Appendix A - How much water do we have available?

A1 Our Water Resource Zones - Redacted

A2 Calculating Deployable Output – Redacted

A3 Impacts of Climate Change on Supply

A3.1 Overview of current approach

The Environment Agency's 2017 Water Resources Planning Guidelines (WRPG) require companies to assess the risk and possible impact of climate change on the deployable output of their current and future sources of water. Companies can use their 2014 Water Resources Management Plan (WRMP14) assessment of climate change, or a method outlined in:

- Environment Agency (2013) Climate change approaches in water resources planning – Overview of new methods
- Environment Agency (2017) Estimating impacts of climate change on water supply

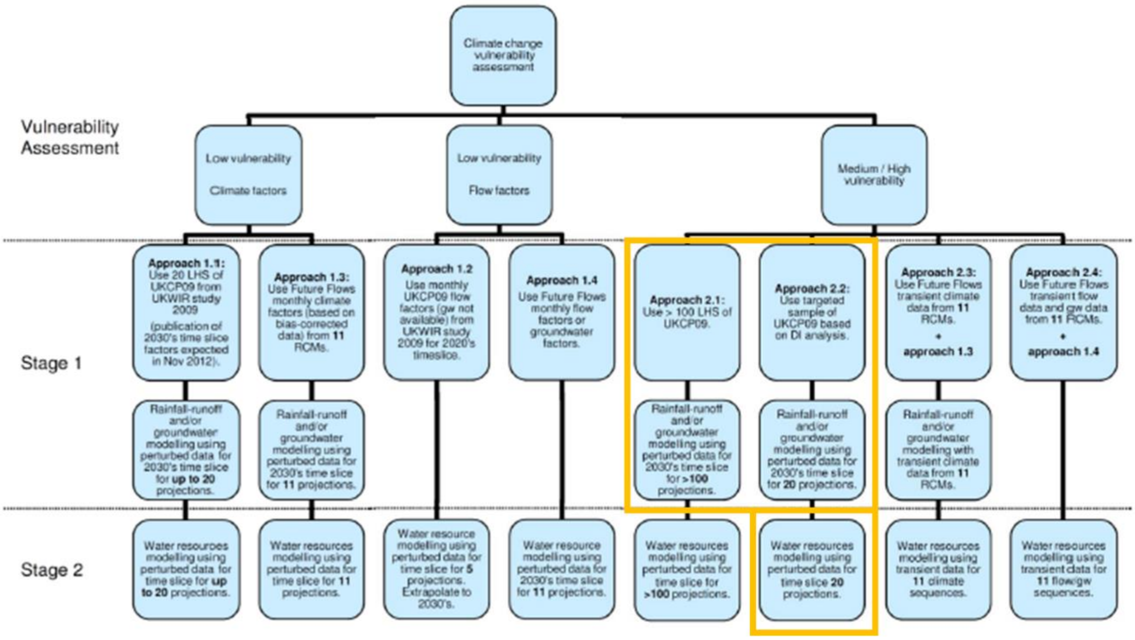
We carried out a vulnerability assessment to identify which of our water resource zones (WRZs) are most sensitive to the potential impacts of climate change. This confirmed our findings from our WRMP14 assessment, which demonstrated that our largest WRZs (the Strategic Grid and Nottinghamshire) were both vulnerable to potential changes in rainfall and temperature. With the exception of groundwater sources in the Forest and Stroud WRZ, the majority of groundwater sources were considered to be low vulnerability. However, in order to maintain spatial coherence across our WRZs (especially zones containing both surface water and groundwater sources), we have opted to apply a "high" vulnerability method to all zones to assess the potential impacts on deployable output. This approach uses the UKCP09 projections (medium emission scenario) directly.

Figure A3.1 shows the range of methodologies recommended in the Environment Agency's WRPG, which was published in 2012. The approach we applied is highlighted by the orange box and consists of:

- Approach 2.1 – Used to derive 100 Latin Hypercube Samples from the full UKCP09 scenarios
- Approach 2.2 – Following Approach 2.1, this was then used to derive a sub-sample of 20 scenarios using a Drought Indicator derived specifically for the sources in our region.

A full explanation of our reasons for choosing this method can be found in Appendix A3.2 of our WRMP14.

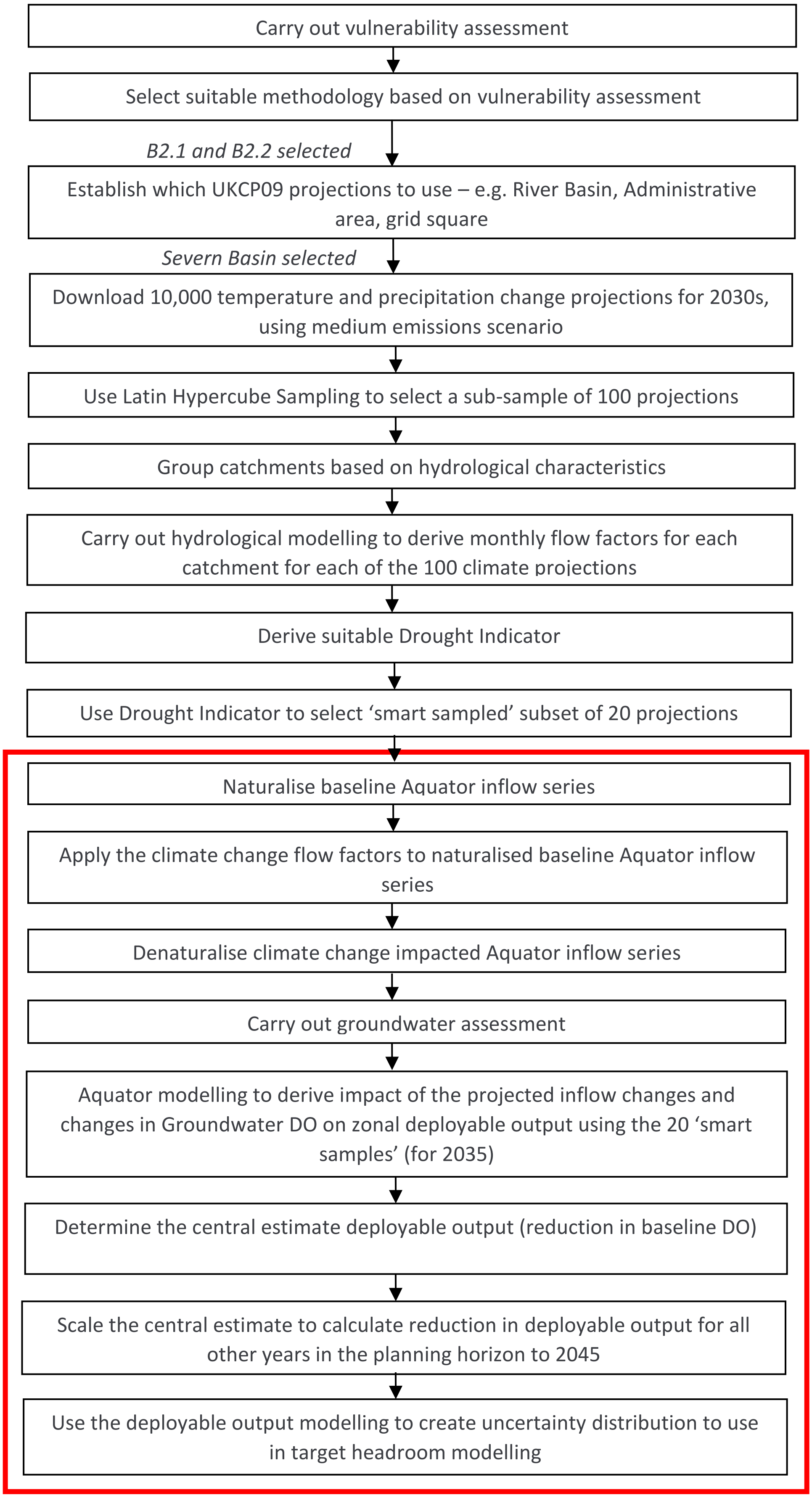
Figure A3.1: Summary of climate change impacts assessment methods



For consistency with our WRMP14 we have used the same methodology to inform our current assessment, using the UKCP09 2030s time slice (2020-2049) to inform our baseline plan. We have also carried out an assessment using the 2080s time slice (2070–2099), which we have used to test the robustness of our long term plan and to understand how sensitive our plan would be to more extreme climate change scenarios. The 2080s projections have not been used to determine the strategy for the 25 year plan. However, they have been used as part of the long time-horizon modelling we have carried out, which looks ahead to 2100. Our assessment of the impacts of the 2080s climate change scenarios can be found in section A3.7.

Figure A3.2 shows an overview of the full methodology we followed for WRMP14. The red box indicates the steps taken for our current assessment and informing our current plan, WRMP19. A step by step description of our approach can be found in section A3.3. An overview of the impacts of climate change on our surface water and groundwater sources can be found in sections A3.4 and A3.5 respectively, and details of the impact on our water resource zone deployable output in section A3.6.

Figure A3.2: Overview of methodology followed to assess WRZ vulnerability to climate change



A3.2 Vulnerability Assessment: Surface water

Vulnerability Assessment: Surface water

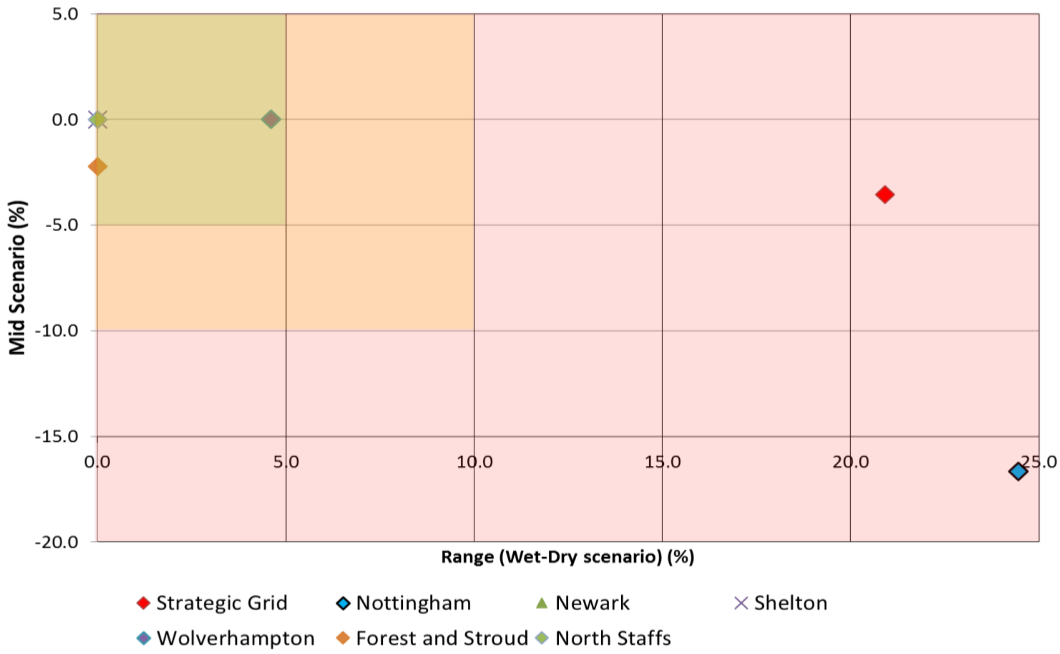
In order to decide which method to adopt, we carried out a vulnerability assessment for each of our water resource zones. By doing this, we were able to identify which zones are likely to be most sensitive to the effects of climate change and to determine whether our previous approach and assumptions are still applicable. Using our 2014 vulnerability assessment as a starting point, we have used a variety of sources of information to refresh and review the conclusions, including:

- Model outputs (deployable output modelling, modelled reservoir drawdown, supply- demand balance)
- Our abstraction licence documents and source information
- Our Drought Plan
- Our WRMP14
- Our climate change adaptation report “Future Proofing”, which was published in 2015.

To quantify the vulnerability of our WRZs to the potential impacts of climate change we used our WRMP14 climate change deployable output assessment. This modelling used our chosen method, Approach 2.2 (shown in Figure A3.1) which reduced the 10,000 UKCP09 projections to a sample of 20 by “smart sampling” using a drought indicator specific to our region. This sub-sample included 10 projections towards the “dry” end of the projection range and 10 projections which were equally spaced across the remaining range. For our WRMP14 we carried out deployable output modelling for each of our conjunctive use WRZs (those zones which use a combination of impounding reservoirs, river abstractions and groundwater sources to supply our customers) using each of these 20 projections. The zones showing the biggest range of impacts were the Strategic Grid and Nottinghamshire.

From the WRMP14 deployable output modelling results we generated a magnitude versus sensitivity plot, shown in Figure A3.3. This plot shows the percentage change in deployable output from the median or “mid” range scenario (rank 50 projection) against the range of uncertainty. The range of uncertainty is based on the difference between the “dry” rank 10 and “wet” rank 90 projections.

Figure A3.3: Magnitude versus Sensitivity plot for our conjunctive use water resource zones showing the climate change mid scenarios percentage change in deployable output (from the baseline) and the uncertainty range



Using the results from the magnitude versus sensitivity plot, we identified the vulnerability classification for each WRZ using the vulnerability scoring matrix shown in Table A3.1.

Table A3.1: Vulnerability scoring matrix

Uncertainty range (% change wet to dry)	Mid scenario (% change in deployable output)		
	< -5%	> -5%	> -10%
<5%	Low	Medium	High
6 to 10%	Medium	Medium	High
11 to 15%	High	High	High
>15%	High	High	High

The magnitude versus sensitivity plot and scoring matrix indicate that our two largest zones, the Strategic Grid and Nottinghamshire, are still both classified as "high" vulnerability. All our other conjunctive use zones are "low" vulnerability.

Vulnerability assessment: Groundwater

Our groundwater vulnerability analysis considered three methods of selecting which groundwater sources to include in the assessment of impacts on groundwater deployable output (DO) due to climate change:

- Option 1: Only consider the sources identified as flow or level constrained (i.e. where the DO defined for the source is limited by the flows or level at the abstraction point). These sources comprise approximately 15% of our groundwater sources. Under this assessment, only the sources that were initially screened as vulnerable to level or flow changes would be assessed for climate change.

- Option 2: Consider the sources identified as flow or level constrained and those in the areas of the West Midlands, Bromsgrove and East Midlands and Yorkshire Sandstone groundwater model, that comprise a number of licence constrained sources. Under this assessment the sources that were initially screened as vulnerable to level or flow changes would be assessed. Also, under this assessment the regional groundwater models would be utilised to predict recharge changes to the groundwater units under the various climate change scenarios. This assessment would proportionally reduce the deployable output of any licence constrained sources in the modelled units by the predicted recharge changes to the unit.

- Option 3: All groundwater sources, including infrastructure and licence constrained sources. Under this assessment the sources that were initially screened as vulnerable to level or flow changes would be assessed. The sources that were licence constrained and fell within the regional groundwater models would be assessed (as Option 2) and sources that were licence constrained and fell outside of the groundwater models would be assessed by applying a company-wide change to recharge and proportionally reducing the deployable output by the predicted recharge (and licence) derived changes to the unit.

We were able to use outputs of the historical WRMP09 and recent WRMP14 assessments and modelling work to undertake the initial groundwater vulnerability assessment. Both the WRMP09 and WRMP14 work showed limited impact on flow or level constrained sources. For our assessment, we therefore selected groundwater sources based on Option 1.

Vulnerability assessment: Water Resource Zone Vulnerability Classification

The vulnerability assessment for our conjunctive use and groundwater only zones followed the methodology described in the Environment Agency's WRPG (2012). For each zone we have produced a table containing the information required, in accordance with Table 3.0 of the WRPG. Table A3.2 shows the vulnerability classification for each water resource zone.

Table A3.2: Water Resource Zone vulnerability classification

WRZ Name	Vulnerability
Bishops Castle	Low
Forest & Stroud	Low/Medium
Kinsall	Low
Mardy	Low
Newark	Low
North Staffordshire	Low
Nottinghamshire	High
Rutland	Low
Ruyton	Low
Shelton	Low
Stafford	Low
Strategic Grid	High
Whitchurch & Wem	Low
Wolverhampton	Low

A3.3 Choice of Climate Change scenarios

As discussed in section A2, we have continued to review and update our Aquator model since the publication of our previous WRMP, WRMP14. In order to take into account changes to our water supply system (for example known changes in water treatment works capacities) and our improved inflow series, we have opted to re-model the sub-set of 20 climate projections for the 2030s time slice rather than use the climate change assessment directly from our previous plan. We have carried out additional analysis using UKCP09 projections for the 2080s (2070-2099) time slice, taking into consideration the methods outlined in "Environment Agency (2017) Estimating impacts of climate change on water supply". This is discussed in more detail in section A3.7.

Consistent with our WRMP14 we have adopted a "high" vulnerability approach for all 15 WRZs, including those classified as "low" or "medium" vulnerability, to ensure consistency in our zonal deployable output modelling. The Strategic Grid zone covers a large area of the Severn Trent region, and includes most of our strategic raw water reservoirs (the exception being Tittesworth reservoir, located in the North Staffordshire zone). The Strategic Grid zone is classified as being "high" vulnerability as the modelling produces a wide range of uncertainty - under very wet conditions, the deployable output could be higher than our baseline and under very dry conditions, deployable output could be much lower than baseline depending on the scenario used.

Although the Nottinghamshire zone is supplied by a number of groundwater sources, it also relies on imports from some of the surface water sources in the Strategic Grid. Our modelling has shown that the surface water imports may be impacted by climate change, which has led to the Nottinghamshire zone being classified as "high" vulnerability. Few imports and exports exist between our other water resource zones, however, several of our zones have "shared resources". For example, the Shelton, Wolverhampton and Strategic Grid zones are not physically connected but all abstract from the River Severn, taking water from different locations. Our largest abstractions from these shared resources are used to supply the Strategic Grid zone. Adopting different climate change assessment approaches for our "low" and "high" vulnerability zones when modelled together could result in climate change flow series which are not spatially coherent, and could over, or under, estimate the impact of the changing climate.

Taking the above into consideration, we have used the UKCP09 projections method. The method we adopted is summarised below. Steps 1 to 4 were carried out for our WRMP14, so did not need to be repeated as the assumptions and processes remain unchanged.

Step 1: Selecting the climate change projections – Severn Basin

The UKCP09 projections are available at different resolutions – at River Basin level, Administration District level and individual 25km grid square level. An analysis of the different projection sets available for our region showed that the UKCP09 climate projections from different aggregate areas across our region all provide similar climate change impacts.

The River Severn is an important source of supply for the Strategic Grid, Shelton and Wolverhampton water resource zones. The Severn River Basin area covers the headwaters and a large stretch of the River Severn and is also close in proximity to the headwaters of the River Trent. It was therefore deemed to be a valid approach to apply the Severn River Basin projection set across the whole of our region, ensuring consistency in the modelling approach. The UKCP09 Severn River Basin Medium Emissions projections for the 2030s were used for our assessment, with a sub-set of 100 projections being selected using Latin Hypercube Sampling (LHS) for use in the hydrological modelling.

Step 2: Grouping of catchments

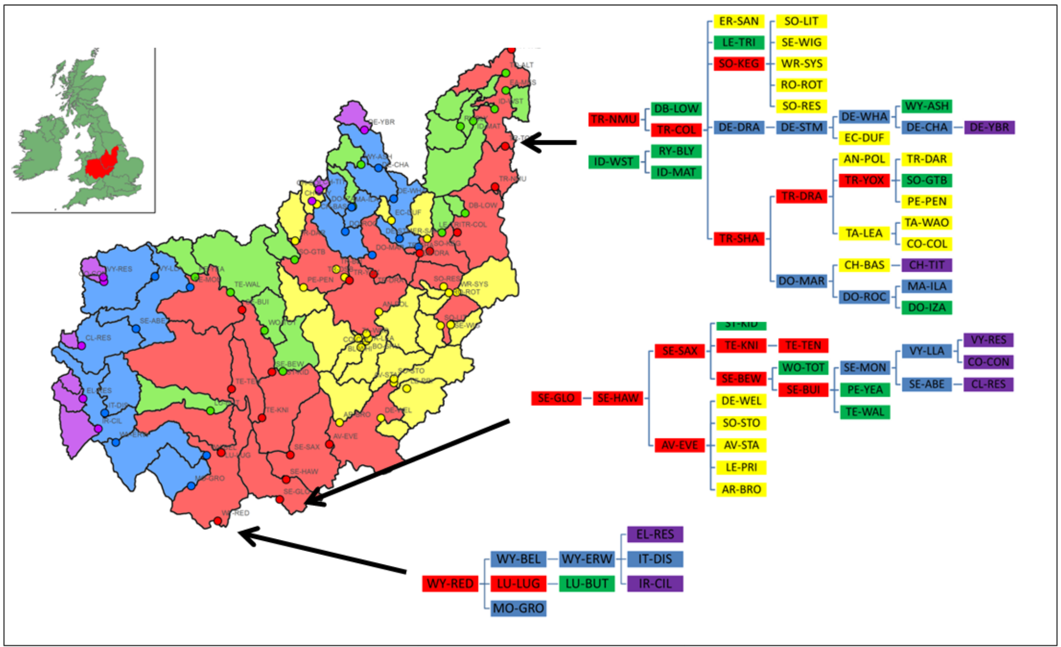
Our Aquator water resource model uses 95 years of daily inflow data for 78 catchment points across the Severn, Trent and Wye catchments. This inflow data series is derived using 81 hydrological models (HYSIM), with the outputs of these HYSIM models being grouped together and adjusted for artificial influences, such as spray irrigation and sewage effluent discharges, to allow them to be used in our Aquator model. An analysis of several different catchment attributes, including topography, Base Flow Index and SAAR (Standard Annual Average Rainfall) allowed us to classify all the HYSIM modelled catchments into five groups with similar hydrological characteristics and responses to climate. The catchment descriptions are shown in Table A3.3.

Table A3.3: Overview of the catchment groupings derived from hydrological analysis

Group	Minimum Area (Km²)	Maximum Area (Km²)	Minimum SAAR (mm)	Maximum SAAR (mm)	Minimum Base Flow Index	Maximum Base Flow Index	Number of models	Description
1	148	2027	936	1386	0.43	0.58	14	Larger intermediary catchments with generally higher rainfall
2	63	869	641	1165	0.59	0.79	13	Catchments with a high Base Flow Index reflecting a larger dominance of base flow
3	46	795	628	976	0.28	0.55	23	Smaller low lying catchments with lower rainfall
4	885	10443	654	1009	0.40	0.61	17	Large downstream, lowland catchments representing the main river reaches
5	10	246	926	1971	0.33	0.45	9	Small typically upland catchments with high rainfall and a flashy catchment response

Figure A3.4 shows the distribution of the HYSIM hydrological models in the Severn Trent Region. The catchment types are indicated by the colouring as shown in Table A3.3.

Figure A3.4: Distribution of HYSIM hydrological models in the Severn, Trent and Wye basins



From these catchment groups, five representative "exemplar" HYSIM catchments models were chosen (one for each catchment group) based on the following criteria:

- Calibration method for the baseline flow series – for the exemplar HYSIM catchment models it was preferable to use models which had been calibrated against naturalised flow data.
- Number of nested upstream models – for the exemplar HYSIM catchment models this was zero as models nested downstream of another HYSIM model incorporate the hydrological response of both the upstream catchment(s) and the nested catchment, which could mask the hydrological response of the nested catchment.

- Proportional size of artificial influences – for the exemplar HYSIM catchment the proportion of artificial influences should be as small as possible so that only the impacts on the natural catchment flow are seen in the climate change modelling. Where artificial influences were included in the baseline flow series, the artificial influences were removed from the models for the climate change analysis and were added on again before being used in the Aquator modelling.
- Additional information collected during the derivation of the baseline flow series regarding the confidence in the model itself.

The five exemplar catchments are:

- Ithon at Disserth
- Wye at Ashford
- Wreak at Syston Mill
- Teme at Tenbury
- Elan Reservoirs

Step 3: Hydrological modelling

The five catchments were modelled in HYSIM using the 100 UKCP09 projections which had been selected from the 10,000 UKCP09 sample set in stage 1 of our approach. This HYSIM modelling generated 100 sets of climate change perturbed flow series for each of the five catchments. These flow series were then used to derive monthly flow factors for each catchment for each climate scenario. This enabled us to estimate the impacts of climate change on natural flows.

Step 4: Deriving a suitable Drought Indicator

In order to reduce the number of projections in the assessment from the 100 which were sampled using Latin Hypercube Sampling, a drought indicator was used to produce a targeted sample of 20 climate projections. The drought indicator analysis identified the climatic drivers for historic droughts in our region. We considered a number of different potential drought indicators, such as aridity indices specific to key strategic reservoirs and changes in flow. We used mean April to September flow change as our "Drought Indicator" as this was based on robust hydrological modelling and used information on the climate sensitive period gathered from the aridity index analysis.

The flow factors from step 3 were reviewed and the Drought Indicator was used to identify a split sample of 20 scenarios for use in our water resources impact modelling. The split sample provided 20 scenarios covering the full range of expected climate change impacts, but with 10 of these scenarios focussing on the drier end of the range.

Step 5: Flow naturalisation of baseline Aquator inflow series and application of climate change flow factors

As previously discussed, our Aquator inflow series is derived using the outputs of 81 HYSIM catchment models, which are grouped together to form the 78 catchments used in our Aquator model and adjusted for any in-catchment artificial influences, such as agricultural abstractions. In creating the climate change impacted inflow series, the artificial influences were removed from each catchment before the climate change factors generated in step 3 were applied to the HYSIM flows for the 20 scenarios selected in step 4. This ensured that only the natural flows were being impacted by climate change.

The catchment groupings were used to decide which factors were used for which catchment. This created 20 climate change impacted naturalised flow series for us to use in our Aquator modelling.

Step 6: Denaturalisation of climate change impacted Aquator inflow series

Once the relevant flow factors had been applied to the naturalised inflow series, the artificial influences were put back in to the flow series and the HYSIM flows were combined into the Aquator catchments so that they could then be used in our Aquator model.

Step 7: Groundwater assessment

A groundwater assessment was completed using the 20 scenarios identified in step 4; this produced estimates of changes in groundwater level and DO for physical and flow constrained sources as explained in section A3.5. Licence constrained sources were assumed to be unchanged.

Step 8: Input of climate change data sets into Aquator

To enable us to model the combined impact of climate change on our inflow series and our groundwater sources in our conjunctive use water resource zones, we created a sequence set (to incorporate the climate change impacted inflow series) and a parameter set (to incorporate the climate change impacted groundwater sources) for each of our 20 climate change scenarios in our Aquator model, using the UKCP09 sample ID as the identifier.

We imported the climate change impacted flow series into our Aquator model, assigning them to the relevant catchment and the climate impacted constraint data for the affected groundwater components. For each climate change run we used the sequence set and parameter set with the same UKCP09 sample ID to ensure consistency between the datasets used. To ensure consistency with the baseline modelling, the climate change impacts were applied to the Aquator model which was used to derive our baseline DO. The same period of record was used in both our baseline and climate change assessments (1920 to 2014).

A3.4 Impact of Climate Change on our surface water sources

Under all 20 of our sub-sampled climate change projections, significant changes in monthly rainfall and temperature are seen to occur, both positive and negative. These changes in climate will have a knock on effect to the flows in the water courses in our region. The annual average change in flows for our five catchment groupings is shown in Table A3.4. Monthly variations within these annual averages range from an increase in flows in some catchments of 28% (compared to the current baseline flows), to a decrease in flows of 31%.

Table A3.4: Annual average change in flows as a percentage change from current baseline flows

		Annual change in flows (%)				
Rank	UKCP09 ID	Catchment Group 1	Catchment Group 2	Catchment Group 3	Catchment Group 4	Catchment Group 5
1	8632	-13%	-19%	-31%	-21%	-13%
2	9855	-9%	-14%	-24%	-13%	-10%
3	3111	-11%	-16%	-28%	-16%	-12%
4	6108	-3%	-8%	-17%	-7%	-3%
5	1090	-9%	-14%	-26%	-15%	-10%
6	2203	-8%	-12%	-20%	-12%	-8%
7	1345	-14%	-20%	-31%	-24%	-13%
8	8282	0%	-5%	-14%	-3%	-2%
9	6461	0%	-4%	-10%	-1%	-1%
10	684	-12%	-17%	-27%	-20%	-11%
15	2726	-5%	-10%	-19%	-11%	-5%

Rank	UKCP09 ID	Annual change in flows (%) Catchment Group 1	Catchment Group 2	Catchment Group 3	Catchment Group 4	Catchment Group 5
20	9701	-4%	-8%	-15%	-6%	-5%
30	3521	6%	1%	-6%	5%	5%
40	281	-5%	-9%	-19%	-9%	-5%
50	3903	-5%	-9%	-17%	-12%	-4%
60	2745	6%	3%	-3%	5%	5%
70	3306	-10%	-12%	-19%	-17%	-7%
80	9623	4%	2%	-1%	3%	4%
90	1467	21%	21%	23%	28%	19%
95	8764	4%	4%	3%	3%	4%

Across all of the catchment groupings there is a general seasonal cycle of summer decreases and small winter increases which reflects the overall pattern of rainfall changes from UKCP09. However, there are a number of different responses to the changing climate between the five catchment groupings which are important to note:

- Catchment groupings 1 and 5 represent higher rainfall regions, catchment 1 being large intermediary catchments with higher rainfall and catchment 5 being small, typically upland catchments with high rainfall and a flashy catchment response. Both of these groups show a similar response to climate change, with very large reductions in flows during the summer months and larger increases in flows in the winter.
- Catchment grouping 3 represents small catchments in lower rainfall areas. The flow factors show more prolonged decreases across the summer months and fewer increases in flows during the winter months.
- Catchment grouping 2 which represents catchments with a higher Base Flow Index, have a much smaller range of flow changes compared with the other groupings. The largest flow reductions occur in September and October, which is later in the year compared to the other groupings.
- Group 4 represents the largest downstream catchments. The flow factors for this grouping have more prolonged summer decreases but are smaller in magnitude than those seen in group 3. The maximum flow decreases occur later in the year, in September and October, reflecting the delayed response due to the larger catchment area.

A3.5 Impact of Climate Change on our groundwater sources

Approximately 34% of our DO is abstracted from groundwater sources. Of our operational groundwater sources, the majority (~88%) abstract from Sherwood Sandstone or sandstone aquifers in the Midlands region, with a small percentage of sources taking water from limestone and river gravels.

The sandstone aquifers have substantive storage; meaning they are generally not sensitive to short term changes in climate. Unlike most chalk or limestone aquifers, the Midlands sandstones generally show only small annual responses in water level due to extreme wet or dry conditions and are generally considered to be resilient to drought conditions. In severe drought it takes several years for water levels to fall in the sandstone aquifers. During the 2008 to early 2012 period, recharge to the Midlands aquifers was significantly depleted by low average rainfall over this period, and some of the lowest ever groundwater levels were recorded across the region. Despite this, at our sources, groundwater level decline during this period was only of the order of <5m. In summary, this means that the impact of climate change is likely to be limited on our sandstone resources in comparison to other aquifer units across the UK.

Possible climatic impacts on our limestone and river gravel sources are likely to be more significant as these aquifers generally have less storage and are potentially more susceptible to changes in climate.

