Draft Water Resources Management Plan 2024

Appendix C – Managing Uncertainty

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C1 The uncertainty modelling approach

The Environment Agency, Natural Resources Wales and The Water Services Regulation Authority (Ofwat) have released Water Resources Planning Guidelines (WRPG; 2021, p. 69) which state that water companies should **“analyse the sources of uncertainty around the components of your supply-demand balance”** and that **“it is recommended… that you provide a headroom value which represents uncertainty”**.

The WRPG highlights three documents, which set out the different approaches:

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

In preparation for our 2024 dWRMP (dWRMP24) we applied the UKWIR problem characterisation approach to assess the size and complexity of the supply demand situation from 2025 to 2085 and concluded that we have a large, complex problem to solve. We have further developed our Water Infrastructure Supply and Demand Model (WiSDM) to enable us to consider multiple scenarios simultaneously and take into account uncertainties in key aspects of the plan, such as supply scheme costs, time to benefit and yield whilst optimising leakage and demand management. This sophisticated modelling tool known as the Decision Making Upgrade (DMU) has helped us to create a “best value” plan for overcoming any supply demand balance deficits. Our modelling approach, including the scenarios we considered, is discussed in more detail in Appendix E.

We have adopted a risk-based approach for assessing uncertainty based on the methodology outlined in ‘An Improved Methodology for Assessing Headroom’ (UKWIR, 2002). This is consistent with the approach taken to inform our 2019 WRMP (WRMP19). Furthermore, in collaboration with Dŵr Cymru Welsh Water and South Staffs Water we have commissioned Atkins to review target headroom for the dWRMP24. The approach we have followed and our assumptions, are described in detail in the remainder of this chapter.

C1.1 Target headroom

Target headroom represents the minimum buffer that companies should plan to maintain between supply and demand for water in order to cater for current and future uncertainties. It is important for water companies to plan for an **“appropriate level of risk”** in their WRMPs as **“if target headroom is too large it may drive unnecessary expenditure”**, whereas **“if it is too small you may not be able to meet your planned level of service”** (WRPG, 2021, p. 69).

To derive the range of target headroom uncertainty for our dWRMP24 we have adopted a risk-based approach to assessing target headroom uncertainty, using Monte Carlo simulation. The approach taken combines the uncertainties around supply and demand to derive an overall probability of supply and demand being in balance.

We have included the following inputs, which are discussed in detail in section C2:

Supply uncertainty:

- S5: Groundwater sources at risk of gradual pollution
- S6: Accuracy of supply-side data
- S8: Uncertainty of the impact of climate change on supply

Demand uncertainty:
- D1: Accuracy of sub-component demand
- D2: Demand forecast variation

In accordance with the WRPG (2016) we have made no allowances for S1 (vulnerable surface water licences) and S2 (vulnerable groundwater licences), and following WRPG (2021) we have made no allowances for S3 (non-replacement of time-limited licences on current terms). The data inputs for the models are discussed in more detail in section C2.

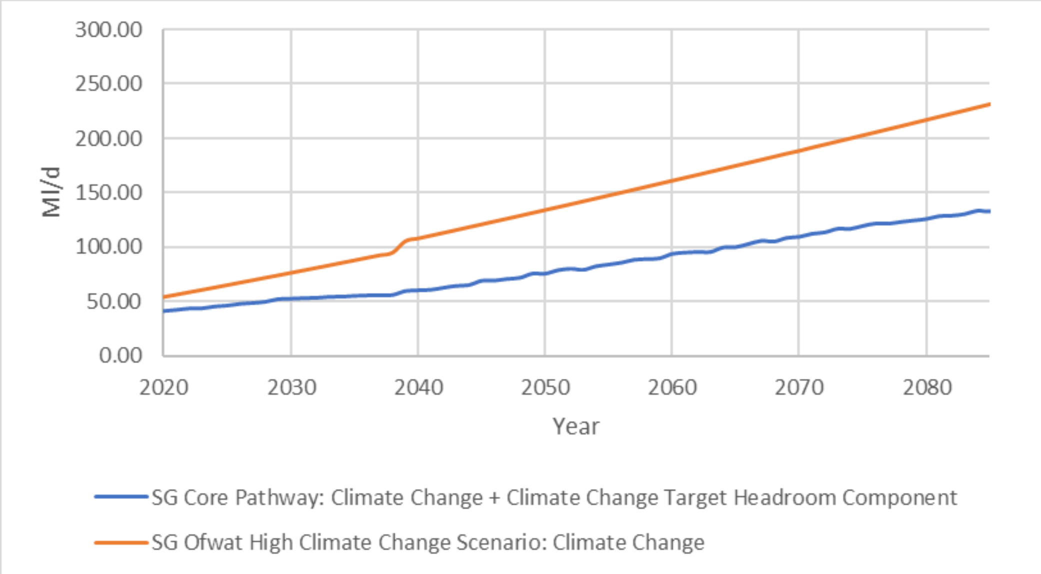
In order to derive the level of target headroom that we plan to maintain, we first need to assess the scale of uncertainties around the components for our projected supply/demand balance and decide on what is the appropriate level of risk to accept in the forecast period as per the WRPG (2021).

The biggest contributors to our overall supply/demand balance uncertainty are:
- Short term – issues around our assessment of deployable output (DO)
- Short term and long term – demand uncertainty
- Short to long term – the impacts of climate change
- Medium to long term – worsening gradual pollution trends impacting on our groundwater DO.

A discussion of the target headroom profile or 'glidepath' we have chosen to adopt in the plan can be found in section C2.3.

Full details regarding the adaptive planning process are documented in Appendix E, but a brief description of our rationale for how we are treating target headroom in the Ofwat common reference scenarios is included in this paragraph. The Ofwat common reference scenarios are sector-wide and **"designed to cover the key drivers of uncertainty around the future costs and benefits of water company activities" (Ofwat, 2021, p. 3).** Water companies are expected to evaluate these common reference scenarios to determine which activities are required in the next and subsequent price review periods to meet objectives. We have reviewed Ofwat common reference scenarios and analysed impacts on DO. This assessment has included comparing the climate change impacts and uncertainty in the core pathway (7.1BL change in DO due to climate change and 46BL target headroom climate change component) to the Ofwat high climate change scenario (7.1BL change in DO due to climate change). Following this investigation, we have determined that the impact of climate change on DO in the Ofwat high climate change scenario (excluding uncertainty in this scenario) is substantially greater than that of the core pathway (including uncertainty in this scenario; Figure C1.1). If the impact on DO of the Ofwat high climate change scenario had not been sufficiently greater than that of the core pathway then it may have been advantageous to have included a target headroom climate change component in the Ofwat high climate change scenario, but due to the divergence between the scenarios this target headroom component is not required. Furthermore, including target headroom components that are part of the forecast scenarios would lead to double counting that component within the adaptive planning process which was discussed during the Atkins WRMP24 Headroom Review. Therefore, we have not included the target headroom component of the Ofwat common reference scenarios.

Figure C1.1: Plot comparing the climate change impacts on deployable output in the Strategic Grid zone for the core pathway (blue; 7.1BL change in DO due to climate change and 46BL target headroom climate change component) to the Ofwat high climate change scenario (orange; 7.1BL change in DO due to climate change).



C2 Target headroom modelling assumptions

Target headroom is intended to provide a buffer that allows for the unavoidable uncertainties involved in estimating future changes to the various components of the supply and demand balance. As previously discussed, the calculation of target headroom follows an established best practice approach, set out in the publication **'An improved methodology for assessing headroom'** (UKWIR, 2002). The key components of the target headroom assessment as described in the UKWIR publication are as follows:

Supply-side components

S1 Vulnerable surface water licences
S2 Vulnerable groundwater licences
S3 Time-limited licences
S4 Bulk imports
S5 Gradual pollution of sources causing a reduction in abstraction
S6 Accuracy of supply-side data
S7 Not used
S8 Uncertainty of the impact of climate change on DO
S9 Uncertain output from new resource developments

Demand-side components

D1 Accuracy of sub-component data
D2 Demand forecast variation
D3 Uncertainty of the impact of climate change on demand
D4 Uncertainty in the outcome from demand management measures

We have assessed each component to estimate the likely range of uncertainty in each case. The range of uncertainty around each component follows the shape of a probability distribution from which such likelihoods are drawn. Since it is these distributions which are co-sampled to create the combined (cumulative) probability distributions from which an appropriate target headroom value is ultimately taken, we have taken care to ensure they suitably represent the uncertainty. We have also undertaken sensitivity tests on the assumptions we have made on the likely range of uncertainties, and on the shape of input distributions, so as to explore the consequences of our choices.

We reviewed the inputs to our target headroom model to ensure that we were not double counting any uncertainty. As described in Appendix C1 of our dWRMP, we made an allowance for groundwater sources at risk of gradual pollution, supply-side data uncertainty, impacts of climate change, accuracy of sub-component demand, demand forecast variation and uncertainty in the outcome of demand management measures. We did not make an additional allowance for bulk imports as we had already made an allowance for uncertainty of supply-side data under the UKWIR publication '*An improved methodology for assessing headroom*' component S6 (accuracy of supply-side data). More detail around our assumptions is provided in section C2.1.

C2.1 Supply-side

S1 and S2 – vulnerable surface and groundwater licences

The WRPG (2021) instruct water companies not to include any allowances in target headroom for uncertainty related to sustainability changes to permanent licences. The guidelines state that the Environment Agency or Natural Resources Wales will work with water companies to ensure that sustainability changes will not impact their security of supply, and so there is no need for a headroom allowance to be made.

In accordance with the WRPG, we have made no allowances for S1 (vulnerable surface water licences) or S2 (vulnerable groundwater licences) issues in our target headroom assessment. All sustainability changes are dealt with outside of target headroom, as part of the supply demand balance calculation. To assess the potential impacts and risks of possible sustainability changes we have carried out sensitivity analysis as part of our future adaptive pathways work.

S3 issues – time-limited licences

The WRPG (2021) instruct water companies not to include any allowances in target headroom for uncertainty related to non-renewal of time-limited licences on current terms. The guidelines (p. 69) state that "**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**". A number of our public water supply licences have time limited conditions on them; these mostly affect small volumes of the total licence quantities. In WRMP19 we made no explicit allowance for this uncertainty in our headroom assessment as we made an allowance for uncertainty of supply-side data under S6 (accuracy of supply-side data) issues and we did not want to double count uncertainty. We are continuing this approach, which is aligned with the updated WRPG (2021).

S4 issues – bulk imports

Any significant bulk transfers are included within the modelled DO, and so any corresponding uncertainty is allowed for under S6 (accuracy of supply-side data) issues, with the exporting zone carrying the associated uncertainty. Consistent with our WRMP19, no explicit allowance has been made for S4 issues in our target headroom assessment.

S5 issues – gradual pollution of sources causing a reduction in abstraction

In our target headroom assessment, we have made an allowance for groundwater sources at risk of gradual pollution, where worsening water quality may potentially affect the ability of the source to maintain the current or future forecast DO value.

The starting point for identifying these gradual pollution risks was to evaluate the future investment plans for proposed water quality schemes that are being assembled for our PR24 submission. This exercise identified where individual sites or blends (where water from multiple source is mixed together) have a risk of failure of the drinking water quality standards and when these failures are likely to occur, up to the year 2050. The principal water quality issue governing the potential loss of DO is from nitrate. Many of our groundwater sources have rising nitrate concentrations and we regularly update the water quality trends and blends to understand the potential consequence of these changes. Additionally, there are other water quality risks that have been accounted for in the headroom calculations including arsenic, pesticides, PFAS, uranium and selenium. Once we understood the forecast trends and blends, an assessment was made of what impact the deteriorating water quality would have upon the individual source or blend DO values. If there was no risk of DO being affected, or the source issue fulfilled one or more of the criteria below they were excluded from the headroom risk assessment:

- The source is no longer in use and is not contributing to DO;
- There is a capital delivery scheme already commenced that will deliver the potential lost DO; or
- The issue presented an outage risk rather than a loss of DO.

Our analysis suggests that several blends and individual groundwater sources could be severely impacted by rising water quality concentrations. It has been assumed that the drinking water quality standard cannot be breached and therefore modifications to any blends would have to be made to maintain compliance.

For nitrate-related issues, there is considerable uncertainty in the values used for all sources, especially those further into the future because the nitrate trend projections are based on profiles that have been determined from water quality data taken over a limited period. It should also be highlighted that these trends are based on observed data thus are not capable of accounting for new perturbations such as changing land use or climatic conditions which will likely cause divergence from the trend profile.

For this dWRMP we have assumed the changes to baseline DO due to gradual pollution shown in Table C2.1 will be overcome with investment, but we have assumed uncertainty of +/- 10% parameterised with a triangular distribution. The reason for the uncertainty distribution is that investment may not fully mitigate gradual pollution, whereas equally investment relating to gradual pollution may improve the water quality so that the source DO or blend ratios can potentially be optimised for greater output. It should be noted that Whitchurch and Wem Water Resources Zone (WRZ) gradual pollution reduces from 3.34 Ml/d to 0 in 2035 because there is a project to reduce the Arsenic control limit exceedance of Overton Scar and increase the resilience of the WRZ. As this project may be extended into AMP8 for formal delivery of a resilience driver too, following the potentially later delivery of the project the gradual pollution risk is removed.

Table C2.1: Forecast potential change to DO caused by deterioration of water quality based on the gradual pollution assessment.

	Potential change to baseline DO due to deteriorating water quality (Ml/d)					
Water Resource Zone	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Bishops Castle	0.00	0.15	0.90	1.15	1.40	1.65
Chester	0.00	0.00	0.00	0.00	0.00	0.00
Forest and Stroud	0.00	0.00	0.00	0.00	0.00	0.00
Kinsall	0.00	0.00	0.00	0.00	0.00	0.00
Mardy	0.00	0.00	0.00	0.00	0.00	0.00
Newark	0.00	0.00	0.00	0.00	0.00	0.00
North Staffordshire	4.27	0.00	0.00	0.25	0.50	0.50
Nottinghamshire	10.50	11.50	12.50	14.00	15.50	16.00
Rutland	0.00	0.00	0.00	0.00	0.00	0.00
Ruyton	1.59	2.09	2.09	5.32	5.32	5.32
Shelton	6.14	9.72	12.69	15.43	16.57	17.57
Stafford	0.00	0.00	0.00	0.00	0.00	0.00
Strategic Grid	9.3	9.3	10.3	10.3	10.8	11.3
Whitchurch & Wem	3.34	3.34	0.00	0.00	0.00	0.00
Wolverhampton	0.00	0.00	0.00	0.00	0.00	0.00

S6 issues – accuracy of supply-side data

This component reflects the scale of uncertainty around our calculation of DO. The target headroom assessment of supply-side data uncertainty has considered groundwater and surface water issues separately. The updated groundwater DO assessment also included a review of the constraints on DO for each source. The assessment has sought to categorise the sources of uncertainty as follows:

S6-1 abstraction licence constraints

Consistent with our assessment for WRMP19, for our abstraction licence constrained groundwater sources we have assumed a triangular distribution with a mean error of 1%, with a maximum of 4% (i.e. a 4% reduction in DO) and a minimum of -2% (i.e. a 2% gain in DO).

