total	0.0

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 Error! No text of specified style in document.**.10: Infrastructure (pump capacity)-constrained sources: headroom distribution**

	Annual Average
Minimum Loss (gain in DO)	0 Ml/d
Best Estimate	0 Ml/d
Maximum Loss (loss in DO)	0 Ml/d

Pumping Water Level

No sources are constrained by potential yield.

Treatment Capacity

The following sources are constrained by treatment works capacity:

Table 12: Treatment-constrained sources DO

	Source	Average Deployable Output affected Ml/d
GW	Prestwood	N/A
GW	Hinksford	5.0
GW	Little Hay	N/A
	Pipe Hill	N/A
	Chilcote	N/A
SW	Seedy Mill WTW	N/A
SW	Hampton Loade WTW	N/A
	Total	GW 5.0 SW 0.0

The range of uncertainty around groundwater treatment processes is small and so we have assumed a +/- 2% figure in headroom. The following range of uncertainty proposed is based on a triangular distribution:

Table Error! No text of specified style in document.**.11: Treatment-constrained sources: headroom distribution**

Groundwater	Annual Average
Minimum Loss (gain in DO)	-0.11 Ml/d
Best Estimate	0 Ml/d
Maximum Loss (loss in DO)	+0.11 Ml/d

Water Quality (Sand Pumping)

Five sources are constrained by sand production (causing excessive turbidity). The relevant constraints are identified below:

Table Error! No text of specified style in document.**.12: Water quality-constrained sources DO**

Source	Average Deployable Output affected in Ml/d
Crumpwood	5.5
Maple Brook	N/A
Hopwas	2.5
Seedy Mill	N/A
Trent Valley	N/A
Total	8.0

The uncertainty in DO associated with sand pumping is considered to be between -2% and +10%. The proposed headroom uncertainty for water quality (sand pumping) is a triangular function as follows:

Table Error! No text of specified style in document.**.13: Water quality-constrained sources: headroom distribution**

	Annual Average
Minimum Loss (gain in DO)	-0.16 Ml/d
Best Estimate	0 Ml/d
Maximum Loss (loss in DO)	+0.80 Ml/d

Accuracy of data for surface water yields

The modelling of deployable output from surface water sources is dependent upon the accuracy of hydrological records and the uncertainty around the derived river flows from catchment models. We have two surface water sources, the River Severn and Blithfield Reservoir, and the yield of these sources is modelled within the water resources model Aquator.

The River Severn (Hampton Loade WTW)

The deployable output of Hampton Loade is constrained by the river flow at Bewdley, storage at Clywedog, and by the status of River Regulation (releases from Clywedog Reservoir and the Shropshire Groundwater Scheme). These parameters are modelled by Severn Trent Water using the regional AQUATOR model, and the output is used as a constraint in the SSW Aquator model.

UKWIR guidance (ref 02/WR/13/2, p.29) suggests that the accuracy of river flow data derived from catchment models is +/- 10 to 20%. In addition to data accuracy, the models used may not fully represent the catchments. On this basis, the total uncertainty around the catchment modelling is assumed to be at the lower end +/-10%, given the extensive work carried out this AMP, although the impact on deployable outputs may be somewhat lower than this.

The dry year annual DO at Hampton Loade is dependent on catchment modelling of inflows to Clywedog reservoir, and inflows to the catchments on the Severn upstream of Bewdley. Data and modelling uncertainty could impact on the ‘reliable yield’ of Hampton Loade during River Regulation. We have retained the assumptions agreed with the Environment Agency for the PR09 FWRMP of +/ 5.0% for the range of error in dry year annual deployable output.

Given the complex range of constraints, a pragmatic approach has been taken with an uncertainty range of +/- 5% around the modelled average DO value of 118.5 Ml/d (excluding Wolverhampton bulk export). This equates to +/- 5.9 Ml/d.

Blithfield Reservoir (Seedy Mill WTW)

The inflow from the Upper River Blithe directly affects reservoir storage levels, and hence deployable output. The total uncertainty around the catchment modelling is again assumed to be +/- 15% and this has been confirmed by sensitivity testing of the Blithfield HYSIM models during refinement of the Aquator model. The range of uncertainty around the dry year annual DO (58.72 Ml/d) is therefore estimated at +/- 10% or +/- 5.9 Ml/d.

The proposed headroom uncertainty is a triangular function as follows:

Table Error! No text of specified style in document.**.14: Surface Water Yields: Headroom Distributions**

	Annual Average
Minimum Loss (gain in DO)	-11.8 Ml/d
Best Estimate	0 Ml/d
Maximum Loss (loss in DO)	+11.8 Ml/d

S8 Uncertainty of Climate Change on Deployable Output

The modelling approach used to determine the impact of climate change on deployable output is described under separate cover.