The process for calculating the change in Deployable Output (DO) for groundwater sources due to climate change has been calculated by taking the UKCP09 projections and assessing the impacts according the GR2 methodology as originally described in the UKWIR2006 guidance. This involved:

- Assessing the sensitivity of pumped sources to water level changes resulting from any changes in recharge.
- For all zones, use of representative synthesized hydrographs (calibrated to observed data) at sources to determine the change in recharge to the aquifer under the various UCKP09 projections, and using the GR2 methodology to determine the modelled range of water level change for each site.
- Converting the modelled water level change into a range of DO changes using the Source Performance Diagrams (SPDs).
- The assessment of likely changes in summer flows at our spring sources as a result of changes in recharge in these catchments.

For WRMP14 we had planned to use the Environment Agency's regional groundwater models to assess groundwater response to climate change driven changes to recharge in our region, under Options 2 and 3 of the vulnerability assessment. This analysis could potentially determine the likely scale of any future licence reductions needed to mitigate effects of climate change on the environment and to prevent mining of groundwater where sources were currently licence constrained.

In WRMP14, we explored this potential approach with the Environment Agency, but it was determined that it would not be appropriate for us to make assumptions about climate change driven abstraction licence changes. We did not pursue assessment under Option 2 and 3 of the vulnerability assessment, and we have followed the same approach for our final WRMP 2019. As such, the risks around climate change driven potential licence changes is not included in WRMP19. The impacts of climate change on our groundwater sources are therefore limited to those sources vulnerable to short term changes in water levels or flow.

Initial Screening

For our groundwater sources, an initial review of individual groundwater source sensitivity to groundwater level change was conducted as a preliminary screening exercise to the overall vulnerability assessment. This screening assessment utilised the source specific Source Performance Diagrams, as illustrated in Figure A3.5, to determine what the current constraint to abstraction was at the source. This can be broken down into five main constituents:

- Licence constrained – the source can abstract up to licence.
- Infrastructure constrained – the source is constrained by infrastructure (usually pump capacity, which is set slightly below the licence in order to prevent breach of licence).
- Level constrained – the source is constrained by a specific level in the borehole below which groundwater levels should not be taken in order to preserve pumping equipment (pump depth), water quality (adits or Deepest Advisable Pumped Water Level (DAPWL)), aquifer resource (DAPWL), borehole integrity (borehole casing, DAPWL, adits) etc. These are site specific and may vary source to source.
- Flow constrained – the source is constrained by gravity fed flows into the site. This is applicable to spring sources.
- Water Quality constrained – the source may not be able to abstract above a certain rate in order to preserve water quality

This review highlighted the following number of sources falling into each constraint category as shown in Table A3.5.

Table A3.5: Number of groundwater sources in each constraint category by WRZ

WRZ Name	Licence	Infrastructure	Level	Flow	Water Quality
Bishops Castle	1	1	0	0	0
Forest & Stroud	3	0	0	3	0
Kinsall	2[1]	0	0	0	0
Mardy	1	0	0	0	0
North Staffordshire	15[2]	10	2	0	3
Stafford	0	5	0	0	0
Newark	2[3]	0	0	0	0
Nottinghamshire	14[4]	6	0	0	2
Ruyton	1	0	0	0	0
Shelton	12[5]	7	0	0	0
Strategic Grid	12[6]	19	0	3	2
Whitchurch & Wem	2	0	0	0	1
Wolverhampton	1	1	1	0	1

Note 1: Two constrained by overarching Group Licence (within Group Licence constrained, at source specific level: one licence and one infrastructure constraint)

Note 2: Seven constrained by overarching Group Licence (within Group Licence constrained, at source specific level: three licence, three infrastructure and one WQ constraints)

Note 3: Two constrained by overarching Group Licence (within Group Licence constrained, at source specific level: one licence and one infrastructure constraint)

Note 4: Eleven constrained by overarching Group Licence (within Group Licence constrained, at source specific level: four licence, six infrastructure and one WQ constraints)

Note 5: Five constrained by overarching Group Licence (within Group Licence constrained, at source specific level: two licence, two infrastructure, one WQ constraint)

Note 6: Five constrained by overarching Group Licence (within Group Licence constrained, at source specific level: four infrastructure and one water quality constraints)

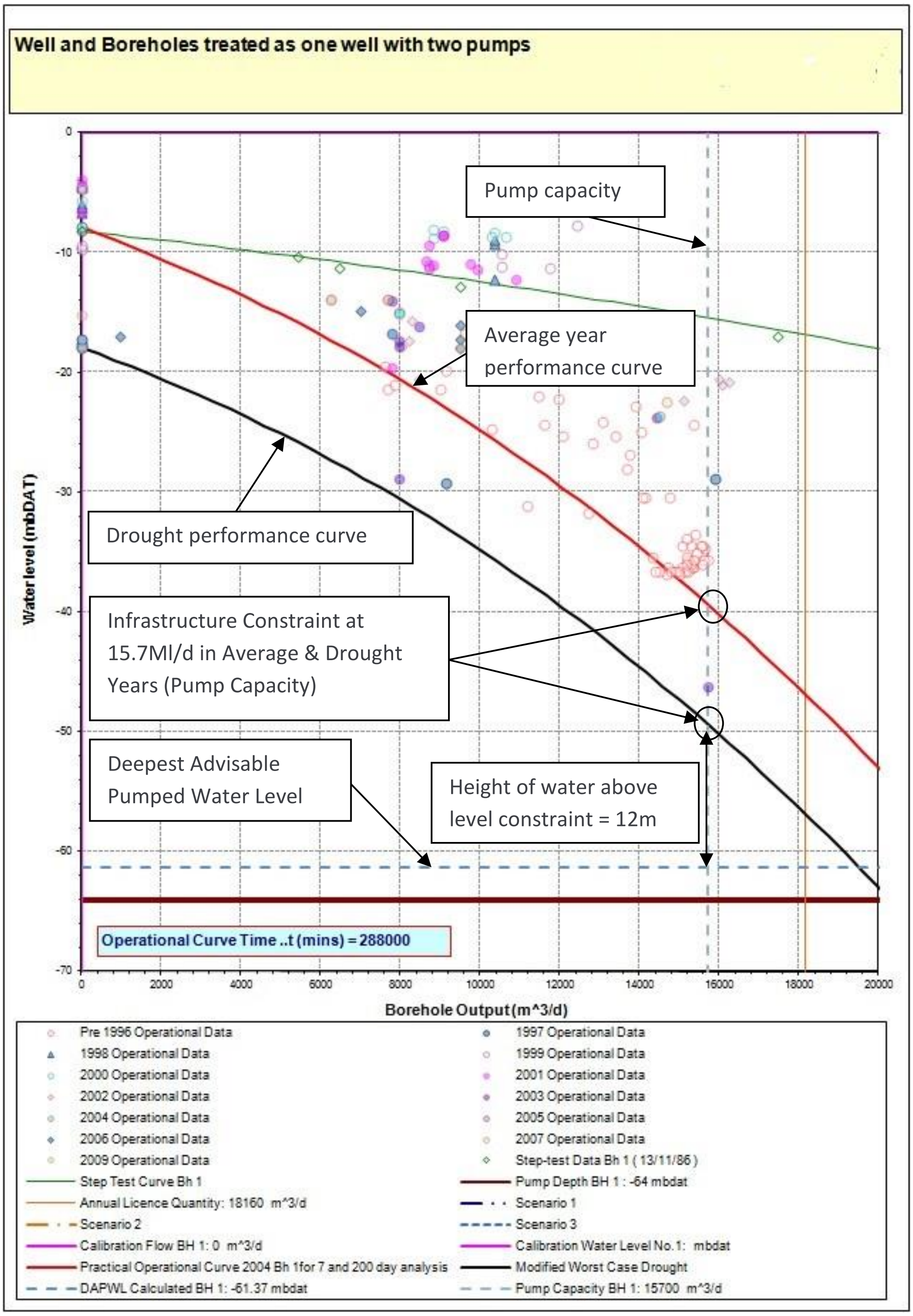
The initial screening assessment utilised the SPDs to determine the operational profile of the source in drought conditions and consider how far this drought curve was above a source specific groundwater level constraint (i.e. borehole pump depth, DAPWL etc). An example SPD is presented in Figure A3.5 and marked up with relevant assessment considerations. The source is constrained by pump capacity at ~15.7Ml/d in both average years (red curve) and drought years (black curve), and when operating at this constraint in drought conditions, there is approximately 12m of groundwater level “headroom” before water levels would start to be constrained by a level constraint (in this instance DAPWL), rather than the pump capacity.

From the initial screening assessment, it was considered that sources that are currently level constrained in drought conditions and sources that are constrained by gravity fed flows (spring sources) should be taken forward for climate change assessment. Fourteen sources were initially highlighted and these sources were considered to be vulnerable to climate change (some of these sources were later found to be constrained by Water Quality (WQ) constraints, so are not shown under the Flow column in Table A3.5). Furthermore, it was considered that sources that had less than 5m of groundwater level “headroom” between the intersect of the drought performance curve and an infrastructure constraint, and a level constraint, should be taken forward for climate change assessment as these were considered to be potentially vulnerable to climate change. Eight sources were initially highlighted.

Sources that had greater than 5m of groundwater level “headroom”, or were currently licence or water quality constrained were considered to be at low vulnerability to climate change and were not assessed. In addition to the initial screening, a series of interviews were conducted with our Operational staff which indicated an additional twelve sources which may be potentially sensitive to dry weather conditions. These sources were considered as potentially vulnerable to climate change and were taken forward for climate change assessment; even though assessment of the SPDs suggested that they were likely to have low vulnerability to climate change. The inclusion of these additional assessments is considered to be conservative.

Figure A3.5: Source Performance Diagram and example initial source vulnerability screening.

Note there is 12m of water level “headroom” in drought conditions, before the constraint on the source would change from an infrastructure constraint (pump capacity) to a level constraint (DAPWL). In this instance the initial screening is low vulnerability to climate change.



Head Dependent Changes in DO (Pumped Sources)

The majority of our groundwater abstractions are from deep boreholes in the Sherwood Sandstone. As there is significant storage in this aquifer, water level changes due to recharge variation are usually buffered and can take several years or decades to have any significant effect. In addition, due to the depth of many of our boreholes, there would usually be space to lower the pumps in the borehole and maintain the same output if regional water levels dropped significantly.

However, for certain sources, a change in recharge could produce a significant borehole water level change within the planning horizon (i.e. the next 25 years), where:

- The aquifer has low storage (e.g. fissured limestone) and responds rapidly to recharge;
- The pumping water level is already close to the base of the borehole;
- There is some inflow feature particular to that source that would cause a rapid loss of yield if water levels dropped beyond a certain level (e.g. an adit or a fissure zone), or;
- The source is an aquifer of very limited vertical or horizontal extent with limited capacity to buffer recharge variation

The screening exercise identified approximately 23 sources that might fall into one or more of the above categories. These were then considered in detail using the UKWIR06 methodology to predict the likely change in water level and thus DO for each of the UKCP09 scenarios. Of the 23 sources, only eight were determined to have climate change impacts after detailed assessment. These are shown in Table A3.6.

Table A3.6: Head dependant groundwater source impact

WRZ	Source	Range of Changes in DO (Ml/d) using 20 smart sampled UKCP09 scenarios	
		Min	Max
Bishops Castle	Oakley Farm	-0.18	0.27
North Staffordshire	Draycott Cross	-0.89	0.74
	Blacklake	-0.46	0.49
Nottinghamshire	Clipstone Forest	-1.26	-0.06
Stafford	Shugborough	-0.11	0.08
Strategic Grid	Meriden Shafts	-0.26	-0.10
	Campion Well[1]	-0.48	0.51
	Ladyflatte[1]	-0.63	0.61

Note 1: For the Campion Well and Ladyflatte sources, the estimates were made on the basis of changes in annual recharge. This is because of the nature of the sources it is not appropriate to apply a conventional GR2 assessment.

The results indicate that Bishops Castle was the only groundwater only zone predicted to have head (level) dependant deployable output impacts resulting from the modelled climate change scenarios. The result from the assessment and the predicted impacts on groundwater sources in conjunctive use zones, as presented above, were then input into our Aquator model.

Head-Dependent Changes in DO (Gravity-Fed Sources)

We have nine abstraction sources fed by springs or drainage tunnels. As these are gravity-fed and in fracture-flow aquifers, they are likely be more sensitive to groundwater level changes than our other sources. For the purpose of our assessment the effects on the Site D source (Merebrook sough) have been considered as part of the surface water source climate change assessment as this was considered more appropriate than assessing as a groundwater source, this is because abstraction at Site D is based not only on flows in the Merebrook sough but also on the HOF at Derby St Mary's on the River Derwent.

Changes to flows in these sources were predicted using the UKWIR06 methodology. This applies the selected climate change projections to actual or synthesized flows from the sources, and the outputs are reported for the average yearly minima and the drought year minima (based on lowest observed year recharge data). Any special conditions at those sites that constrain reported DO (e.g. minimum observed flow, licence condition or infrastructure constraint), are noted. Of the ten gravity fed spring sources, six were determined to have climate change impacts after detailed assessment. These are shown in Table A3.7.

Table A3.7: Head dependant gravity-fed spring source impact

WRZ	Source	Range of Changes in DO (Ml/d) using 20 smart sampled UKCP09 scenarios	
		Min	**Max**
Forest & Stroud	Bigwell	-0.26	0.16
	Chalford	-1.87	1.09
	Lydbrook	-0.19	0.36
Strategic Grid	Coombe	-0.18	0.10
	Millend	-0.23	0.14
	Site D[1]	Perturbed flow series provided for assessment within Aquator	

Note 1: Assessed as part of the surface water climate change assessment

Gravity fed springs sources at Postlip, Pinnock and Charlton Abbots springs were assessed and considered to not be impacted by climate change as they are disused.

The results indicate that none of our groundwater only zones are predicted to have head (gravity fed) dependant deployable output impacts resulting from the modelled climate change scenarios. The predicted impacts on spring sources in conjunctive use zones, as presented above, were then input into our Aquator model.

A3.6 Modelling the impact of Climate Change on Deployable Output

As previously discussed, we have modelled the impact of climate change on our surface water and groundwater sources in our conjunctive use WRZs using our Aquator model. Modelling of each scenario provides us with estimates of deployable output for the year 2035. We applied the climate change perturbed flow series to our existing model, to establish what the potential impacts could be if the system and reservoir control curves remain unchanged.

By adopting Approach 2.2 we were able to reduce the 100 UKCP09 projections selected using Latin Hypercube Sampling for Approach 2.1, based on a drought indicator to a targeted sample of 20. This targeted sample included 10 projections towards the “dry” end of the projection range and 10 projections, which were equally spaced across the remaining range.

Each of the targeted samples was given a “weighting” to estimate the probability of this projection occurring. The weight describes the relative probability of each projection in the sub-sample of 20 with respect to the original 100. Including 10 samples towards the “dry” end of the projection range means we could be including some “outliers” in our assessment, i.e. extreme changes in climate which have a low probability of occurring. By applying the weighting we were able to assign a low probability to these outcomes, but are still able to consider the full range of potential impacts in our overall assessment.

The current guidance on how to apply the climate change methodologies does not include any recommendations for how water companies should derive a suitable "central estimate" for use in the supply / demand balance calculations. Similarly, there is no best practice guidance on how to appropriately deal with the wide range of uncertainties presented by the multiple scenarios. We have therefore tested the impacts of adopting different "central estimates" of future climate change impacted supplies, along with different approaches to capturing the range of uncertainty around this estimate.

One option is to derive a "weighted average" impact on deployable output from the full range of scenarios. This uses a statistical calculation taking into account the weightings assigned to each scenario and the change the scenario causes to deployable output. Alternatively we could choose to use the outputs of a particular high-weighted scenario, such as the rank 50 which is also the median of the 100 Latin Hypercube Sample.

There are mathematical reasons for adopting a weighted average approach, because it includes the full range of scenarios, including all drier scenarios and any potential "outliers". However, by applying a weighted average approach we would be unable to relate the implications back to any one UKCP09 climate change scenario or modelled hydrological dataset. Therefore to maintain transparency in our impact assessments, we prefer to base our modelling on the outputs from the specific UKCP09 climate change scenarios, each of which have probability weightings attached to them.

Consistent with our WRMP14 our preference is to use the values from the median model output (rank 50) scenario from the Latin Hypercube Sample as our central estimate of climate change impacts in our baseline plan. We believe this better represents a physically plausible hydrological scenario and is more representative of what could happen to our region. We have assessed the range of uncertainty around this central estimate using our target headroom model. We have also used each of the 20 UKCP09 climate projections to produce individual climate change impacted scenarios in our Decision Making Upgrade (DMU) model. By doing this we are able to consider the impacts of each of the climate change scenarios – which are all equally likely – and remove uncertainty around climate change from target headroom. Further details about this assessment can be found in Appendix E.

The full range of the modelled impact of the climate change scenarios on our deployable output in 2035 are shown in Figure A3.6 to Figure A3.10. As our vulnerability assessment indicated, the greatest impacts of climate change are seen in the Strategic Grid and Nottinghamshire water resource zones. Our modelling showed there was no impact on the deployable output of the Wolverhampton and Newark WRZs under any of the 20 climate projections modelled. Wolverhampton WRZ is supplied by a combination of a river abstraction and groundwater sources, whilst Newark WRZ is supplied by groundwater sources and groundwater derived imports, both of which are highly resilient to the potential impacts of climate change.

Both the Strategic Grid and Nottinghamshire WRZs are most affected by the potential impacts the changing climate may have on our surface water sources – the Strategic Grid WRZ is affected directly by reduced river flows and reservoir refill, which in turn reduces the availability of water in the Strategic Grid WRZ to export to the Nottinghamshire WRZ. Our source assessment has shown that few of our groundwater sources are vulnerable to potential future changes in climate and where groundwater sources are vulnerable the resultant change in source yield is likely to be relatively small. The groundwater sources in the Nottinghamshire WRZ are largely resilient to climate change.

Figure A3.6: Strategic Grid zonal impacts of climate change using the 20 smart sampled UKCP09 scenarios

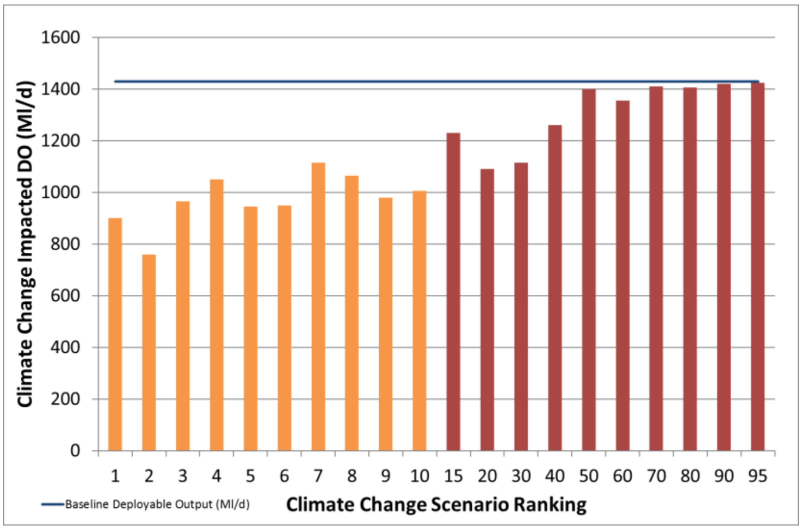


Figure A3.7: Nottinghamshire zonal impacts of climate change using the 20 smart sampled UKCP09 scenarios

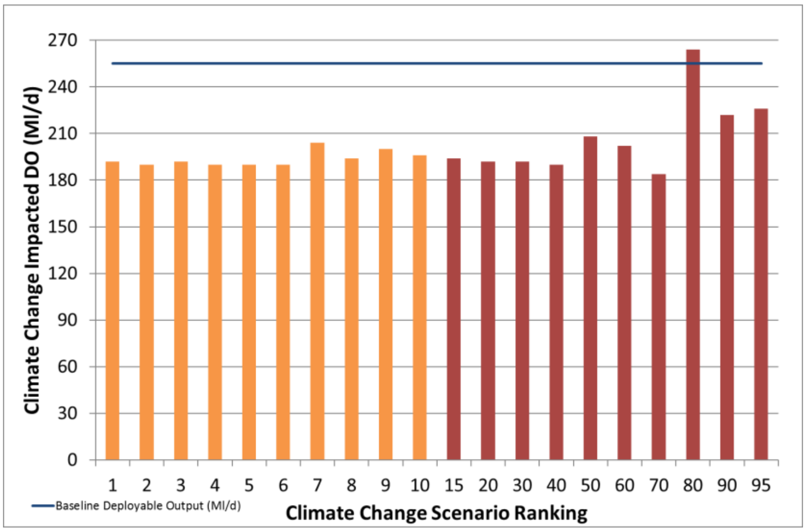


Figure A3.8: Shelton zonal impacts of climate change using the 20 smart sampled UKCP09 scenarios

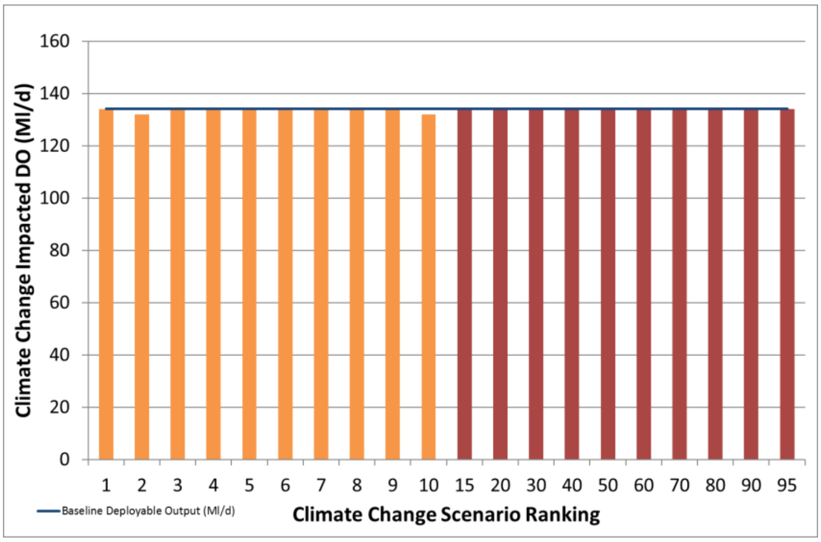


Figure A3.9: Forest and Stroud zonal impacts of climate change using the 20 smart sampled UKCP09 scenarios

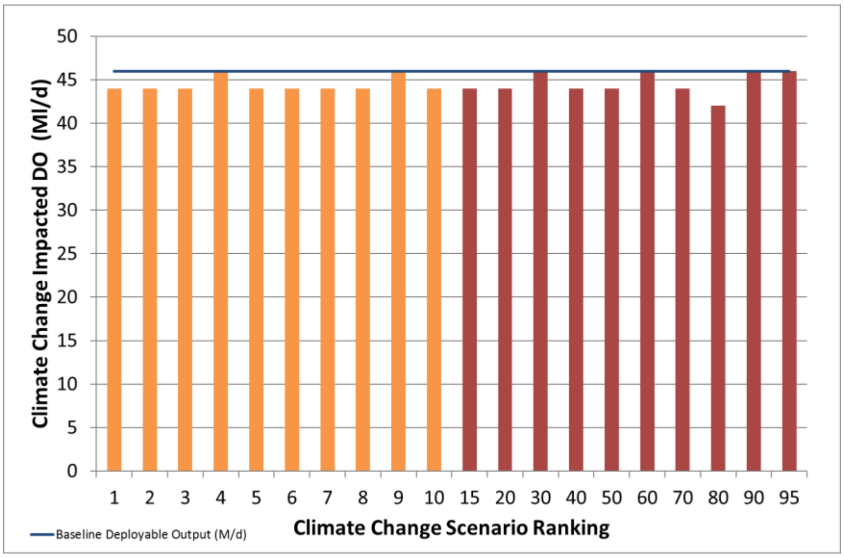
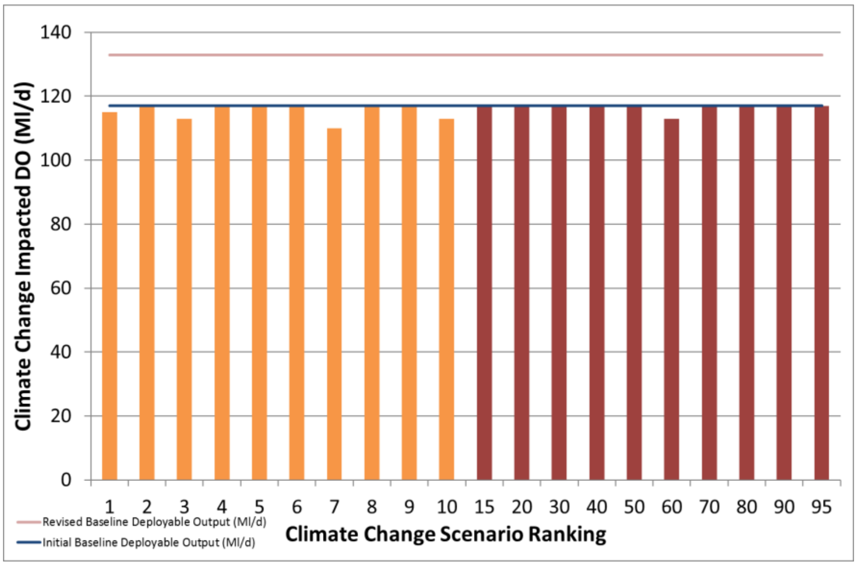


Figure A3.10: North Staffordshire zonal impacts of climate change using the 20 smart sampled UKCP09 scenarios



The climate change modelling was carried out prior to the revision of baseline deployable output for North Staffordshire WRZ. The impacts for this zone were seen to be minimal. We have tested the impacts of climate change in North Staffordshire WRZ for the final WRMP to enable us to incorporate uncertainty around climate change in target headroom. A detailed description of how we have tested and used the range of uncertainty around climate change is provided in Appendix C2.

A3.7 Impact of 2080s climate change projections on deployable output

Our climate change assessment also includes the use of UKCP09 projections for the 2080s time slice following the guidance in "*Environment Agency (2017) Estimating impacts of climate change on water supply*". This analysis used the same 20 climate change projections identified in Step 4 of section A3.3 for the 2030s time slice. These projections were used to investigate DO impacts following the same approach explained in Steps 5 to 9 of section A3.3 for our conjunctive use WRZs and section A3.5 for our groundwater only WRZs.

For each time-horizon and emission scenario UKCP09 provides 10,000 projections (as monthly, seasonal and annual changes) which have all been assigned specific scenario IDs. The Met Office Hadley Centre advise caution if attempting to 'stitch together' time series. However, projections with the same scenario ID at a different 'timeslice' can be used for comparison purposes. As part of our 2080s assessment we wanted to understand where our 20 sub-sampled UKCP09 2030s projections sat within the full range of 10,000 UKCP09 2080s projections. We used the same drought indicator (April to September precipitation changes) to select the 20 projections from the 2030s 'timeslice' and to rank the 2080s projections. The rankings are shown in Table A3.8.

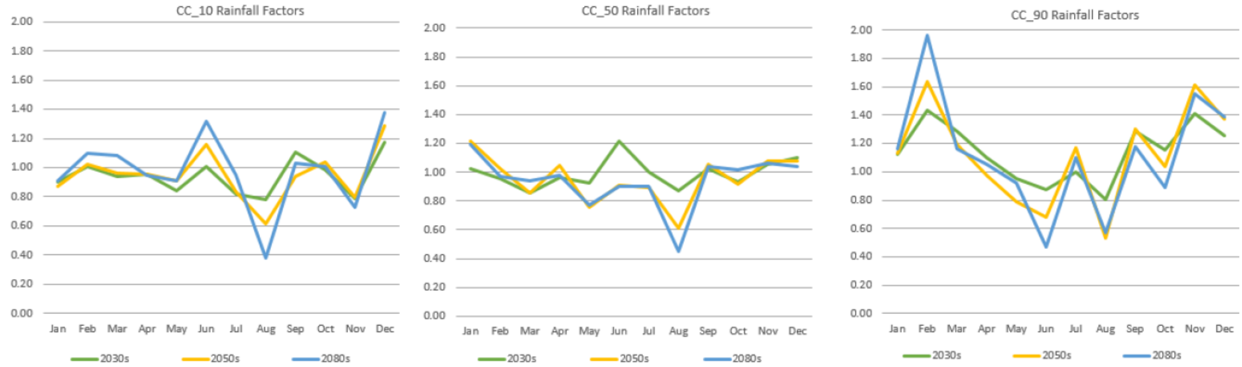
The comparison highlighted that the scenarios provide a reasonable coverage of the UKCP09 ensemble for the 2080s when considering seasonal and annual climate metrics. They were therefore suitable for carrying out sensitivity analysis.

Table A3.8: 2030s UKCP09 projections with 2080s ranking based on April to September rainfall

UKCP09 ID	2030s rank	2080s rank
8632	1	2
9855	2	8
3111	3	15
6108	4	29
1090	5	8
2203	6	9
1345	7	57
8282	8	35
6461	9	9
684	10	64
2726	15	60
9701	20	12
3521	30	26
281	40	36
3903	50	39
2745	60	58
3306	70	39
9623	80	53
1467	90	58
8764	95	99

Figure A3.11 shows the range of percentage change in precipitation captured in our climate change assessments for the 2030s and 2080s. The 2050s has been included for comparison as this represents a 'tipping point' in the projections – beyond the 2050s the projections become much more severe particularly in the summer reductions in rainfall. Rank 90 (CC_90) represents our 'wet' scenario, rank 50 (CC_50) is our 'central estimate' and rank 10 (CC_10) is our 'dry' scenario.

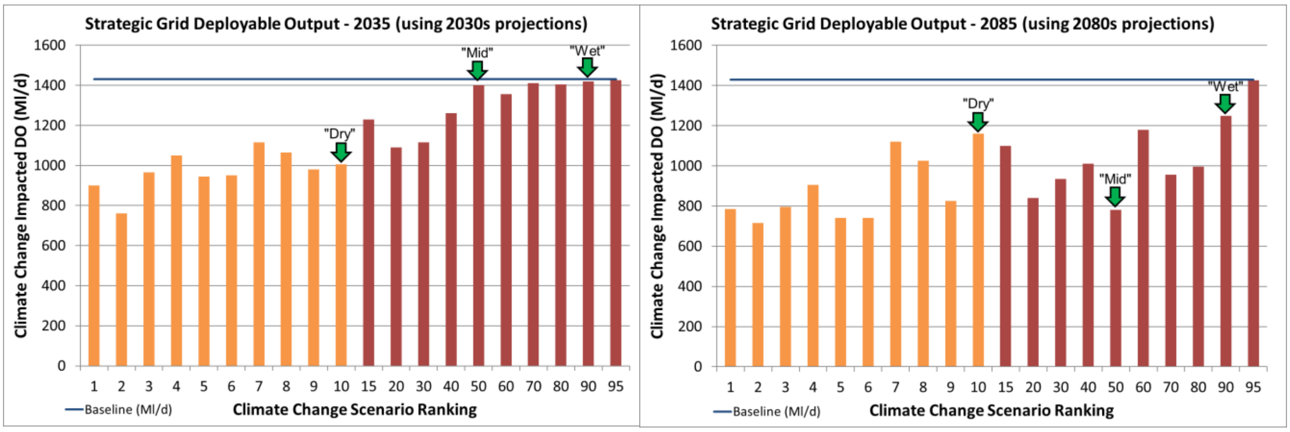
Figure A3.11: Percentage change in precipitation in UKCP09 projections



Assessment of the maximum deployable output that can be achieved during each climate change scenario in our largest WRZ (the Strategic Grid) is illustrated in Figure A3.12. This shows that by the 2030s, almost all scenarios suggest some loss of deployable output compared with our current baseline deployable output.