All of our surface water abstractions on the River Severn are considered to be licence constrained. For these sources, we have adopted the same triangular distribution as licence constrained groundwater sources, with a maximum potential loss of output of 4%, with a mean value of 1% and a potential gain of 2%.

S6-2 aquifer constraints

For groundwater sources where the constraint is considered to be the aquifer, uncertainty is assumed to be a maximum of +/-20%, following a normal distribution. The relatively high figure reflects the uncertainty in establishing the safe yield of groundwater sources and is, again, the same as was included in the WRMP19.

S6-3 infrastructure constraints (e.g. pumping capacity & treatment capacity)

For sources constrained by infrastructure, uncertainty is assumed to be a maximum of +/-10%, and follow a normal distribution, as it was in the WRMP19. Most infrastructure constrained sources are limited by pumping capacity, although in a few cases the capacity of the transmission main from the source is the limiting factor.

S6-4 source yield constraints (surface water deployable output)

Where the constraint has been identified as the yield of the source, the adequacy of the data used in the assessment has been reviewed in order to arrive at a reasonable figure for uncertainty. As per the UKWIR 2002 method, for our surface water sources uncertainty is assumed to be between +/-10% for sources with good long flow records and +/-20% for sources with short flow records or dependent on simulated flows.

Uncertainties for source yield constrained supplies are ascribed a normal distribution as it is considered more appropriate for uncertainty that may be represented as a random distribution about a mean.

In preparation for the dWRMP24 we have reviewed the constraints on each of our sources, leading to some sources changing category. This has resulted in minor changes to the total target headroom for some water resource zones (WRZs). The changes are shown in section C2.3.2.

S8 issues – uncertainty of the impact of climate change on deployable output

As discussed in Appendix A3, we have assessed the potential impacts of climate change across our region by applying the methodology recommended in the WRPG. Our DO modelling of the wide range of climate change impacted scenarios, using the UK Climate Projections 2018 (UKCP18) has shown us that this remains a large area of uncertainty for many WRZs that have a climate change impact in our dWRMP24. This is reflected in the impact that this issue has on target headroom in section C2.3.2.

The methodology we have applied uses 20 probabilistic and 12 regional climate model (RCM) UKCP18 projections for our region. The median of the 12 RCMs have been used to represent our central estimate of DO impacts which is used in our Water Resources Planning tables as our reduction to baseline DO. We have tested different approaches including assessing which distributions might be best suited to representing the broad range of uncertainty around this central estimate in target headroom. Based on the data we have available, normal and triangular distributions are the most suitable options and they are outlined below.

Option 1: Using a triangular distribution

For WRMP19 we used a triangular distribution for this component and for dWRMP24 we have assessed using a triangular distribution around our central climate change estimate. The 10th and 90th ranked impacted scenarios from the 20 probabilistic UKCP18 projections were used to derive the minimum and maximum changes in DO respectively. It should be noted that in WRMP19 the ranked values were 10th – greatest DO impact (drier), to 90th – lower DO impact (wetter), whereas for dWRMP24 the values are ranked the opposite way around. In Table C2.2 it can be seen that rank 10 has a larger gain in DO than rank 90 has loss in DO compared to the climate change central estimate. Using this skewed triangular distribution when selecting a 'glidepath' with a high level of certainty (e.g. 95% during AMP8) then caused issues because the climate change component of target headroom provided a positive contribution, meaning that it effectively reduced the total target headroom. The skewed distribution resulted in a greater chance of climate change DO impacts being less severe than the central estimate rather than more severe than the central estimate. In UKWIR, Risk Based Planning (2016, p. 208), there is a warning about using skewed distributions stating that by using them you are **"effectively indicating that [you] don't really believe that the supply/demand forecast without uncertainty is actually [your] best 'central estimate' of the future".** As the 'glidepath' risk was decreased the climate change component of target headroom became negative as typically required but this did not fit with our 'glidepath' strategy and level of risk that we were willing to accept for the other components. Additionally, as there is still risk around climate change we wanted to capture this in target headroom and ensure that we were being conservative in our target headroom modelling. Therefore, we decided that a triangular distribution was not suitable for use with this skewed climate change data in our target headroom modelling.

Table C2.2: Example of probabilistic scenarios for the Strategic Grid zone which were used to derive target headroom climate change uncertainty by calculating their standard deviation and multiplying by the temporal scaling factor.

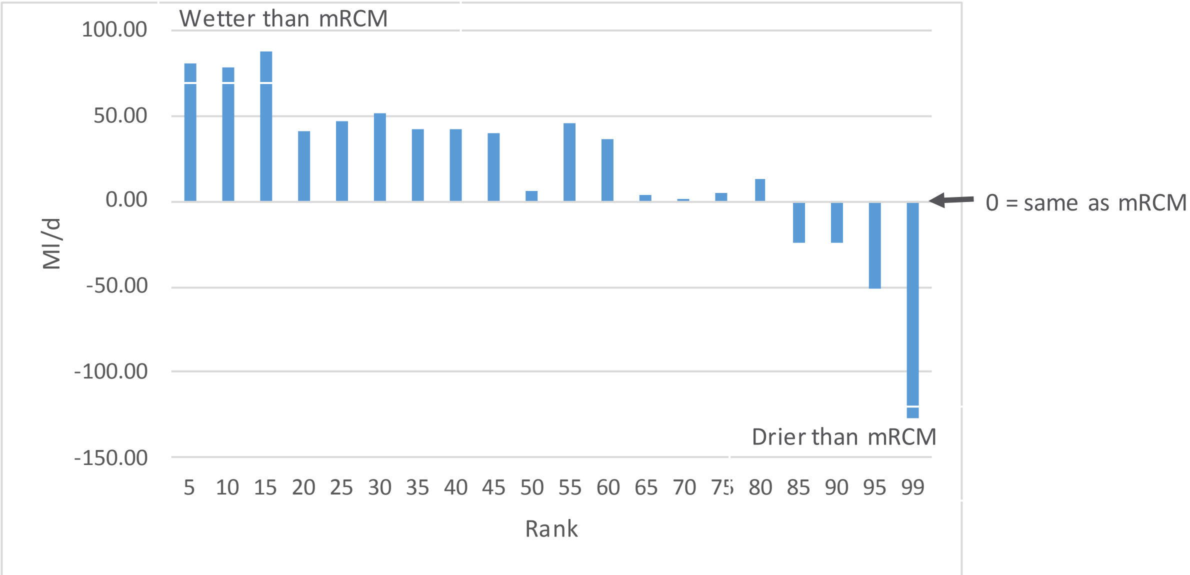
Index	UKCP09 ID	Rank	Change in zonal DO relative to central estimate (Ml/d)
1	Sc77	5	81.02
2	Sc44	10	78.94
3	Sc72	15	87.78
4	Sc37	20	41.66
5	Sc79	25	47.13
6	Sc87	30	51.28
7	Sc96	35	42.78
8	Sc85	40	42.85
9	Sc80	45	39.52
10	Sc86	50	6.27
11	Sc19	55	45.64
12	Sc100	60	36.33
13	Sc68	65	3.99
14	Sc83	70	1.32
15	Sc88	75	4.55
16	Sc21	80	13.59
17	Sc61	85	-24.21
18	Sc2	90	-23.96
19	Sc17	95	-51.21
20	Sc82	99	-126.35

Option 2: Using a normal distribution

This approach was consistent with the WRPG 2021 guidance and supplementary guidance which states that companies should integrate climate change into the WRMP in the same manner as for WRMP19. As a result of our sensitivity analysis for our dWRMP24 we have opted to use a normal distribution around our central climate change estimate. The normal distribution was parameterised using a value of 0 as the mean as this uncertainty is around the central estimate of climate change which we believe to be the most likely outcome. The standard deviation of the 20 probabilistic UKCP18 projections were used to derive the maximum and minimum changes in DO with gain and loss equally likely as the distribution is normal.

We have used the 5th to 99th ranked scenarios, which mean that the more extreme wettest (less than 5th percentile) and driest (greater than 99th percentile) scenarios produced by the UKCP18 projections for our region are not included. Figure C2.1 below illustrates for the Strategic Grid zone how the probabilistic scenarios that we have used to describe climate change uncertainty are predicted to affect the WRZ DO relative to the central estimate of climate change. As can be seen in Figure C2.1, for the Strategic Grid the rank 5 to 80 scenarios are wetter than the median of the RCMs, thus they represent an increase in WRZ DO compared to the central estimate of climate change. In contrast, the rank 85 to rank 99 cause a further reduction in WRZ DO compared to the median of the RCMs.

Figure C2.1: Impact on deployable output in the Strategic Grid zone in 2070 under the 20 UKCP18 probabilistic scenarios relative to the median of the RCMs (mRCM) which is the central estimate of climate change.



Within our target headroom model, we can include uncertainty around the central estimate of climate change impact on supply as a series of normal distributions. We parameterised these using a value of 0 as the mean and standard deviation was calculated for the probabilistic scenarios. The probability distributions for individual years were then derived using the scaling equations (which are described in section A3.8 of Appendix A), which produces a range reflecting the increasing uncertainty around climate change as we move through the planning period. An example of the impacts and distribution around the central estimate of climate change for the Strategic Grid zone is shown in Table C2.2. We have not included scenarios beyond the 99th rank. If we were to include the full range of the more extreme scenarios in our dWRMP24 assumptions, then these scenarios would trigger the need for significant future investment in new supply capacity when their probability is very low. We believe it is more appropriate to use all 20 climate change projections as 'alternative futures' through our adaptive planning, Ofwat common reference scenarios and DMU analysis (described in Appendix E3) to test the robustness of our plan against each of the equally likely climate futures. The adaptive planning process highlights decision points where we may need to change our plan to accommodate a change in the future, e.g. if we find in reality we are actually faced with a rank 40 climate future what steps would we need to take to ensure resilience of our supply demand balance? We can determine this using the DMU which allows us to explore which climate change scenarios drive different investment programme decisions.

To ensure transparency regarding the climate change allowance in target headroom the relative contribution of the climate change component is compared to the other components. This is discussed in more detail in section C2.3.2.

C2.2 Demand side

D1 issues: accuracy of sub-component demand

Uncertainty in the number of new property connections

The WRPG 2021 explicitly instruct water companies to account for the local council projections of household growth for supply capacity planning purposes. In light of this, we are adopting the Local Council projection of growth from AMP7 onwards for the dWRMP24 central housing growth forecast.

However, the local authority forecasts for our region represent a stepped increase in new households over historic and current observed numbers. Historic observed growth in our region has been around two thirds of the local authority projections. Therefore, there is already headroom included in the central estimate of this component of the demand forecast. For uncertainty analysis we have assumed a triangular distribution using the Local Planning Authority (LPA) growth projections and historically observed growth in our region.

- Upper/central assumption – LPA projections
- Lower bound – historic average observed growth rate

Uncertainty in population numbers

For population projections we have used the latest Government projections for England. These are taken from the 2018 base sub-national population projections for England from the Office of National Statistics (ONS). The annual percentage rates of change for local authorities are applied to the base year population estimates at postcode level and then aggregated up to WRZ level. This gives the underlying change in population due to births, deaths and migration in the Severn Trent region.

For target headroom we also take the ONS 2018 profiles for overall high and low projections. These are based on the ONS projections combining variants of high birth, high immigration with low mortality, and low birth, low immigration with high mortality.

D2 issues: demand forecast variation

Uncertainties in household demand

We use data from Defra's Market Transformation Programme (MTP) to account for uncertainty in the household consumption forecast. The MTP produced predictions of water use for different water using appliances in 2030 for three different scenarios:

- Reference scenario (equivalent to the baseline scenario)
- Policy scenario (assuming more effective implementation and accelerated take-up of more sustainable products)
- Early best practice (EBP; assuming a more positive impact than the policy scenario and an early take up of innovative water efficient products).

The reference scenario underpins the baseline forecast, with the policy and EBP scenarios used to define upper and lower ranges of household consumption.

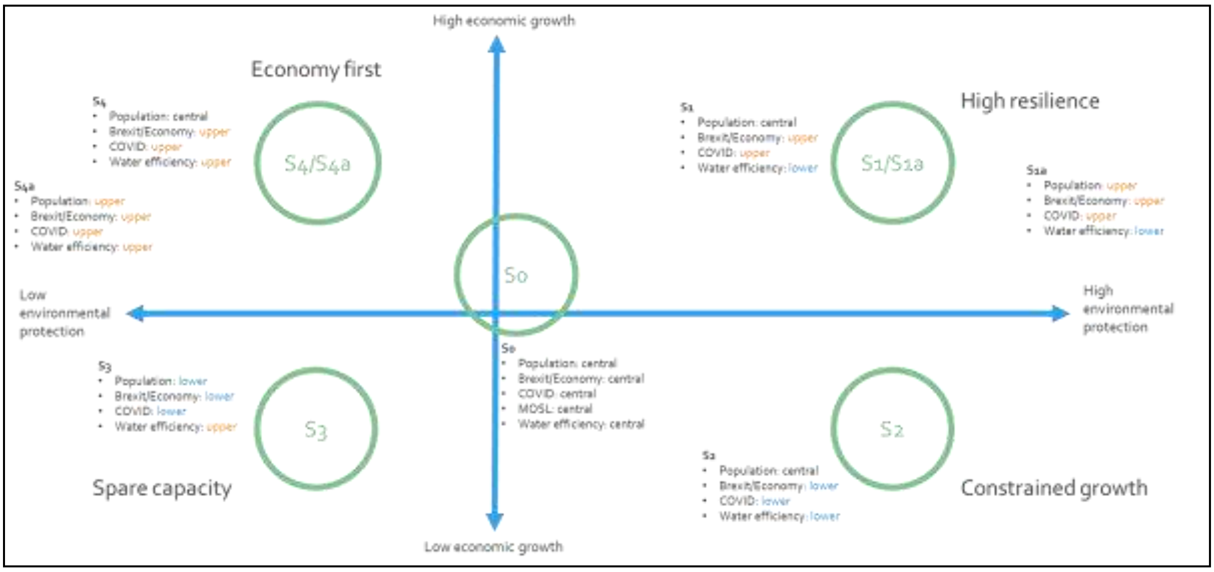
Uncertainties in COVID-19 impact

At the start of the COVID-19 stay at home restrictions in March 2020, we could not have foreseen the impact on water consumption in homes, which when combined with the hot and dry weather resulted in some of the highest peaks in water demand that water companies have ever seen. In our region, we have seen an uplift in household demand as a consequence of the COVID-19 pandemic. Factors causing this increase include the health advice on hand washing, more people staying at home as we moved into the lockdown period, home schooling and home working along with periods of hot weather. Although household consumption has reduced from the highs of 2020 as customers return to work, we continue to see high levels of consumption and have factored in short-term and long-term assumptions for the impacts of COVID-19. Our forecast uncertainty range for COVID-19 impact on household consumption is 0% to 4% in target headroom.