The wet and dry climate change scenarios modelled in the Aquator model represent the range of uncertainty around the mid-range scenario up to 2080. The range of uncertainty used in the headroom assessment is based on the difference between the corrected wet/dry scenarios and mid-range scenarios, as shown in the following table.

Table Error! No text of specified style in document.**.15: Modelled uncertainty in DO resulting from climate change impacts on yield**

Scenarios at 2070	Base DO (Ml/d)	Mid-Range Estimate	Base Year	Year of impact	Range of Uncertainty (Wet) (Ml/d)	Range of Uncertainty (Dry) (Ml/d)
Dry Year	338	317 (-13)	2018	2070	7.1	9.9

The wet and dry uncertainty has been interpolated/extrapolated over the planning period as a time-varying series in the headroom model, assuming a linear trend from the base year of 2018.

This uncertainty range has been incorporated into dry year annual average by assuming a triangular distribution with the upper and lower limits defined by the wet and dry scenario results. The mid-range estimate is assumed to be zero as the correction 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.

S9 Uncertain output of new resource developments

We have no new resources due to be commissioned in our baseline supply/demand forecast. We also do not have any new resources selected as options in the preferred plan and therefore there is no requirement for S9 in our headroom calculation.

4.2 Demand Components

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.

We have assumed an equal accuracy measurement 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 Error! No text of specified style in document.**.16: Source Deployable Output and Distribution Input Meter Status**

SOURCE NAME	Annual Average DO (Ml/d)	Distribution input meter
Slitting Mill	5.0	Yes
Moors Gorse	2.94	Yes
Seedy Mill	5.0	Yes
Maple Brook	8.5	No
Crumpwood	5.5	Yes
Churchill	10.0	No
Cookley	18	No
Kinver	9.0	No
Prestwood	20.0	No
Ashwood	18.0	No
Hinksford	5.0	No
Mayfield	0.52	No
Hopwas	2.45	No
Slade Heath	0.54	Yes
Somerford	0.0	Yes
Bourne Vale	4.5	No
Little Hay	Yes	
Shenstone	Yes	
Pipe Hill	Yes	
Trent Valley	Yes	
Fradley	Yes	
Chilcote	Yes	
Total groundwater DO		
Total GW DO separate DI meters		
Hampton Loade	Yes	
Blithfield Reservoir	Yes	
Total surface water DO		
Total DO		
Total DO with separate DI meters		

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

Table Error! No text of specified style in document.**.17: Distribution Input Meter Accuracy: Headroom Distribution**

	Annual Average
Minimum Headroom (decrease in demand)	-4.8 Ml/d
Best Estimate	0 Ml/d
Maximum Headroom (increase in demand)	+4.8 Ml/d

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 dry year factor used in the annual average demand forecast has 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, number of meter optants and dry year adjustment 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. For the population and properties uncertainty, we apply the UKWIR guideline errors to a normal distribution. Modelling error was accounted for using normally distributed regression coefficients (an assumption consistent with using ordinary least squares as the best linear unbiased estimator). The overall Household Consumption uncertainty is +33.5 to -34.1 Ml/d by 2050 for DYAA conditions.
- Non-Household Consumption: Uncertainty around non-household consumption is estimated to be +4.5 to -8.1 Ml/d by 2050. This range was determined by looking at the range of different forecasts that were derived from different trend analyses and or linear models (with economic variables) and taking the upper, central and lower scenarios.[1]
- Leakage: Uncertainty around leakage has been determined as +/-5% of target leakage. This equates to +4.8 to -3.2 Ml/d in 2022, decreasing to +3.0 to -2.0 Ml/d by 2045: a triangular

distribution has been used accordingly. This is consistent with work on SELL for the business plan.[1]

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 Error! No text of specified style in document.**.18: Total Demand Headroom Annual Average 5 yearly intervals**

Annual Average	2019/20	2024/25	2029/30	2034/35	2039/40	2044/45
Minimum Headroom (decrease in demand)	-33.04	-35.88	-38.60	-41.14	-43.40	-45.10
Best Estimate	0.00	0.00	0.00	0.00	0.00	0.00
Maximum Headroom (increase in demand)	29.53	32.20	35.19	37.97	40.04	40.93

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.