Figure A3.12 also shows that by the 2080s almost all scenarios suggest an extreme impact on deployable output. Having analysed and understood the extreme impacts suggested by the 2080s scenarios, we have chosen not to use them in our WRMP and PR19 investment planning decisions. The scale of investment needed to accommodate these potential impacts would be disproportionate given the very long timescales involved and the increasing uncertainty in the UKCP09 projections themselves in the later 'timeslices'. Instead we have used the less extreme 2030s climate change scenarios to inform our WRMP 25 year plan and PR19 investment plan. Our approach is to accommodate the range of uncertainty implied over this shorter time horizon. This approach avoids us having to commit to very long term investment decisions and instead focus on more modular solutions matched to nearer term deficits.

Figure A3.12: Modelled impact of climate change on the Strategic Grid deployable output using 2030s and 2080s UKCP09 projections



A3.8 Scaling the impacts of climate change to 2045

Before scaling the modelled impacts of climate change we first needed to establish whether any impacts are currently being experienced in our existing river flows and other sources. To investigate whether any climate change signal is currently detectable in our river flows we carried out a series of statistical tests for trend detection. For each of the identified five catchment groups (our "exemplar" catchments described in Step 2 of section A3.3) a single river flow dataset was analysed. In order to fully capture any trend we used data from our extended historic record for the period 1884-2014.

The results of this analysis (shown in Table A3.9) indicate that there is no observed trend for three of the five catchment groups and the two catchment groups with an observed trend both detect an increase in river flows over the 131-year analysis period.

Table A3.9: Catchment group trend detection summary

Catchment Group	Trend Observed
1	Yes - Increasing ↑
2	No
3	Yes - Increasing ↑
4	No
5	No

This trend analysis supports finding of academic studies such as Hannaford (2015) which have found that there is currently no strong evidence of anthropogenic warming influences on river flows in the UK. These findings are also supported by the Living with Environmental Change (LWEC) Water Climate Impacts Report Card 2016; this document summarises the findings of a variety of research papers investigating climate change impacts on water. We have also analysed the impact of extending our baseline Aquator inflow series which previously covered 1920 to 2010, by 4 years to 2014. The extended flow series captures the 2010-2012 period, which was for much of the UK was classed as a drought. The inclusion of this period caused no change to our deployable output. Although 2011 was very dry for most of our region (2nd or 3rd driest for most sub-catchments) for the catchments where the bulk of water is taken (Elan & Derwent) it was only the 29th and 16th driest year respectively.

We have therefore assumed no reduction in DO has occurred due to climate change in our scaling calculations, so have zero DO reductions in our base year 2016/17 in accordance with the scaling method described in the Environment Agency's Water Resources Planning Guidelines (2012).

In order to estimate the impact of climate change for each year of the planning period from the base year up to 2045, we scale the DO change using two sets of equations. These equations enable us to interpolate and extrapolate the 2035 DO estimates to produce a smooth time series which we can then include in our supply demand balance calculations. Consistent with our previous 2014 WRMP we have used the scaling equations described in the Environment Agency's Water Resources Planning Guidelines (2012) but with a revised base year to reflect the fact we have experienced no loss of DO to date.

We have applied these equations to our central estimate for each water resource zone.
Equation 1 is used to extrapolate from 2030/31 onwards. In the equation "Year" is the year of interest.

$$\text{Scale factor} = \frac{\text{Year} - 1975}{2035 - 1975} \qquad \textit{Equation 1}$$

Equation 2 is used to avoid a step change in 2016/17 between baseline deployable output and the underlying trend. It interpolates linearly between 2016/17 and 2029/30 (inclusive).

$$\text{Scale factor} = \frac{\text{Year} - 2016}{2031 - 2016} \qquad \textit{Equation 2}$$

A3.9 Assessing the impact of climate change on our scheme options

Demand-side options

In our draft WRMP we did not explicitly consider the climate change uncertainty associated with our demand management measures. Instead, we focussed on the more significant climate change uncertainty associated with our supply side options. To fully comply with direction 3(e) we have extended our analysis to our demand management measures.

Our WRMP uses demand forecasts that reflect our assumptions around 'dry-year' demand for water, and so they reflect the impacts of hot, dry weather conditions on customers' water consumption. We also make a further allowance for the likely climate change impacts on household water consumption using the data and guidance given in *UKWIR 13/CL/04/12 Impact of Climate Change on water demand*. In the UKWIR study, median percentage climate change impacts on household demand at 2040, relative to 2012 are published for each river basin within the UK - the Severn and South Humber basins are used for Severn Trent. For our WRMP, the annual average forecasts use the average of the factors for these basins, therefore have a 0.905% increase in consumption over that period. As the base year for our modelling is now 2015/16 and the final forecast year is 2044/45 the percentage change is shifted along as there has been no further evidence since this report.

As per the UKWIR technical guideline, the additional demand caused by climate change has been added to the external use micro-component only, which means that the overall effect is relatively small. Table 6 of the WRMP data submission (Customer side management) shows the volumetric demand management benefit of our metering strategy and includes a climate change impact equivalent to 0.9% by 2045. The annual percentage impact profile is as per line '27- Percentage of consumption driven by climate change' in Table 3.BL.

Consistent with the conclusions of the UKWIR study, because the impacts of our water efficiency activities on our demand forecasts already reflect the impacts of hot, dry weather any additional effects of climate change are small and only apply to external use of water. Therefore, in our WRMP we assume that climate change has no impact on our internal household water efficiency measures. Table A3.10 summarises the climate change impact on demand management options.

Table A3.10: Projected climate change impacts on demand management options across the planning period

Period	2020-25	2025-30	2030-35	2035-40	2040-45
Climate change impact on demand management options	zero	zero	zero	zero	zero

Supply options

To help inform our supply-side option selection process we carried out deployable output (DO) modelling of options on our constrained list using our water resources model, Aquator. This established a 'central estimate' of deployable output benefit for each option that we subsequently used in our investment optimisation and least cost planning modelling, described in Chapter 8 of our final WRMP.

There were several iterations of the investment optimisation modelling. A number of options that were selected most frequently (including all options in our preferred programme) were subject to further scenario assessments using our Aquator model. These scenarios assessed the sensitivity of the options to the potential impacts of climate change and changes made to our abstraction licences as a result of the Water Industry National Environment Programme (WINEP). These assessments were carried out using zonal and 'local' modelling using our Aquator model to estimate the DO benefits at both a water resource zone and localised supply area level. In some cases the zonal modelling approach masked the predicted benefit of the option. Consequently, local supply area modelling was carried out to provide greater transparency and granularity in terms of the predicted magnitude and location of the benefit.

We assessed the potential impact of combining the rank 50 2030s climate projection with likely WINEP licence changes to better understand the future supply network constraints in the 2030s. The rank 50 climate projection represents our 'best central estimate' for climate change within our plan and has been used to inform the predicted reduction in DO due to climate change in the water resources planning tables. This combined scenario results in a reduced zonal DO across most zones when compared to our baseline position.

Table A3.11 shows the modelled deployable output benefit of the options within our preferred programme in our final WRMP for the central estimate (which is modelled using our baseline Aquator model) and the combined climate change with WINEP scenario. Although showing some variability, generally the benefit of each option is greater under the combined scenario than the baseline in most cases. This is because the option deployable output benefit has been optimised to help us regain some of the DO lost by WINEP licence changes as well as make the most of water when it is available in the climate change scenario. We will carry out further scenario modelling as part of our feasibility assessments during AMP7.

Table A3.11 Preferred programme of options and deployable output benefit

Option Code	Option Name	Central Estimate DO (Ml/d)	DO under climate change with WINEP combined scenario (Ml/d)
MEL29	Carsington Reservoir support to Site Q WTW with Site Q WTW enhancements	26	25
CRO06	River Soar to support Site B WTW	17	19
GRD18	Peckforton Group BHs rehabilitation and treatment enhancement	36	30
WTW05	East Midlands raw water storage (Site CQ) including new WTW	45	38
DAM07	Site C Reservoir capacity increase (Size A) with transfer main from Site C WTW to Coventry	9	17
NOT04	Heathy Lea to North Nottinghamshire transfer solution	25	22
WIL05	Site E WTW expansion and transfer main supported by raw water augmentation of the River Trent	35	50
CRO05	Thornton Reservoir to support Site B WTW	8	8
DOR08	Site B WTW enhancements	3.6	14
BAM03	Site R WTW to Grindleford pipeline capacity increase	7.5	7.5
OGS01	Site J WTW expansion	15	4
BHS06	Maximise deployment from Diddlebury WTW and Munslow BH	0.9	19
DOR05	Site C WTW enhancements	8	8
LIT01	Site F WTW expansion	10	8
BHS07	Ladyflatte BHs recommissioning	2.7	7
DAM01	Stanford Reservoir capacity increase (Size A)	2.5	7
DAM02	Lower Shustoke capacity increase (Size A)	2.5	11
DAM03	Site A Reservoir capacity increase (Size A)	2.5	7
DOR02	Site I WTW enhancements	2	2
NOT01	Ambergate to Mid Nottinghamshire transfer solution	30	18
NOT05	Site E to South Nottinghamshire transfer solution	30	19
UNK07	Improve Site L WTW outputs during low raw water periods	7	54

References for Appendix A3

- Hannaford, J., 2015. Climate-driven changes in UK river flow: A review of the evidence. Progress in Physical Geography, 39(1), pp. 29-48.
- LWEC, 2016. NERC Living with Environmental Change Report Card 2016: Water. Accessed at http://www.nerc.ac.uk/research/partnerships/ride/lwec/report-cards/water/
- UKWIR, 1995. A Methodology for the Determination of Outputs of Groundwater Sources. UKWIR Technical Report 95/WR/01/2.
- UKWIR, 2000. A Unified Methodology for the Determination of Deployable Output from Water Sources. UKWIR Technical Report 00/WR/18/2.
- UKWIR, 2012. Water Resource Planning Tools 2012. UKWIR WR27 Technical Report 12/WR/27/6.

A4 Restoring Sustainable Abstraction (RSA)

Some of our existing water abstractions may be having a detrimental effect on the environment, particularly during dry weather periods when river flows are low. Throughout AMP6 we are investigating the impacts of those abstractions identified by the Environment Agency as possibly causing harm to the environment. Through our investigation work we are gathering site specific evidence of the extent of damage being caused, and whether our activities are the main cause, or just part of the problem.

Upon investigation, where our abstractions are identified to be the cause of the problem we acknowledge that we need to find and implement solutions. These solutions might include revoking or reducing our abstraction licences at the affected sites and possibly finding an alternative source of supply. Sustainability reductions to licences may be required to protect international or national designated conservation sites (Habitats Directive, Sites of Special Scientific Interest or Biodiversity 2020 sites), to protect locally important sites or to deliver Water Framework Directive (WFD) objectives.

For our draft WRMP we included short and long term measures to remove or offset the impacts of environmentally damaging abstractions, and to help the associated water bodies achieve Water Framework Directive (WFD) objectives. We have worked closely with the Environment Agency throughout AMP6 to understand where our sources of abstraction could be contributing to low flow problems in hydraulically connected watercourses, and which of our sources have the potential to cause any future deterioration.

During development of our draft WRMP, we based our plan on the list of abstraction changes and water body priorities that we expected to see in version 2 of the Environment Agency's Water Industry National Environment Programme (WINEP). Since we published our draft WRMP, the Environment Agency have updated their list of priorities and objectives in version 3, known as WINEP3. Information associated with WINEP 3 made available by the Environment Agency in April 2018.

Also since publishing our draft WRMP, we have completed our AMP6 investigations into the potential environmental impacts of abstraction. The conclusion of these investigations in February 2018 included agreement with the Environment Agency on our priority sites for reducing unsustainable abstraction along with a range of agreed solutions for helping the associated water bodies improve their WFD status.

The conclusions of our investigations and WFD risk assessments, along with any agreed actions were incorporated by the Environment Agency into WINEP version 3 (WINEP3). We have included the WINEP3 changes into our development of our final WRMP.

A4.1 RSA Sustainability Changes

In the preparation of our previous PR14 business plan, the Environment Agency's National Environment Programme (NEP) for AMP6 set out the waterbodies and protected sites where it was suspected that our abstractions were unsustainable and causing detrimental environmental impact. Throughout AMP6 we have worked with the Environment Agency to complete environmental investigations and solution appraisals at these sites. When we published our draft WRMP we had not completed these AMP6 solution appraisals. This options appraisal process has now complete and the Environment Agency have incorporated our results into WINEP3 that was released in April 2018. The outcomes of these appraisals have also been reflected in our final WRMP.

Where the investigations have concluded our activities are having a damaging impact, then our WRMP includes the solutions we have agreed with Environment Agency to remove or mitigate these effects. These solutions take the form of:

- 'Local' solutions, such as changes to our compensation flows at surface water sites or environmental improvement measures such as river habitat restoration.
- 'Strategic' new supply-side solutions that will allow us to reduce abstraction from a number of our unsustainable groundwater sources.

Where we need to reduce unsustainable abstraction, we have agreed with the Environment Agency that we will make changes to the associated abstraction licences by end of AMP7 (2025). However, we have also agreed with the Environment Agency that in some cases we may take an 'upfront permitting' approach to these licence changes. This will mean that in some cases the changes will not take effect immediately, allowing us time to complete the required engineering changes to our water supply network and protect our customer's security of supply. In such cases, we will implement local schemes in AMP7 to mitigate for the effects of ongoing abstraction by making improvements in stream habitat. All licence reductions and our required interventions will come into effect and be applied by 2030.

Where our AMP6 low flow investigations had SSSI drivers in the NEP, and our options appraisal indicated a solution was required, these schemes will be fully implemented in AMP7.

RSA timing

When we published our draft WRMP, there was uncertainty regarding the scale and timing of any abstraction changes required from the WINEP process. We sought to manage this uncertainty by using scenario analysis in our draft WRMP. However, the uncertainty made it difficult for us to explain our approach in our draft WRMP and many consultees commented that this part of our WRMP required greater clarity. We also acknowledge this to be the case and the need for further explanation of the differing figures reported in different parts of our draft WRMP.

The investment modelling scenarios used to determine our approach to RSA in our draft WRMP were completed in April 2017. These were based on our best estimate of the potential scope of RSA reductions that might be required as defined by our AMP6 investigations up to that point. We generated a range of high, medium and low impact scenarios based on the following assumptions:

- A low scenario which equated to a 13Ml/d reduction in site deployable output by 2025.
- A mid scenario which equated to a 40Ml/d reduction site deployable output by 2025.
- A high scenario equated to a 65Ml/d reduction site deployable output by 2025.

For our final WRMP, we have moved away from this scenario analysis and we have instead used WINEP3 as our central planning scenario. Our WRMP deployable output forecasts have been updated to include this information.

WINEP3 includes the agreed sustainability changes for each individual site. These site level changes have been modelled in aggregate using our Aquator water resources model to derive the WRZ deployable output impact. This value is reported in the data tables accompanying our WRMP. The site based reductions have been used as input to our central best estimate to assess the combined impact of both RSA and WFD No Deterioration impacts on our deployable output.

Table A4.1 to A4.6 below lists those sources where our AMP6 Restoring Sustainable Abstraction investigations concluded that abstraction reductions or other environmental solutions may be required. The sites listed in these tables were included in the Environment Agency's April 2018 WINEP3 and carried an 'implementation' driver. A short description of the nature of the solution has been added for clarity.

Table A4.1: WINEP RSA groundwater schemes (measure and status taken from WINEP3 - April 2018) – Forest & Stroud WRZ

WRZ	RSA Investigation Site	Measure	Description of scheme
Forest & Stroud	Cinderford Brook	Sustainability Change & Land Management/ Habitat Restoration/ Physical Improvement	Catchment/River Restoration Measures Sustainability change to prevent risk of future deterioration.

Table A4.2: WINEP RSA groundwater schemes (measure and status taken from WINEP3 - April 2018) – North Staffordshire WRZ

WRZ	RSA Investigation Site	Measure	Description of scheme
North Staffordshire	Aldford Brook	Sustainability Change	Catchment/River Restoration Measures Sustainability change to prevent risk of future deterioration

Table A4.3: WINEP RSA groundwater schemes (measure and status taken from WINEP3 - April 2018) – Nottinghamshire WRZ

WRZ	RSA Investigation Site	Measure	Description of scheme
Nottinghamshire	Dover Beck and Oxton Dumble	Sustainability Change & Land Management/ Habitat Restoration/ Physical Improvement	Catchment/River Restoration Measures in waterbodies Combined sustainability reduction of up to 23.5 Ml/d off 15 year recent actual abstraction.
Nottinghamshire	Rainworth Water	Sustainability Change & Land Management/ Habitat Restoration/ Physical Improvement	
Nottinghamshire	Bevercotes Beck	Sustainability Change & Land Management/ Habitat Restoration/ Physical Improvement	
Nottinghamshire	Vicar Water	Sustainability Change & Land Management/ Habitat Restoration/ Physical Improvement	

Table A4.4: WINEP RSA groundwater schemes (measure and status taken from WINEP3 - April 2018) – Shelton WRZ

WRZ	RSA Investigation Site	Measure	Description of scheme
Shelton	Lower Worfe - Stratford Brook, Albrighton Brook & River Worfe	Sustainability Change & Land Management/ Habitat Restoration/ Physical Improvement	Catchment/River Restoration Measures Sustainability reduction of up to 3Ml/d off 15 year recent actual
Shelton	River Strine (multiple waterbodies)	Land Management/ Habitat Restoration/ Physical Improvement	Catchment/River Restoration and local flow support measures
Shelton	Upper Worfe - Burlington Bk	Sustainability Change	Continuation of WRMP14 Scheme
Shelton	Upper Worfe- Neachley Bk	Sustainability Change	Continuation of WRMP14 Scheme

Table A4.5: WINEP RSA groundwater schemes (measure and status taken from WINEP3 - April 2018) – Strategic Grid WRZ

WRZ	RSA Investigation Site	Measure	Description of scheme
Strategic Grid	Batchley Brook	Sustainability Change & Land Management/ Habitat Restoration/ Physical Improvement	Catchment/River Restoration Measures Sustainability reduction of up to 1.5Ml/d off 15 year recent actual.
Strategic Grid	Confirmed Coventry Coal Measures (River Sowe and Sherbourne)	Sustainability Change & Land Management/ Habitat Restoration/ Physical Improvement	Catchment/River Restoration or local flow support measures. The scheme includes revoking a disused licence Sustainability reduction of up to 4.4 Ml/d off 15 year recent actual
Strategic Grid	Hartlebury Common SSSI	Sustainability Change	Local flow support measure (small associated sustainability reduction of up to 0.5Ml/d off 15 year recent actual abstraction.)
Strategic Grid	Battlefield Brook	Sustainability Change	Continuation of WRMP14 Scheme

Table A4.6: WINEP RSA surface water schemes (taken from WINEP3 - April 2018)

WRZ	RSA Investigation Site	Measure	Description of scheme
Strategic Grid	Carsington Reservoir (Henmore Brook)[1]	Sustainability Change & Land Management/ Habitat Restoration/ Physical Improvement	Catchment/River Restoration and small change to local flow support measures
Strategic Grid	River Dove at Egginton	Sustainability Change	Solution to be agreed with EA following further assessment.
North Staffordshire	Tittesworth Res (R. Churnet)	Sustainability Change	Local flow support measures. Solution to be agreed with the Environment Agency following further assessment.
Strategic Grid	Stanford Reservoir	Sustainability Change	Continue local flow support measures
Strategic Grid	Quorn Brook (Cropston and Swithland Resrs)	Sustainability Change & Adaptive Management	Local flow support measures. Compensation volume of up to 4Ml/d.
Strategic Grid	River Ashop[1]	Sustainability Change	Change to local flow support.
Strategic Grid	River Noe[1]	Sustainability Change	Change to local flow support.

Note 1: These sites are listed in WINEP3 with a no deterioration driver. They have been included in table A4.2 of our WRMP as they are AMP6 RSA investigation sites and scheme was agreed though RSA options appraisal.

These site based sustainability changes arising from the RSA schemes outlined in Table A4.1 to A4.6 have been included in the zonal deployable output reductions in the appropriate WRMP Tables. The loss of deployable output at a WRZ level is listed in Table A5.3 and includes both RSA and WFD No Deterioration reductions due to the way we have combined these in our central best estimate modelling. There has been a variation to our central best estimate between our draft and final WRMP19 as a result of completing the RSA options appraisal. However this has not been a material change to our WRMP.

A5 Achieving Water Framework Directive objectives

A5.1 Background to WFD No Deterioration

Under the Water Framework Directive (WFD) we have an obligation to prevent the deterioration of the quantitative and qualitative status of a waterbody. Deterioration of the quantitative status of a waterbody could arise if our abstractions increase in the future due to growth. If this occurred, we would be taking more water out of the environment. Taking action to prevent deterioration now will prevent us from having to repair damaged waterbodies in the future, which would be more expensive. Our abstractions need to be more sustainable and we need to achieve this without compromising the supply of water to our customers.

The Environment Agency (EA) undertook a risk assessment of the likelihood of our abstractions causing deterioration as part of the 2nd cycle of River Basin Management Plans (RBMPs) released in 2015. This risk assessment was based on the consequence of our licences being used at their full capacity. In October 2016, the EA indicated that their initial assessment could have a significant impact on our security of supply and would drive unnecessary investment. Following this statement, the EA issued a second assessment, which is risk-based and considered to be more representative of the actual risk of deterioration. The trigger to assess whether deterioration would occur was set by using a future predicted scenario based on PR14 and WRMP14 planned growth figures. These figures were used in combination with the Environmental Flow Indicator (EFI) as a means to undertake a nation-wide screening of ecological impact related to a future deterioration risk. The EFI, which is a hydrological indicator, is the EA's best available, nationally consistent indicator of the impact of abstraction on flow and ecology.

Waterbodies, and consequently abstractions from those waterbodies, were grouped into categories, depending on where the planned growth falls against the EFI. A planned increase in abstraction may not pose a deterioration risk if flow is currently above the EFI and is likely to remain above the EFI with the planned growth in abstraction. The EA grouped waterbodies in the following categories:

- Waterbodies suffering from seriously damaging abstractions (Category 1)
- Waterbodies where deterioration is likely to occur by 2027 (Category 2)
- Waterbodies where deterioration is likely to occur by 2040 (Category 3)
- Waterbodies where deterioration will not occur by 2040 (Category 4)

We wanted to improve our understanding of the risk associated with taking more water from water bodies that may be subject to deterioration. We took the EA's work a step further as we wanted to further explore the potential impacts on water supply to our customers. Our first step was to undertake our own growth assessment, and use this to understand where growth may occur.

In 2016, we obtained the most recent Local Authority (LA) household year by year growth figures and we mapped these to our Water Quality Zones (WQZs). We then mapped WQZs to the individual sources supplying these WQZs. We added household growth figures for the period 2015-2027 and 2027-2040 to the household numbers for 2015 to determine the total number of households in 2027 and 2040 respectively. Then, we multiplied the number of households in each period by the current average household occupancy rate to estimate the total potential population growth in each WQZ. We converted the population to a volume of additional demand for water for each period using our current estimate of per-capita water consumption. We then used these demand growth projections to determine which sources of water would need to increase future output. We classified sources that had planned abstraction growth by 2027 as Category 2 sites while we classified those that had planned abstraction growth by 2040 as Category 3 sites. We shared our assessment in advance of the EA releasing version 1 of the Water Industry National Environment Programme (WINEP1) in March 2017.

Since 2016, Local Authority household growth figures have been updated by a small number of Councils and these were incorporated into the modelling carried out to inform our draft WRMP19. These updated figures could not be included into WINEP version 3 (WINEP3). However, we have compared WINEP3 to our final WRMP and there are no significant inconsistencies that could affect our plan.

WINEP1 listed a total of 134 abstraction sources (123 groundwater and 11 surface water) that were situated in either Category 1 or Category 2 water bodies. The groundwater sources alone were putting approximately 160 Ml/d of our deployable output at risk. A no deterioration investigation driver was set against 88% of the sources. We considered this large AMP7 investigation programme to be too big to manage for us and for the EA. We required a more manageable approach that brought other lines of evidence into the assessment.

We need to put plans in place to manage the risk of deterioration. This and the need for a more manageable AMP7 investigation programme has led us to take a no-regrets approach that has been incorporated into our methodology. We shared this methodology with the EA in advance of their release of WINEP2 at the end of September 2017.

We have a long history of environmental investigations, which started in AMP2. Most of the 134 sources on WINEP1 were investigated in past AMP cycles and we hold significant amounts of data and tools that we have developed over the years. Our no-regrets approach is based on the idea that we have a good understanding of the risks surrounding no deterioration for all those sources that have been investigated in the past under our National Environment Programmes (NEP). For all the others, we will have to undertake environmental investigations so that we better understand the risk around no deterioration.

We have categorised all of the sources listed on WINEP1 using the categories listed below and have used these to inform our future approach for managing the risk of waterbody deterioration. We used this categorisation to inform what we thought the NEP driver should be and shared this with the Environment Agency. The Environment Agency have considered our recommendations and incorporated these in WINEP2 where relevant. Our categories are as follows:

Adaptation: Sources that require an adaptation approach

These are sources where we understand that deterioration will occur if we increase our abstractions. In WINEP2, these sources have a No Deterioration implementation driver where action is required. They are shown with either green or amber certainty. There are also multiple drivers (for example WFD no deterioration, Restoring Sustainable Abstractions, resilience, catchment wide water quality issues, etc.), often within the same WRZ. We want to take action now to prevent future deterioration and we realise that strategic solutions will deliver more holistic approaches for resolving the complex nature of the problems in these areas, as opposed to a multitude of local solutions. Such strategic solutions are likely to require several AMP cycles for delivery and alternative solutions will be required to prevent deterioration in the interim. We realise that there may be a need to invoke WFD Article 4.7[1] however, at this stage, we believe that this will not be necessary as our interim measures should prevent deterioration from occurring. We will aim to focus on catchment and partnership measures as alternative interim measures while the strategic solutions are being delivered. We believe that this is a more cost effective way of delivering solutions across the short, medium and long term. We will apply for licence changes by 2025 and have accounted for a consequent loss of deployable output in our WRMP by 2030 in our central best estimate for each source in this category.

[1] Article 4(7) of the WFD sets out the conditions for derogation in the event of new modifications to the physical characteristics of a body of surface water, alterations to the groundwater levels within a groundwater body or new sustainable human development activities

Prevention/Mitigation: Sources that require prevention/mitigation

For sources in this category, we believe that we understand the risk of deterioration and that we can manage the risk through a series of actions that will prevent deterioration occurring.

Measures such as local flow support, hydromorphology measures to improve environmental resilience, catchment and partnership solutions, localised demand management will help us mitigate against the risk of deterioration. Other measures such as enhanced source abstraction management controls through better Instrumentation Control and Automation (ICA) and telemetry and new distribution links to more sustainable sources of water will help us prevent the risk of deterioration. We would seek to use an adaptive management approach where possible but we realise that future sustainability reductions may be required at some point. Due to the lack detailed feasibility assessments, we have accounted for some of this uncertainty in our WRMP by running different scenarios with high, medium or low WFD scenarios. We have assumed that we may lose up to 50% of the difference between our current deployable output (DO) and our 'Recent Actual' (RA) abstractions. This is driven by the potential need to still request five or ten year rolling average licences by 2025 for many of our groundwater sources, despite taking action to prevent deterioration. Ultimately, this would lead to a net reduction of our average licence over the five to ten year period. We have therefore accounted for a consequent loss of deployable output in our WRMP by 2030 in our central best estimate for each source in this category.

Investigation: Sources that require investigations and options appraisal in AMP7

These are sources where we have no environmental data and therefore do not fully understand the risk of deterioration. We believe that we will need to collect data and undertake further assessments to improve our understanding of the risks. We would be promoting sources within this category for no deterioration investigations in AMP7. Here too we have to manage uncertainty and have reflected this uncertainty in our WRMP central best estimate. We have done this by considering a potential loss of 50% of the difference between our current DO and RA abstractions in our central best estimate for all sources in this category.

We are required to determine whether our existing abstractions are meeting RBMP sustainability objectives and in cases where there is risk of not meeting these, we must determine the changes that will be required to our abstractions to meet RBMP objectives. In order to meet these requirements, we have assumed DO losses against RA based on the category (one of the three categories as defined above) in which it falls. For our surface water sources, the EA only classified a relatively small number as category 1 or 2. Out of this modest number of sources there are Hands-off Flow (HoF) conditions in many of the licences. In most cases, the HoF provides appropriate protection for the environment. If the HoF is not considered an appropriate protection mechanism then we will have already investigated the sources as part of previous Habitats Directive (HD) or Low Flows programmes.

A5.2 Preventing WFD status Deterioration - Groundwater

Our WRMP includes measures that to protect waterbodies against the risk of deterioration occurring from unsustainable abstractions, both under normal conditions and under drought conditions. Similar to the assumptions made around RSA drivers, our draft WRMP assumptions around preventing WFD Deterioration were based on the best available information and reflected what we expected the Environment Agency to include in WINEP3.

During the consultation of out draft WRMP, we received a number of comments requesting clarification of our explanation of WFD scenarios and how these impacts were mapped to the data tables.

In summary, we do not believe that the new information within WINEP3 leads to any overall significant change to our WRMP. The sustainability changes in WINEP3 are defined against recent actual abstractions for all lines where a 'sustainability measure' is identified. Section A5.1 describes the assumptions we have made to quantify the assumed deployable output (DO) losses. Our assumptions were made around potential DO loss for each source depending on recent actual abstractions and on the WRMP category the groundwater sources falls in (Adaptation, Prevention/Mitigation, Investigation). For example, all sources within in our 'Adaptation' category have sustainability changes defined against recent actual abstractions. This means we have assumed a loss of 'spare capacity' from the source, assumed to be the difference between the modelled DO and recent actual abstractions.

The modelling scenarios listed in Table A5.1 were completed in April 2017 and were based largely on WINEP1. Our approach to assessing WFD Deterioration risks evolved and became clearer as we progressed towards WINEP2. The transition from WINEP1 to WINEP2 involved several significant steps:

- We defined our Adaptation, Prevent/Mitigate and Investigation approach (i.e. our WFD No Deterioration strategy) and categorised our sources accordingly (described in section A5.1).
- Whilst all our sources were under an 'Investigation' driver in WINEP1, a significant proportion (c. 60%) of our sources were moved to various WFD No Deterioration implementation drivers in WINEP2.
- We incorporated our medium WFD No Deterioration scenario (broadly consistent with the total of the Medium Scenario in Table A5.1) and our RSA DO losses into our central best estimate for our baseline scenario (line 8.2BL+) in the data tables accompanying our WRMP.

The transition from WINEP1 (scenario modelling stage) to WINEP2, did not result in significant changes to deployable output at a company level. When we published our draft WRMP, we felt we had a good understanding of the potential extreme scenarios for WFD No Deterioration scenarios. Consequently, we did not feel that further scenario modelling was needed for WFD No Deterioration at WINEP2 stage. We felt that the size of the problem had been well defined by our central best estimate and this was well within the range of our scenarios extremes for WFD No Deterioration.