Uncertainties in measured non-household water consumption

There are multiple and complex links between non-household demand and a wide range of factors, from international and national macroeconomic trends to local investment strategies and population growth. This complexity could present challenges for forecasting; in terms of what factors to consider and the range of scenarios needed to capture a suitable range of futures. Therefore, we have developed seven scenarios to reflect the impact from a broad range of drivers and pressures. The scenarios each result in a different mid-century non-household forecast. These scenarios help to take account of a range of uncertainties and risks and help identify opportunities for resilient responses. We chose to adopt this scenario approach because of the specific short-term impacts likely as a result of COVID-19 and Brexit, alongside other medium to long term impacts associated with the other factors considered. The scenarios have been developed and assessed using a Drivers, Pressures, States, Impacts and Responses (DPSIR) framework to identify how the scenarios are related and their performance.

Figure C2.2: Positioning of seven Scenarios (S) based on environmental protection and economic growth representing an economy first, high resilience, spare capacity or constrained growth future. N.B. MOSL is Market Operator Services Limited.



The scenarios take the current 'landscape' of non-household demand in summer 2020 as a starting point. They are characterised in terms of two of the main drivers of future water availability/consumption – economic growth and environmental protection. These form the axes in Figure C2.2 and help position the scenarios. Whilst other drivers could be used for the axes, this would not fundamentally impact the scenarios, which are designed to represent a range of plausible future 'states of the world'. There are seven different scenarios within five main headings, each is briefly described below numbered Scenario 0 to Scenario 4.

Scenario 0: Current landscape
Existing (summer 2020) non-household demand for water. This is suppressed (lower than usual) because of the COVID-19 pandemic.

Scenario 1: High resilience
Economic growth is partly driven and facilitated by technological change and innovation. This is matched by high environmental standards aimed at addressing increased water scarcity, leading to a greater focus on water efficiency, reuse and collaborative working. There are two variants (Scenario 1 and Scenario 1a) of this scenario using the central and upper population forecast.

Scenario 2: Constrained growth
Economic growth is heavily impacted by the COVID-19 pandemic and Brexit, as well as by the need to protect and enhance the environment, leading to legislative and regulatory policies that drive more efficient water use, and by the use of pricing and tariffs.

Scenario 3: Spare capacity
Economic growth is heavily impacted by the COVID-19 pandemic and Brexit, as well as by low levels of innovation and low population growth. Environmental protection is given a low priority and there is spare capacity in the provision of water services, with water efficiency and demand management measures deemed largely unnecessary.

Scenario 4: Economy first
Economic growth is prioritised, resulting in higher than average growth in both the service and non-service sectors. Water companies need to identify new potable and non-potable sources to maintain the supply demand balance. Collaboration, among water companies and between sectors, is limited, with a greater focus on competition. There are two variants of this scenario (Scenario 4 and Scenario 4a) using the central and upper population forecast. We have adopted Scenario 0 for our central forecast and Scenario 2 (low demand scenario) and Scenario 4 (high demand scenario) to account for the widest range of uncertainty in the long-term forecasts.

Uncertainties in leakage
Leakage uncertainty is set using uncertainty parameters from our annual water balance reporting that account for District Metered Area (DMA), and Trunk Mains and Service Reservoir (TMSR) leakage uncertainty. For the forecast leakage uncertainty we have assumed 12.38% above and below the central leakage projection

Uncertainties in minor components
Minor components of demand consist of distributional system operational use and water taken unbilled. Minor component uncertainty is set using parameters from our water balance annual reporting. For uncertainty we have assumed 50% above and below the central leakage projection.

D3 issues: uncertainty impact of climate change on demand

No uncertainty has been attached to the best estimate of climate change impact on demand.

D4 issues: uncertainty of the outcome from demand management measures

There are inherent uncertainties within the water efficiency forecast as our assumptions about the impact of our activity on demand (of uptake by customers and demand reduction) are reliant on customer behaviour. Where we send devices to customers, we are reliant on the correct devices being ordered, actual installation of the device and devices then remaining installed.

For all water efficiency devices, we already assume that demand savings decay over time:

- as customers either dislike retrofit products or they are gradually removed as customers upgrade their kitchens and bathrooms over time, and
- we think we will have all but exhausted the customer base who are sufficiently engaged on water efficiency that they have requested free and subsidised water efficient products meaning the cost of promoting these products is likely to outweigh the benefit of supplying them.

We estimate the decay rate using the half-life from the Waterwise (2010) Evidence Base report and our own previous experience until we assume zero savings after 15 years.

Our uncertainty ranges are generally consistent between options (Table C2.3) as most involve the installation of water saving products. However, we have slightly greater confidence in activity that we have been carrying out for longer or for which we have measured savings. This applies to both the assumed uptake by customers and the likely volume of demand savings.

Table C2.3: Lower and upper uncertainty distribution for options.

Option	Lower	Upper	Description
Free Products (free and paid is now a single option)	-10%	10%	Product distributed is accurate and we account for uncertainty of install in our savings assumptions
Paid Products	-10%	10%	Product distributed is accurate and we account for uncertainty of install in our savings assumptions
Home Water Efficiency Check (HWEC) Overall	-25%	10%	Majority of saving is from leak alarms
Leak Alarm HWEC	-10%	10%	New programme and lack confidence in accuracy of savings reported
Social Housing HWEC	-25%	25%	Data is based on measured data from a previous programme
Green Recovery	-25%	25%	No reason to assume any more certain than Social Housing
High Consumption (not included but will be for final plan)	-30%	10%	Well established programme but lack of logger data or meter read follow up means concern about savings assumed

C2.3 Target headroom profile

One of the most important elements of our dWRMP24 is the decision around how to deal with uncertainty in our long-term plan. Using the traditional Economic Balance of Supply and Demand (EBSD) approach, uncertainty is dealt with using target headroom. The amount of target headroom we include determines the scale of investment needed to maintain an adequate buffer between future supply and demand for water in order to accommodate the uncertainties outlined in the sections above.

C2.3.1 The target headroom profile

In the short term, the main uncertainty in our planning assumptions is around the accuracy and reliability of our source DO. Accuracy of supply data (S6) is constant over the period, with its absolute target headroom contribution affected by the 'glidepath'. For many of our WRZs, the only increasing sources of longer-term uncertainty are around the trajectory of future demand for water (De), the potential impacts of climate change (S8) and gradual pollution (S5). In many of our zones we are adopting a target headroom profile that maintains a high degree of planning confidence across the full period. Our strategy is to maintain this high level of confidence in these zones through our leakage and demand management plans, and making best use of our existing sources of supply.

In our Strategic Grid and North Staffordshire zones, the longer-term uncertainty around the impacts of climate change increases over time. As already described, we have chosen an approach to estimating climate change uncertainty that excludes the more extreme, drier scenarios suggested by UKCP18 for our region. Our chosen risk profile in these zones reflects the fact that we have already discounted some of the higher impact / lower probability scenarios by adopting a normal distribution around the median of the 12 RCMs in our assessment. As a result, we have adopted a target headroom risk profile that gives us high confidence in the short to medium term that we can meet our planned levels of service while coping with the range of planning uncertainties.

The long-term headroom profiles for the Strategic Grid, North Staffordshire and Wolverhampton zones change to accept an increasing and manageable degree of risk over time. The longer-term uncertainties around climate change for the Strategic Grid and North Staffordshire, and demand for Wolverhampton can be managed using the adaptive management responses we have set out in our plan, and through the five yearly update of our water resources strategy. Therefore, it would be inappropriate to plan to maintain a higher level of target headroom throughout the whole planning period.

The target headroom profiles or 'glidepaths' used in our dWRMP24 are set out in Table C2.4. The target headroom risk percentile shown in the table represents the level of confidence we have of achieving our target level of service.

Table C2.4: Target headroom profiles used in the dWRMP24. NA means not applicable.

Water Resource Zone	AMP8 2025-2029	AMP9 & AMP10 2030-2039	AMP11 onwards 2040-2085
Bishops Castle	95%	90%	90%
Chester	95%	90%	90%
Forest & Stroud	95%	90%	90%
Kinsall	95%	90%	90%
Mardy	95%	90%	90%
Newark	95%	90%	90%
North Staffordshire	95%	Transition 95% to 85% (in even target headroom steps)	85%
Nottinghamshire	95%	Transition 95% to 90% (in even target headroom steps)	90%
Rutland[1]	NA	NA	NA
Ruyton	95%	90%	90%
Shelton	95%	90%	90%
Stafford	95%	90%	90%
Strategic Grid	95%	Transition 95% to 85% (in even target headroom steps)	85%
Whitchurch & Wem	95%	90%	90%
Wolverhampton	95%	Transition 95% to 85% (in even target headroom steps)	85%

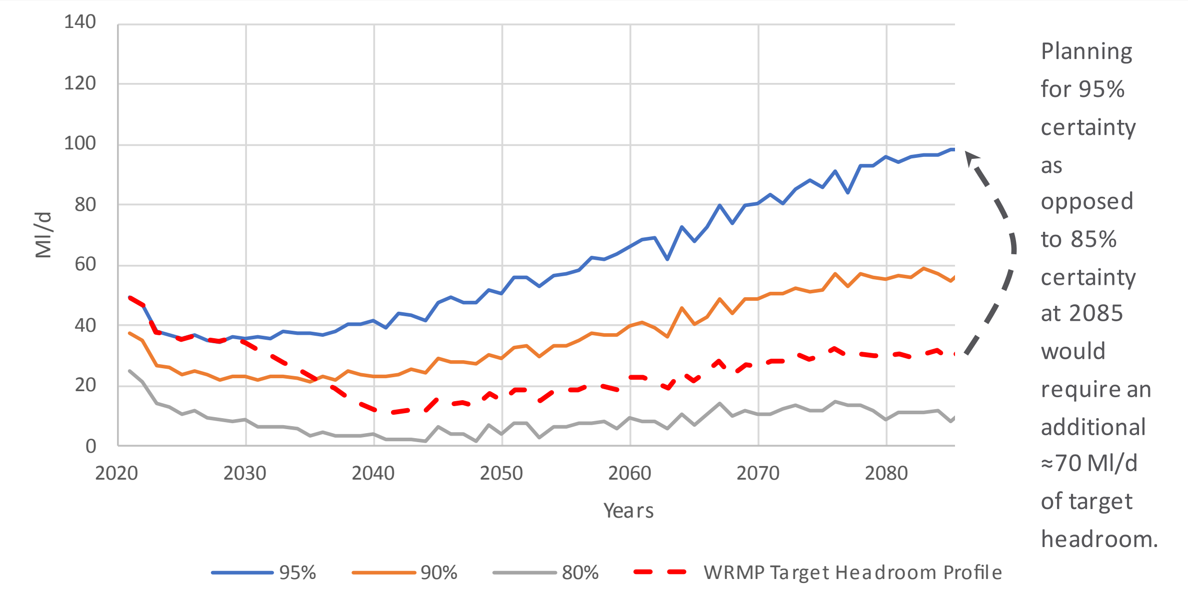
The ‘glidepaths’ that we have adopted are shown in Table C2.4. They all follow the WRMP19 ‘glidepath’ strategy of maintaining a 95% level of certainty in the initial AMP then reducing the level of certainty and accepting greater risk from the following AMP onwards. When the risk increases in 2030 the target headroom values decrease, potentially creating a step in the target headroom profile. We have reviewed the options for smoothing this transition of the ‘glidepaths’ as this results in greater consistency between consecutive years, and due to this we stated in the WRMP19 that we would do this for the dWRMP24. The outcome of this review is that small step changes (<1.5 Ml/d) in the target headroom profile for Bishops Castle, Chester, Forest and Stroud, Kinsall, Mardy, Newark, Ruyton, Shelton, Stafford, and Whitchurch and Wem will remain. For WRZs which would have had a larger step (≥1.5 Ml/d) we have smoothed the target headroom values from 2030 to 2039 so that there is a gradual target headroom transition to the determined ‘glidepath’ certainty percentile of either 90% or 85% in 2040. The WRZs that have been smoothed to 85% in 2040 are North Staffordshire, the Strategic Grid and Wolverhampton, with Nottinghamshire smoothed to 90% in 2040.

We have opted for a low level of risk until 2029 as due to the relatively short timeframe we must plan to ensure that we can meet our levels of service. The ‘glidepath’ level of risk is higher from 2030 onwards as demand and climate change uncertainty typically increase over time. Our approach to managing long-term risk and uncertainty means that we avoid having to commit to potentially large-scale investment decisions in AMP8 that would be driven by very uncertain long-term scenarios. Our dWRMP delivers a high level of confidence for AMP8, but accepts an increasing amount of risk beyond that. The increasing risk will be managed with adaptive planning and re-evaluating target headroom in subsequent WRMPs. If we were to

[1] Target headroom was not calculated for Rutland as all WRZ DO is from potable water imported, thus target headroom for Rutland’s water has been calculated with the exporting zone to ensure that the import is resilient.

require the same level of planning certainty throughout the long-term planning horizon, we would need to commit to even more investment to achieve this. Figure C2.3 illustrates how our target headroom profile compares with other potential profiles that could have been adopted to accommodate an even wider range of uncertainty ranging from 95% certainty to 80% certainty. It can be seen in Figure C2.3 that for the Strategic Grid zone, our approach avoids the need to invest in approximately 70 Ml/d of supply/demand headroom capability by 2085 through accepting an increased level of risk in our 'glidepath'.

Figure C2.3: Planning for uncertainty – target headroom required to accommodate 80% certainty to 95% certainty with dWRMP24 target headroom profile for the Strategic Grid.



Our strategy is based around delivering a target headroom that provides a 95% level of confidence that we will meet our target levels of service during AMP8. Over the 60 year horizon, our target headroom profile varies to reflect the fact that many of the medium to long term uncertainties can be managed over time. We believe this profile is appropriate given that:

- A proportion of the uncertainty in our AMP8 headroom assessment is related to our assessment of DO and the data that is available. It would not be appropriate to plan further significant capital investment to deliver the maximum level of confidence when the uncertainty around the supply/demand balance gap could be reduced by utilising improved data with further analysis.

- The growing long-term uncertainties can be managed over time through an adaptive planning response. If we were to plan to maintain a very high target headroom requirement over the 60 years, this would create large headroom shortfalls and would likely trigger the need for significant new water resources investment that would need to begin in the next AMP period. Instead, the timing and scale of the leakage reduction, demand management and new water supply enhancements proposed in our dWRMP24 mean we will be able to adapt the delivery of our strategy as our understanding of the long-term planning uncertainties improve over time. The nature of the options we are proposing for the next five to ten years mean that these are 'no regret' decisions that will improve security of supply, as well as reduce the amount of water we abstract from the environment and reduce the likelihood of us causing future environmental deterioration. The water resources planning process requires that WRMPs are reviewed and updated every five years, and we believe that the long-term planning risks can be managed and mitigated within this structured process. Therefore, we have adopted a target headroom profile that accepts an increasing amount of uncertainty over the 60 year period.