We have selected the Severn Trent water model as it better simulates the water using behaviour of our customer base. We have used probability data on increase in demand in the South Humber region as this geographically matches the majority of our supply area. The data tables contain forecast values for the percentage increase in household consumption and these have been directly applied using our 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. All impacts are scaled to a mid-value of zero to avoid double counting the base CC demand impacts (which are included in baseline demand). Probability data have been used to produce a triangular distribution.

Table Error! No text of specified style in document.**.19: Climate Change Demand Uncertainty Annual Average: 5 yearly Headroom**

D3 Issues	2025	2030	2035	2040	2045	2050
Maximum decrease in forecast	-0.17	-0.37	-0.56	-0.77	-0.97	-1.13
Best estimate	0.00	0.00	0.00	0.00	0.00	0.00

[1] Adjusted WRMP19 leakage targets for sensitivity analysis

Maximum increase in forecast	**0.25**	**0.47**	**0.74**	**0.97**	**1.25**	**1.51**

D4 Uncertainty of demand management solutions

The D4 component is computed from our preferred demand management programme by:

- Assigning uncertainty percentages to each option, to get upper and lower values for the yield.
- Compute the upper and lower yield for HH and NHH options per year.
- Calculate the min and max around zero per year (balanced around zero and with the correct sign for headroom).
- Building a triangular distribution around min, max and the mode (zero).

4.3 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.

5 Results and conclusions

Target Headroom Results

The results of the target headroom modelling under dry year average conditions are shown in Figure 4.1 below. The chosen risk profile is also shown. Target headroom starts at 10.04 Ml/d in 2025, increasing steadily along the 80th percentile profile to a maximum of 14.4 Ml/d in 2050 and 20.1 Ml/d by 2100.

Figure Error! No text of specified style in document.**.1: DYAA Target Headroom Results and chosen risk profile**

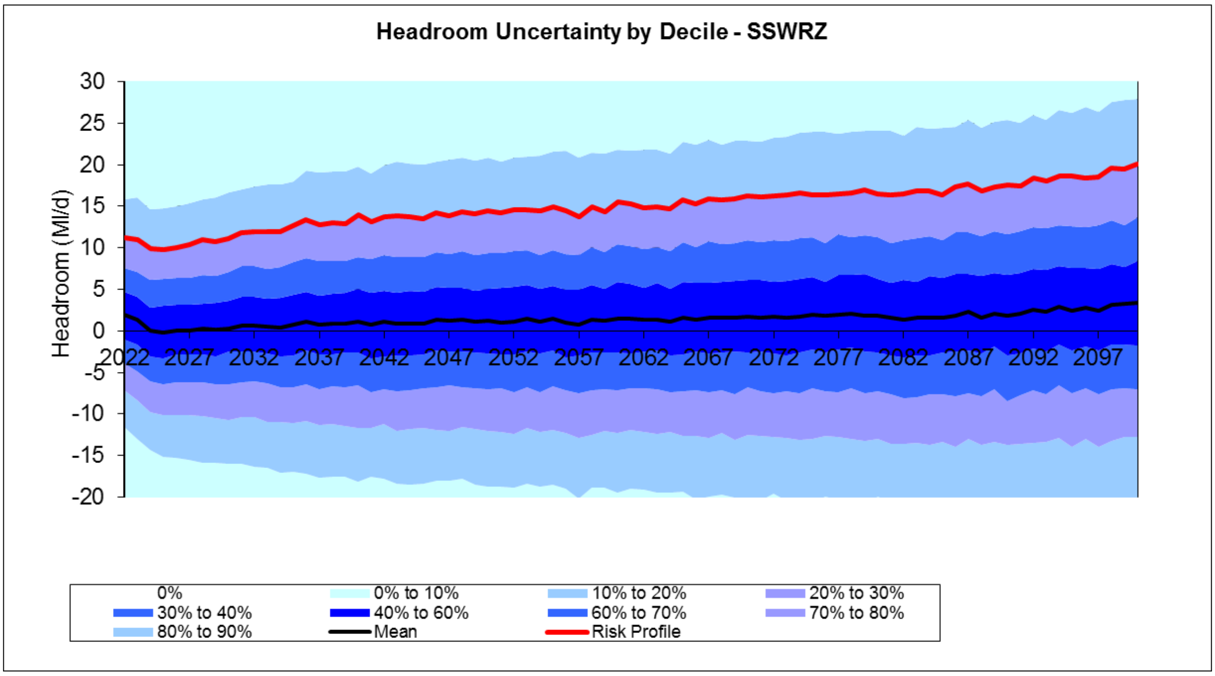
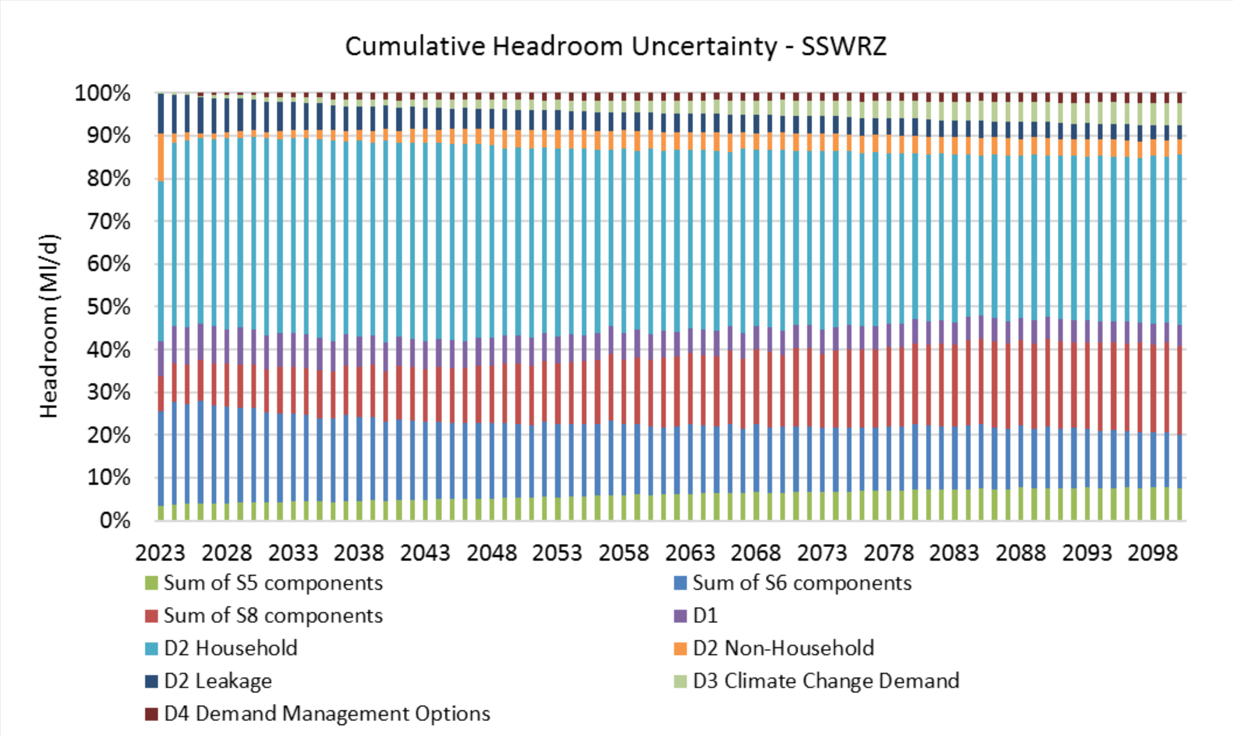