In line with our approach to RSA described in section A4, in April 2017 (just after the release of WINEP 1) we used three investment modelling scenarios for both surface and ground water sources to determine our approach to WFD No Deterioration in our draft WRMP. These scenarios were:

- **A lower scenario:**
  That accounted for a 50% loss of deployable output above recent actual abstraction values; losses of deployable output would occur from 2030 onwards.
- **A middle scenario:**
  That accounted for an 80% loss of deployable output above recent actual abstraction values; similarly to the low scenario, losses of deployable output would occur from 2030 onwards.
- **An upper scenario:**
  That assumed that our sources are capped at recent actual abstractions from 2020 onwards (recent actual abstractions are calculated using the average of the last 5 or 15 years of abstraction figures, depending on the geological nature of the aquifer for the groundwater sources).

The extent of the deployable output impacts to our WRZs by 2035 arising from WFD No Deterioration alone are shown in Table A5.1. These reflect the early stages of our thinking (early 2017) around our WFD No Deterioration strategy when all of our groundwater sources had an Investigation & Options Appraisal (OA) driver in WINEP1.

Table A5.1: Range of DO losses considered in our scenario modelling for our draft WRMP (WINEP1 impact)

WRZ	Low Scenario DO loss (Ml/d	Medium Scenario DO loss (Ml/d)	High Scenario DO loss (Ml/d)
Nottinghamshire	20	10	20
Shelton	10	23	33
Forest of Stroud	2	3	4
Strategic Grid	11	97	105
North Staffordshire	0	8	11
Bishops Castle	0.69	1.1	1.38
Kinsall	0	0	0
Mardy	0.54	0.86	1.08
Newark	0	0	5
Ruyton	0	0	0
Staffordshire	0	0	0
Wolverhampton	0	2	3
Whitchurch & Wem	1.09	1.75	2.19
TOTAL	**45.3**	**146.7**	**185.7**

As we progressed towards WINEP2, the Environment Agency provided further guidance around WFD No Deterioration and we were able to better define our strategy around this challenge. The timing of WINEP2 information release meant that we could not incorporate the small changes relating to WFD No Deterioration into our draft WRMP in time for publication. These changes included an abstraction reduction at our intake on the River Wye, which is no longer required as this source was removed from WINEP2. The subsequent release of WINEP3 include the addition of the Caunton source in our Nottinghamshire WRZ, which slightly increased our assessment of DO losses in this zone.

Almost all our groundwater sources had an Investigation & Options Appraisal driver in WINEP1. Many of our groundwater sources in Shropshire (in our groundwater only WRZs such as Bishops Castle and Whitchurch & Wem) have had an Investigation driver throughout the various WINEP stages and the assumptions have not changed for these. This means that the DO losses provided in the WRMP data tables for those WRZs align with the 'low' modelling scenario shown in Table A5. However, the WINEP drivers for most of our remaining sources were changed between WINEP1 and WINEP2. Consequently, the assumptions underpinning our DMU scenario modelling would have been different to those underpinning the data in our draft WRMP tables.

In our final WRMP, we have included WINEP3 WFD requirements in our best central estimate of future deployable output. The total deployable output impact across all WRZs broadly coincides with our draft WRMP Medium Scenario shown in Table A5.1. However, in the modelling for our final WRMP, we combined the WFD No Deterioration losses with RSA sustainability reductions discussed in section A4 and reported the output of this modelling as combined DO losses in our final WRMP data table lines 8.2BL+.

The best central estimate of DO for our final WRMP is based on the deployable output losses outlined in Section A5.1:

- A 100% loss of deployable output above recent actual abstraction for all sources in the Adaptation category, associated with licence changes set to recent actual abstractions.
- An average 50% loss of deployable output above recent actual abstraction for all sources in the Prevent/Mitigate category to account for the lack of detailed feasibility around possible measures.
- An average 50% loss of deployable output above recent actual abstraction for all sources in the Investigation category to reflect the uncertainty around the outcome of the investigations (i.e. one in two sources would not cause environmental deterioration based on predicted growth figures).

In our calculations, we have considered the 15 year (2001-2015) recent actual abstraction for our Permo-Triassic sandstone sources and 6 year recent actual abstraction (2010-2015) for all other sources. The above WRMP assumptions are aligned with WINEP3 drivers and measures.

A5.3 Preventing WFD status deterioration – Surface Water

During the consultation phase of our draft WRMP, the Environment Agency requested clarification regarding our WFD deterioration risk assessment of surface water abstraction licences, particularly those with a hands off flow (HOF) condition. In our draft WRMP, for our surface water abstractions with potential to cause WFD deterioration, we chose to analyse the effect of licence reductions for category 1 and 2 sources using a similar methodology as we used with groundwater reductions. We used this approach because we had not at that point received guidance from the Environment Agency on the preferred methodology to use with surface water abstractions. Due to the timing, our modelling was also conducted prior to WINEP3 and before the AMP6 RSA investigations and options appraisal conclusions were finalised.

The methodology we adopted assessed the recent actual annual average abstraction and compared this with the modelled source deployable output. In line with the ground water methodology we looked at three different potential scenarios for our sensitivity modelling for the draft WRMP. These were the Low, Medium and High impact set of scenarios defined in section A5.2.

For our draft WRMP we used the medium scenario from this earlier sensitivity modelling as our central estimate of the surface water abstraction reductions required to ensure no future WFD status deterioration. These were built into a combined model run with groundwater WFD no deterioration reductions and our assessment of the likely RSA licence reductions. These reduced abstraction licences were entered into our Aquator water resources model as annual constraints on the amount of water available to abstract. Specifically for our Egginton abstraction site on the River Dove, we modelled the potential effect of the WFD no deterioration licence reduction rather than the RSA removal of the lower HOF. We considered that modelling both changes at the same time would have been double counting of the risk and effect.

During the Medium scenario for our draft WRMP we assumed that for WINEP1 category 1 and 2 surface water abstractions (Egginton, Ambergate & Mitcheldean) there would be no abstraction licence changes implemented before 2030. This is because the impact on zonal deployable output was so significant it would require strategic scale water supply investment to offset the effects on drought security of supply.

Our WFD No Deterioration approach for surface water abstraction was changed for our final WRMP. In January 2018 we received updated guidance from the Environment Agency regarding WFD No Deterioration in the Environment Agency's publication *'Guidance on water resources investigations into the risk of WFD water body deterioration'*. This guidance for the first time explicitly included information for analysing surface water abstractions in relation to compliance with the Environmental Flow Indicator (EFI). Consequently, it was clear that our draft WRMP methodology for modelling surface water reductions was unsuitable for certain sources e.g. Egginton, as it did not fully consider the EFI. Following the new guidance issued, in February 2018 we updated our process for assessing WFD no deterioration at surface water sites.

For our final WRMP we have categorised our surface water abstractions into five classifications:

- **River abstraction with HOF > EFI**
  Where an abstraction is on a river, if the river has a HOF for that abstraction which is above (or the same as) the EFI then the HOF will stop our abstraction causing deterioration. Therefore these abstraction licences do not need to be changed.
- **Regulated river abstractions**
  Where our abstractions are on a regulated river such as the River Severn, we believe the regulation on the river will stop the abstractions causing deterioration. Therefore these abstraction licences do no need to be changed.
- **Abstraction from source subject to RSA/HD assessment**
  Where an abstraction is on a river/ reservoir which has recently had an RSA or Habitats Directive (HD) assessment, if this assessment has considered the full impact of the licences, the abstractions will not cause a risk of deterioration. Therefore these abstraction licences do no need to be reduced.
- **Reservoir abstraction with compensation > EFI or reviewed by an RSA assessment**
  Where an abstraction is on a reservoir with a compensation, if the compensation is either above the EFI or has been recently reviewed and actions put in place through an RSA assessment this will stop the abstraction causing deterioration. Therefore these abstraction licences do no need to be changed.
- **Other**
  If none of the above are true, then the source/abstraction needs to be assessed to see whether there is likely to be a higher abstraction in the future.

The most material impact of our revised approach is seen at our Egginton abstraction on the River Dove. As stated previously, we concluded that the method of modelling reduced annual licence used in our draft WRMP was unsuitable and specifically for Egginton and that this should be modelled as a removal of the lower HOF condition, stopping any abstraction below the upper HOF.

Since our draft WRMP was published, we have carried out a number of modelling assessment with and without the lower Egginton HOF removed. We have additionally tested the effect of adding Temporary Use Ban (TUB) and Non-Essential Use Ban (NEUB) curves to the Dove reservoirs (triggering a level of service demand reduction earlier) with the lower HOF removed.

The removal of the lower HOF causes very large reductions in deployable output across all scenarios, with zonal reductions between 61 – 98 Ml/d. The use of the lower HOF is triggered by the joint reservoir storage in the two River Dove reservoirs dropping below a prescribed storage levels curve. Abstraction between the upper and lower HOFs only occurs in seven years in the 95 year baseline model run. Out of these, three years have abstractions for longer than 20 days. In total out of the 34,700 day model run, there is abstraction below the upper HOF for 283 days, with the longest abstraction in a single drought year being 91 days.

Overall, our final WRMP incorporates our updated WFD No Deterioration methodology for surface water sources and is consistent with the Environment Agency guidance released in 2018. Our new methodology ensures surface water sources with HOFs that may be insufficient to achieve the EFI are appropriately prioritised according to potential growth in abstraction. Our final WRMP includes for the effect of removing the lower HOF at Egginton by 2030.

A5.4 Managing the risks around WFD Deterioration

Our approach to managing WFD deterioration risk has always been to target environmental investigations where the uncertainties are greatest (Section A5.1). This is what led us to categorise our sources into Adaptation, Prevent/Mitigate and Investigation. In January 2018, the Environment Agency issued its guidance '*Guidance on water resources investigations into the risk of WFD water body deterioration*'. This guidance sets out clear principles upon which water companies, including us, should prioritise no deterioration investigations. Focus should be given to prioritising high risk waterbodies and we have developed a technical framework that is consistent with this guidance. We have shared this framework and the resulting prioritisation with the Environment Agency.

During consultation of our draft WRMP, we received some stakeholder comments expressing concern about the potential use of alternative flow targets to the EFI when assessing our WFD Deterioration risk. As indicated in our draft WRMP, we were still developing our strategy around WFD No Deterioration when our draft WRMP was published. As part of the initial work, we wanted to better understand the range of potential sustainability changes that could arise from WFD No Deterioration. In July 2017, we proposed a range of possible sustainability changes to the Environment Agency for WINEP2, under '*Sustainability Change (to Daily Licence Volume) Ml/d*'. This ranged from precautionary '*capping licences to recent actual abstractions*' to less precautionary, more risk based approach, based on historical datasets and predictive tools. The less precautionary approach was based around our assessment of sustainable abstraction relying on data and evidence collated to date.

The Environment Agency released (WINEP3) in April 2018. Our final WRMP is now aligned with WINEP3 and the sustainability changes are defined against recent actual abstractions for all sources where a 'sustainability measure' is identified, rather than our sustainable abstraction figures.

At the time of publishing our draft WRMP, we were also in discussion with the Environment Agency around the use of our hydro-ecological model as a tool to inform the risk of deterioration. Since our draft WRMP was published, we have also initiated a collaborative project with the Environment Agency to further develop our hydro-ecology model and understand when it can be used as a supporting predictive tool for assessing WFD No Deterioration in the Permo-Triassic Sandstone. When this work is complete, we feel it will better inform how we assess the risk of deterioration from our groundwater sources.

In July 2018, we shared with the Environment Agency our draft '*No Deterioration Technical Framework*' that we propose to follow in AMP7. In the document, we confirmed that our WFD No Deterioration investigations have been prioritised based on the EFI.

We recognise that we are required to determine whether our existing abstractions are meeting River Basin Management Plan (RBMP) sustainability objectives. Where there is a risk of not meeting these we need to identify the required changes to our abstractions in order to meet those objectives. For WFD No Deterioration purposes, the sustainability changes presented in WINEP3 are calculated against the recent actual abstractions for the sources affected. We are carrying out an ongoing collaborative project with the Environment Agency to improve our predictive tools. We will use the results from this project to inform our approach to future abstractions from sources under investigation, subject to agreement with the Environment Agency.

In our WRMP we committed to reducing our impacts from current groundwater abstractions under RSA by 23 Ml/d in the Nottinghamshire WRZ. We also committed under WFD No Deterioration, to not take up spare licence capacity by up to 88 Ml/d at our groundwater sources abstracting from the Sherwood sandstone aquifer. Through our WRMP, we have also committed to ambitious demand management and leakage reductions in the Nottinghamshire WRZ. These measures alone will improve the long term resilience of the aquifer.

However, we acknowledge that more work will be required to support a more holistic understanding of the aquifer resilience. To this end, we are committed to working with other stakeholders in the Nottinghamshire area as we want to improve our understanding of such a complex problem like groundwater resilience. We believe that further assessments will be required and that these should be carried forward in collaboration with existing stakeholder groups like the CaBA groups. The recent announcement by the Environment Agency to focus on the Idle and Torne as an initial priority catchment (IPC) for the Abstraction Plans will represent a good opportunity to:

- Improve our understanding of aquifer resilience.
- Provide a platform to launch initiatives and studies around complex catchment issues, such as current land use and catchment pressures.
- Provide an understanding of how land use and catchment specifics might change in the future and how these would change under different climate change scenarios.

The outcome of such collaborative initiatives will provide a common understanding around the medium to long term water quality and water quantity issues in the zone. We will use these outcomes to guide our future WRMP and business plans.

A5.5 WFD No Deterioration and drought

We have followed industry best practice for drought planning purposes and our approach is summarised in our Drought Management Plan (DMP). The programme for preparing DMPs is slightly different to the WRMP process. Our current DMP for period 2014-2019 is available on our website. We have published our draft DMP for period 2019-2024 for consultation on our website and the final version of the DMP 2019-2024 is expected to be published in 2019. Referring to our draft DMP 2019-2024, we have measures in place to prevent or mitigate for the environmental impacts of drought actions. Most raw water sources included in our DMP have a WFD assessment which appraises the risk of deterioration occurring from abstractions during drought conditions. For our groundwater sources, particularly those drawing from the Permo-Triassic aquifer, the inter-annual fluctuations arising from a drought is likely to be buffered by the storage of the aquifer.

We accept that if the emergency sources listed in our DMP were to be used during a drought event, the effects of the abstraction would be compounded to those already in place under normal, average conditions within the waterbody. This may potentially lead to unsustainable abstractions in the interim within these waterbodies. We would mitigate for any long term effects of any short term abstraction changes.

While the emergency sources listed on our DMP are not specifically listed on our WINEP programme, some groundwater sources are located on waterbodies that are listed on WINEP. Any compounding effects arising from the additional abstraction from the emergency sources would be considered through our WFD No Deterioration work. As an additional consideration, we have a responsibility to ensure that deterioration of waterbodies is prevented from abstraction at all our surface water and groundwater sites regardless of whether there is an entry listed in the WINEP programme.

Our DMP states that for emergency sources, we will consider the need for assessments against waterbody deterioration if there was a likelihood that these sources would be required during a drought event. This is justified due to the long lead in time before we may need to use these sources. However, we will further consider within our technical WFD No Deterioration framework whether the sources most likely to be required during a drought should be investigated as part of our wider AMP7/8 WFD No Deterioration programme. We will continuously liaise with the Environment Agency regarding the need to undertake further work at our surface water and groundwater sources, regardless of whether they are listed in the WINEP programme.

A5.6 Modelling the effects of WINEP3 on deployable output

As already described in previous sections, the timing misalignment between our draft WRMP and the Environment Agency's release of WINEP information meant that we based our draft WRMP on the best available understanding of what was likely to be included in the final WINEP programme. During development of our draft WRMP, we worked with the Environment Agency to ensure the RSA schemes likely to be included in WINEP were incorporated into our best central estimate for our draft WRMP. We also included our best assessment of the likely impacts of abstraction licence changes needed to prevent future WFD status deterioration.

Since we published our draft WRMP, we have confirmed with EA the conclusions of our AMP6 RSA investigations and we have updated our assessment of WFD deterioration risks. The licence changes associated with these updates were included in the Environment Agency's WINEP3 release and are now included in our final WRMP.

These updates mean some changes to the assumptions used in the draft WRMP. For example:

- The conclusions of our RSA investigation and options appraisal into the impact of our sources on Cinderford Brook and Aldford Brook indicated that we should focus on in-river and habitat improvement measures to help improve the status of these brooks rather than make long term reductions in abstraction. We should also reduce the abstraction licences to limit future abstraction growth and prevent future deterioration of WFD status.
- Potential schemes for the River Maun, Rudyard Reservoir and River Blythe pumped intake were removed from WINEP between version 2 and 3 based on the outcome of our impact assessment. However, only one of the schemes (Rudyard Reservoir) was included as a potential sustainability reduction in our draft WRMP central best estimate. The Options Appraisal process concluded that this was not required and was not included in WINEP3. The outcome of the removal of the Rudyard Reservoir scheme has slightly reduced our estimated deployable output loss in North Staffordshire WRZ.
- Our draft plan assumed an abstraction change related to WFD No Deterioration at our intake on the River Wye, however this is no longer required as this source was removed from WINEP.
- Other WFD changes between WINEP2 and WINEP3 include the addition of our Caunton source in our Nottinghamshire WRZ, which slightly increases our final WRMP assessment of DO losses in this zone.

Overall, these changes have resulted in some small changes to the modelled impacts on zonal deployable output. However, the sustainability reductions listed in WINEP3 are within the bounds of the scenarios we used to develop our draft WRMP and they align closely with the medium scenario we used for our best central estimate in our draft WRMP.

Tables A5.2 and A5.3 provide a comparison of the WINEP related deployable output changes between draft and final WRMP. Table A5.2 shows the total loss of the individual groundwater licence changes that were used as an input to the Aquator zonal deployable output modelling for draft and final WRMPs. The tables summarise both the water resource modelling inputs and outputs respectively for both RSA and WFD No Deterioration combined.

Table A5.2: Comparison between our draft WRMP model inputs and our final WRMP input (for groundwater sources only)

WRZ	Model inputs for our draft WRMP (Ml/d)			Model inputs for our final WRMP (Ml/d)		
	2025	2030	2035	2025	2030	2035
Bishops Castle	0	0.7	0	0	0	0.5
Forest and Stroud	0	3.5	0	0	2.8	0
Kinsall	0	0.5	0	0	0.5	0
Llandinam and Llanwrin	0	0	0	0	0	0
Mardy	0	0.5	0	0	0.5	0
Newark	0	1.6	0	0	1.8	0
North Staffordshire	0	25.9	4.4	17.8	8.1	2.5
Nottinghamshire	0	84.8	0	0	88.5	0
Rutland	0	0	0	0	0	0
Ruyton	0	0	0	0	0	0
Shelton	0	18.6	0	7.6	12.5	0.2
Staffordshire	0	0.7	0	0	1.2	0
Strategic Grid	0	23.3	4.6	2.0	14.4	5.4
Whitchurch and Wem	0	1.1	0	0	1.1	0
Wolverhampton	0	3.9	0	0.5	2.6	0
Company	**0**	**165.1**	**9**	**27.9**	**134**	**8.6**

Table A5.3: Comparison between our draft WRMP modelled output and our final WRMP outputs (all sources).

WRZ	Model inputs for our draft WRMP (Ml/d)			Model inputs for our final WRMP (Ml/d)		
	2025	2030	2035	2025	2030	2035
Bishops Castle	0.0	0.5	0.5	0	0	0.5
Forest and Stroud	0.0	6.0	6.0	0	0	0
Kinsall	0.0	0.5	0.5	0	0.5	0.5
Llandinam and Llanwrin	0.0	0.0	0.0	0	0	0
Mardy	0.0	0.5	0.5	0	0.5	0.5
Newark	0.0	0.0	0.0	0	0	0
North Staffordshire	36.0	36.0	36.0	36	36	36
Nottinghamshire	0.0	30.0	30.0	1	38	43
Rutland	0.0	0.0	0.0	0	0	0
Ruyton	0.0	0.0	0.0	0	0	0
Shelton	2.0	14.0	14.0	2	11	11
Staffordshire	0.0	0.0	0.0	0	0	0
Strategic Grid	35.0	85.0	95.0	5	90	95
Whitchurch and Wem	0.0	1.1	1.1	0	1.1	1.1
Wolverhampton	0.0	0.0	0.0	0	0	0
Company	**73.0**	**173.6**	**183.6**	**44**	**177.1**	**187.6**

*The above figures provide a snapshot of deployable output at the indicated year and are not cumulative.

Both water resource modelling input and output figures show how the impacts of source output reductions in one water resource zone (e.g. Nottinghamshire) are shared across to other linked zones (e.g. Strategic Grid) by the model. The modelled water resource output columns in Table A5.3 can be directly mapped to the data in WRMP tables line 8.2BL.

Table A5.2 demonstrates that at the time of preparing our draft WRMP, the total combined RSA and No Deterioration licence reductions that informed our central best estimate amounted to 174.1 Ml/d (combined total of all losses from all our WRZs). In our final WRMP, the total combined RSA and No Deterioration losses combined across all of our WRZs is 170.5 Ml/d.

Table A5.3 indicates that our modelled DO losses for 2030 and 2035 are comparable for both our draft and final WRMP. The difference between our draft and final WRMP for year 2025 is explained with the different timings of sustainability reductions to surface water abstractions. We do not consider the small changes to be a material change and so the release of WINEP3 is not a major driver for changes to our programme. Further explanation of the details surrounding the timings and scale of changes to our preferred programme of options between our draft and final WRMP is provided in Appendix D.

A5.7 Representing WINEP3 in final WRMP tables

In our draft WRMP we used Table 7 (final plan) of the Water Resource Planning tables to demonstrate how we proposed to implement sustainability reductions. Table 2 (baseline) showed the baseline sustainability reductions, as outlined in WINEP2, with licence reduction implementation dates commencing in AMP7. We added a new row to Table 7 to show how in the final plan scenario we would use ‘up front permitting’ to delay the impact of these sustainability reductions until AMP8. This formula change in Table 7 was only made in our Strategic Grid WRZ.

In response to the consultation feedback we received from the Environment Agency, in our final planning tables we have removed this change to the calculation in Table 7 and have shown the reductions we are planning, based on WINEP3, in Table 2 row 8.2BL for all WRZs. This ensures consistency with other water companies. For WINEP3 we have specifically modelled the removal of the Egginton lower HOF from 2030, as this causes a very large drop in deployable output which we would not be able to be accommodated by 2025.

A6 Invasive non-native species (INNS)

Invasive non-native species (INNS) are animals or plants that have the ability to spread outside their native range, which are having a detrimental impact on the economy, wildlife or habitats. Of particular concern are species that are:

- New to the country;
- On the list of European Union concern;
- Listed on schedule 9 to the Wildlife and Countryside Act (1981), or;
- Not ordinarily resident in the wild.

Some of the activities that we undertake have the potential to create pathways to spread INNS. These activities include recreational activity at our sites and some of the activities we undertake when we treat water and waste water. As part of our supply network we transfer raw water between waterbodies and this can be a potential pathway for spreading INNS.

The Environment Agency has informed us of their position on raw water transfers and has provided a list of sites to investigate through the Water Industry National Environment Programme (WINEP). This has assisted us to develop our approach to INNS in our WRMP, which focuses on the pathway that the transfers create, not where INNS currently occur. The ways we will deal with INNS in our supply system are:

- Where new schemes create a connection between locations not already connected we will design mitigation measures into the scheme to ensure INNS cannot be spread by the new transfer.
- Where new schemes create a connection between locations that have an existing hydrological link, we will undertake an assessment of the increased risk that the scheme poses and develop mitigation measures if required.
- For our existing transfers which have been operating for many years, implementation of mitigation on existing transfers will be gradual and prioritise those of greater risk first. We have provided a list of our major transfers in Table A6.1. We are planning to work with the Environment Agency and carry out a detailed risk assessment of these transfers by 2022.

Table A6.1: Major raw water transfers in our region

Licence	Description of transfers
3/28/38/18	River Ashop and River Noe into Derwent reservoirs (Derwent and Ladybower)
18/54/10/0717, 18/54/10/07 & 18/54/12/053	River Avon to Draycote Reservoir and Leam catchment
03/28/40/121	River Derwent to Ogston and Carsington Reservoirs
03/28/36/147 & 03/28/36/148	River Dove to Staunton Harold & Foremark reservoirs in Trent catchment
03/28/56/030	Rothley Brook and Swithland Reservoir to Cropston Reservoir
n/a	Site S from Elan Valley Reservoirs to Site U
n/a	River Cownwy and River Marchant diversions into Lake Vyrnwy

We have the infrastructure and a licence to allow us to transfer water from Rothley Brook into Reservoir. Due to the presence of signal crayfish in Rothley Brook we are unable to use this transfer, so we have not included it in our assessment of deployable output (DO) for the our WRMP. This is the only reduction to DO at our sites that has been specifically driven by INNS.

A7 Abstraction reform and licences

Water Minister Therese Coffey announced at the end of March 2017 that there are no immediate plans to progress with abstraction reform or associated changes to primary legislation. In line with this announcement we have not included any changes to DO from abstraction reform. On the 14th September 2017 Defra released its 'abstraction plan' which sets out a vision for reforming abstraction management using local catchment leadership using solutions developed on a voluntary basis.

With specific regard to our sources that have unused licence volumes that are required for emergency and/or drought purposes, this information can be found within our statutory draft Drought Plan which was published for consultation in 2018 and covers the period 2019-2024.

We operate using abstraction licences within three cross-border catchments (Rivers Dee, Wye and Severn). Where there are unused licenced volumes associated with licences that fall within these catchments our WRMP19 options appraisal has considered whether we can utilise this licensed volume within our supply / demand options. We are also exploring the future possibilities for water trading and how we can make best use of any underutilised licensed quantity within these catchments.

Any of our abstraction licences that have the potential to cause environmental harm have been flagged through the Restoring Sustainable Abstraction work or through the Water Industry National Environment Programme (WINEP) analysis that has been jointly undertaken by the Environment Agency and Severn Trent.

Abstraction Incentive Mechanism

We have not previously adopted AIM because the sandstone nature which dominates our aquifers means there is a long-term response time between changes in groundwater abstraction and experiencing realised impacts on surface water flow. However, for our PR19 business plan we are committing to utilise AIM. We have used Ofwat's AIM methodology to devise a version that is suitable and applicable for our region and still follows many of the guiding principles so that we commit to reduce abstraction at selected environmentally sensitive sites. The methodology that we have proposed to Ofwat has been discussed and approved with our Customer Challenge Group.

The approach we are using for our PR19 business plan utilises the results of WINEP3 to select our AIM sites, as per the Ofwat AIM guidelines. Following our WINEP prioritisation work, we identified a total of 33 sites that were potential AIM sites. These were then reduced to 17 sites once we removed sites that where abstraction could not be reduced due to their supply criticality. Further sites were removed by assessing each site using Ofwat's criteria. Any sites where the abstraction licence was a compensation licence were removed as this abstraction already takes place for environmental benefit. Any source where AMP6 interventions were already taking place to change the abstraction licence to a compensation source were also removed.

Our operational teams were consulted to understand any supply issues in relation to water quality that may affect site selection. This resulted in removing any sites with interdependency to other site, for example where blending water from more than one source is required to enable us to meet water quality requirements. Ultimately, we screened our initial 33 sites to a total of four sites that are suitable for AIM, however only two of these sites have suitable observation boreholes close to their sites that could be used to set trigger thresholds based on groundwater levels. These two sites are:

- Highgate borehole
- Dunhampton borehole

Managing abstraction at these two sites have been included in our PR19 business plan as AMP7 performance commitments.

The AIM threshold will be based on groundwater level trigger points instead of surface water flow trigger levels. We will monitor the water level within an identified observation borehole that is close to the AIM site and within the same groundwater management unit from which the source abstracts. Once the groundwater level in the observation borehole falls to below the trigger threshold, we will reduce our abstraction in line with the baseline average daily abstraction value for the site. The AIM calculation will work exactly the same as if the trigger level was a surface water flow.

We have adopted the full Ofwat definition of the Abstraction Incentive Mechanism (AIM) as per the guidelines released by Ofwat in February 2016. Our monitoring metric will be the difference in abstracted volume (measured in Mega (million) litres, Ml) between the set baseline daily average abstraction value and the actual abstraction at our identified AIM sites during periods when the AIM threshold has been crossed. A negative number will signify our average abstraction is less than the baseline and hence an improved performance.

A8 Outage - Redacted

A9 Imports and Exports - Redacted

A10 Levels of service and consistency with our drought plan

Levels of service are a contract between a water company and its customers, setting out the standard of service that customers can expect to receive. Our WRMP sets out our recommended strategy for maintaining the minimum standard of service that our customers can expect for restrictions on water use.

If we ever had to restrict our customers' use of water we would either impose a temporary use ban (TUB) or, in a more severe drought, we could apply to Government for a drought order to restrict wider use through a non-essential use ban (NEUB). A TUB is roughly equivalent to what we would have called a hosepipe ban prior to the change to the legislation / regulation in 2010.

Based on the analyses carried for our supply forecast and drought resilience we consider that our current annual average risk of drought restrictions of 3% will not change across the planning period. This annual average risk value has been calculated based on the frequency of Temporary Use Bans (TUBs) and Non-Essential Use Bans (NEUBs) water use restriction that we used in our calculation of deployable output in our Aquator water resources model. NEUBs are also known as Ordinary Drought Orders. We have not changed our stated levels of service for customer restrictions since our previous WRMP in 2014. Our levels of service in response to drought is shown in Table A10.1.

Table A10.1 Company Level of Service and Annual Average Risk of Drought Restrictions for each AMP from 2020 to 2045

Drought Restriction	Our levels of services	2020-25	2025-30	2030-35	2035-40	2040-45
Temporary Water Use Ban	3 in 100 years (3% annual risk)	3%	3%	3%	3%	3%
Ordinary Drought Orders (Non-Essential Use Restrictions)	3 in 100 years (3% annual risk)	3%	3%	3%	3%	3%
Emergency Drought Orders	We consider these unacceptable	<0.2%	<0.2%	<0.2%	<0.2%	<0.2%

Our drought resilience analysis demonstrates that we are able to meet DEFRA's reference level of service (a 1 in 200-year drought) without the use of emergency drought orders. As described previously, we consider planning on the basis of relying on the use of emergency drought orders as unacceptable. However, for reporting purposes we have supplied the likelihood of requiring these in the table above, this has been calculated using the data included in Table 10 -Drought plan links, of our final WRMP. These tables show that where we have drought vulnerability, even if there is a drop in deployable output under a 1 in 300 (0.33%) or 1 in 500 (0.2%) year drought scenario this would be offset by the use of drought actions (such as Drought Permits and emergency sources) that we would put into place before an emergency drought order would be used. However under a 1 in 1000 (0.1%) year the drop in deployable output is too large to be managed using these drought actions. Therefore, our likelihood of requiring an emergency drought order is between 0.2% and 0.1%.

Further information on our drought resilience work can be found in Section A11. We have also ensured alignment of these figures with our current Drought Plan 2014 and our draft Drought Plan 2018. For information on drought resilience and levels of service for our new Chester WRZ please Appendix F4.1.

To put our current levels of service in context, we have not restricted our customers' use of water since the 1995-96 drought. The period since 1996 includes the twelve month period to February 2012 which was the driest in the Midlands region since records began in 1910 (as demonstrated by the Environment Agency's Water Situation Report dated February 2012). Despite this extremely dry period we were able to manage our water resources without recourse to customer restrictions. Although we have not needed to implement restrictions on use for two decades and we managed without rota cuts / standpipes in the 1975-76 drought, we are not complacent about drought resilience.