C2.3.2 Relative contributions of target headroom components

Figures C2.4 to C2.17 illustrate, for each of our WRZs, the relative contributions that the different target headroom components make to the overall target headroom requirement.

In the graphs the S6 issues (uncertainty around supply-side data) have been separated into the four categories discussed in section C2.1, where:

- S6-1 is uncertainty around licence constrained sources
- S6-2 is uncertainty around aquifer constrained sources
- S6-3 is uncertainty around infrastructure constrained sources
- S6-4 is uncertainty around surface water source yields.

Many of our WRZs are supplied by small groups of groundwater sources, which our climate change assessment has shown will be resilient to future changes in climate. In these zones, the sources of uncertainty are limited to demand-side, supply-side and gradual pollution data, except for Bishops Castle. However, the overall target headroom in these zones is relatively small. As mentioned in section C2.1, in preparing for our dWRMP24 we have reviewed the constraints on each of our sources of supply, leading to some sources changing category. Due to the distributions used to characterise the S6 categories, sources changing from one category to another typically have little impact on the overall target headroom value.

In Chester, North Staffordshire, Shelton, Stafford, the Strategic Grid and Wolverhampton WRZs for some years demand components provide a positive contribution to target headroom, meaning that they effectively reduce the total target headroom. In years where a component has a positive contribution to target headroom, as recommended by the Atkins WRMP24 Headroom Review, we have capped the target headroom contribution of that component to zero. The causes of this positive headroom in demand are property forecasts that result in the demand central estimate value being larger than the mean modelled demand and uncertainty for the given 'glidepath' percentile because the WRPG requires that plan-based demand forecasts should form the central estimate of demand. This results in the target headroom value inverting, becoming positive as opposed to negative, which components typically are. In the Strategic Grid zone the demand modelling shows a positive (capped at zero) or marginal contribution to target headroom between 2037–2064.

As discussed in Appendix A3.6, the Strategic Grid and North Staffordshire are the most affected by the potential impacts of climate change. All of our groundwater only zones are not affected by the impacts of climate change except for Bishops Castle which has a relatively small amount of climate change. As can be seen in Figures C2.4, C2.6, C2.10 and C2.15, which show Bishops Castle, Forest and Stroud, North Staffordshire and the Strategic Grid WRZs respectively, the relative contribution of uncertainty around climate change increases through the planning period. In the Strategic Grid it should be noted that climate change uncertainty becomes the dominant factor (largest uncertainty) by 2023, and by 2035 makes up greater than 50% of target headroom. Climate change uncertainty is flat and negligible in Chester (Figure C2.5).

There have been some changes to the findings of the gradual pollution assessment (section C2.1) between WRMP19 and dWRMP24. The most notable changes are the identification of new gradual pollution in Bishops Castle and Ruyton since WRMP19, and the removal of gradual pollution in Stafford for dWRMP24 which can be seen in Figures C2.4, C2.12 and C2.14 respectively.

Figure C2.4: Components of target headroom for Bishops Castle WRZ.

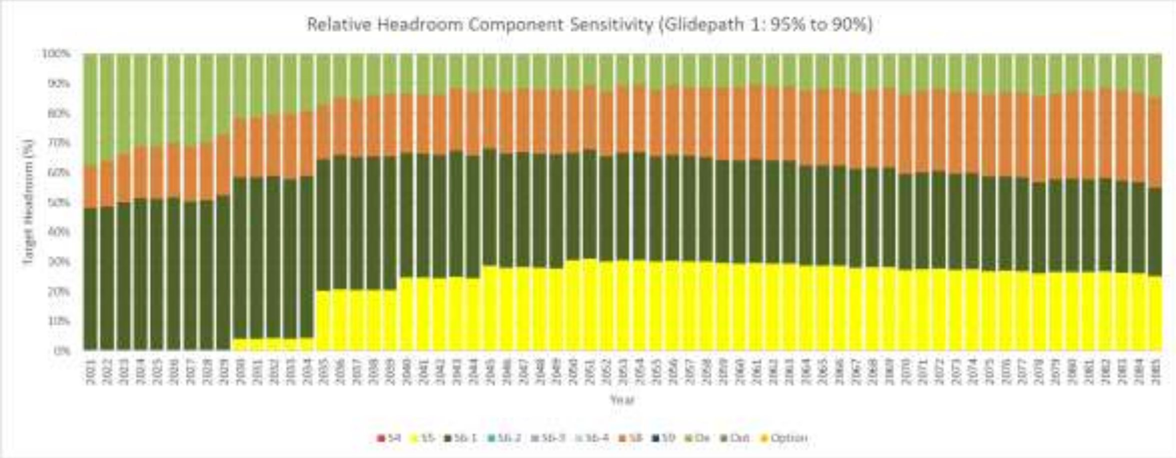


Figure C2.5: Components of target headroom for Chester WRZ.

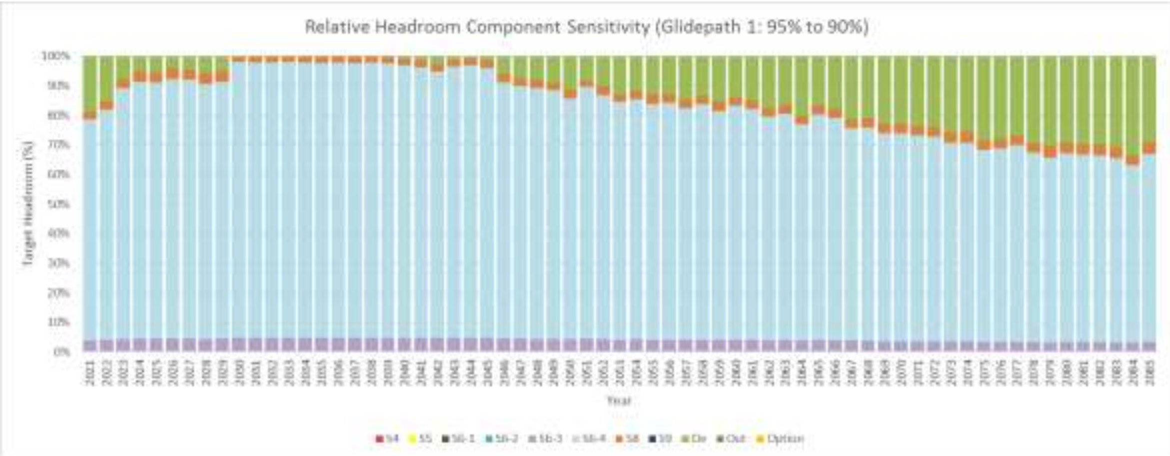


Figure C2.6: Components of target headroom for Forest and Stroud WRZ.

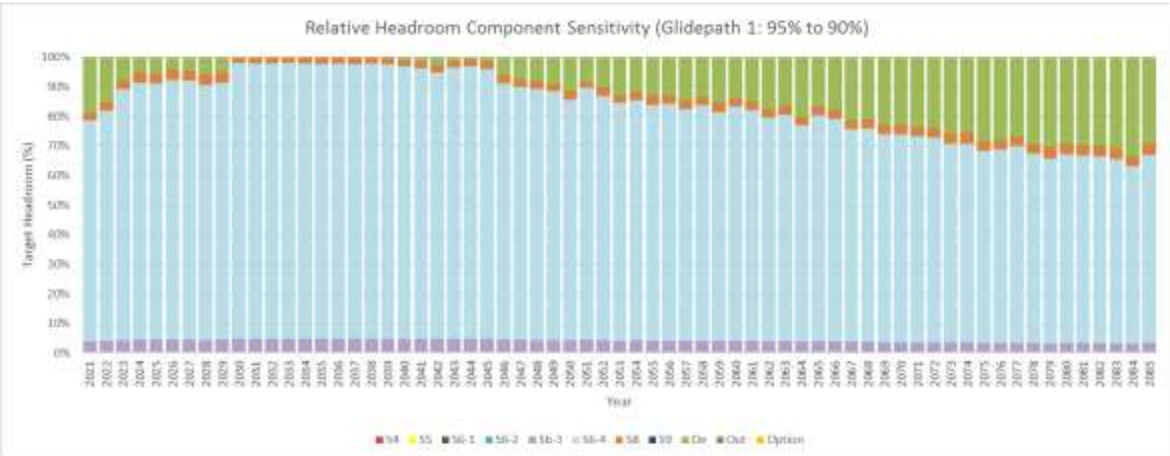


Figure C2.7: Components of target headroom for Kinsall WRZ.

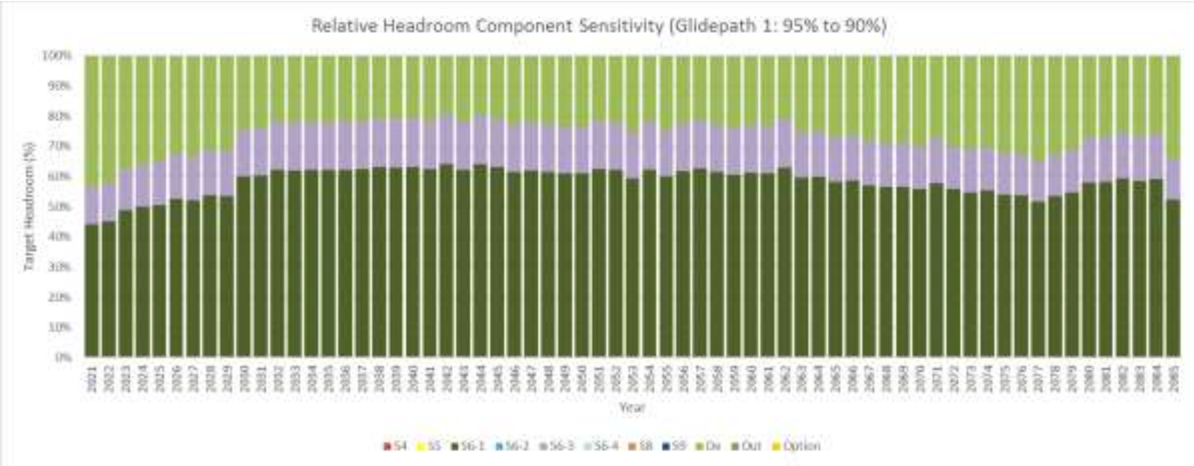


Figure C2.8: Components of target headroom for Mardy WRZ.

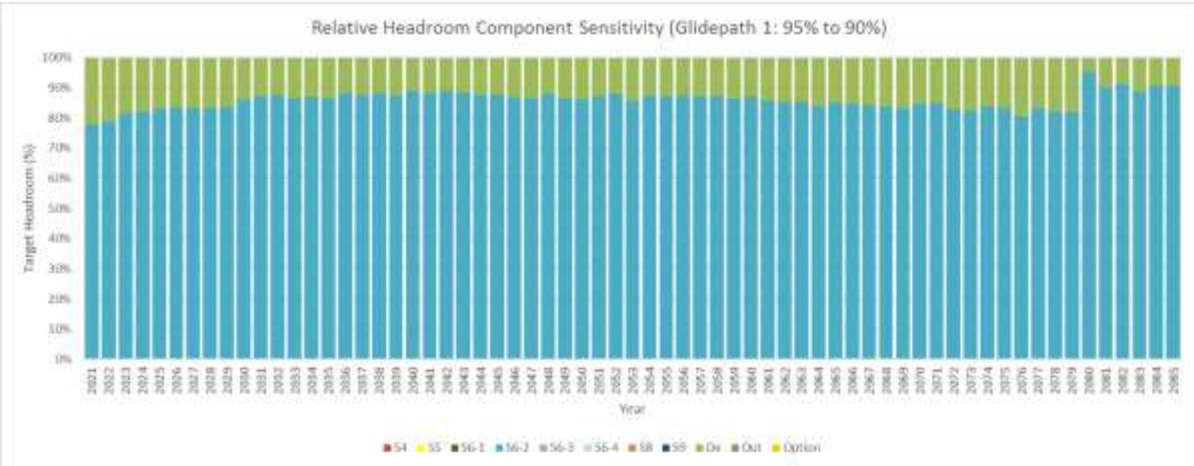


Figure C2.9: Components of target headroom for Newark WRZ.

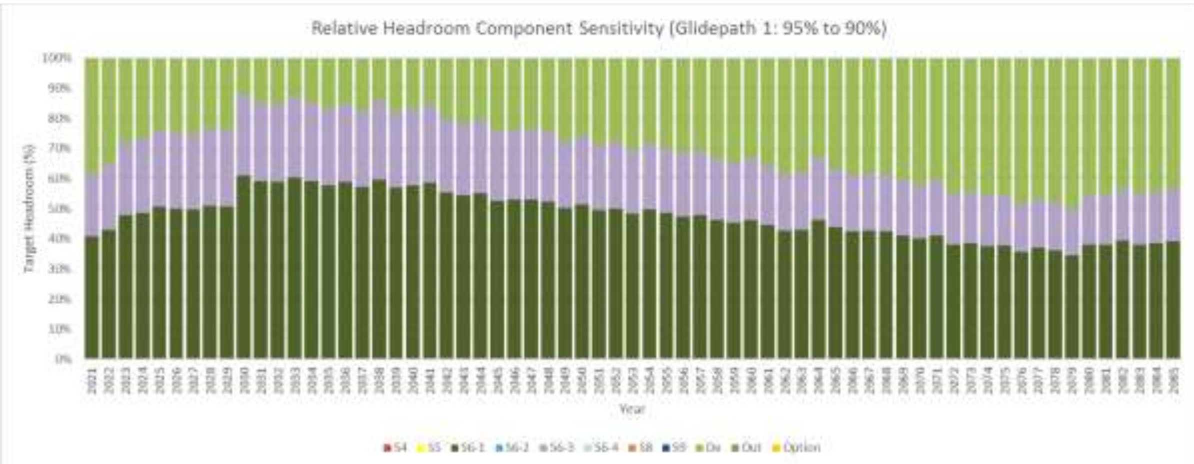


Figure C2.10: Components of target headroom for North Staffordshire WRZ.