Figure 4.2 shows the proportional breakdown of target headroom by component for the selected risk profile.

Figure Error! No text of specified style in document.**.2: % Breakdown of DYAA Target Headroom by sub-component**



Chosen Risk Profile

The headroom values for the chosen risk profile for each year of the planning period and the corresponding percentile are summarised in the tables below. We are accepting a higher level of risk in the future than at present which is expected as, over time, aspects of uncertainty included in headroom will be resolved.

Table Error! No text of specified style in document.**.20: Headroom values in Ml/d for the chosen risk profile**

Year	DYAA Headroom (climate change components)	DYAA Headroom (other components)
2021 / 22	0.80	10.36
2022 / 23	0.91	10.04
2023 / 24	0.92	8.99
2024 / 25	0.96	8.87
2025 / 26	1.01	9.03
2026 / 27	1.11	9.33
2027 / 28	1.17	9.76
2028 / 29	1.17	9.57
2029 / 30	1.20	9.85
2030 / 31	1.29	10.48
2031 / 32	1.42	10.54
2032 / 33	1.45	10.48
2033 / 34	1.44	10.49
2034 / 35	1.58	11.08
2035 / 36	1.64	11.69
2036 / 37	1.64	11.12
2037 / 38	1.73	11.28
2038 / 39	1.76	11.16
2039 / 40	1.85	12.17
2040 / 41	1.85	11.29
2041 / 42	1.94	11.73
2042 / 43	1.95	11.92
2043 / 44	1.99	11.78
2044 / 45	1.96	11.52
2045 / 46	2.10	12.08
2046 / 47	2.15	11.72
2047 / 48	2.21	12.09
2048 / 49	2.25	11.81
2049 / 50	2.37	12.03

6 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.