For example, one of the conclusions of the Environment Agency (EA) report '*Water supply and resilience and infrastructure: Environment Agency advice to Defra*' dated October 2015, was that many water companies are overstating their resilience to extreme drought events. We have reproduced the relevant section of this report in Figure A10.1. We think this is a valid conclusion.

Figure A10.1: Extract from 2015 EA report

Executive summary

This advice report sets out information to support Defra in delivering the Water White Paper[1] commitments related to assessing future needs for water resilience and associated strategic water infrastructure.

In this document, we treat resilience as the capacity to maintain essential services under a range of circumstances from normal to extreme.

Our advice is based on a review of the available evidence across sectors which rely on water and encompasses the economic, social and environmental impacts which would result from compromised supplies.

The review has focused on supply pressures associated with severe and extreme droughts, although it does note some non-drought hazards. The options to enhance resilience levels to drought could have wider benefits in terms of other threats to security of supply.

Our review of the evidence has concluded seven key findings:

1. Large parts of society, industry and commerce are currently exposed to the risk of emergency water restrictions (stand pipes, rota cuts etc.) at a likelihood in the order of 1% every year. The risk is often uncertain and is probably understated in some water company plans. The future risk of emergency water restrictions is likely to increase due to a combination of growth pressures and changes to droughts associated with climate change, unless water companies and other businesses invest to maintain current resilience.

We still consider emergency measures such as rota cuts or standpipes are unacceptable and we will do everything we can to avoid them. However we accept that we may have to resort to them in the unlikely event that we experience a drought more severe than the 1 in 500 year droughts we have modelled. We describe our drought modelling in Section A11.

Although we provide a higher level of service than most companies, we do this at the lowest possible cost to our customers. If we planned on the basis that we will never impose restrictions even during times of drought, it would not be economically or environmentally feasible to meet unrestrained consumer demand in all possible circumstances. If we planned never to restrict the use of water, our customers' bills would have to be higher. Conversely there are potential savings if we planned to restrict customers more frequently. We have taken on board the outcomes from our customer engagement when preparing our plan as described in Section A10.3. We believe that our balanced approach to our level of service presents the most acceptable and best value plan for our customers.

Consistency with our drought plan

Every 5 years we produce both a WRMP and a drought plan. A drought plan is a plan that guides our operational response to a drought during a five year period. It is not a costed investment plan. A WRMP is more strategic and looks much further ahead (a minimum of 25 years). Our WRMP is part of our PR19 plan and shows activities that we intend to do (such as reducing leakage or increasing levels of metering) that require funding via the Ofwat Periodic Review 2019 (PR19) process.

We have used our stated level of services in the modelling we have carried out for both our WRMP and for our drought plan. This means that our stated and modelled frequency of service restrictions is consistent between our WRMP and our drought plan.

Additionally, our stated levels of service are consistent with those we have quoted in our previous publications, such as our previous WRMP in 2014, our 2014 drought plan and the draft drought plan we published in 2018 to cover the period 2019-2024. In our drought plan we explain how we respond when drought indicators, such as strategic reservoir storage, enter different drought trigger zones. We use our drought plan to help our decision making during a drought. Our water resource model (Aquator), our drought trigger zones and our assumptions in relation to demand reductions are consistent between our WRMP, the associated tables and our drought plan. Section A11 provides more information on the drought resilience work we have carried out to produce our PR19 plans.

Consistency with the EA and NRW drought plans

When preparing our draft drought plan and this WRMP we have considered and referred to the Environment Agency's 2016 National Drought Framework. We have also referred to the EA area drought plan and/or Natural Resources Wales drought plans as appropriate and where available. We can confirm that there is consistency between the EA/NRW drought plans that we have reviewed and our own plans.

Do our levels of service change over time?

All water resources modelling to predict baseline deployable output, sustainability reductions, climate change, drought resilience and supply option DO benefits have been carried out using a 3 in 100-year frequency of TUBs and NEUBs. If there is a supply-demand deficit in any WRZ we have reported the timing and magnitude of it (in Ml/d) in our baseline WRMP tables. In our final planning scenario we show how any supply-demand deficits forecast will be resolved through our preferred programme of supply-side and demand-side options. Therefore, we assume that with the implementation of these options, the actual level of service will match the planned level of service over the 2020 to 2045 planning horizon. In summary, we plan to maintain the level of service we currently provide to our customers and not make any changes to it. Over the 25-year planning period (2020 - 2045) this equates to a 75% risk of implementing these water use restrictions

One of the planning scenario options we have modelled included increasing the frequency of customers' use restrictions to help us resolve any supply / demand balance deficits. However, this option to balance supply and demand has not been selected as part of our best value configuration of options. Section A2 provides an overview of the relationship between DO and different levels of service as quantified by our Aquator model.

Our approach to groundwater drought

We have considered the resilience of our groundwater sources to long term droughts in particular multiple year droughts. As part of our climate change investigations, we assessed the impacts of multiple year droughts on the deployable output from our groundwater source water production sites. This study concluded that a small number of our borehole sources would be impacted by a prolonged multiple year drought, however only peak deployable output would be affected.

A10.1 Reference levels of service

As suggested in the current Water Resources Planning Guideline (WRPGs, interim update April 2017) we have "*set out a reference level of service that would mean resilience to a drought with at least an approximate 0.5% chance of annual occurrence (i.e. approximately a 1 in 200 year drought event). Resilience in this context would be avoiding emergency drought orders that allow restrictions such as standpipes and rota cuts*". We explain how we have selected and modelled this drought event and numerous other drought scenarios in Section A9 and we present the results of these scenarios in table 10 of the tables that accompany our WRMP. In addition, we have written a drought resilience statement in Section A11.2.

As described below, the DO effect of the reference level of service (1 in 200 drought) is minor. As the DO reduction does not cause any WRZs into deficit we achieve the reference levels of service described in the WRPGs throughout the 25 year planning period.

A10.2 Additional Deployable Output (DO) required

Our Aquator modelling has indicated a reduction of 2 Ml/d DO in the Forest & Stroud WRZ in a number of 1 in 200-year droughts. However, this does not cause the WRZ supply / demand balance to be in deficit. As a result it does not drive the need for investment.

This modelling also indicated that we could continue to supply water throughout a 1 in 200 drought without the need for emergency drought orders. However, it is worth noting that there is no single 1 in 200 year drought. There are an extremely large number of plausible droughts that all have return periods of 1 in 200 years. Section A11 provides more information on our drought resilience work.

As demonstrated in Figure A10.1, we are not planning any changes to our levels of service during the WRMP planning period so the planned frequency of TUBs and NEUBs remains constant throughout the period. We have used the information from our reference level of service when we gather our customers' views but we have been careful to use this information in a way that truly engages customers.

A10.3 Customer views on our levels of service

During the preparation of our WRMP19 we considered it necessary to review and consider the applicability of previous customer engagement that we carried out during development of our previous WRMP14. This established that when preparing WRMP14, we reviewed the evidence held about customer support for different levels of service.

In summary, notable outputs from our customer engagement process for WRMP14 included:

- We carried out willingness to pay research and also produced an online 'sliders' game that allowed visitors to our website to see the impact of competing priorities on total water and wastewater bills.
- Evidence from our customer survey in 2012 suggests that customers may not have been clear about the options that we proposed.
- During the PR14 and WRMP14 customer engagement activities, our customers supported a frequency of water usage restrictions of once every 38 years.
- At that time, the frequency of water usage restriction accepted by our customers was not significantly different to our level of service standard (usage restrictions occurring not more than once every 33 years). We subsequently did not change our level of service standard in our PR14 Business Plan.
- During the customer research we did not made a distinction between temporary use bans (TUBs) and non-essential use bans (NEUBs). We believed that this helped to avoid confusion.

During development of our WRMP 2019, we have carried out further customer engagement as described in Appendix E. When we gathered customer views on levels of service for WRMP19, we improved our approach by carrying out different phases of work:

- **Willingness to Pay (WTP) work**
  This is similar to the work we carried out for WRMP14.
- **Immersive research**
  We did not carry out research like this for WRMP14 but this has many advantages over the other approaches as it means we can 'immerse' selected customers in more detail so that they are properly informed before we ask them for their views on these (often technical and complex) issues. This work also allows customers to consider competing priorities. Figure A10.2 is and extract from the immersive research that we carried out into the topic of drought and levels of service.

Figure A10.2: Extract from immersive research

Our customer engagement found that customer awareness of our supply / demand challenge is very low. According to our customer tracker only 7% of customers think that we won't have enough water in 10 years' time and 10% in 20 years' time. The inference being that severe drought is not something that customers anticipate will affect the UK.

Since drought is not something customers consciously consider, we used deliberative research to discuss and understand our customer's informed views (in line with our strategic research framework). We used a drought 'story board' to help customers imagine the development of a drought situation over time, with progressively more serious customer impact as outlined in Figure A10.2.

Our customer engagement established that the occurrence of a drought would be seen as exceptional and outside of the water company's control. Climate change and changing weather patterns give rise to some concern that droughts could become more common in the UK, and a feeling that this would have a negative impact on the water service. While 'hosepipe bans' were mentioned spontaneously, these are generally seen as quite common and linked to 'hot summers' and not 'droughts', which as a term is interpreted as an extreme scenario that is unlikely to occur. In the engagement quiz about Severn Trent that we ran on Tap Chat, and in our deliberative research, we found that most respondents mistakenly believed that there had been a hosepipe ban in the region since 1996.

The summarised results of this work and how our customers felt about different drought restrictions are:

- **Drought restriction level 1: Encouraging customers to use less water**
  They would feel little impact from scenario 1 (i.e. being encouraged to use less water), and therefore find the current frequency (once every one to two years) acceptable.

- **Drought restriction level 2: Temporary Use Bans (TUBs)**
  Temporary Use Bans (TUBs) are considered acceptable in principle; customers describe them as a pragmatic approach in such circumstances, provided that we can demonstrate we are taking additional steps to limit own water loss. Some customers believed that they had experienced a TUB recently and were surprised to learn that it has been more than 20 years since one has been implemented in our region. Many customers noted that the likely impact on them from a Temporary Use Ban was minimal.
  Due to the perceived minimal impact of temporary use ban (TUB) restrictions, the expected frequency (once every 33 years) is mostly seen as acceptable.

- **Drought restriction level 3: Non-Essential Use Bans (NEUBs)**
  Most customers in our engagement did not consider Non-Essential Use Bans (NEUBs) to have direct impact on them, but they did worry about the impact of such restrictions to businesses.

- **Drought restriction level 4: Emergency Drought Order**
  Participants recognised that requiring the use of standpipes would only occur due to severe and exceptional weather conditions. Therefore they regard our response in those circumstances as proportionate to the seriousness of the situation. However, they are clear that support would need to be put in place for vulnerable customers. The described predicted frequency of 'never (once every 200 years)' for these events is seen as acceptable by most customers. There was no willingness to accept a lower level of service in exchange for a bill reduction. Information on levels of drought resilience for other companies was discussed in the session and not found to influence our customers' view.

Overall, our deliberative research found little support for further investment for the purposes of reducing the risk of requiring TUBs from the current level. Likewise there was no support to reduce the risk of requiring standpipes. Our willingness to pay research also showed that reducing the risk of needing to use standpipes is a very low priority for customers. As part of our valuation research programme we did a survey which we have called the budget game. In the budget game we interviewed customers using a large 'board game' to present them with different service levels (a current level and two improvement options). Each improvement option was costed in terms of a potential bill impact. Customers were able to select their preferred plan using tokens. The total 'cost' of the plan was then calculated and customers had the option of reviewing their choices. Using this approach we found that only 10% of customers selected an improved level of service for standpipe usage.

We think that this useful and in depth customer insight work has shown that the current levels of service we provide and those that we plan for in our drought plan and WRMP are in line with customer views and expectations.

As suggested in the 2017 Water Resource Planning Guidelines (WRPGs), we considered using the United Kingdom Water Industry Research (UKWIR) risk based planning report directly in our customer research in relation to drought resilience. We did not think that this work was suitable for the WTP phase of our work but we have adapted elements of it to assist with our immersive research.

When carrying out our PR19 WTP work we focused our research on emergency drought measures such as rota cuts and standpipes. We expected customers to have stronger views on these than they did on TUB or NEUB frequency. The WTP research showed that our customers were willing to pay £3.8m to halve the risk of standpipes. This may sound like a large amount of money but it was actually smaller than the WTP values for some of the other improvements we asked customers about. We will not make any decisions about the level of service that we offer our customers without clear evidence. Table A10.2 shows the modelled frequency of different restrictions:

Table A10.2: Modelled frequency of restrictions on customers' use

Restriction	Number of events in the record from water resources modelling simulation	Length of record (years)	Frequency per 95 year length of record (%)	Company stated LoS frequency
Level 1 Temporary use ban (TUB)	2 (1976 and 1984 both affecting Elan Valley group)	95	3.3	Not more than 3 in 100
Level 2 Non-essential use ban (NEUB)	1 (1984 for Elan Valley)	95	1.1[Note 1]	Not more than 3 in 100
Level 3 Rota cuts/ standpipes	0	95	0	Not acceptable

Note 1: This is the frequency of this occurring in our baseline deployable output model run – it will differ in other modelled scenarios and does not change the stated company levels of service

We are aware that there are challenges involved in helping customers to better understand the likelihood of extreme drought events. We have reproduced the table produced as part of UKWIR work on the topic of resilience metrics and included this as Table A10.3. It provides an illustrative example of different ways in which companies can describe drought. It does not apply to Severn Trent but we have included it here to show that we are looking at different ways of communicating drought risk.

Table A10.3 Illustrative example of different approach to describe drought severities

Drought Severity Band	Qualitative description: What are the chances of this happening to me in the next 25 years?
1	Just under 50/50
2	Some chance
3	Small chance
4	Unlikely
5	Highly unlikely
6	Implausible

A10.4 Critical droughts within our 95 year hydrological record

Our baseline deployable output (DO) modelling of the 95 year period from 1920 to 2014 shows that the two most critical droughts in our region in terms of causing TUBs or NEUBs are those that include the years 1976 and 1984. Our water resource modelling shows that these are the droughts when we would have needed to impose customer restrictions. Our modelling also shows that reservoirs such as the Derwent Valley reservoir group and Tittesworth reservoir cross the TUB and NEUB triggers but they do so outside of 'summer' period in which we would impose restrictions. These 'winter' crossings at Tittesworth and Derwent occur in the 1933-34 and the 1995-96 droughts. The following Figures A10.3 and A10.4 show both a 'winter' and 'summer' crossing of the trigger zone E and zone F.

Figure A10.3: Tittesworth reservoir modelled baseline DO storage entering drought trigger zones E and F in the 1995-96 'winter'

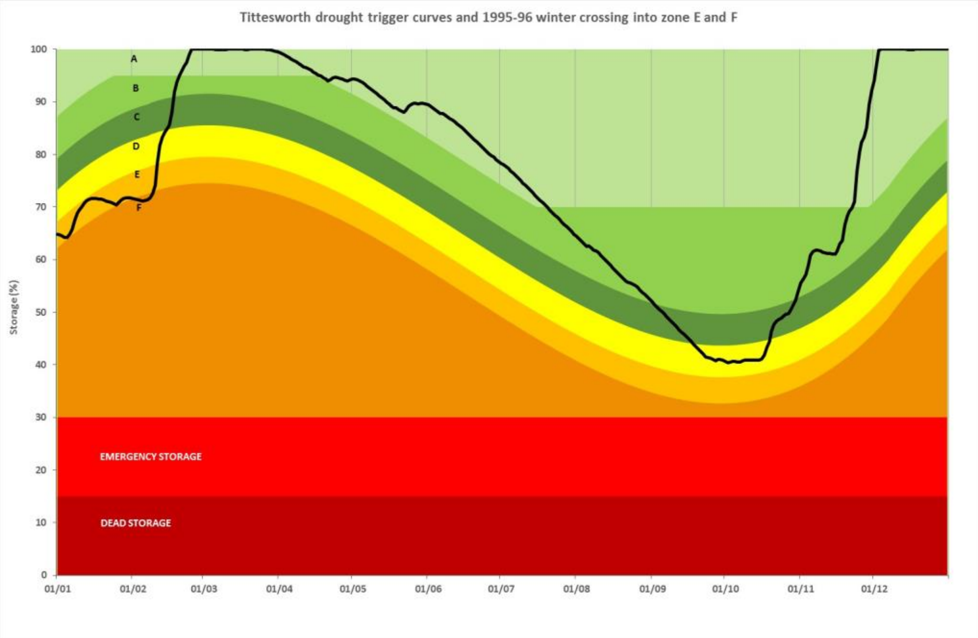
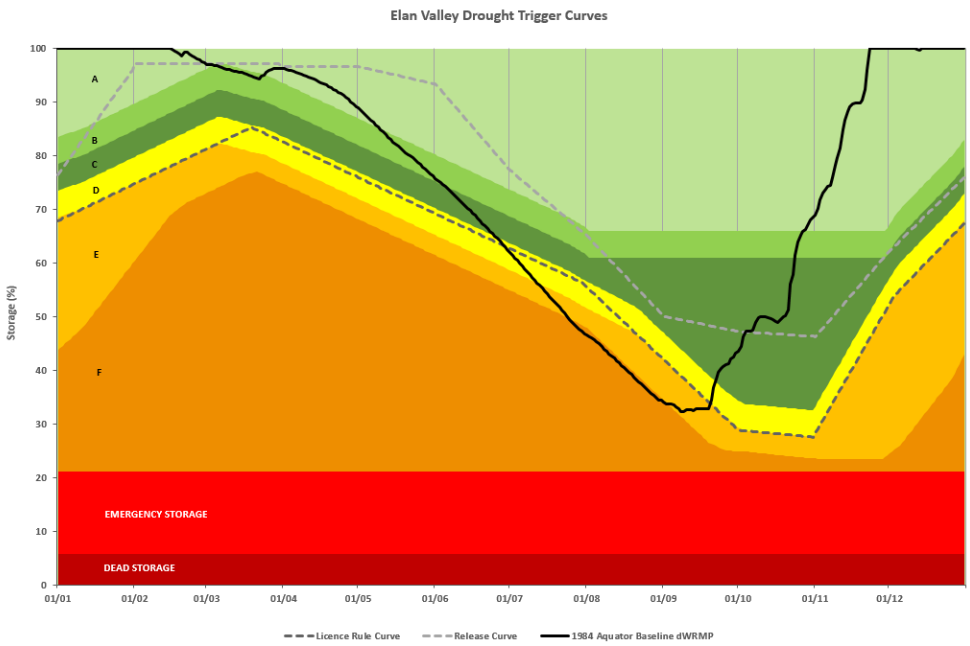


Figure A10.4: Elan Valley reservoir modelled baseline DO storage entering drought trigger zones E and F in the 1984 'summer'



A10.5 Extending the period of our hydrological analysis

The modelling we undertook to support our WRMP19 used a 95 year flow time series for catchments across our region. This flow record extends from 1920 to 2014. As a frequency of three TUBs in 95 years is equivalent to 3% of the modelled years having TUBs, we consider this to be consistent with our three in 100 level of service.

In order to provide us with further confidence in our ability to meet our stated level of service, we have worked with University of Liverpool to study rainfall records within our region that date back to the 1800s. We provide more details on this work in section A11. Section A11 also describes the other techniques we have used to better quantify the impact of extreme droughts on our region.

A10.6 Drought Resilience and our changing boundaries

In 2017 we welcomed Dee Valley Water as part of Severn Trent Plc with the shared purpose of serving our communities and building a lasting water legacy.

This has required us to assess the level of drought resilience achieved in the former Dee Valley Water area that has been transferred into our Severn Trent area, namely Chester WRZ. We describe the modelling we have undertaken for the Chester zone in Appendix F4.1

A11 Drought Resilience

A11.1 Testing our plan with challenging droughts

We have made a step change in terms of improving our understanding of drought resilience for our WRMP19 when compared to previous WRMPs. In developing this plan we have used three techniques that have enabled us to investigate how our water resource system copes with a variety of droughts including a range of severities and durations. The WRMP guidelines suggest that water companies should, as a minimum, use the worst drought on record to assess drought risk. In our case this includes droughts observed between 1920 and 2014 (the period of observed data we use in our baseline Deployable Output assessment described in section A2). Our approach considers not only the worst droughts in the 1920 to 2014 record but also:

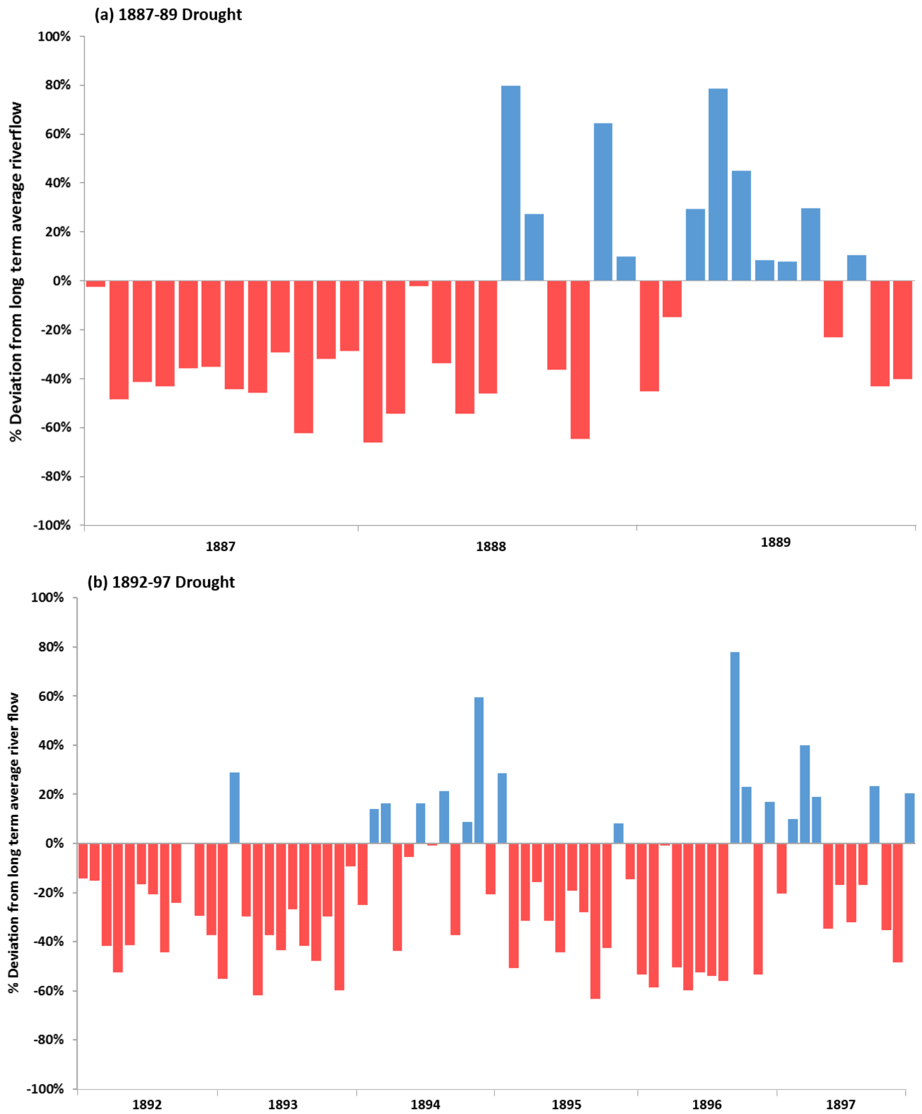
- Late 19th Century droughts
- Drought response surfaces
- Stochastically generated drought scenarios

Late 19th Century droughts

Our baseline modelling to assess deployable output uses 95 years (1920-2014) of climate data and this period captures a number of historic droughts (1921, 1933-34, 1975-76). This allows us to test how our current water resource system would respond if those events were to occur within our 25-year planning period (2020-2045). However, as each drought is unique (in duration and severity), it is important to understand how our system responds to different droughts. We simulated what could happen to our current system if we had a repeat of the long dry periods that occurred between the 1880s and 1910s. We know through Research and Development (R&D) work with the University of Liverpool that some of these droughts were more severe or lasted for longer than the droughts observed in our 95-year observed record. Part of this R&D work involved the co-funding of a PhD project, which used historic climatic data to improve our understanding of drought characteristics, propagation and impacts on water resources across the Severn Trent region. This research has better enabled us to quantify this challenge.

Our analysis of historic climate data identified two notable droughts- (1) 1887-89 and (2) 1892-97. The 1887-89 drought ranks as one of the most severe 24-month droughts in the 1884 – 2014 record in our region (Figure A11.1). Between January 1887 and December 1889 25 of the 36-months have flows below the long-term average conditions. Whilst the 1887-89 drought was identified as a severe flow deficit event, the 1892-97 drought was one of the longest duration events observed in our region (Figure A11.1). We used historic records of rainfall available across our region dating back to 1884 to create a 131-year dataset to investigate the impact of the identified historic droughts. We used this rainfall data to model river flows using the same rainfall-runoff modelling approach outlined in section A2. We also used groundwater models with the historic climate data to reconstruct groundwater levels and borehole output for the extended analysis period. We then used this modelled river flow and groundwater data in our water resource system model (Aquator) to assess whether the historic droughts had an impact on deployable output. Results of this extended modelling showed that the late 19th Century events did not reduce the deployable output values calculated using our 95-year baseline record. However, our extended 1884-2014 modelling results highlighted the severity of these earlier droughts. For example, we would have had to implement temporary use bans in 1896 and 1897 in the final two years of the 1892 – 1897 drought. As this work is based on a limited number of rain gauges, there is more uncertainty than there is in our current 95-year record. Therefore, we are only using these droughts as scenarios to test our water resources system rather than as part of our baseline deployable output modelling.

Figure A11.1: Late 19th Century Drought events- (a) 1887-89 and (b) 1892-97

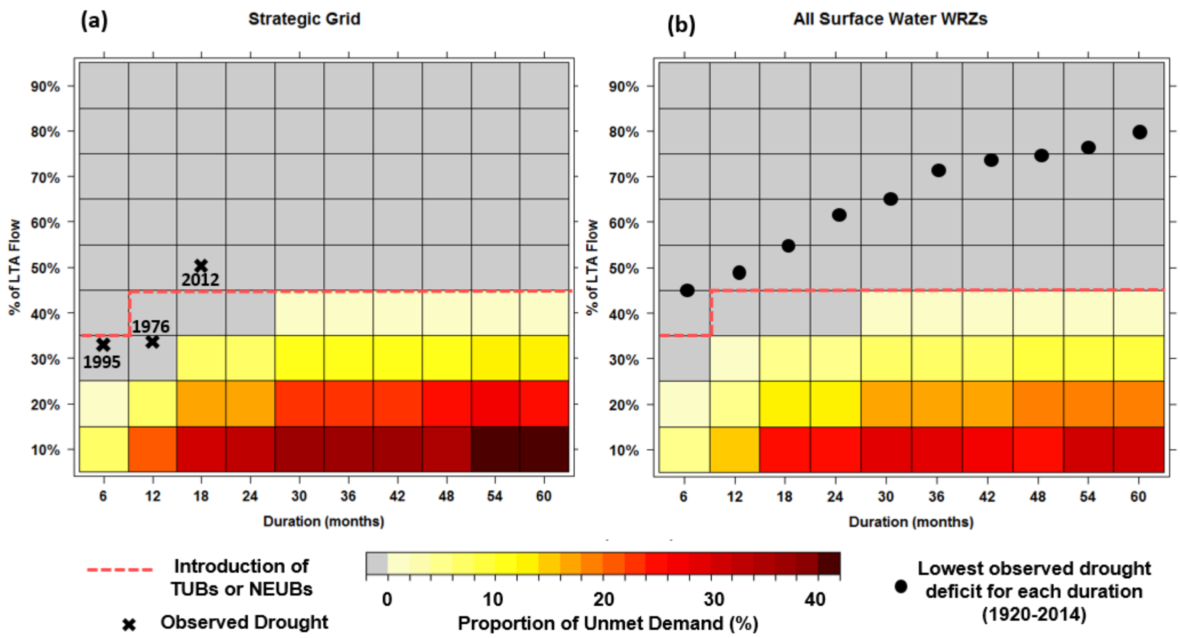


Drought response surfaces

The Environment Agency produced a report in 2016 entitled "Understanding the performance of water supply systems during mild to extreme droughts". We have used the approach outlined in the report to show the impact on customers of droughts with different durations and different river flow deficits (severities). A river flow deficit is a way of saying how much drier a drought is compared with average conditions. For example, if a certain six month period has half as much water flowing down a river than average we would refer to this as a 50% of long term average (LTA) river flow deficit; Figure A11.2 illustrates this. Each of the 81 boxes represents a different drought scenario. For example, the box in the bottom right represents the exceedingly unlikely scenario in which there is only 10% of average river flow for 60 months (5-years). By contrast the box in the top left is the much more likely scenario of having 90% of average river flow for six months.

In the example (Figure A11.2) we have used colour coding to show the proportion of demand that would not be met for each of the 81 drought scenarios. The grey boxes show that all water demands can be met whilst the boxes shaded from yellow to dark red indicate the proportion of demand that would be not met under each drought scenario. We have developed drought response surfaces for the WRZs that we model in Aquator. As this approach requires Aquator modelling we did not use it for the other (groundwater only) WRZs. These other WRZs are more drought resilient (see later section on drought risk composition). We consider that producing drought response surfaces would be disproportionately complex for the WRZs that have high drought resilience.

Figure A11.2: Drought Response Surface for the (a) Strategic Grid WRZ and (b) all surface water WRZs



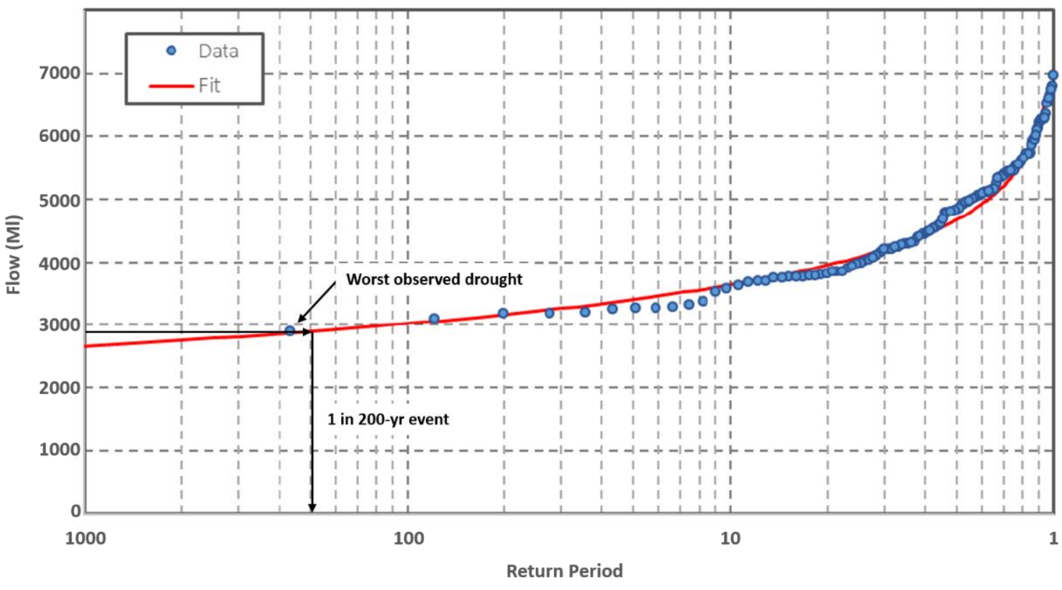
We developed these drought response surfaces by using synthetic droughts for severity and duration characteristics between 6 and 60 months for river flow deficits between 10% (most severe) and 90% (least severe) of the long-term average conditions. We created 81 synthetic drought scenarios using our baseline observed data from 1920 and 2014. We produced these synthetic droughts by selecting a month known to have been part of a drought e.g. January 1976, February 1995 etc. for each month of the year to develop a "drought profile" to represent river flow characteristics during a drought which could then be scaled to reflect each of the duration/severity scenarios. Under each scenario, the drought begins in April with a varying end month to reflect the drought duration e.g. a 6 month drought would have an end date of September. We used this process to create scenarios for the 64 river catchments we use in our Aquator water resources model. We then used each scenario to model whether supply can meet demand. We plotted the results of this onto a grid using a range of colours to represent the impacts. We added additional information to the drought response surfaces to show the characteristics of past significant droughts (see Figure A11.2a) and the lowest observed river flow deficit for all durations between 6- and 60-months (see Figure A11.2b). This information provides useful context for how plausible the synthetic drought scenarios are compared to observed events. We have used elements of the UKWIR Drought Vulnerability Framework project when preparing our drought plan and WRMP19.