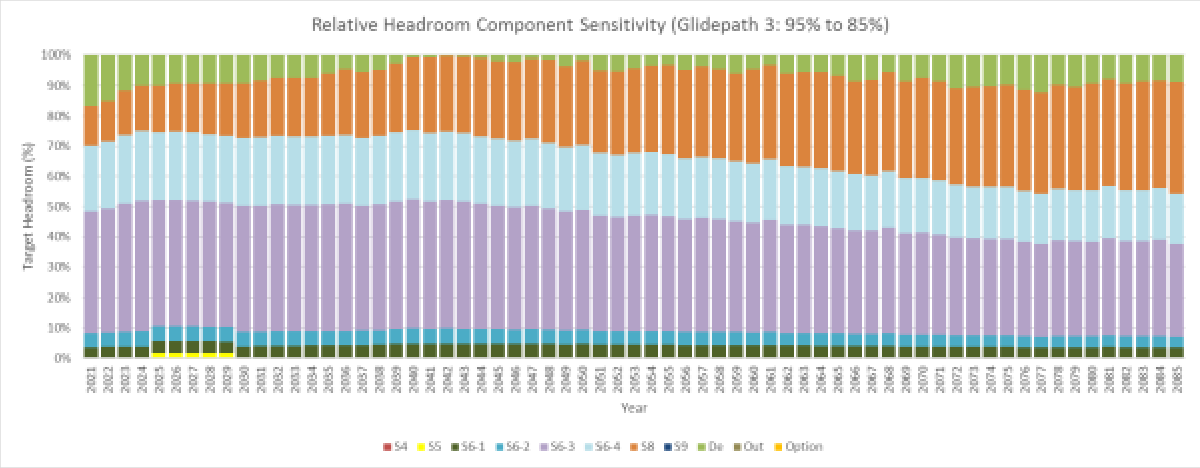


Figure C2.11: Components of target headroom for Nottinghamshire WRZ.

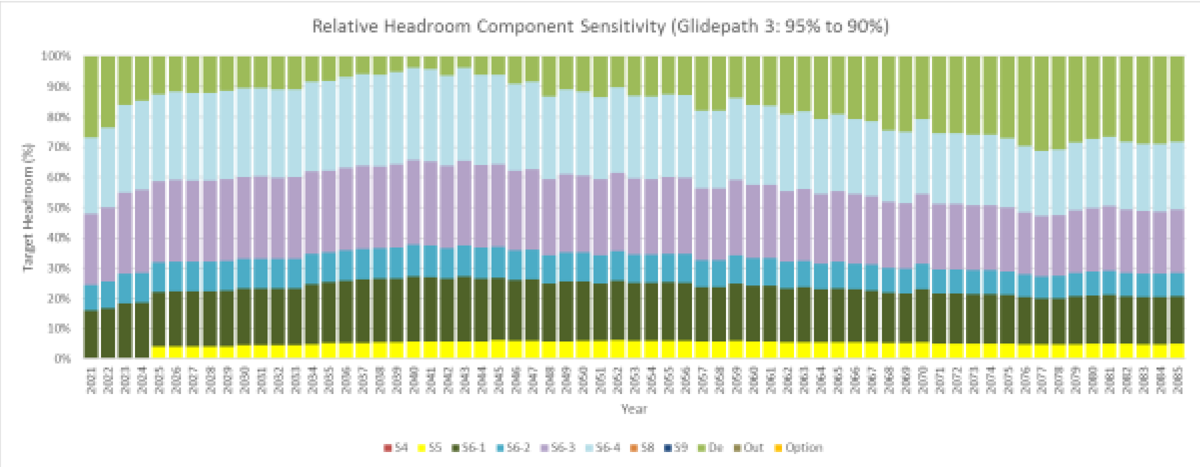


Figure C2.12: Components of target headroom for Ruyton WRZ.

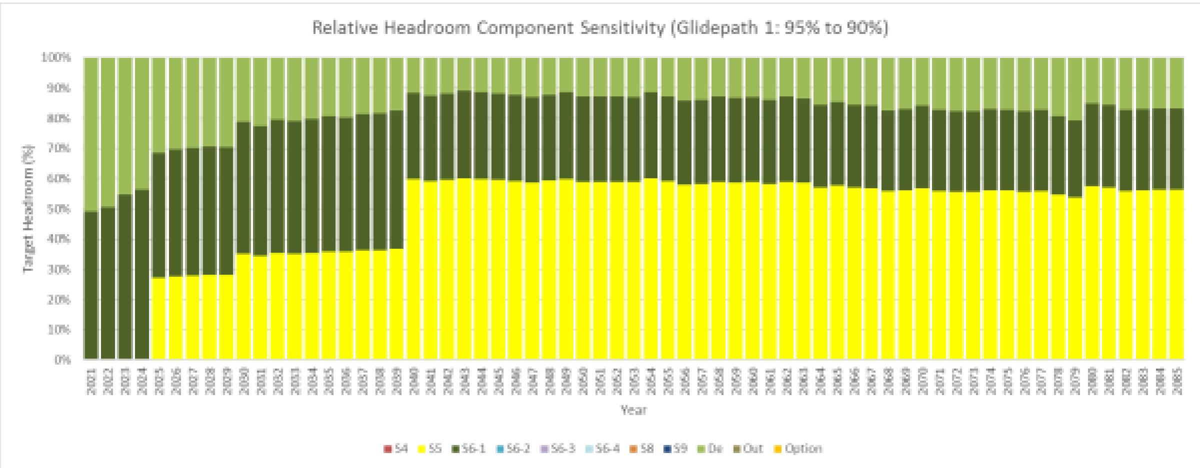


Figure C2.13: Components of target headroom for Shelton WRZ.

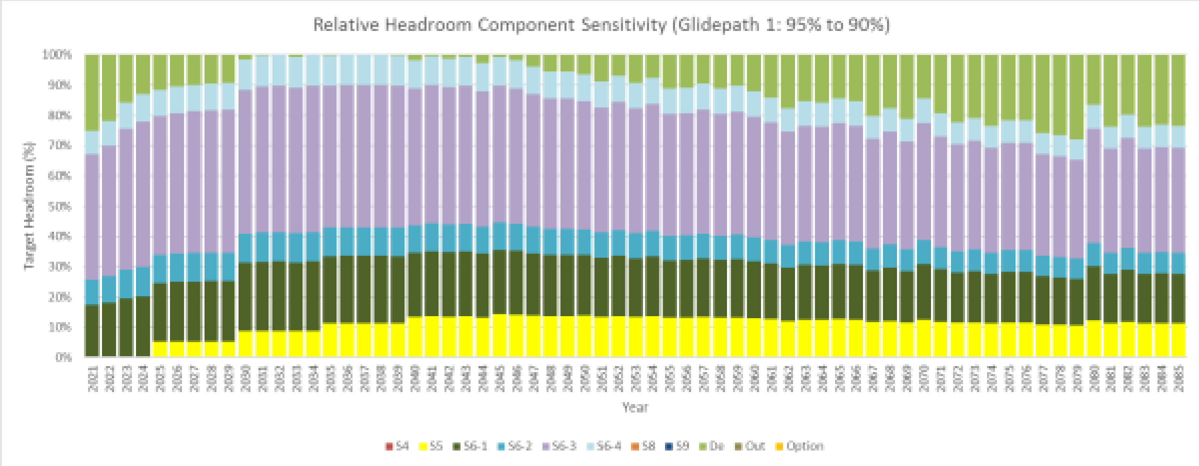


Figure C2.14: Components of target headroom for Stafford WRZ.

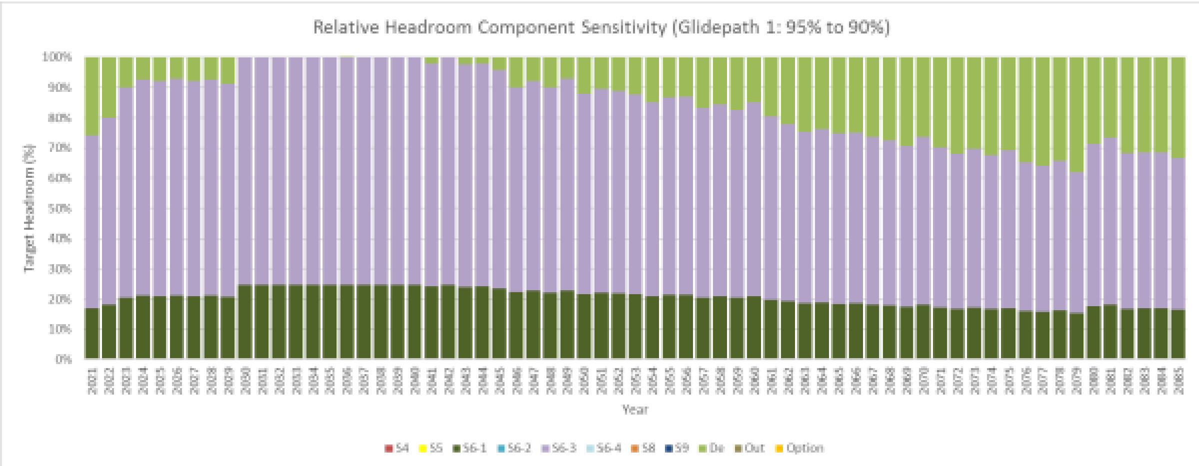


Figure C2.15: Components of target headroom for Strategic Grid WRZ.

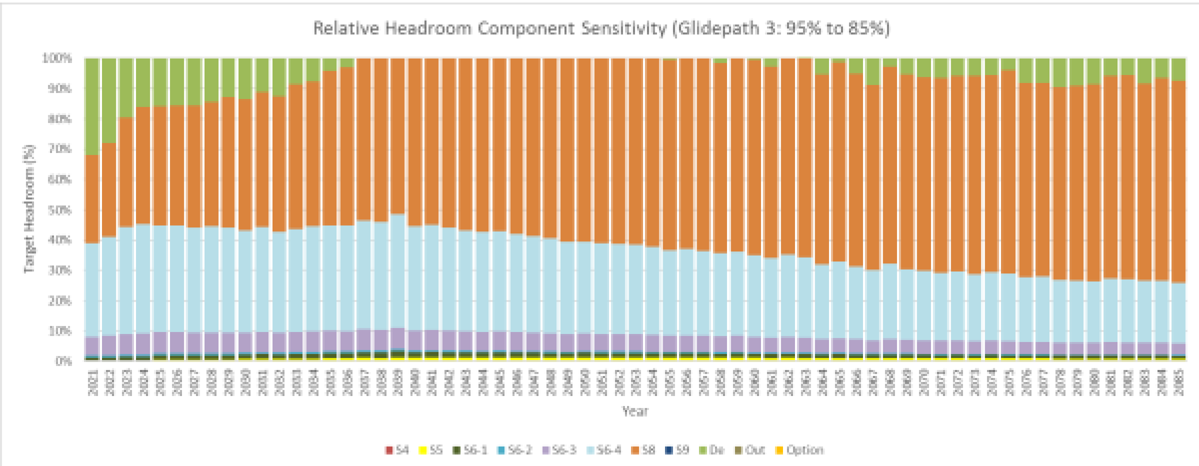


Figure C2.16: Components of target headroom for Whitchurch and Wem WRZ.

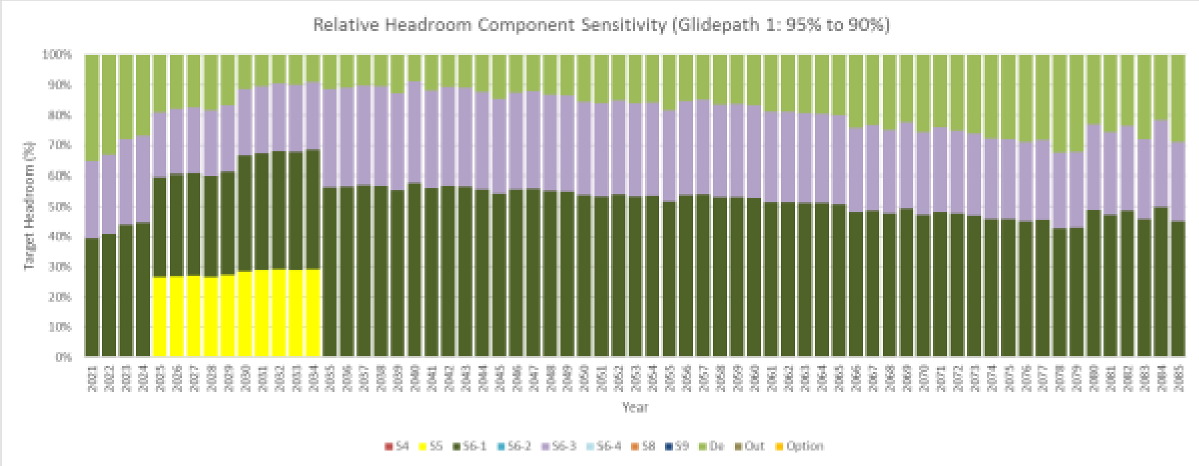
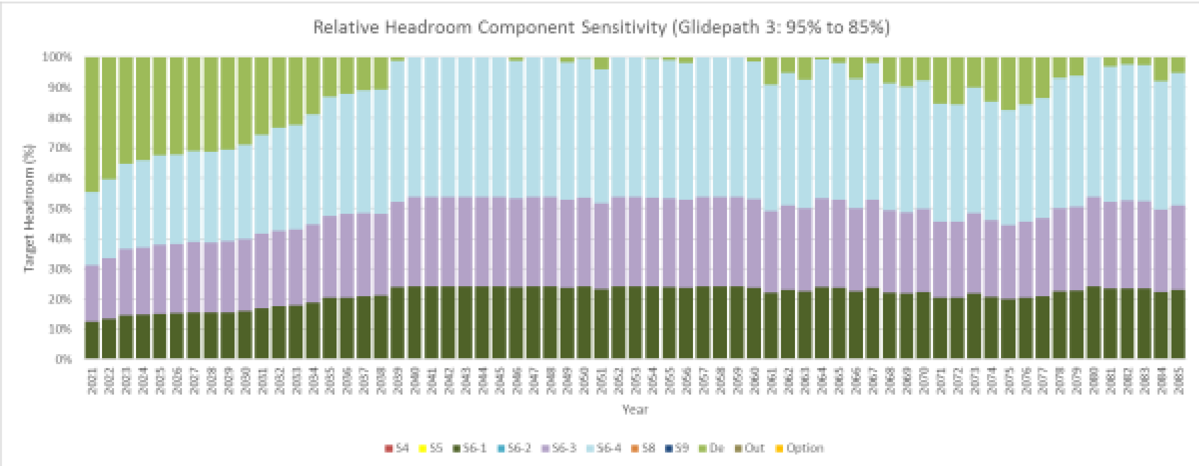


Figure C2.17: Components of target headroom for Wolverhampton WRZ.



C3 Baseline supply/demand balance projections

The methodologies and assumptions behind our projections of our future supply capability, outage risks, demand for water across our region and headroom uncertainties are described in detail in Appendices A, B and C. The analysis of these issues comes together in our assessment of the overall balance of water supply and demand over the next 60 years. Below we discuss our assessment of the 'baseline' supply demand balance position from now until 2085.