Stochastic Drought Scenarios

In order to test how our water resources system responds to droughts that are worse than those observed in our baseline and in the 19th Century analysis we adopted an additional approach. The approach we selected was the creation of a number of stochastically generated drought 'what if' scenarios that haven't happened but plausibly could. The WRMP19 Methods – Risk Based Planning: Guidance (UKWIR, 2016) has informed the techniques we have used to develop our stochastic drought scenarios. We created our scenarios using a stochastic weather generator to develop 200 'what if' drought scenarios. Stochastic weather generation is a modelling technique which uses the relationship between climate drivers and our observed rainfall data over the 20th Century. We then used these 200 sets of rainfall data and corresponding evapotranspiration data to model river flows using the same rainfall-runoff methods used for our baseline DO assessment and the 19th Century drought assessment. We also used the stochastic rainfall and evapotranspiration data to model groundwater level changes within spreadsheets. We then transposed these data onto Source Performance Diagrams (explained more in section A2) to determine the corresponding borehole deployable output.

To select drought scenarios which are more severe than observed events we used extreme value analysis (EVA) techniques to assign return periods to observed droughts and to estimate the return periods of more severe events. The graph in Figure A11.3 shows an example of how we have used these techniques. This example is for 18-month duration droughts but we have also used similar techniques for droughts of different durations. The blue circles represent actual river flows accumulated over an 18-month period for each year across the 130-year flow record. We derived the red line statistically from the observed data and used it to estimate the return periods of 18-month droughts up to 1 in 1000 year events. We used the same type of EVA approach to estimate the return periods of 24-month and 30-month droughts with return periods up to 1 in 1000-years.

Figure A11.3: Example of Extreme Value Analysis to estimate drought return periods



The EVA enabled us to estimate what the total accumulated river flows would be across our region for droughts with a specific event duration and return period (severity). For example, in Figure A11.3 an 18-month duration 1 in 200 year event has an estimated 18-month flow total of 2,900 Ml. We then searched the 200 stochastic flow scenarios to identify a similar 18-month accumulated flow value. We repeated this process a number of times to identify suitable droughts to test our water resources system for droughts with duration characteristics of 18, 24 and 30 months and for return periods (drought severity) up to approximately 1 in 1000 years. From the 200 stochastic scenarios, we selected 30 for analysis in our Aquator model. Figure A11.4 provides an overview of our stochastic drought scenario generation and modelling. We have also added borehole deployable output values in to the Aquator model to account for changes in output from our groundwater sources. As the surface and groundwater drought stochastic scenarios were developed using differing methods the borehole deployable output values have a smaller range of return periods (1 in 200 years and 1 in 500 years) than the surface water scenarios. In our Aquator modelling the surface water scenarios with a return period greater than 1 in 500 years are all modelled using 1 in 500 year groundwater DO values. As there is little variability between the stochastic groundwater DO values we consider this a suitable modelling approach.

Results of this modelling indicates that for a range of drought scenarios between 1 in 190 years to 1 in 330 years there is a small reduction in DO in the Forest and Stroud WRZ. This is a reduction of 2 Ml/d. In all other WRZs these drought scenarios had no reduction in DO from the baseline 1920-2014 modelling. We found that larger decreases in deployable output occurred for scenarios with return periods between 1 in 500 years and 1 in 1000 years with a maximum deployable output reduction at approximately 230Ml/d for a 1 in 1000 year 24 month drought. We have presented a selection of drought scenario DO values in Table 10 of our WRMP data tables.

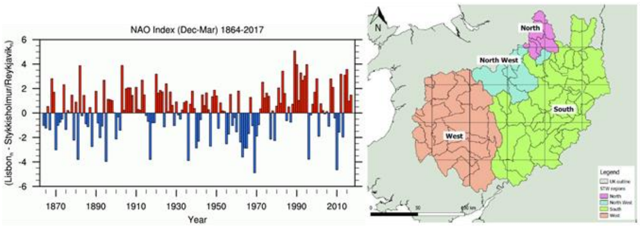
We note that drought is a complex phenomenon, the events we have selected for analysis provide an understanding of how future severe droughts could impact our water resource system however the results should only be regarded as estimates. This is recognised by the Environment Agency guidance on the completion of WRMP19 tables, which describes some of the more extreme scenario values they expect to be in WRMP table 10 as “a series of estimates”. Although this is true, we will continue to stay abreast of relevant R&D and innovation as techniques, modelling and knowledge improves. We will reflect these advances in our future plans. Whilst two drought events could have the same return period and duration (e.g. a 1 in 500 year, 18 month event) the unique characteristics of these droughts could result in different water supply impacts. However, by analysing a large number of drought scenarios with varying drought characteristics we are able to better understand a range of potential impacts and provide challenging drought scenarios for our investment modelling.

We also note that there is some uncertainty in estimating the return periods of our extreme droughts. Whilst extreme value analysis is a very useful method, return period estimates are dependent on number of factors including data length and the choice of statistical analysis approaches. We have improved the robustness of our EVA estimates by using our extended flow records developed through the 19th Century drought analysis. This provided 130 years of data rather than the 95 years of our baseline data. The longer dataset provided a wider range of flow conditions including a larger number of droughts which has resulted in a better quantification of drought return periods.

We have worked in close collaboration with South Staffordshire Water (SSW) to ensure we assess the impact of extreme droughts in a way that is consistent with this neighbouring company. It is particularly important that we are consistent with SSW in work of this sort as we both operate within the River Trent and River Severn hydrological catchments. We share one source on the River Severn (Site N) and we share our Aquator models and output too. We have also been in contact with Dŵr Cymru Welsh Water (DCWW) to compare consistency between our stochastic drought inflows for the Elan Valley Reservoirs.

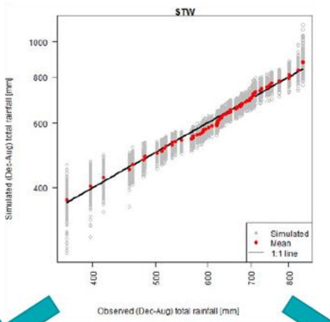
Figure A11.4: Stochastic Drought Analysis Flow Diagram

Stochastic Drought Analysis Flow Diagram



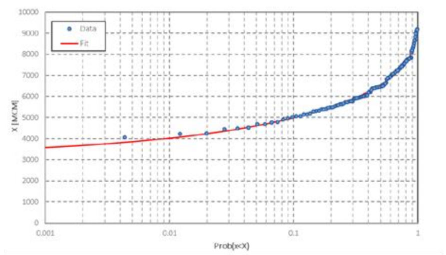
Statistical relationship between observed rainfall across our region and climate drivers used to develop weather generator model.

Observed rainfall records covering our region from 1920 to 1990 (71 years) are used by the weather generator to create 200 'what ifs' that contain a number of drought phases that are more severe than in the observed records.



Surface Water

The 200 rainfall and evapotranspiration scenarios are used to model river flow across the 64 catchments in our region using the rainfall-runoff model Hysim.



Extreme value analysis is used to estimate the return period of droughts with specific durations e.g. 18-, 24- and 30-months. Each return period and drought duration will have an associated 'target' river flow total. The 200 scenarios are searched for these 'target' river flows to identify 30 scenarios with return periods between 1 in 200 and 1 in 1000 years.

Ground Water

The observed rainfall (P) and evapotranspiration (PET) records are analysed to estimate accumulated values for droughts with return periods between 1 in 200 and 1 in 500 years with durations of 18-, 24- and 60-months. These target values are used to identify 6 corresponding droughts within the 200 'what if' rainfall scenarios.

The P-PET data for the worst case historical droughts, and the corresponding 6 synthetic droughts, are used with the groundwater GR2 models to determine changes in groundwater levels from droughts.

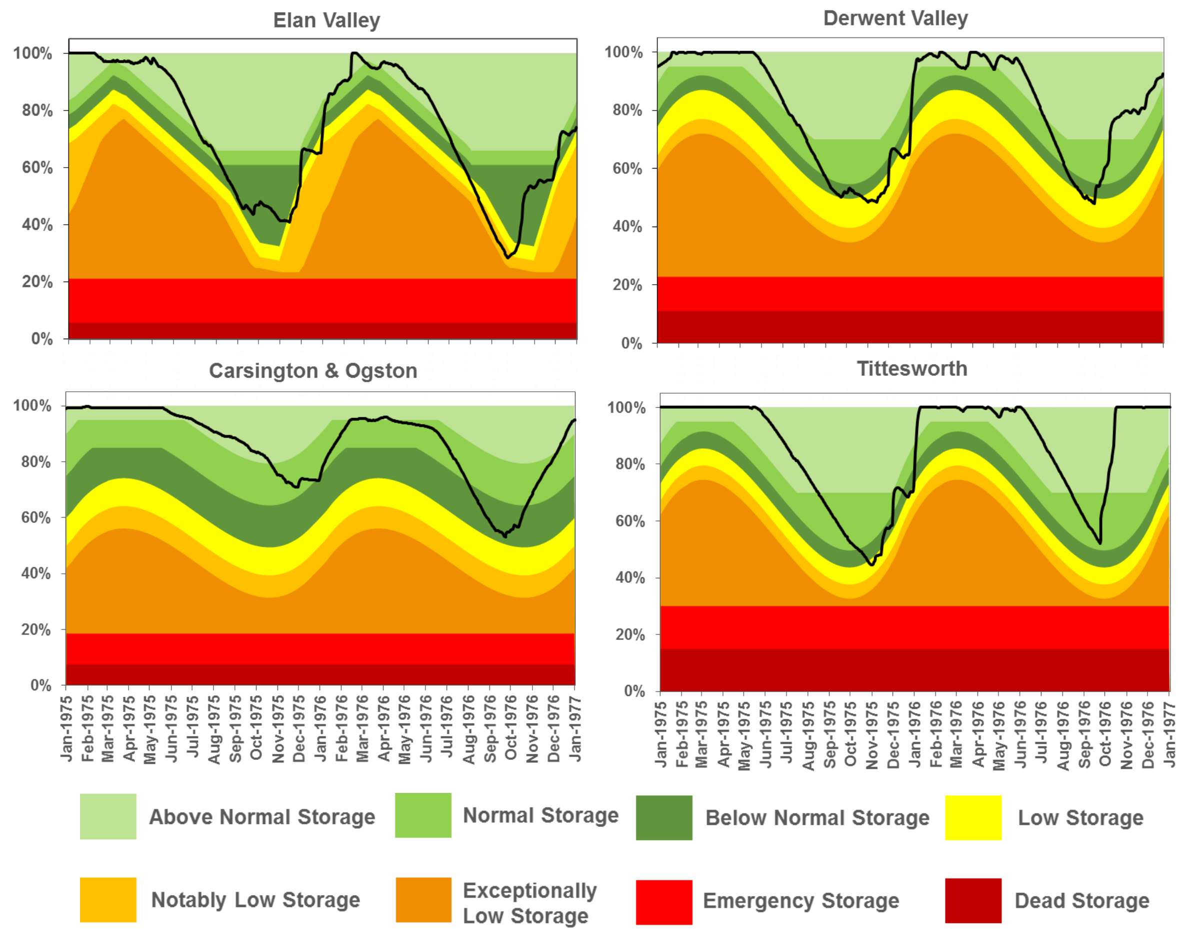
Changes in Deployable Output at the groundwater sources are calculated from the modelled groundwater level change and the transposition on to the source performance diagram, to indicate a range of DO changes for drought scenarios with return periods between 1 in 200 and 1 in 500 years.

30 scenarios modelled in Aquator to provide a range of deployable output values. This allows us to better understand how droughts with different severity and durations can impact on water resources.

Design drought

The Water Resource Management Plan Guidelines state that our base supply forecast should be based on a design drought which should be either (1) our worst drought on record or (2) a more challenging event. Our base supply forecast uses our baseline flow record (1920-2014) therefore, our design drought is our worst historic drought; 1975-76. This analysis period also includes a number of other droughts to test our base supply forecast (e.g. 1933-34 and 1995-96). Analysis of our baseline flow record and our extended 19th Century record indicated that accumulated river flows in the 18-months from April 1975 to September 1976 were the lowest across our region. The selection of our worst historic drought was also informed by our stochastic drought modelling results which identified a very minor change in DO between the baseline data (1920-2014) and a 1 in 200-year stochastic event (-2 Ml/d). We observed significant reductions in DO for droughts with return periods between 1 in 500 years and 1 in 1000 years but we consider that using these events is unsuitable for our base supply forecast. In addition to our modelled findings, our customer research to date has indicated that customers show little appetite to pay for increased drought resilience. Figure A11.5 shows the modelled storage levels in four of our reservoirs during the design drought. We have plotted these with our drought trigger zones to highlight the impact of this event on the water resource system. These results show that this drought has the greatest impact on the Elan Valley and Derwent Valley reservoirs.

Figure A11.5: Reservoir Storage during Design Drought



Risk composition

We have developed our drought resilience work using the WRMP 2019 Methods – Risk Based Planning: Guidance (UKWIR, 2016). A key component of this guidance is the need to state our risk composition. This composition indicates how we have incorporated drought resilience into our WRMP analysis.

Table A11.1: Our risk composition- "Resilience Tested" Plan

Table Source: WRMP 2019 Methods – Risk Based Planning: Guidance (UKWIR, 2016)

Risk Composition	What is it?	Specifics of what is Involved (supply, demand, investment)
1 – The 'Conventional' Plan	Estimates of supply capability are based on the historic record, perturbed for climate change. Any testing of droughts outside of the historic record is done using a simple 'top down' method and is only done to examine supply / demand risk under more extreme conditions (i.e. sensitivity analysis only). Uses a simple representation of dry year/normal year demand.	*Supply* – conventional 'Deployable Output' (DO) or historically based timeseries. *Demand* – dry year/normal year estimates. *Investment* – inputs to the Decision Making Tool (DMT) are based on analysis of the historic record and the investment programme therefore represents the 'best value' response to maintaining Levels of Service and resilience against the historic record.
2 – The 'Resilience Tested' Plan	Companies use 'Drought Events' to test the Plan and look at the implications of alternative/more severe droughts on the 'best value' investment programme. These 'Drought Events' can be derived using a variety of top down methods, but their 'plausibility' (approximate level of severity) is checked using *metrics* of rainfall, aridity or hydrology. More complex representation of demand *variability* can be tested.	*Supply* – conventional plus 'event based' DO or timeseries. *Demand* - conventional, or can use demand/weather models to create equivalent demands for generated events. *Investment* – Events are used to test the programme; either by comparing the resilience of similar NPV programmes, or to look at the cost implications of achieving LoS commitments and resilience to droughts outside of the historic record.
3 – The 'Fully Risk Based' Plan	Companies use modelling methods to evaluate a full range of drought risks to their supply system, supported by more sophisticated approaches to matching this with demand *variability*. This is used to generate a 'best value' WRMP at a level of resilience that is linked to Levels of Service and the Drought Plan.	*Supply* – companies use generated data sets to explore the yield response to drought severity and patterns. Inputs to system-simulation DMTs are based on probabilistic sampling of the drought response. *Demand* - demand variability to drought is incorporated, although methods/complexity can vary. *Investment* the Plan is developed to represent the 'best value' response to overall drought risk, according to the Company's stated LoS and drought resilience.

We consider that our plan is at least at risk composition 2, as it is a "resilience tested" plan (see Table A11.1). In addition to our baseline supply forecast we have used our stochastic drought events to test our plan and examine the implications of more severe droughts on our investment programme through our Decision Making Upgrade (DMU) analysis. This choice of risk composition reflects the complexity needed as part of our wider decision making approaches (see Appendix E for more information).

We used the stochastic drought analysis outlined above to investigate drought resilience across all of our conjunctive use WRZs (Strategic Grid, Nottinghamshire, Forest and Stroud, North Staffordshire, Shelton and Wolverhampton, Chester) and some of our groundwater only zones (Newark, Stafford, Bishops Castle and Mardy). We consider that the zones outlined above have a "resilience tested" risk composition. We did not carry out the stochastic drought assessment across the remaining groundwater only WRZs (Whitchurch and Wem , Ruyton, and Kinsall) and they are therefore risk composition 1- "conventional plan" see Table A11.2. These WRZs were not included in the stochastic drought assessment as these zones to have low vulnerability to drought. The deployable outputs in these zones are not typically constrained by water level but by other constraints, such as pump depth, due to the nature of the sandstone aquifers. This follows the same approach as our climate change assessment in these groundwater only zones. The WRZs not included in this assessment account for a very small percentage (approximately 2%) of our overall company level DO.

Table A11.2: Risk composition used for each WRZ

WRZ	Risk composition	Comment
Strategic Grid	Composition 2 - "resilience tested"	Conjunctive use WRZ
North Staffs	Composition 2	Conjunctive use WRZ
Chester	Composition 2	Conjunctive use WRZ
Forest and Stroud	Composition 2	Conjunctive use WRZ
Shelton	Composition 2	Conjunctive use WRZ
Wolverhampton	Composition 2	Conjunctive use WRZ
Nottinghamshire	Composition 2	Conjunctive use WRZ
Newark	Composition 2	Groundwater only WRZ – we assessed that these could be vulnerable to drought
Stafford	Composition 2	As above
Bishops Castle	Composition 2	As above
Mardy	Composition 2	As above
Whitchurch and Wem	Composition 1- "conventional plan"	Groundwater only WRZ – we assessed this WRZ as having low drought vulnerability
Ruyton	Composition 1	As above
Kinsall	Composition 1	As above
Rutland	n/a	Entirely supplied by bulk import – see section A7

Drought interventions and their impact

Table 10 of the WRMP data tables provides a link between the WRMP and Drought Plan. Within Table 10 we report a range of deployable output values from our drought resilience modelling. We based these DO numbers on a number of model runs which includes DO for historic droughts in our baseline data (1920-2014) and for a number of stochastic drought scenarios with return periods between 1 in 200 years and 1 in 1000 years. In both cases we report DO values for three conditions; (1) no demand saving restrictions; (2) with demand saving restrictions e.g. demand savings linked to Temporary Use Bans (TUBs), and; (3) with drought permit/order interventions e.g. measures taken during a drought to increase water abstractions above permitted limits. Modelling DO under these varying conditions allows us to understand and quantify the benefit of demand saving measures and drought permit/ order interventions under a range of drought conditions. We outlined all of the drought interventions/ actions we consider in our 2014 Drought Plan. We have also included them in our 2018 draft Drought plan which was published for consultation in June 2018. We are currently making updates to the 2018 draft drought plan to reflect the new information we found out during the 2018 drought. An updated draft will be published during 2019.

Our baseline supply forecast does not include drought permits or drought order interventions but it does include several ‘lower level’ drought actions. For example, we list several drought management actions in our Drought Plan that we consider when we are in drought trigger zones C or D. Reference can be made to our Drought Plan for more detail on our drought trigger zones and the associated drought management actions. For example, our Drought Plan contains some options that involve reversal of flow along a bi-directional link. Where we model these links as bi-directional in Aquator, this option is built into our base DO. Another example of drought management actions being part of our baseline DO is actions that involve ‘maximise source X’. Operationally, during wet or average years we may choose not to use a certain source if we have other, possibly cheaper, sources of water but in a drought we would use it if our drought action team decide we need it. Our Aquator modelling represents this scenario by using low cost sources first but, when resources become scarcer, it over rides the financial considerations and uses sources based on their availability instead of their cost.

As stated above we quantify the impacts of demand interventions (such as TUBs and NEUBs) as well as drought permits and drought orders in table 10 of the WRMP tables. Table 11.3 below shows the estimated yield benefits from the supply side drought management actions that are not part of our base DO and are not TUBs, NEUBs, drought permits or drought orders:

Table A11.3: Estimated yield from supply side drought interventions

WRZ	Drought Measure / source	Estimated peak yield Ml/d	Estimated average yield Ml/d	Comment
North Staffs	None	n/a	n/a	n/a
Strategic Grid	Witcombe	8.7	1.4	We assume this is licence constrained but we would undertake flow gauging and/ or a hydrological yield assessment if we were going to use it.
Strategic Grid	Linacre	9.1	6.8	As above
Strategic Grid	Monkdale	2	1.5	As above
Strategic Grid	Stanley Moor	2.2	0.5	As above
Strategic Grid	Norton emergency	n/a	0.7	As above and in addition, we cannot split out a daily/ peak max for the emergency part of this licence as much of the overall daily total of 24 Ml/d is used BAU for public supply. The real constraint to this emergency supply is the 5-year maximum.
Strategic Grid	Beechtree Lane emergency	18.0	0.9	We assume licence constrained but we would undertake flow gauging and/ or a hydrological yield assessment if we were seriously thinking of using it.

WRZ	Drought Measure / source	Estimated peak yield Ml/d	Estimated average yield Ml/d	Comment
Strategic Grid	Blackbrook	14.5	6	We calculated a dry year hydrological yield of 6 Ml/d by using Q70 inflows, 10 % unusable storage, compensation flow of 0.136 Ml/d and a critical period of 18 months (548 days). We also used the minimum cumulative 548 day inflows and that also gave a 'yield' of 6 Ml/d so this adds to the reliability of the Q70 estimate.
Nottinghamshire	None	n/a	n/a	Covered by the Strategic Grid East actions that affect the Grid to Notts transfer
All of the other WRZs	None	n/a	n/a	n/a

We note that there are other drought management actions such as 'raise awareness internally' or 'speak to the Environment Agency or neighbouring companies' that are important actions but do not necessarily bring direct yield benefits. We give more detail on all of the drought management actions in our Drought Plan.

A11.2 Drought Resilience Statement

We have planned our system so that it can withstand any drought that is as severe as those we have seen over the last 95 years and up to a 1 in 200 year event. We have also tested our investment proposals against a range of plausible future droughts not seen in the historic record that have quantified probabilities for drought severity and duration. We are confident that our plans represent a good balance between cost, environment and resilience to severe droughts. Our stochastic drought modelling indicates that we are resilient to a 1 in 200 year drought without the need for emergency drought orders.

A12 Baseline supply projections

The following section shows graphically for each water resource zone the baseline deployable output projections and the impacts of WINEP3 (which is discussed in detail in section A5) and climate change (which is discussed in detail in section A3). We also show the projected "baseline" Water Available For Use (WAFU) in each zone, taking account of outage risks. For some zones (such as Forest and Stroud) where bulk supplies have not been included in our baseline deployable output assessment, bulk imports are also shown, reflecting "total" WAFU as reported in the WRMP tables. Data for Chester WRZ is presented in Appendix F.

Bishops Castle Zone

Figure A12.1: Bishops Castle baseline deployable output

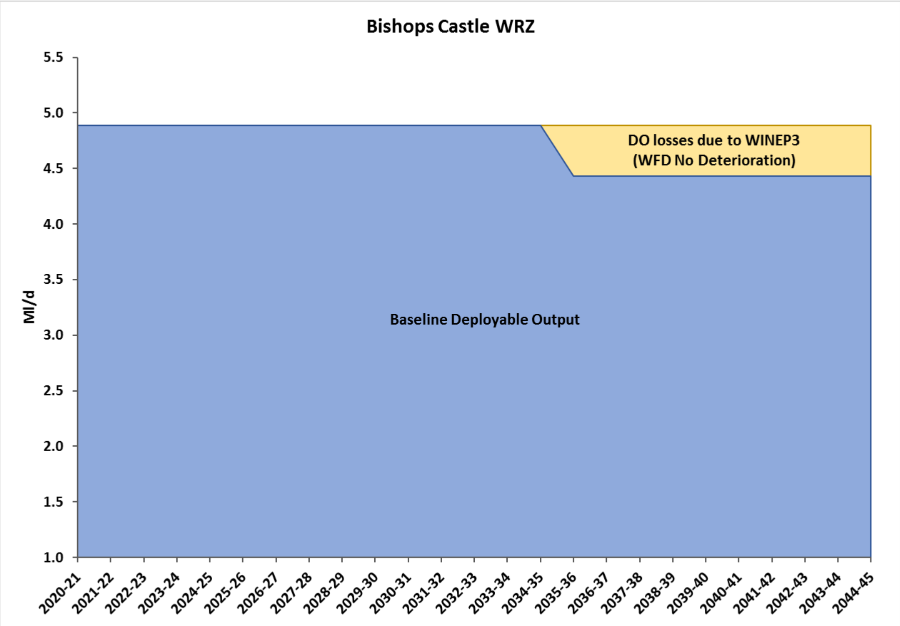
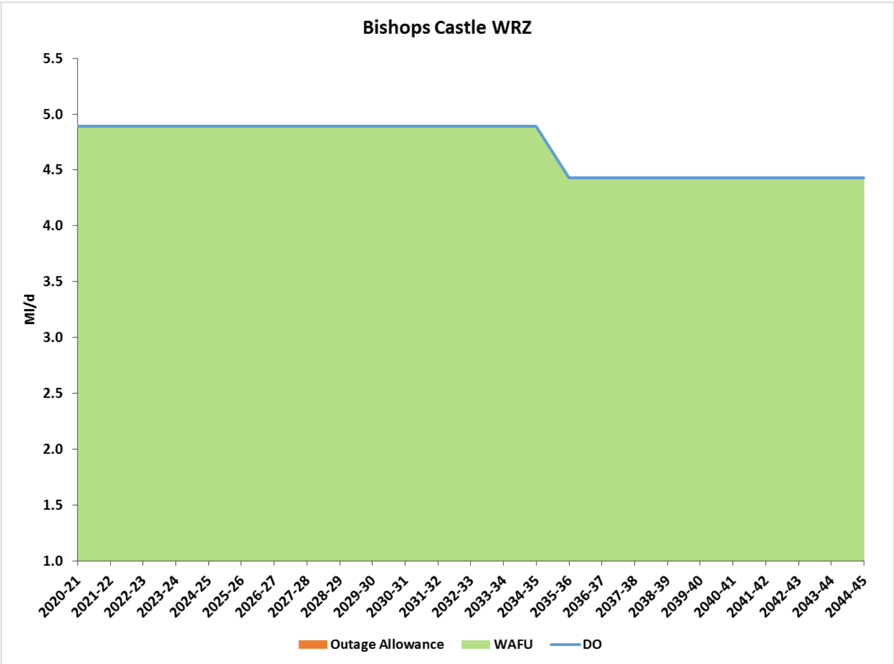


Figure A12.2: Bishops Castle baseline water available for use



Forest and Stroud zone

Figure A12.3: Forest and Stroud baseline deployable output

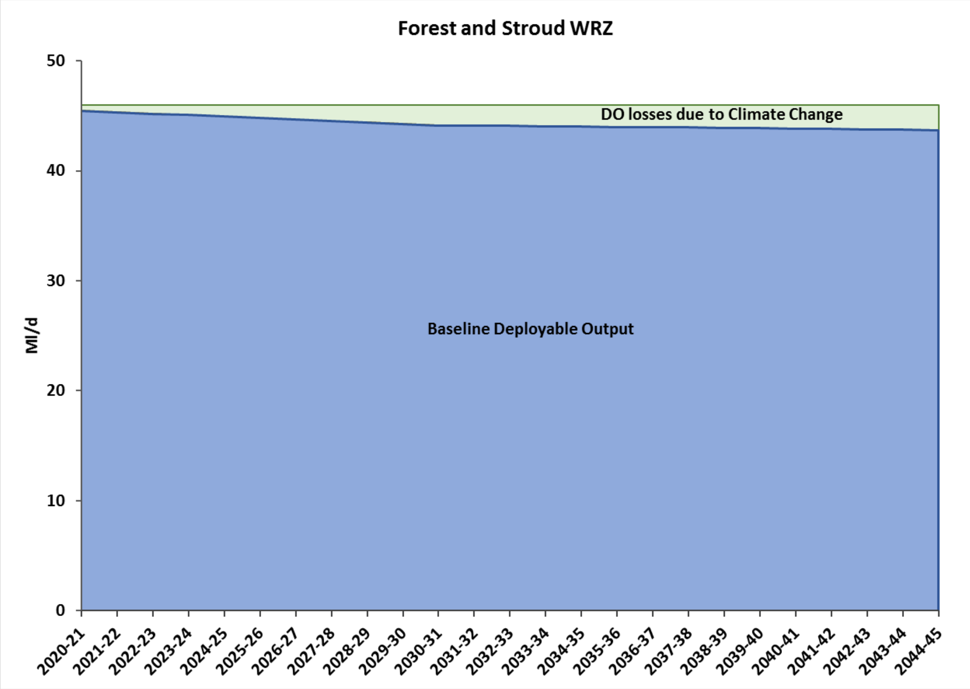
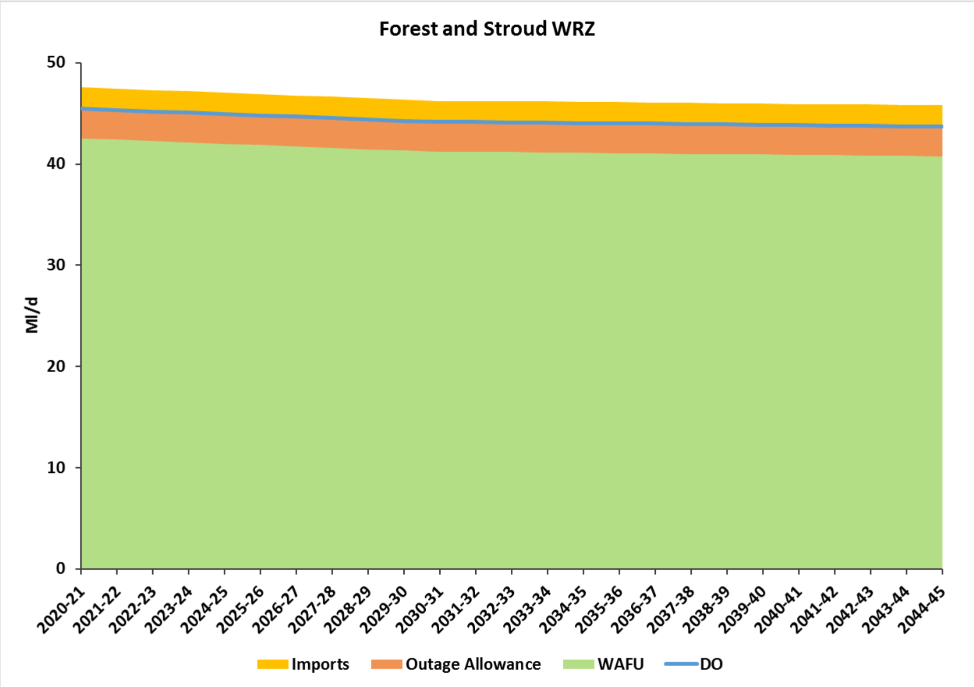