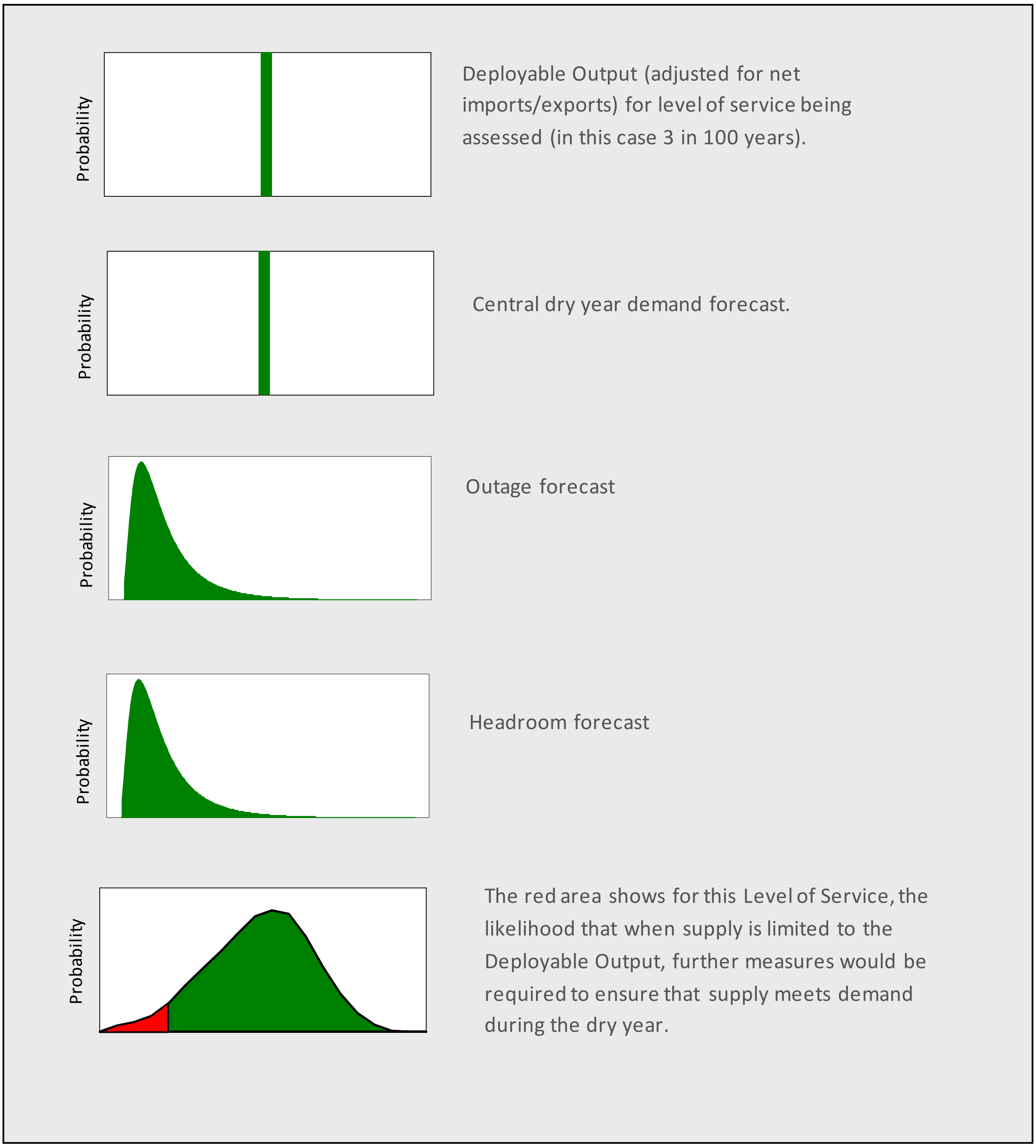
The 'baseline' scenario demonstrates what the supply/demand outlook would be based on our projected changes to future demand and water available for use, but assuming no future investment in new supplies and no change from our current AMP7 demand management and leakage policies. It depicts a scenario in which a dry year could occur in any year between now and 2085. Under that scenario we have assessed the demand for water we would expect to have to meet using the resources we could rely upon under those conditions, with the likely outage and headroom requirements taken into account. This scenario is used to test whether future investment will be required to maintain the balance of supply and demand and to ensure that we can meet our target levels of service.

The principal equation governing the calculation of the supply demand balance is:

Balance of Supply = Deployable Output – Exports + Imports – Outage – Headroom – Demand

Using this approach, the balance of supply is calculated for each year in the planning period (2025–2085). Both the headroom and outage requirements have been assessed on a probabilistic basis. The impact of this probabilistic assessment on the calculated supply demand balance is illustrated in Figure C3.1. Our analysis has been carried out over the 60 year planning period to derive the mean balance of supply in each year along with the range of uncertainty around the mean. The range of uncertainty has been plotted to show the probability that the supply and demand will be in surplus, in balance or in deficit.

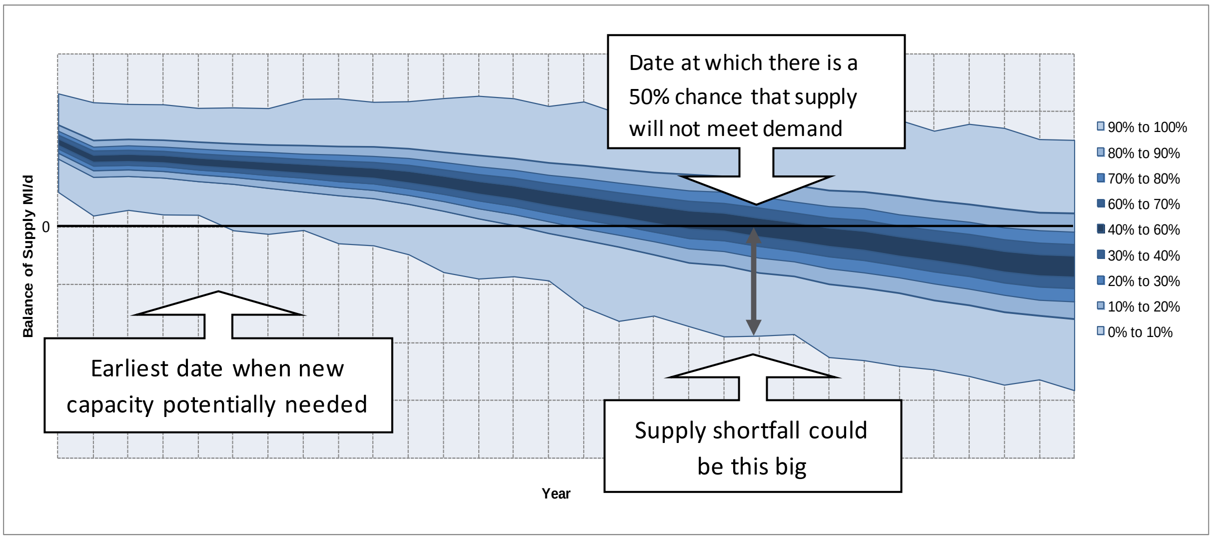
Figure C3.1: Calculating the balance of supply and demand in a WRZ.



C3.1 Interpreting supply demand balance uncertainty

Figure C3.2 below shows a typical result from the supply demand balance uncertainty analysis. The percentile ranges show the probability of supply meeting demand in future years given the uncertainties that have been assessed for each of the key planning components.

Figure C3.2: The supply demand balance with different levels of certainty/uncertainty. The exact temporal range and specific years of the x-axis below is not important but for reference it represents a period of approximately 30 years.



The example shown in Figure C3.2 shows a general trend of loss of DO over time combined with a growth in demand for water, resulting in a worsening supply/demand position. The percentile distribution about the mean projection increases through the planning period reflecting greater uncertainty going forward.

Generally, the supply demand balance graph can be used as the basis for investment planning for a resource zone. We make our investment decisions on the need for additional demand management measures (including leakage reduction, metering and water efficiency) and new water sources based on maintaining a given level of certainty in the balance of supply.

The point at which the 0%ile crosses the 0 Ml/d axis in Figure C3.2 shows the earliest point at which new sources or demand management measures could be required to ensure the level of service will be met, accounting for all identified uncertainty in the resource zone. The larger the risk the company is prepared to accept that supply may not meet demand; the longer it will be before these measures will need to be implemented.

The size of any supply/demand shortfall, and the scale of any resulting investment, is to some extent determined by the level of planning uncertainty that the company is prepared to accept. As explained in section C2.3.1, for our dWRMP24 we have adopted a target headroom requirement that reduces over time. The target headroom profile reflects the fact that medium to long term uncertainties can be managed over time, and so it would be inappropriate to plan to maintain a high level of target headroom throughout the whole planning period. Instead, we plan to accept a manageable degree of risk in our AMP8 supply demand balance and to accept an increasing level of risk in our longer-term planning horizon.

C3.2 Baseline supply demand balance results for individual WRZs

The results of our baseline supply demand balance assessment of our 15 WRZs are shown in Figures C3.3 to C3.17. In many of our zones we see step changes within the balance of supply graphs as a result of the DO reductions to restore sustainable abstraction and DO reductions for Environmental Destination. The resultant loss of DO is represented within the supply demand balance. We make no allowance for the loss or reduction of abstraction licences in our target headroom assessment.

The figures show that for the Bishops Castle, Forest and Stroud, Kinsall, Mardy, Newark, North Staffordshire, Nottinghamshire, Ruyton, Shelton, Stafford, Strategic Grid, Whitchurch and Wem, and Wolverhampton zones, there is a high probability that without new investment, either in demand management and/or supply options, we will not have sufficient supplies available to meet expected water demand from our customers. In the Chester zone there is some risk later in the planning period that we may need to take measures to ensure we can maintain our target levels of service. However, the risk may be reduced by our leakage and demand management programmes in these zones. For Rutland, the figures illustrate that we have high confidence that we will be able to meet expected demand from our customers without the need for investment in new sources of water.

Figure C3.3: Balance of supply for Bishops Castle WRZ.

Figure C3.4: Balance of supply for Chester WRZ.

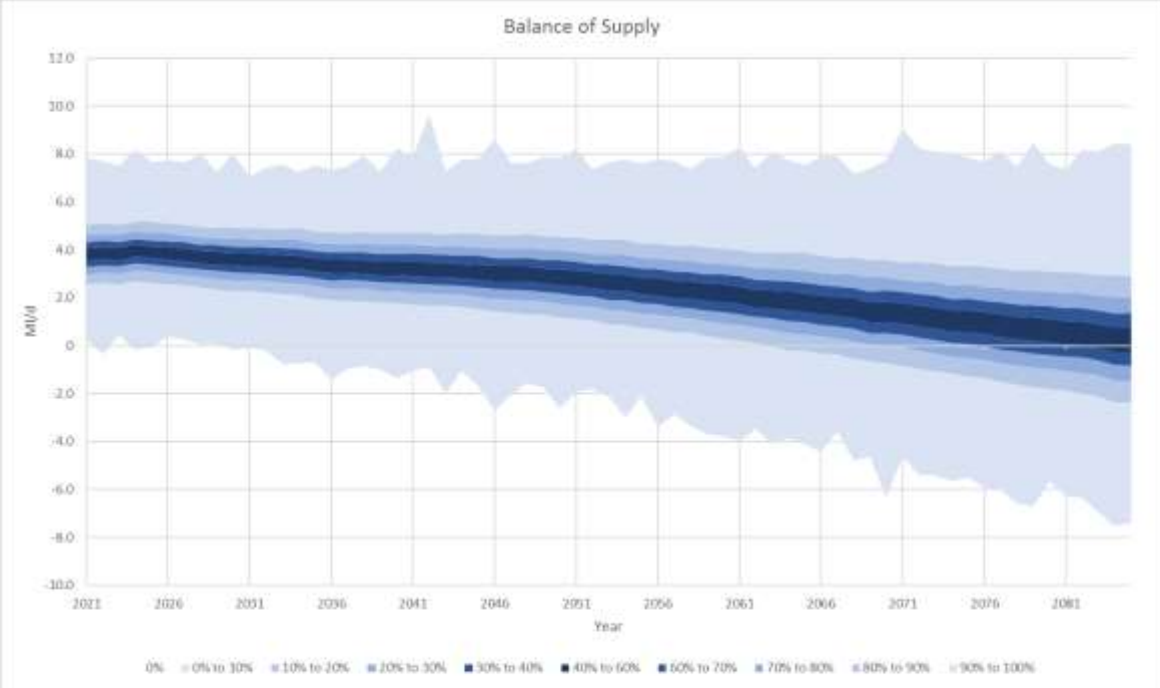


Figure C3.5: Balance of supply for Forest and Stroud WRZ.

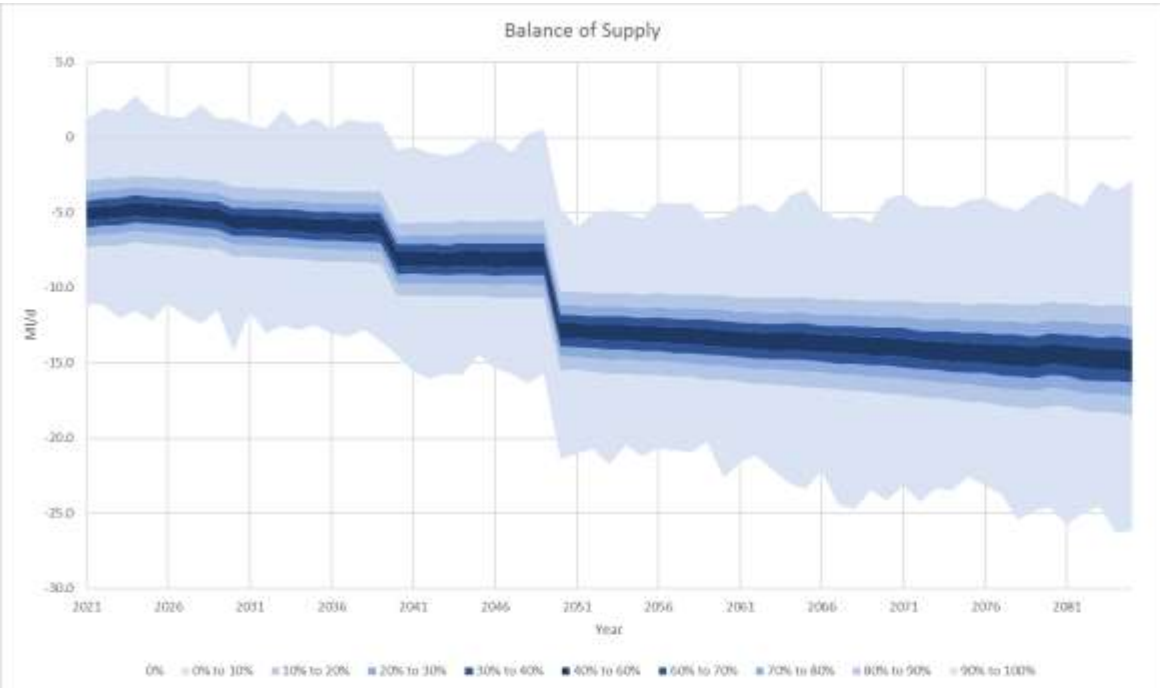


Figure C3.6: Balance of supply for Kinsall WRZ.