Figure A12.4: Forest and Stroud baseline water available for use



Kinsall zone

Figure A12.5: Kinsall baseline deployable output

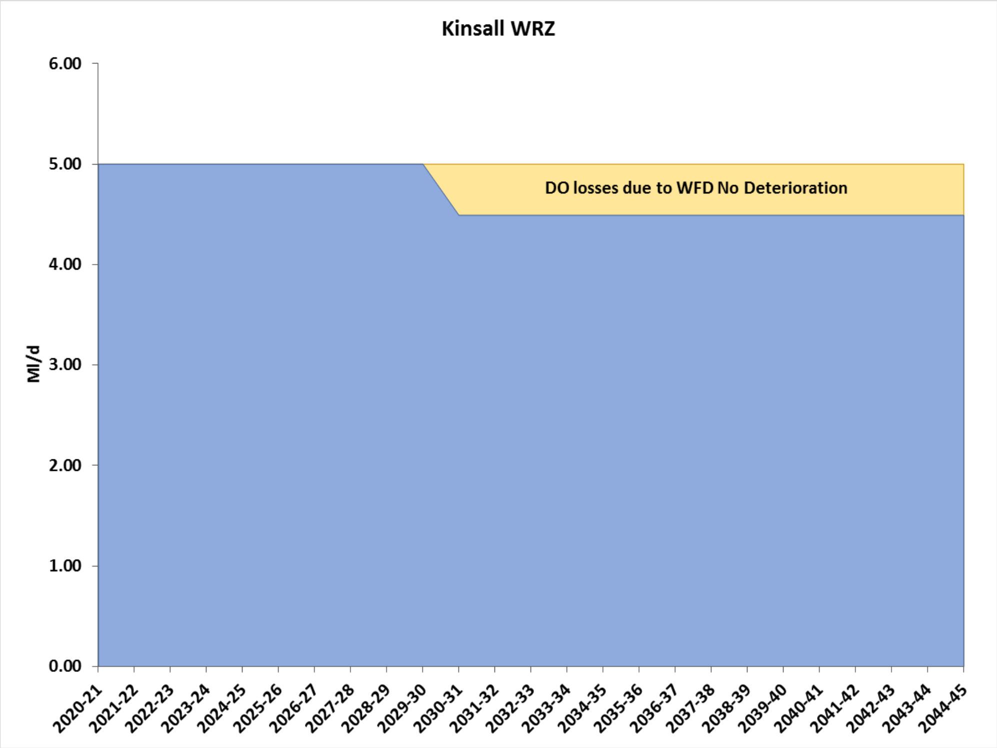
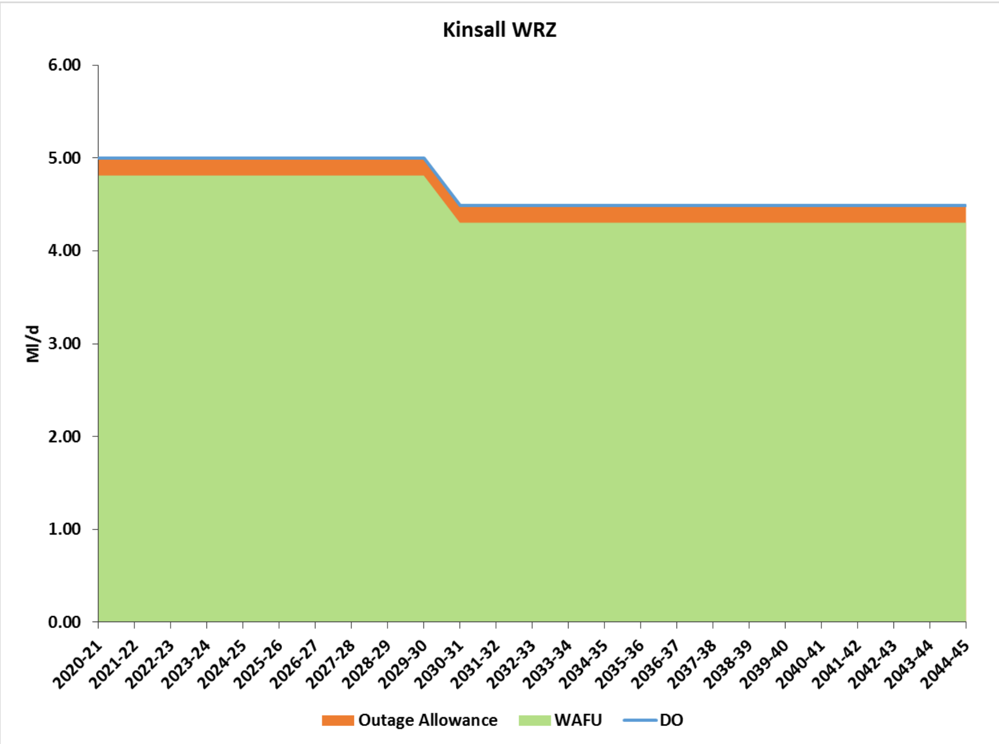


Figure A12.6: Kinsall baseline water available for use



Mardy zone

Figure A12.7: Mardy baseline deployable output

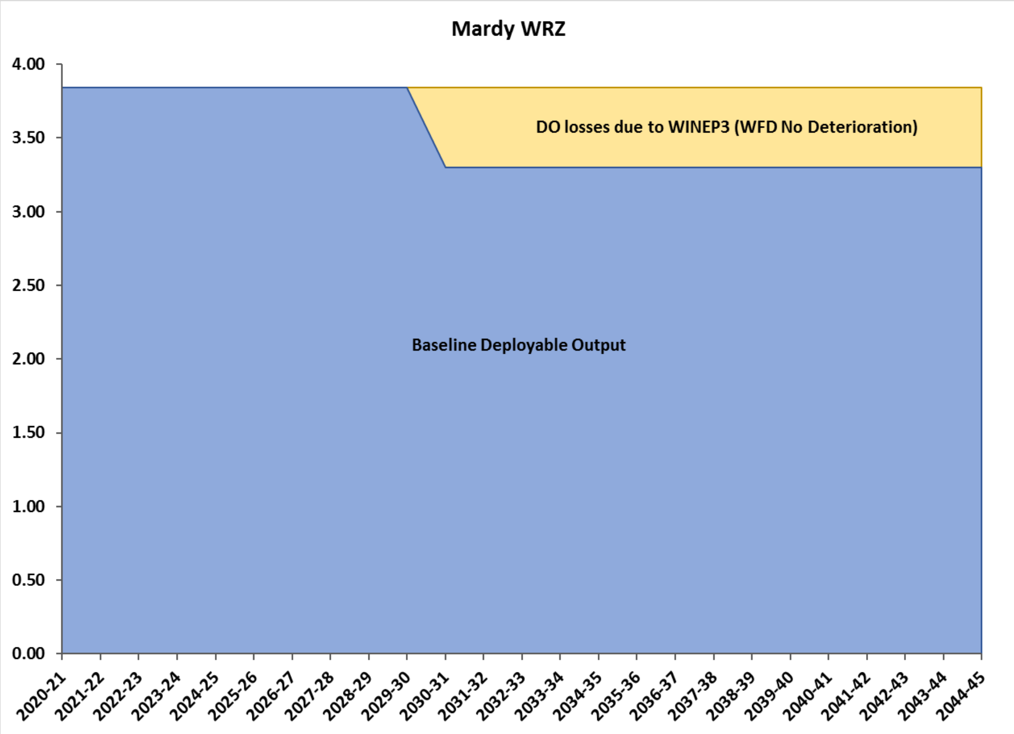
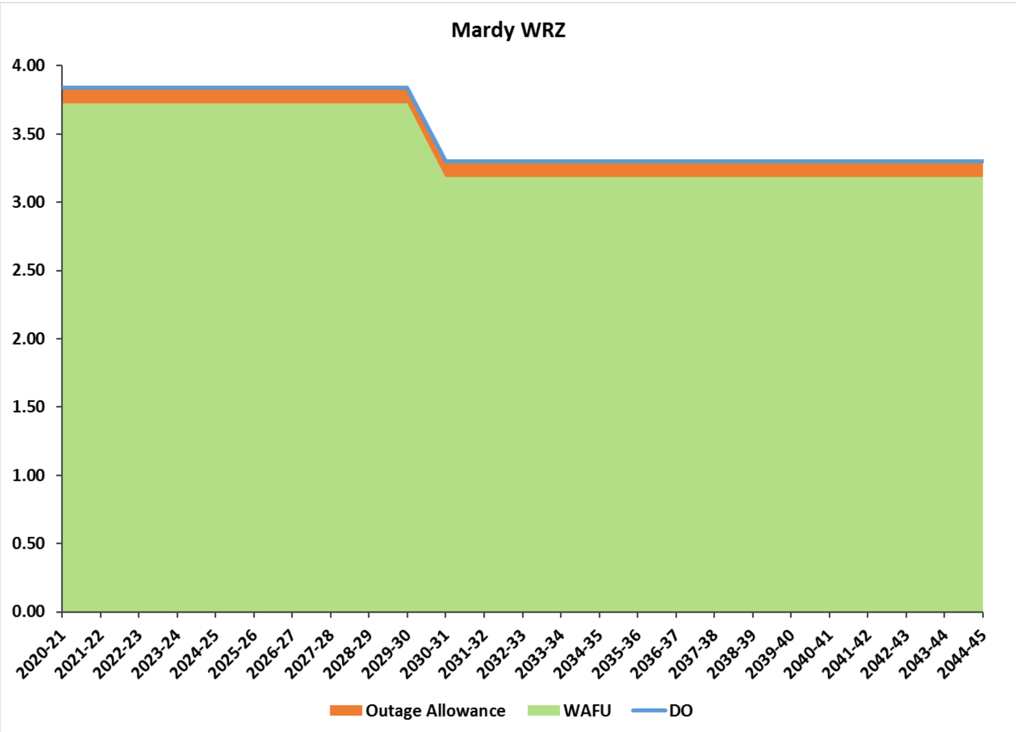


Figure A12.8: Mardy baseline water available for use



Newark zone

Figure A12.9: Newark baseline deployable output

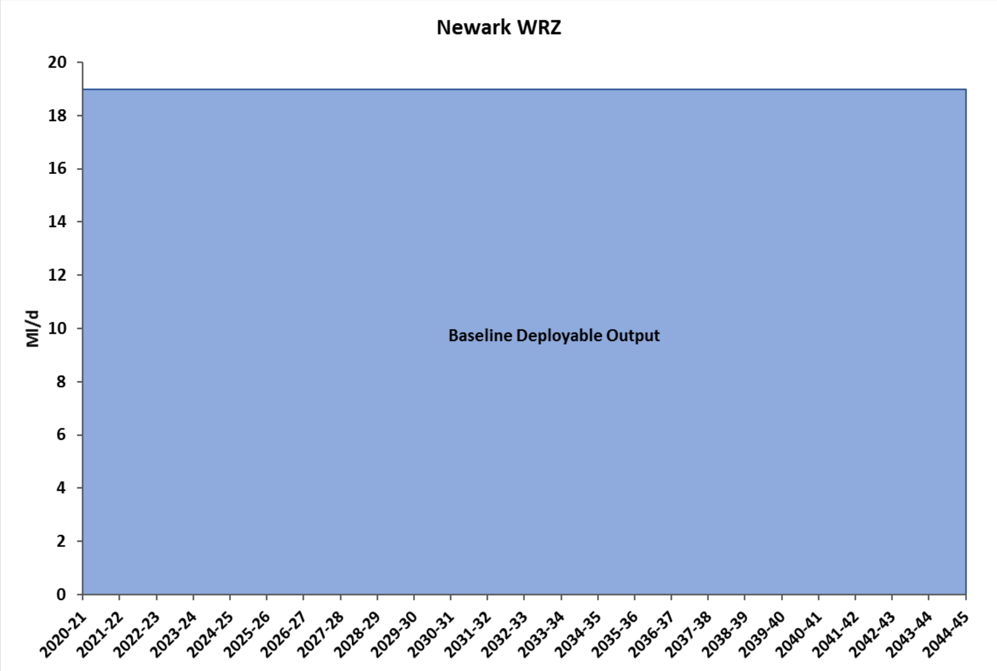
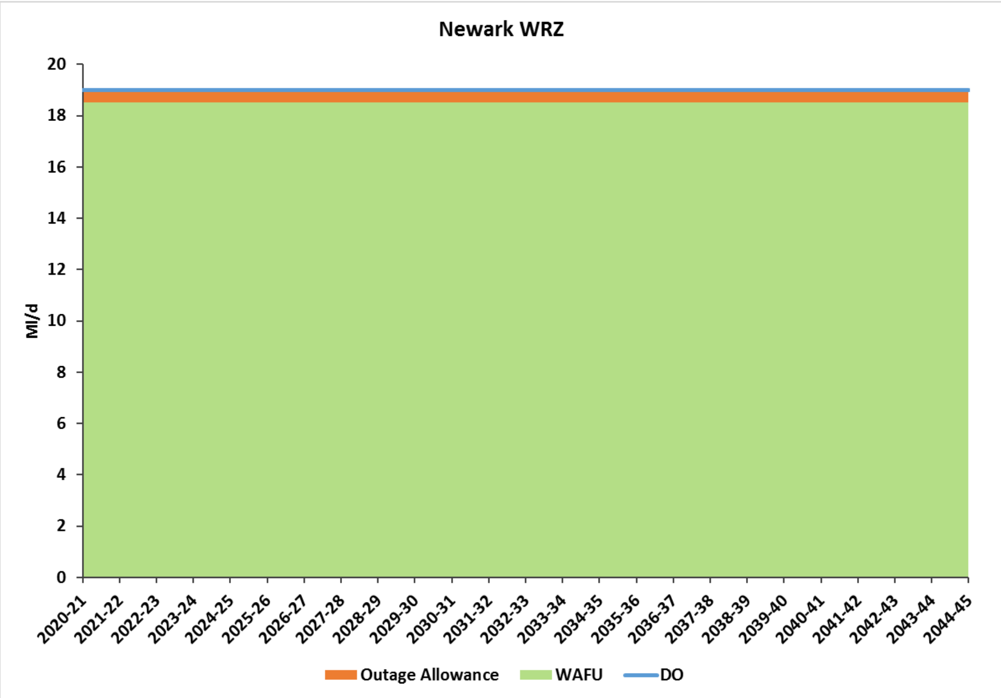


Figure A12.10: Newark baseline water available for use



North Staffs zone

Figure A12.11: North Staffs baseline deployable output

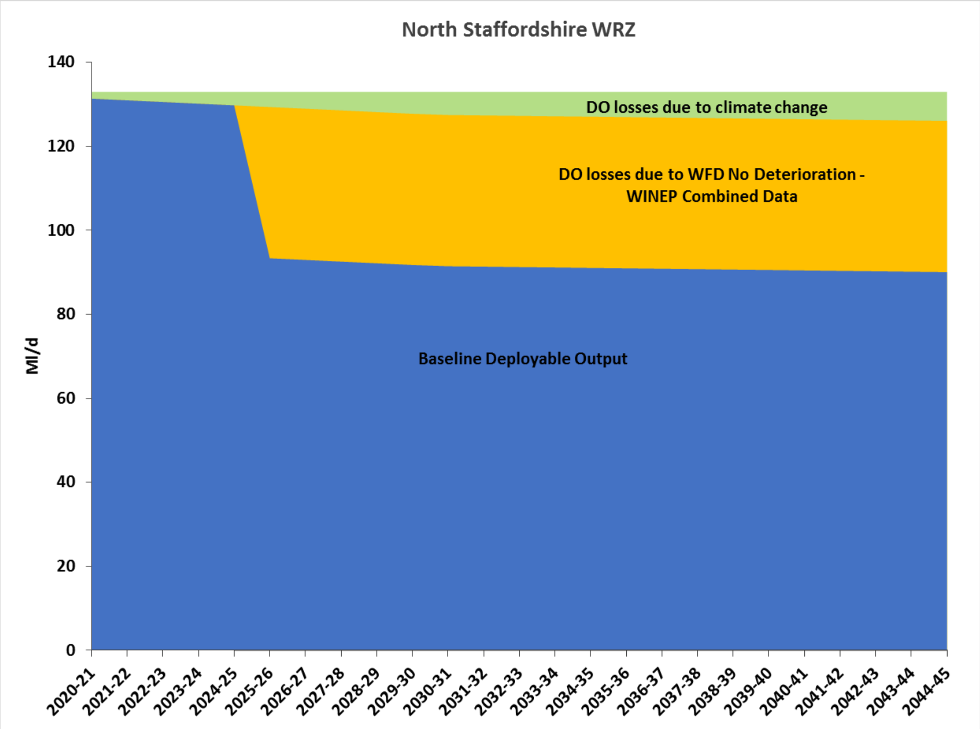
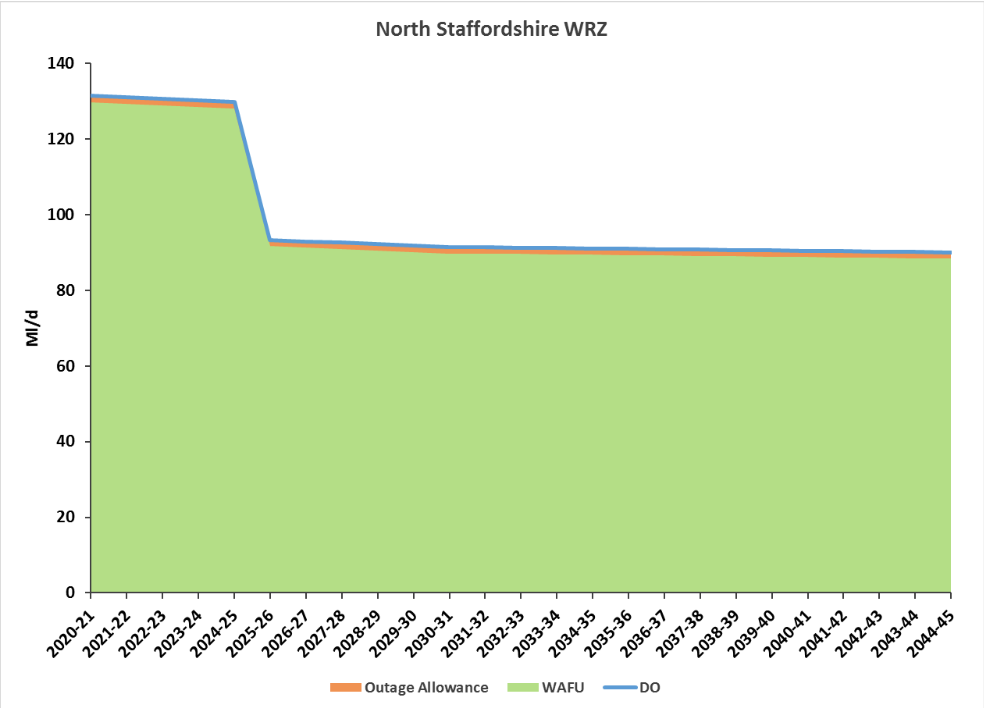


Figure A12.12: North Staffs baseline water available for use



Nottinghamshire zone

Figure A12.13: Nottinghamshire baseline deployable output

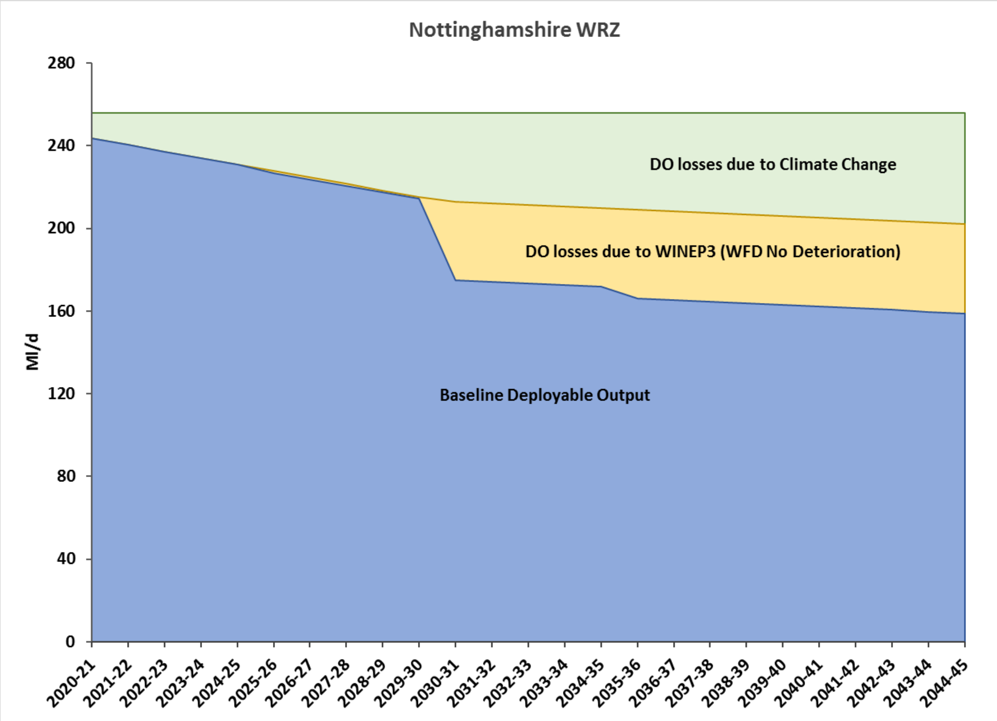
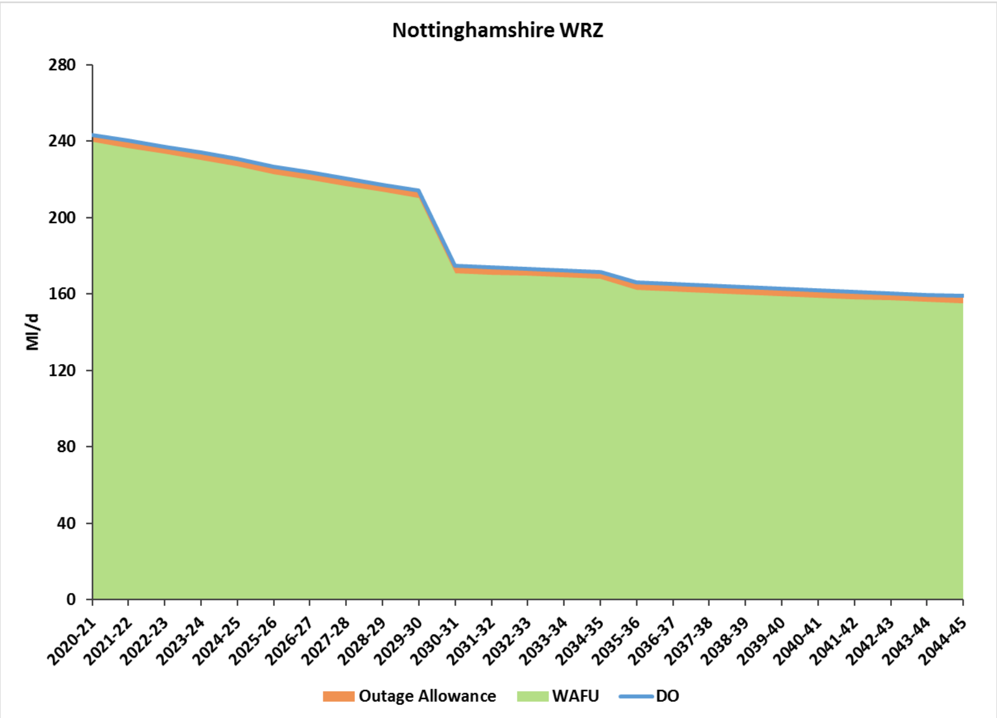


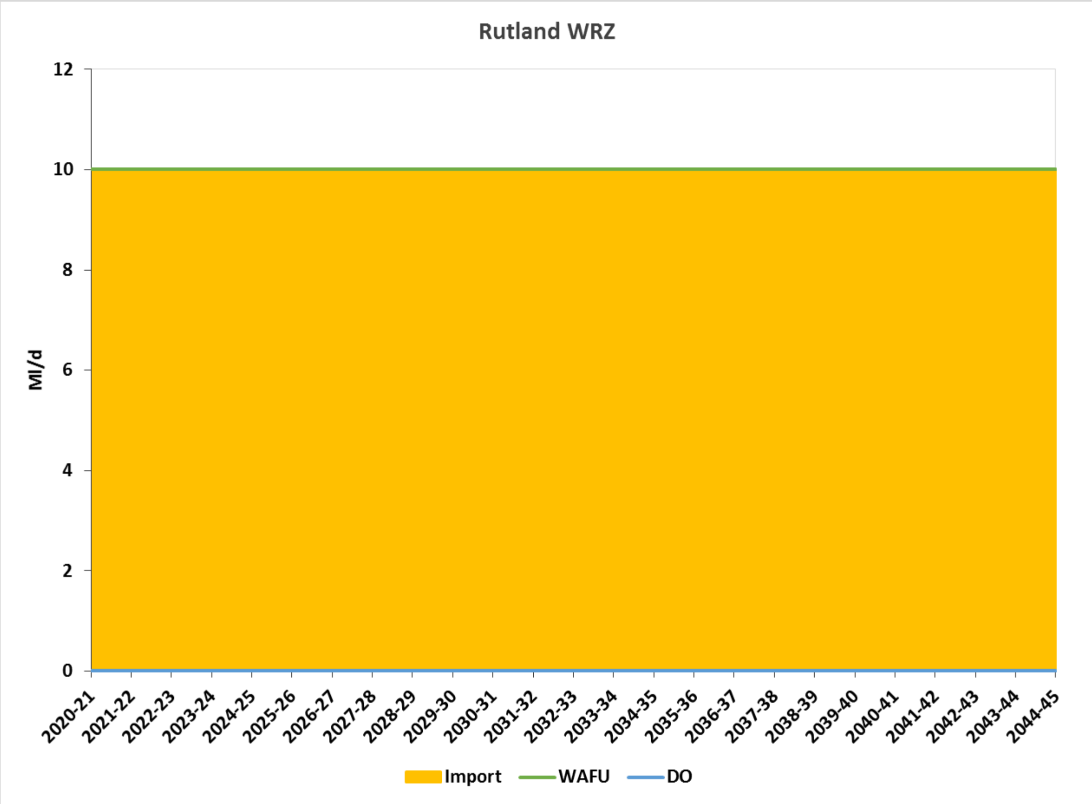
Figure A12.14: Nottinghamshire baseline water available for use



Rutland zone

The Rutland Water Resource Zone is supplied by a bulk import. Baseline deployable output for this zone is zero.