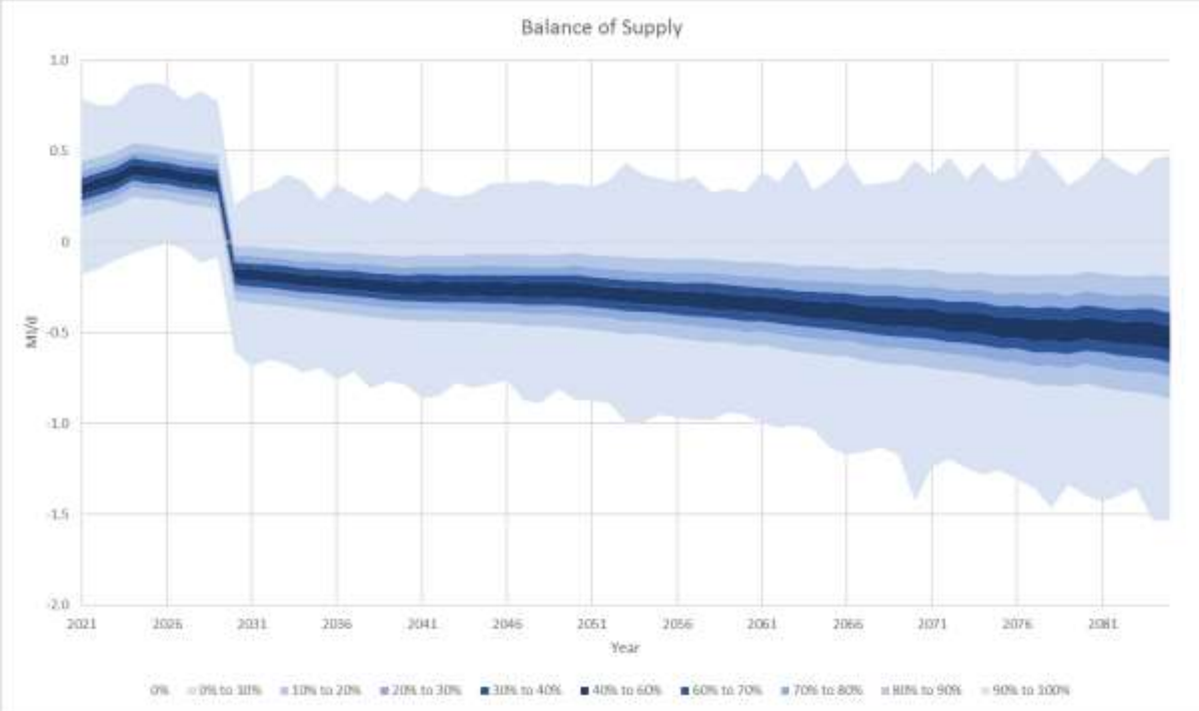


Figure C3.7: Balance of supply for Mardy WRZ.

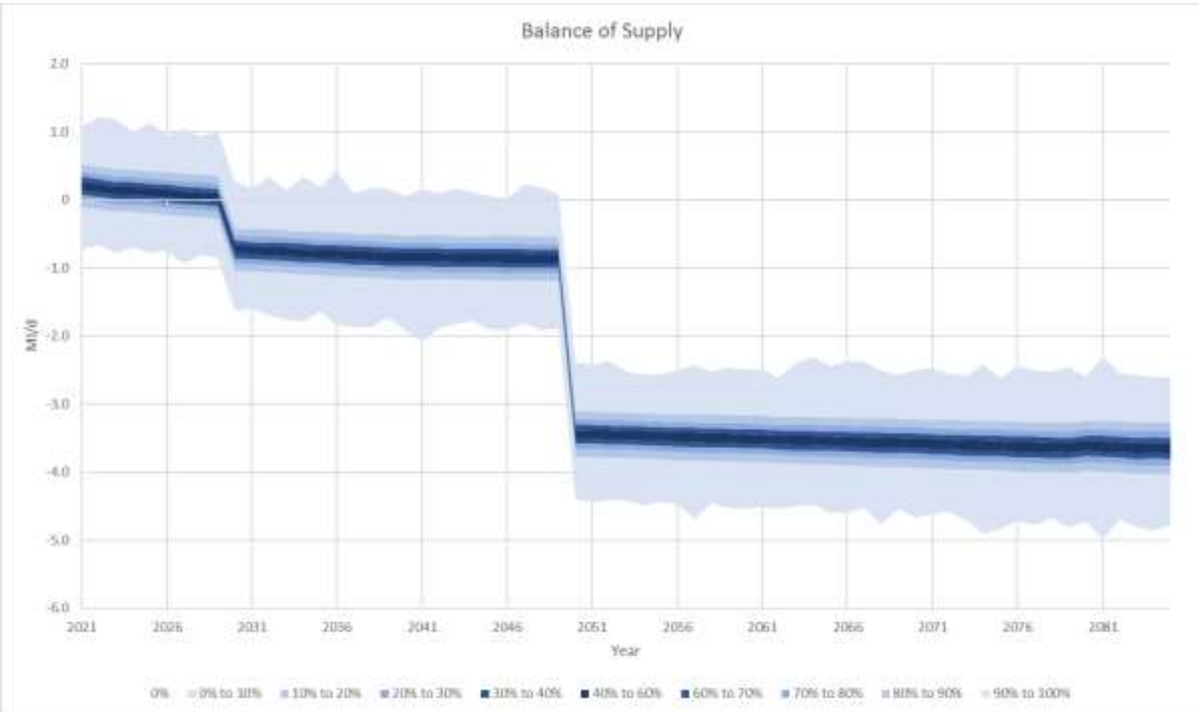


Figure C3.8: Balance of supply for Newark WRZ.

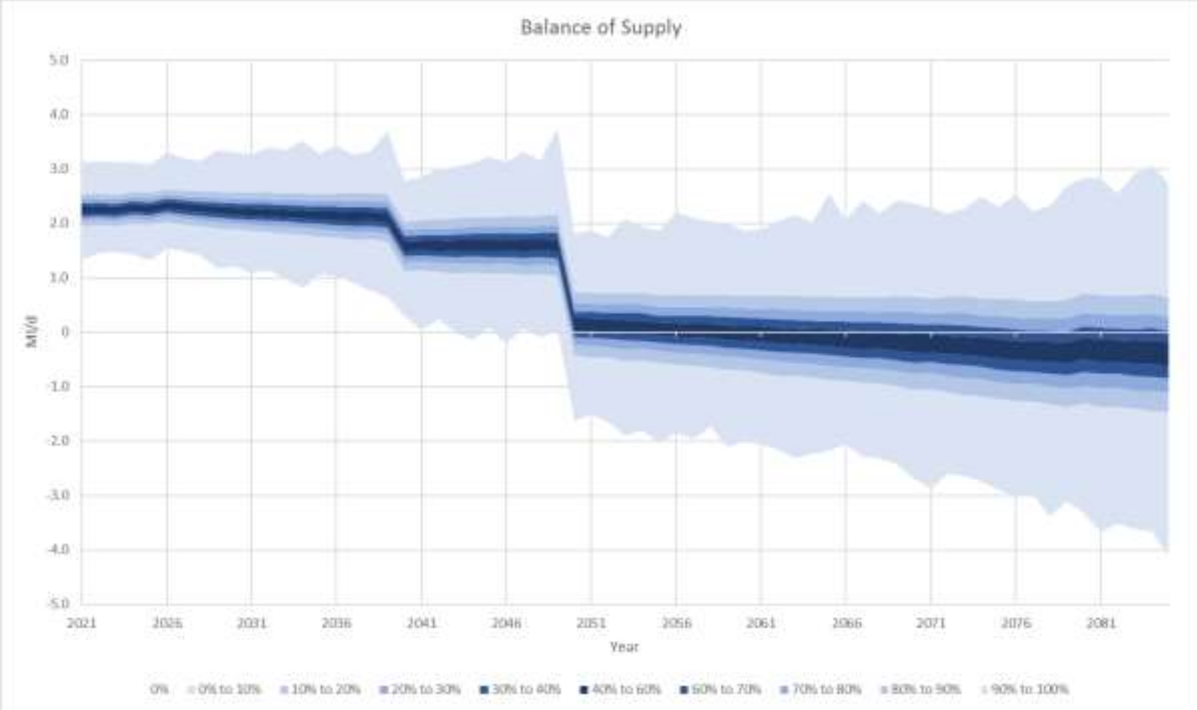


Figure C3.9: Balance of supply for North Staffordshire.

Figure C3.10: Balance of supply for Nottinghamshire WRZ.

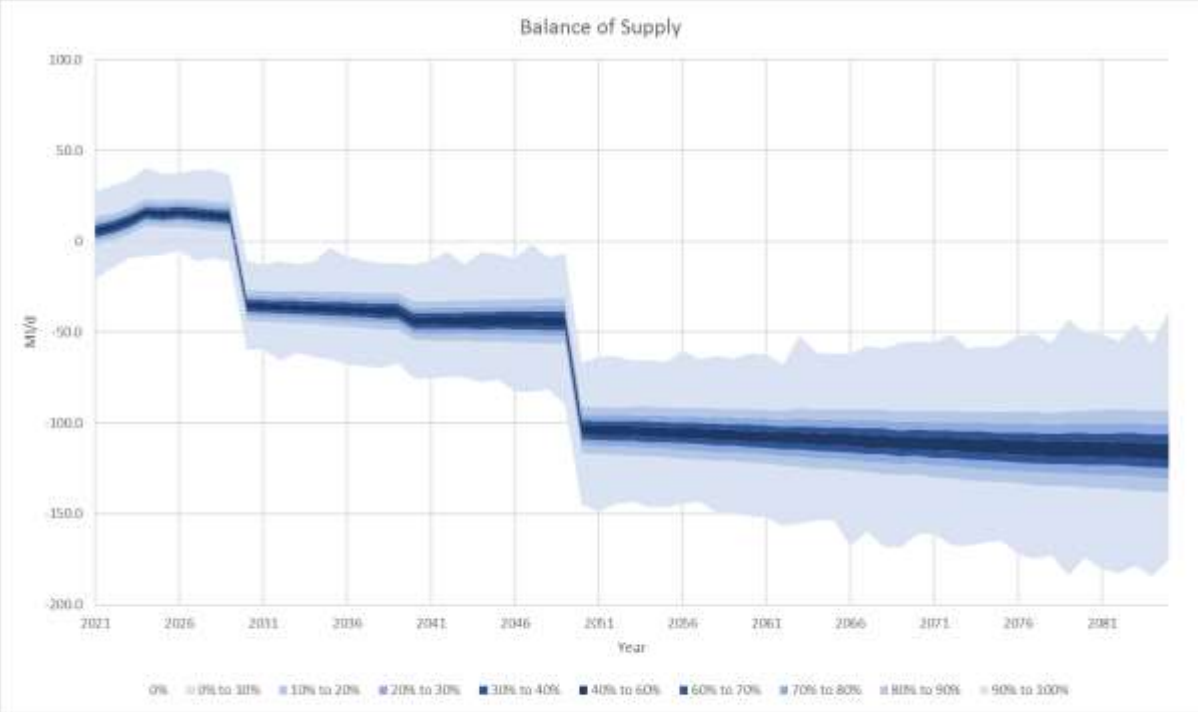


Figure C3.11: Balance of supply for Rutland WRZ.

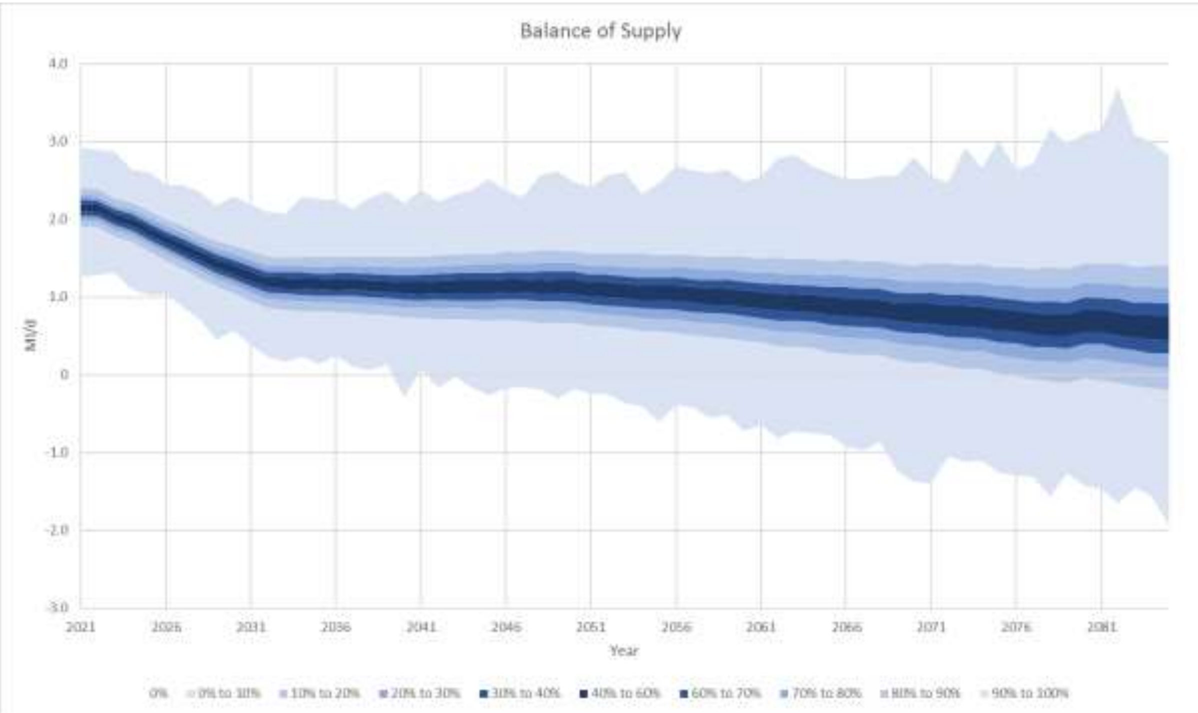


Figure C3.12: Balance of supply for Ruyton WRZ.

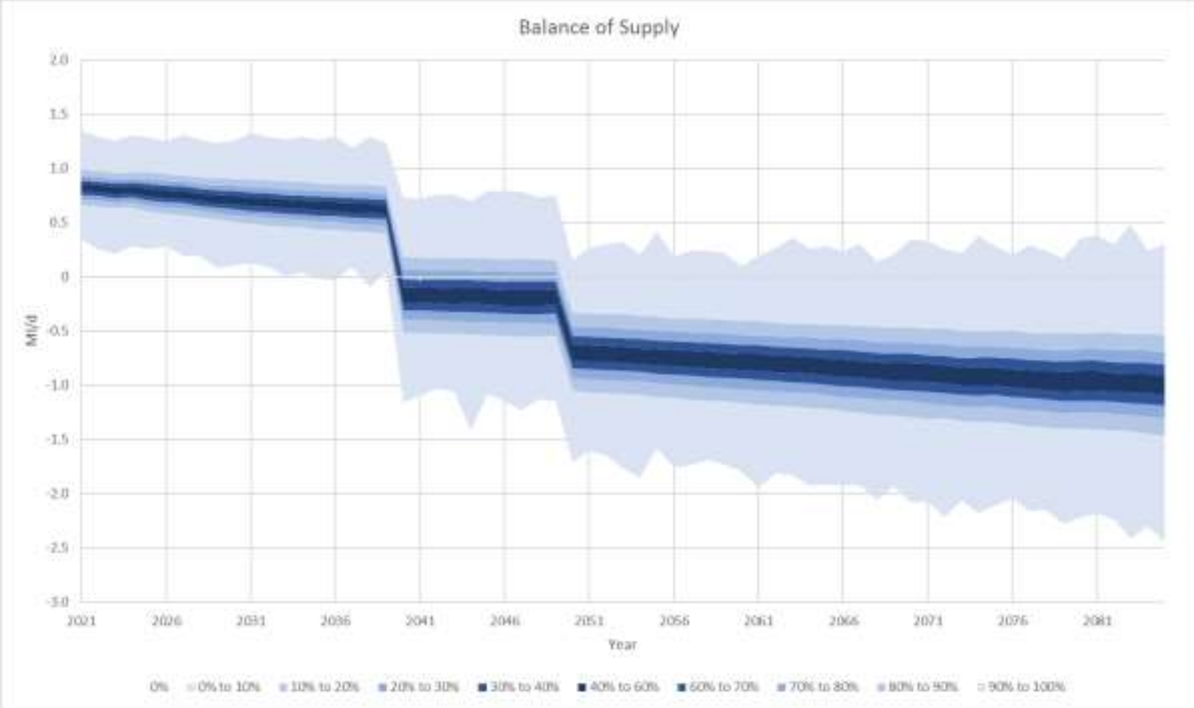


Figure C3.13: Balance of supply for Shelton WRZ.

Figure C3.14: Balance of supply for Stafford WRZ.

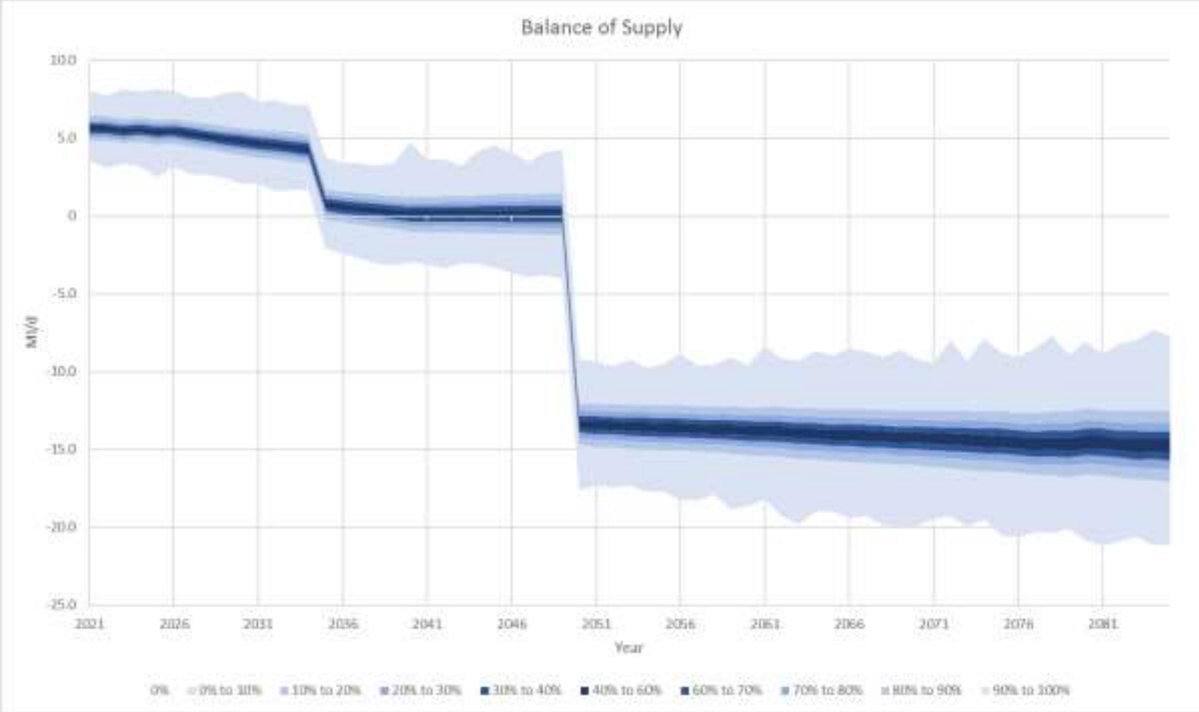


Figure C3.15: Balance of supply for Strategic Grid WRZ.

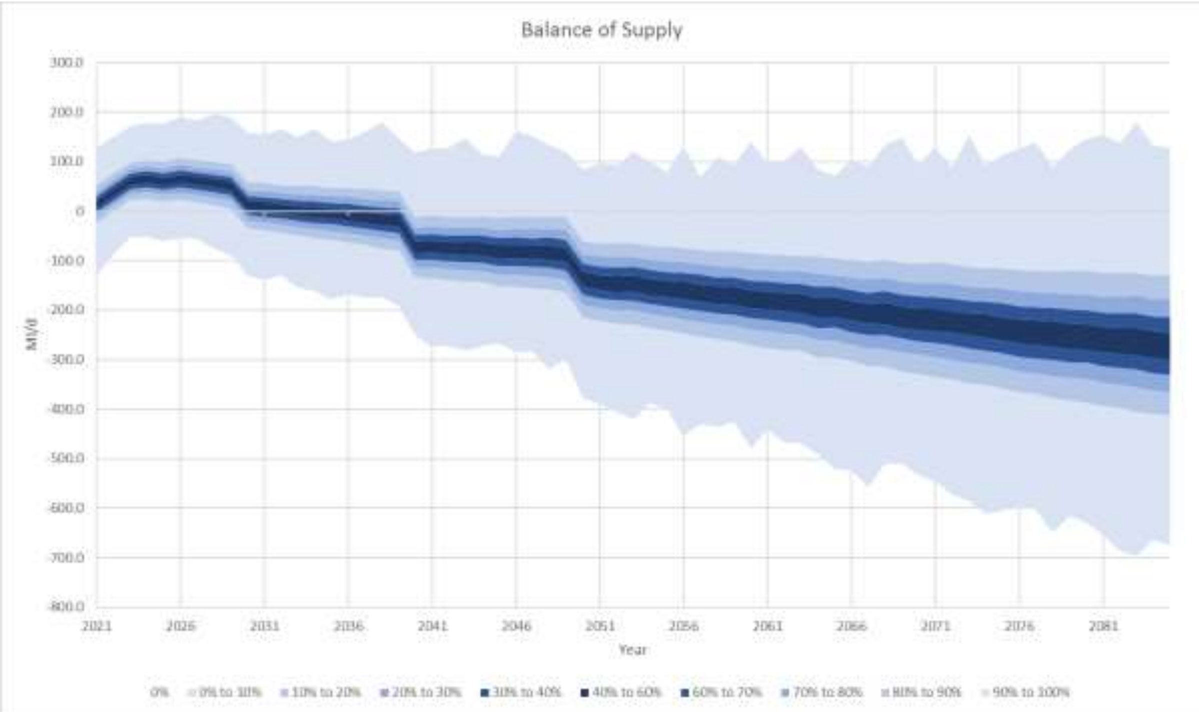


Figure C3.16: Balance of supply for Whitchurch and Wem WRZ.

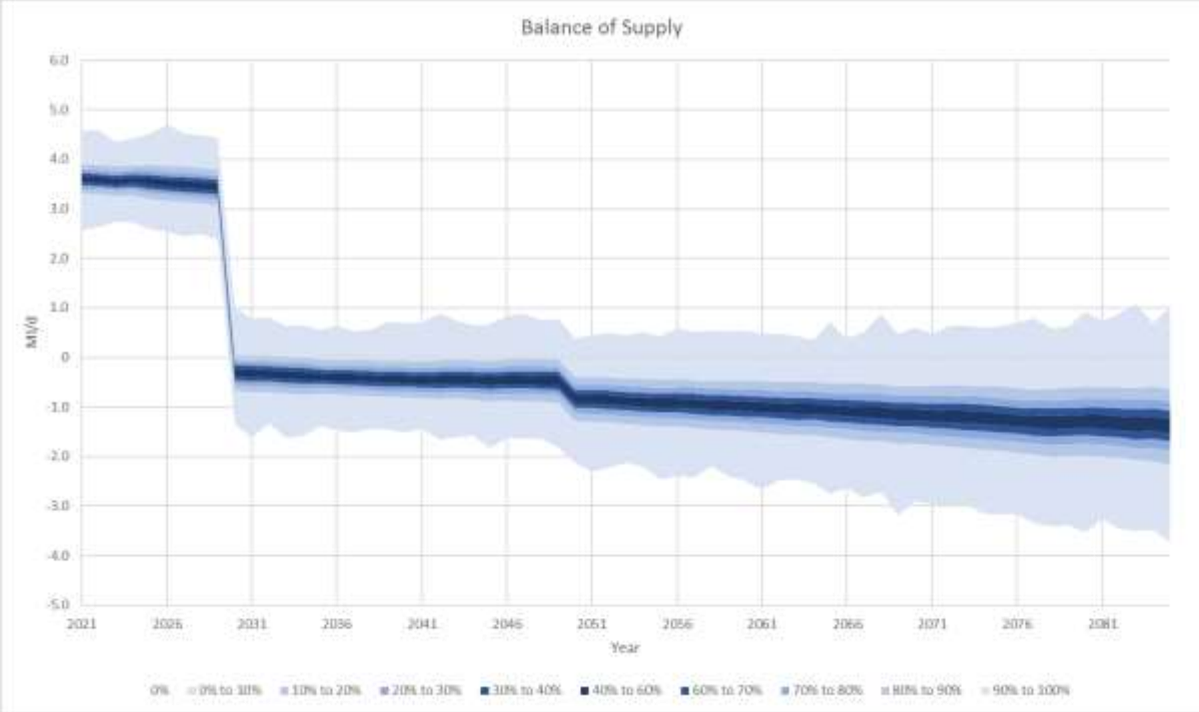
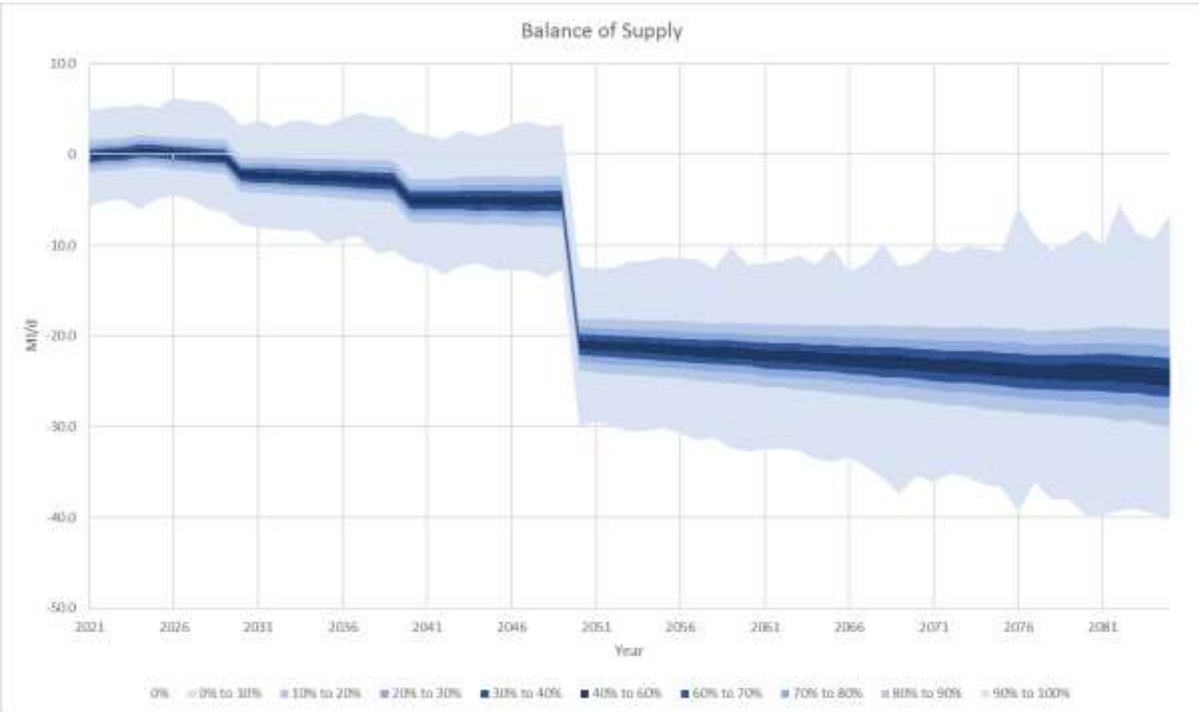


Figure C3.17: Balance of supply for Wolverhampton WRZ.



References

Met Office Hadley Centre (2018). United Kingdom Climate Projections 2018 (UKCP18) Probabilistic Climate Projections, Met Office Hadley Centre, Exeter, UK.

Ofwat (2021). PR24 and beyond: Long-term delivery strategies and common reference scenarios, https://www.ofwat.gov.uk/consultation/pr24-and-beyond-long-term-delivery-strategies-and-common-reference-scenarios/

UK Water Industry Research Limited (UKWIR) (2002). An improved methodology for assessing headroom, Report Ref. No. 02/WR/13/2

UK Water Industry Research Limited (UKWIR) (2016). WRMP 2019 methods – decision making process: Guidance, Report Ref. No. 16/WR/02/10

UK Water Industry Research Limited (UKWIR) (2016). WRMP 2019 methods – risk based planning, Report Ref. No. 16/WR/02/11

Waterwise (2010). Evidence base for large-scale water efficiency in homes: Phase II interim report, https://waterwise.org.uk/wp-content/uploads/2019/10/Evidence-base-for-large-scale-water-efficiency-in-homes.phase-ii-interim-report.pdf

Environment Agency and Cyfoeth Naturiol Cymru Natural Resources Wales (2016). Water Resources Planning Guideline (WRPG)

Environment Agency, Ofwat and Cyfoeth Naturiol Cymru Natural Resources Wales (2021). Water Resources Planning Guideline (WRPG), https://www.gov.uk/government/publications/water-resources-planning-guideline/water-resources-planning-guideline