Figure A12.15: Rutland baseline water available for use



Ruyton zone

Figure A12.16: Ruyton baseline deployable output

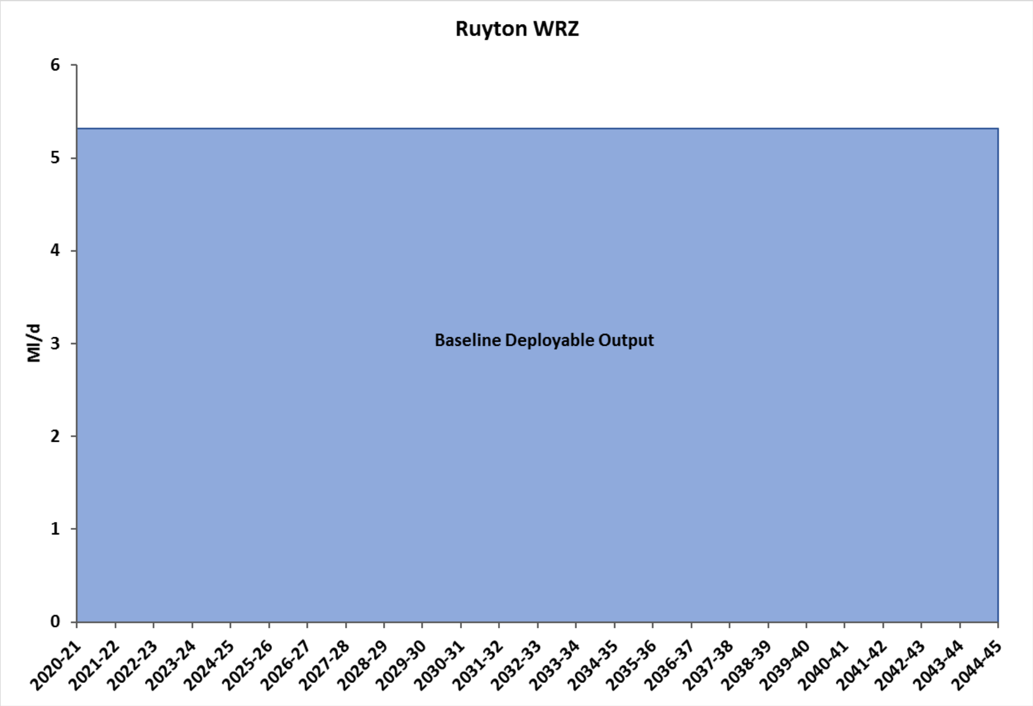
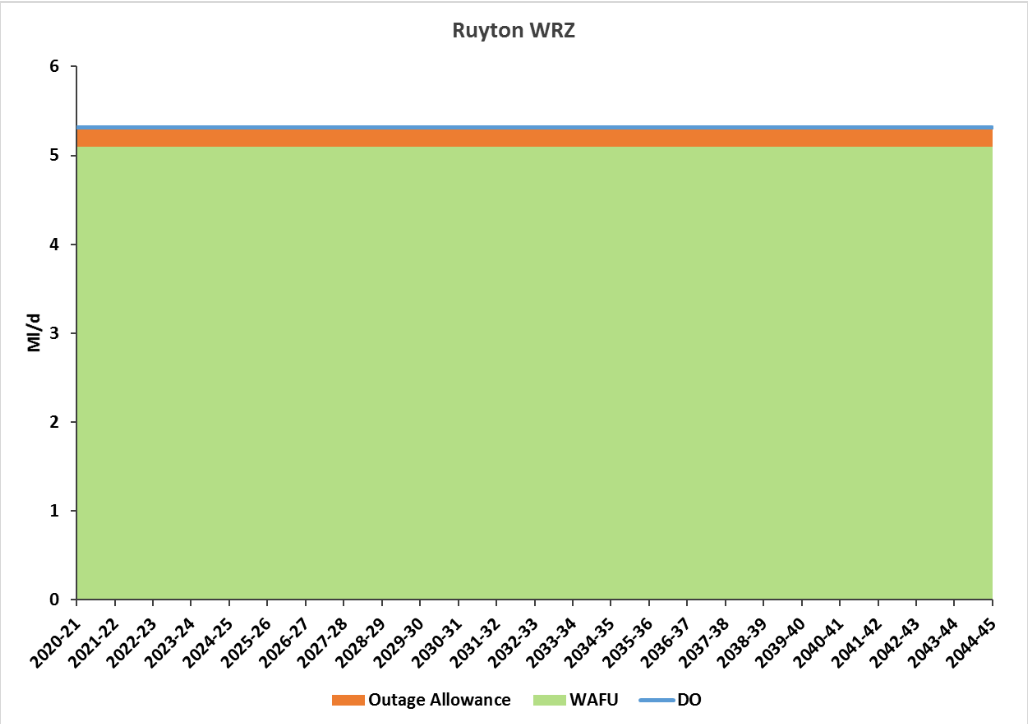


Figure A12.17: Ruyton baseline water available for use



Shelton zone

Figure A12.18: Shelton baseline deployable output

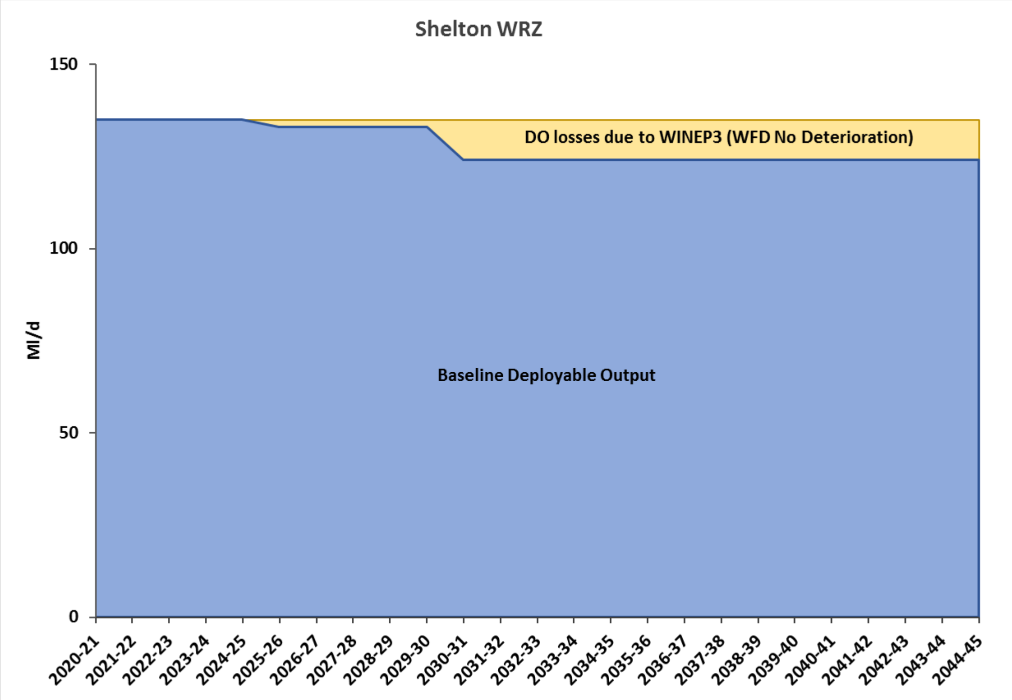
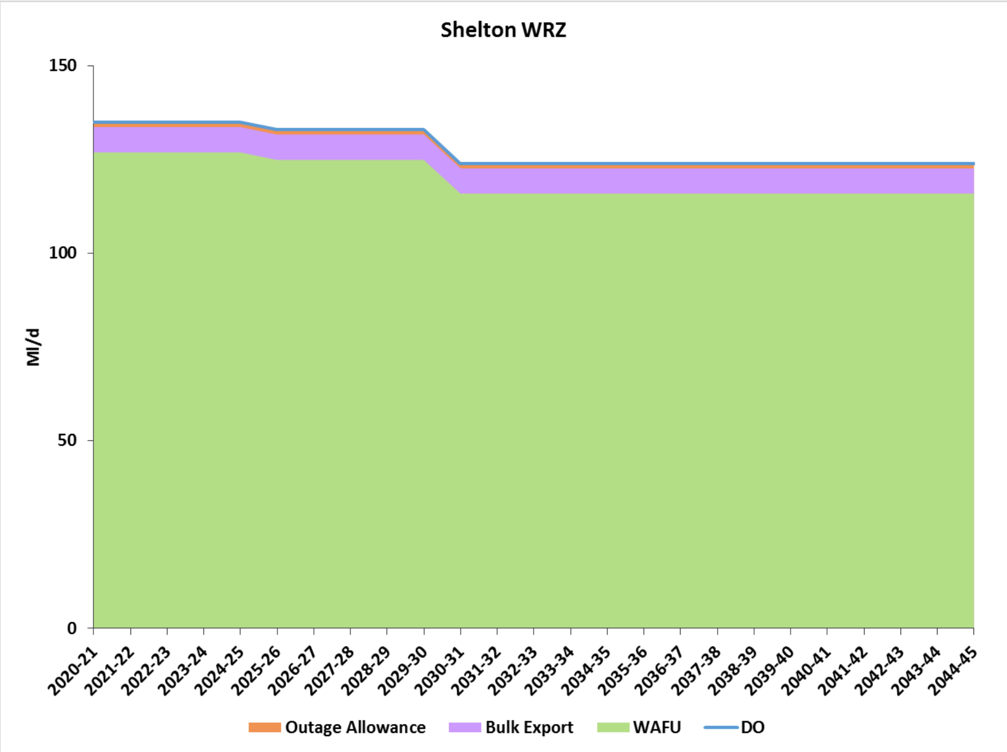


Figure A12.19: Shelton baseline water available for use



Stafford zone

Figure A12.20: Stafford baseline deployable output

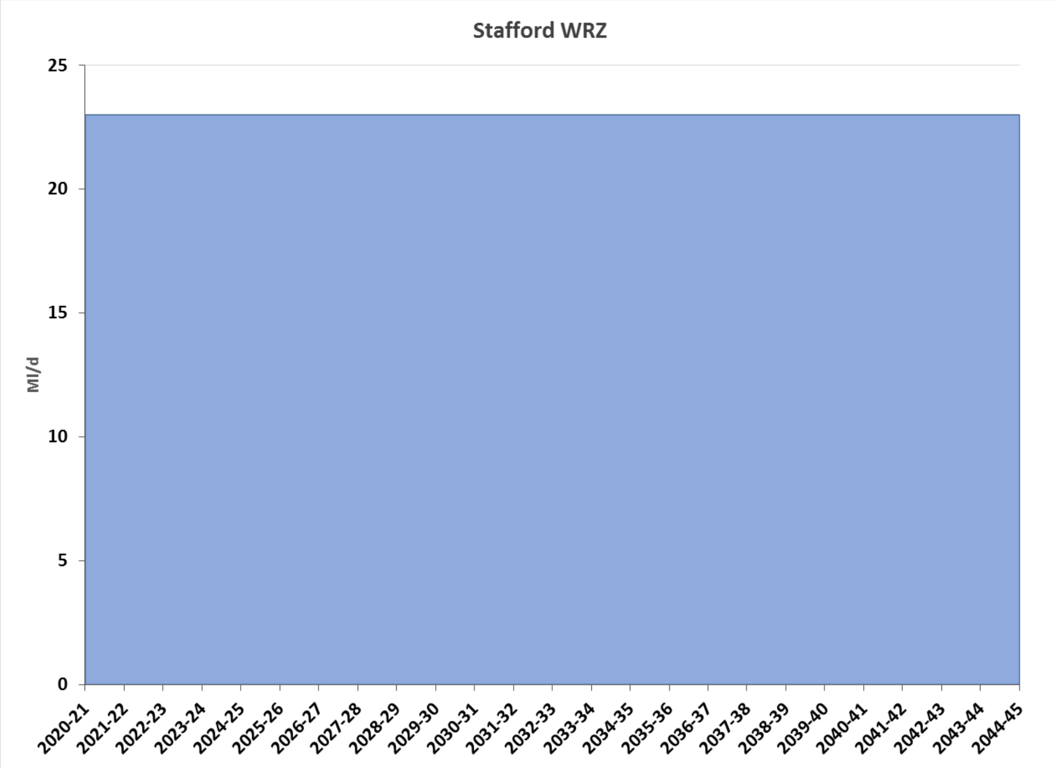
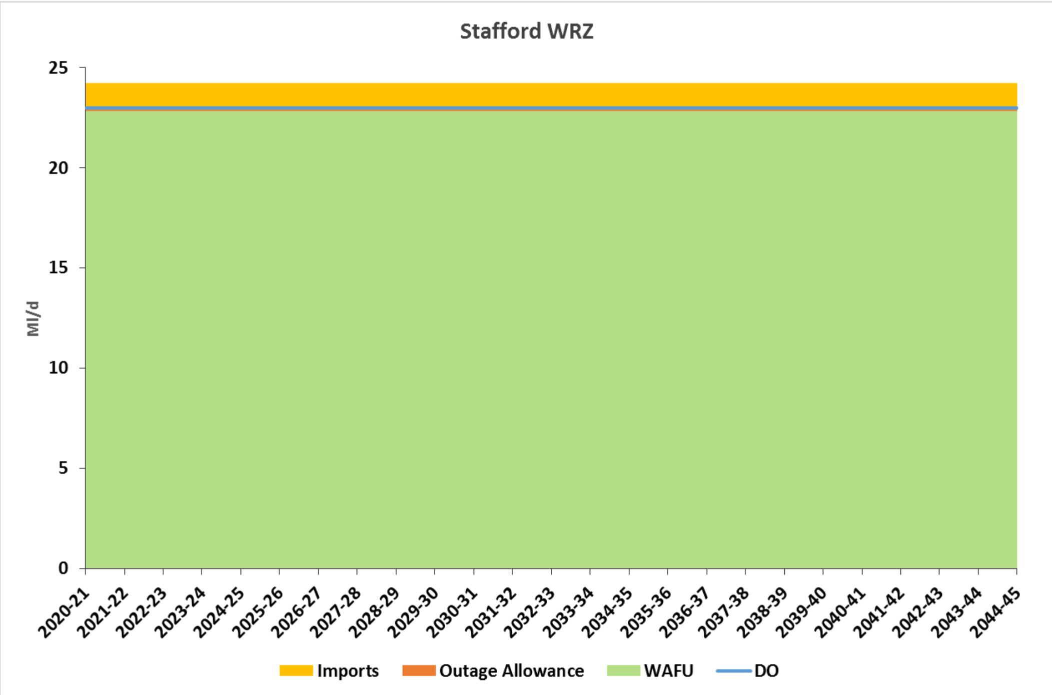


Figure A12.21: Stafford baseline water available for use



Strategic Grid zone

Figure A12.22: Strategic Grid baseline deployable output

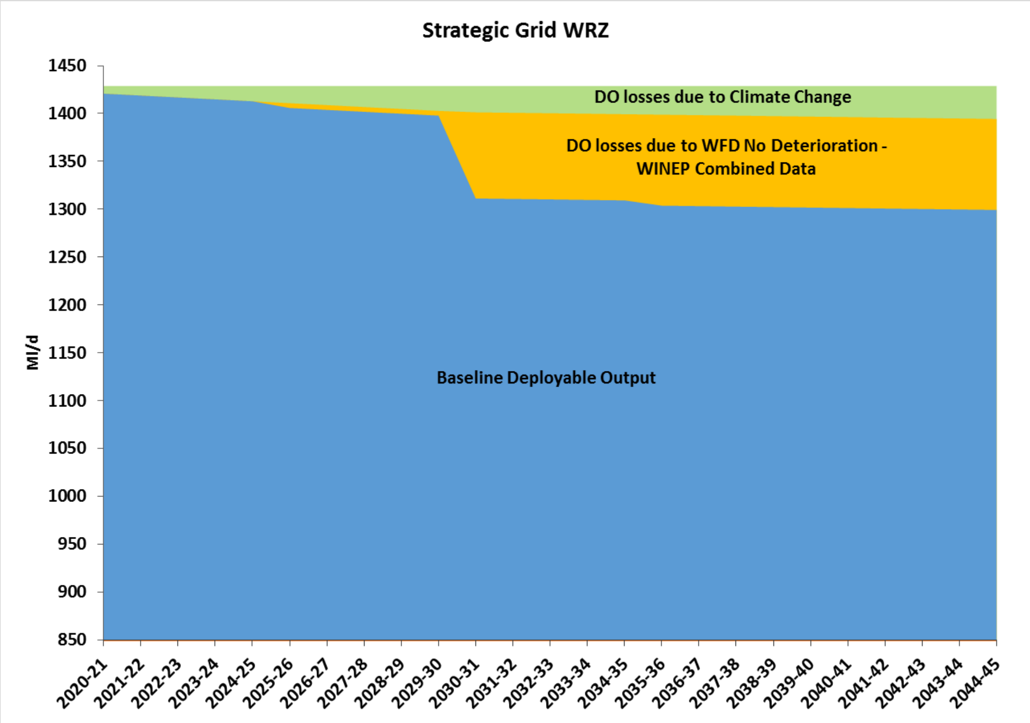
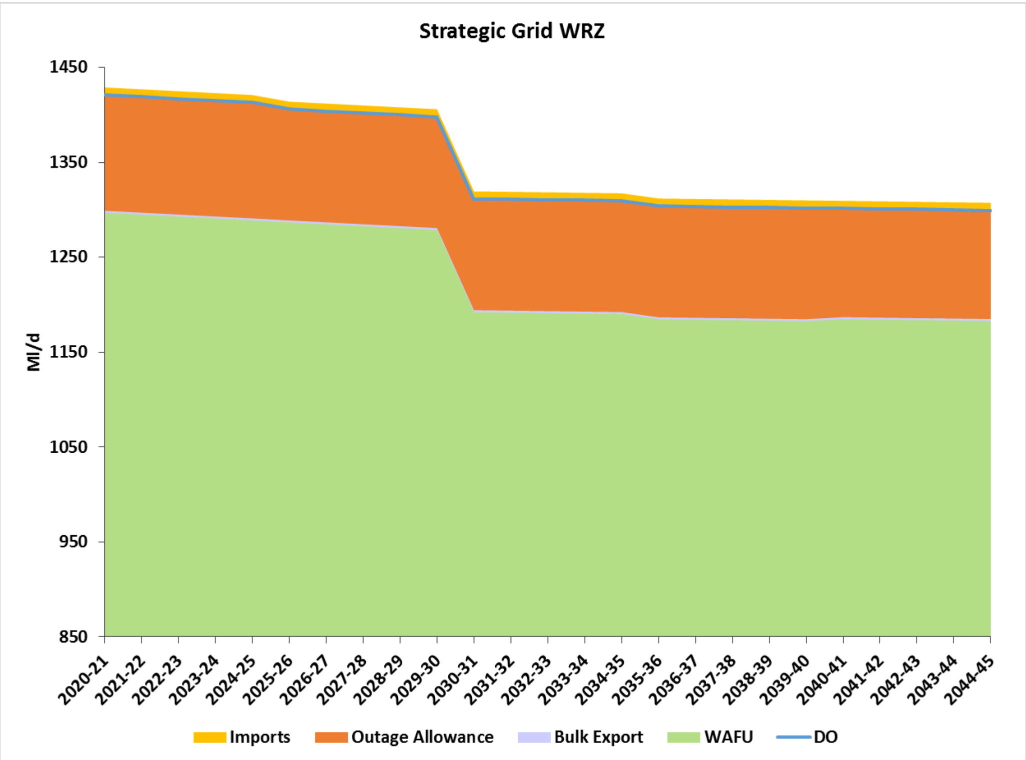


Figure A12.23: Strategic Grid baseline water available for use



Whitchurch and Wem zone

Figure A12.24: Whitchurch and Wem baseline deployable output

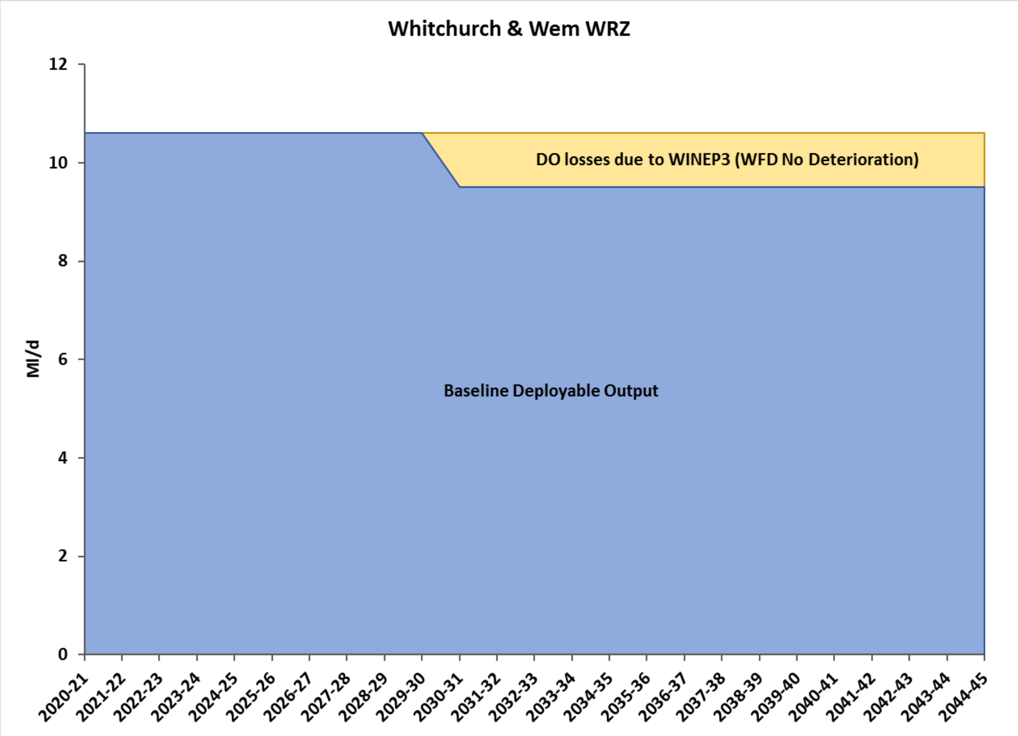
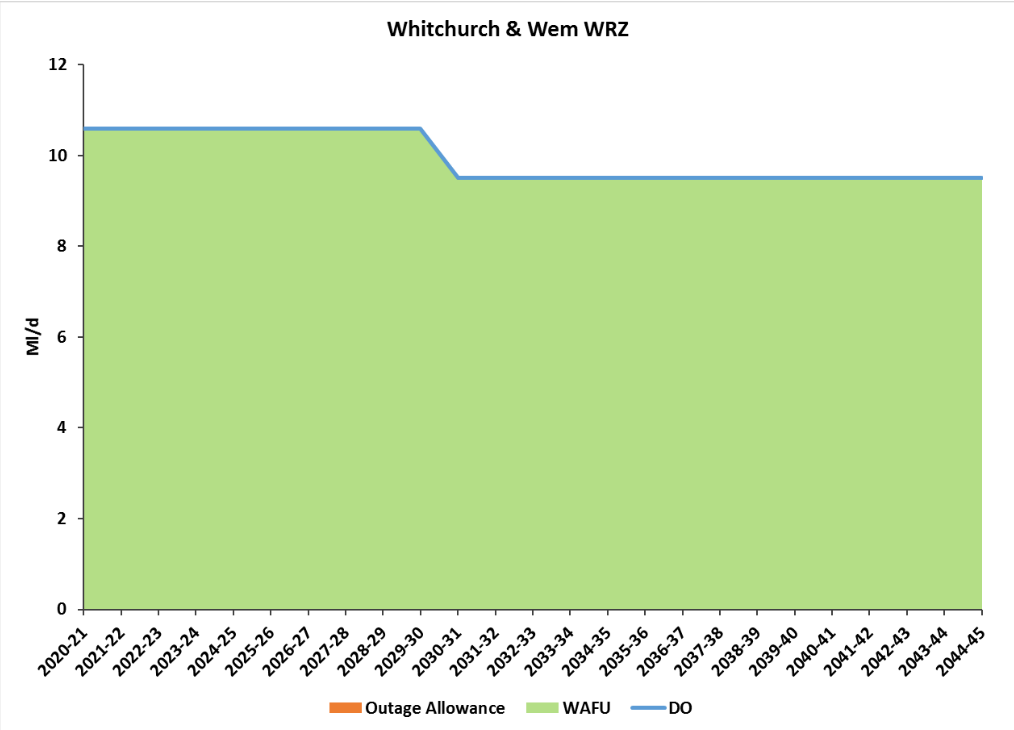


Figure A12.25: Whitchurch and Wem baseline water available for use



Wolverhampton zone

Figure A12.26: Wolverhampton baseline deployable output

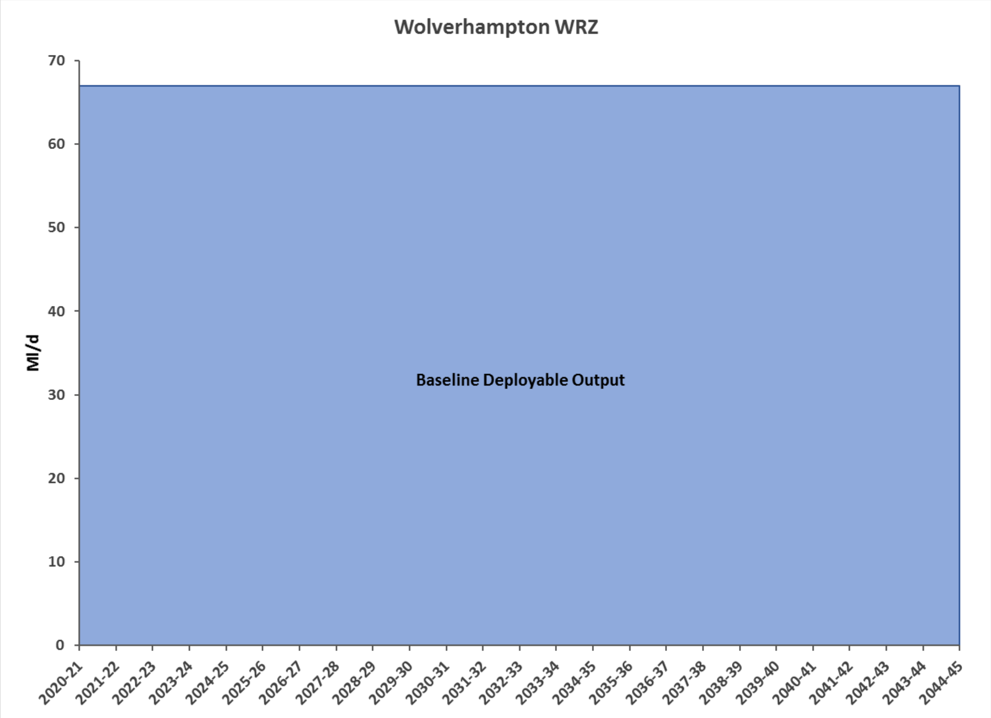
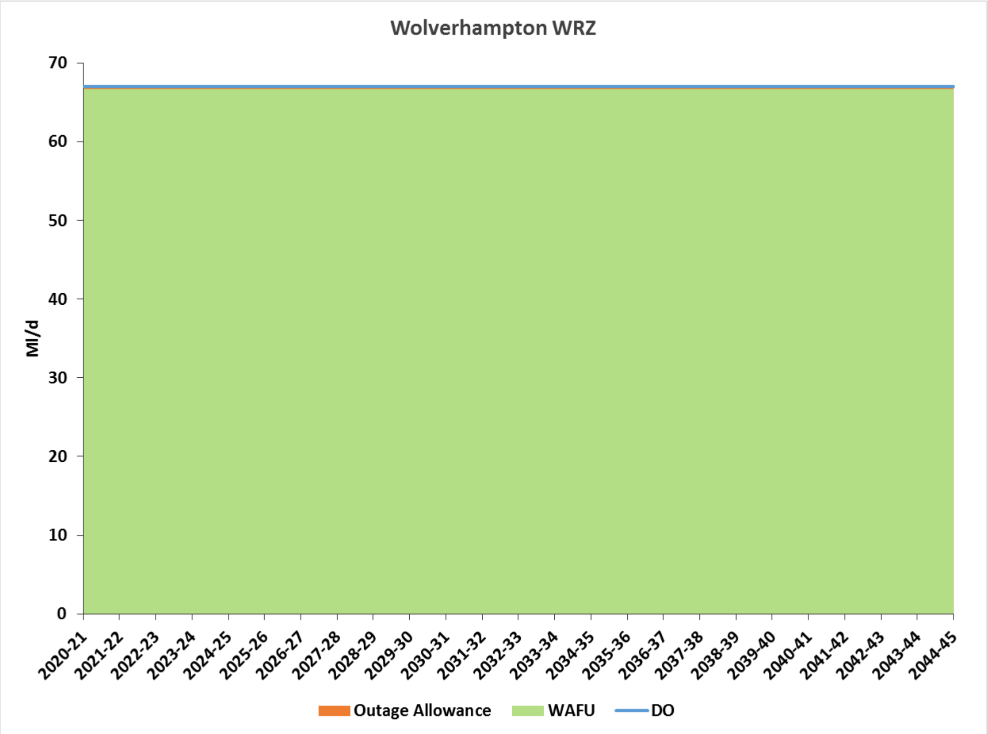


Figure A12.27: Wolverhampton baseline water available for use



A13 Protecting drinking water quality

On 12th September 2017, the Drinking Water Inspectorate (DWI) issued supplementary guidance to water companies relating to long term planning. The guidance included the following requirements:

> *"3.1 We would draw to your attention to two specific requests for information contained within the guidance note on long term planning for the quality of drinking water supplies:*
>
> *a. A statement from the Board Level Contact for each company that the company's draft Water Resources Management Plan (WRMP) takes account of all statutory drinking water quality obligations, and plans to meet all drinking water quality legislation. This statement should be sent to the Inspectorate when the company's final draft WRMP is submitted to Ministers for approval, and it will inform any advice that the Inspectorate may subsequently provide to Ministers that is relevant to their decision (para 4.3.10); and*
>
> *b. To provide assurance that risk assessments for drinking water quality include a long term view. Each company is requested to prepare and submit to the Inspectorate, a concise statement that sets out significant new future risk mitigation measures that a company considers it will need to provide for by the end of May 2018. New measures are those that are beyond routine provisions for current risk mitigation for all of a company's supplies from source to tap…"*

In order for us to maintain our position as an authorised holder of a water supply licence, Severn Trent continually works to meet all regulatory requirements set out under:

- Water Industry Act;
- Drinking Water Directive;
- Water Supply (Water Quality) Regulations 2016, and;
- All other regulatory framework requirements.

This includes reporting to and liaison with the DWI.

Of utmost importance to us is ensuring the water we supply from both our own and imported sources (transfers) is wholesome for all our customers. We check water quality meets drinking water standards by collecting around 500,000 tests each year, analysed for all relevant water quality parameters. These tests are taken from source to tap, including from works, reservoirs and customer taps across all our water supply zones. We also sample imported sources of water. We consistently achieve a pass rate of over 99.9% with a result last year (2017/18) of 99.96% compliance. We also ensure that any breaches of water quality and associated regulations are investigated and reported to DWI accordingly.

We have a planned sampling and testing programme (our Annual Sampling Plan) to ensure we comply with the number, frequency and location of our samples and analysis for each water quality parameter as specified by the regulations. We determine the samples and analysis required based on the volume of water supplied (at reservoirs or works) or population served (at water supply zones) as required and in accordance with the regulations. We update our Annual Sampling Plan each year and monitor our adherence to it.

All surface water and groundwater sources in our region each have a catchment risk assessment. These cover all Drinking Water Protected Areas (DWPAs). Risk assessments are undertaken for all contaminants based on a source, pathway and target model as part of our Drinking Water Safety Planning Process. The risk assessments were first undertaken in 2008. We continue to review our risk assessments in line with our Drinking Water

Safety Planning (DWSP) Framework which is managed by our DWSP Team. To date we have produced 16 surface water catchment risk assessments and in the region of 180 groundwater risk assessments.

The following Sections explain how we have incorporated the need to fulfil water quality obligations into the process of developing our long term plan that is described in this Water Resources Management Plan. In summary, protecting drinking water quality affects our supply projections and on the scope and design of any new water supply investment option that we include in our WRMP:

- Our water supply modelling includes an assessment of future raw water quality, and our plan explains what measures we propose to take to prevent any deterioration. We then build drinking water quality requirements into the decision making process, and;
- Our water supply investment optioneering explicitly takes drinking water quality obligations into account when designing and costing the scope of the potential solutions.

A13.1 Impacts on deployable output

Appendix A2 explains the detailed pumping, treatment and distribution components that we take into account in our water resources Deployable Output (DO) modelling. We consider current water quality constraints in our modelling of surface water and groundwater DO, and we take a view on how they might change in the future.

In our assessment of surface water source DO using our Aquator model, we have sought to incorporate potential raw water quality influences at sources with a known risk. An example of this is our approach to modelling our Eathorpe abstraction on the River Leam where we have represented the effect of not being able to abstract for approximately 15 days a year between September and December due to metaldehyde pollution risk. The need to suspend abstraction during higher risk periods then becomes a constraint on our modelled DO.

In our assessment of groundwater DO, the dry year average and peak source yield of each of our operational sources are included in our Aquator model as either an individual source or a group of sources. Source output constraints include the abstraction licence daily, annual or multi-year conditions as well as the need to maintain water quality blending requirements in multi-source locations.

For our groundwater DO projections we include a review of nitrate concentrations and trends, and the consequent impact on source output up to 2045. A series of nitrate blend scenarios were evaluated to determine the impact that rising nitrate concentrations would have on source DO over this period without interventions.

In our target headroom assessment, we have made an allowance for the risk of gradual pollution, where worsening water quality will affect the ability of the source to maintain the current DO. We have based this assessment on the list of groundwater sources identified through our Drinking Water Safety Plans as being at risk of deteriorating water quality. Through an initial screening assessment, these sources were then investigated further in order to determine what, if any, impact the deteriorating water quality would have upon the source DO. If there was no risk of DO being affected, or the source fulfilled one or more of the criteria below, the sources were excluded from the headroom risk assessment.

- There is no reference to water quality problems by area managers or in Severn Trent's lists of sources at risk or in the Water Framework Directive Article 7 list of pollution risks;
- The source is no longer in use and is not contributing to DO;
- The issue presented an outage risk rather than a loss of DO.

We have also assessed the uncertainties around the loss of DO due to increasing trends in groundwater nitrate concentrations. Many of our groundwater sources have rising nitrate concentrations, which prompted a review of all groundwater nitrate trends to be undertaken in 2016. The results of this investigation were then used to indicate which blends or individual sources would be at risk of breaching the Prescribed Concentration Value (PCV) by 2045. Where a risk has been identified a blend calculator was constructed and a high resolution study into the potential impacts and mitigations was carried out.

Our analysis suggests that several blends and individual groundwater sources could be severely impacted by rising nitrate concentrations before 2045. An estimate of these potential impacts to DO has been made using projections of existing trends for all groundwater sources at potential risk of exceeding the PCV of 50 mg/l. The outputs of this study have been incorporated with our wider evaluation of our projected future supply / demand balance.

A13.2 Catchment Management to protect drinking water quality

Catchment management is an important part of our strategic planning 'toolkit', but it cannot solve all of the current and future water challenges and it needs to be targeted in the right places at the right time for maximum benefit. It is also widely acknowledged that it can take significantly longer to achieve the desired outcomes than using traditional engineering solutions. Sustaining these outcomes is likely to require continuing effort over numerous AMPs and the use of significant financial and practical resources. Consideration of the resource, time and risk to achieve the desired outcomes is necessary when considering where to apply this approach.

Our drinking water strategy is to, where possible, use catchment management techniques to reduce the number of drinking water failures and minimise or delay future water treatment expenditure on raw water quality deterioration. This will be achieved through collaboration with Environment Agency (EA), Drinking Water Inspectorate (DWI) and OFWAT along with other key stakeholders and catchment partnerships. It will also deliver our obligations under the Water Framework Directive (WFD), further enhance catchment risk assessments that support our DWSPs and reduce carbon usage.

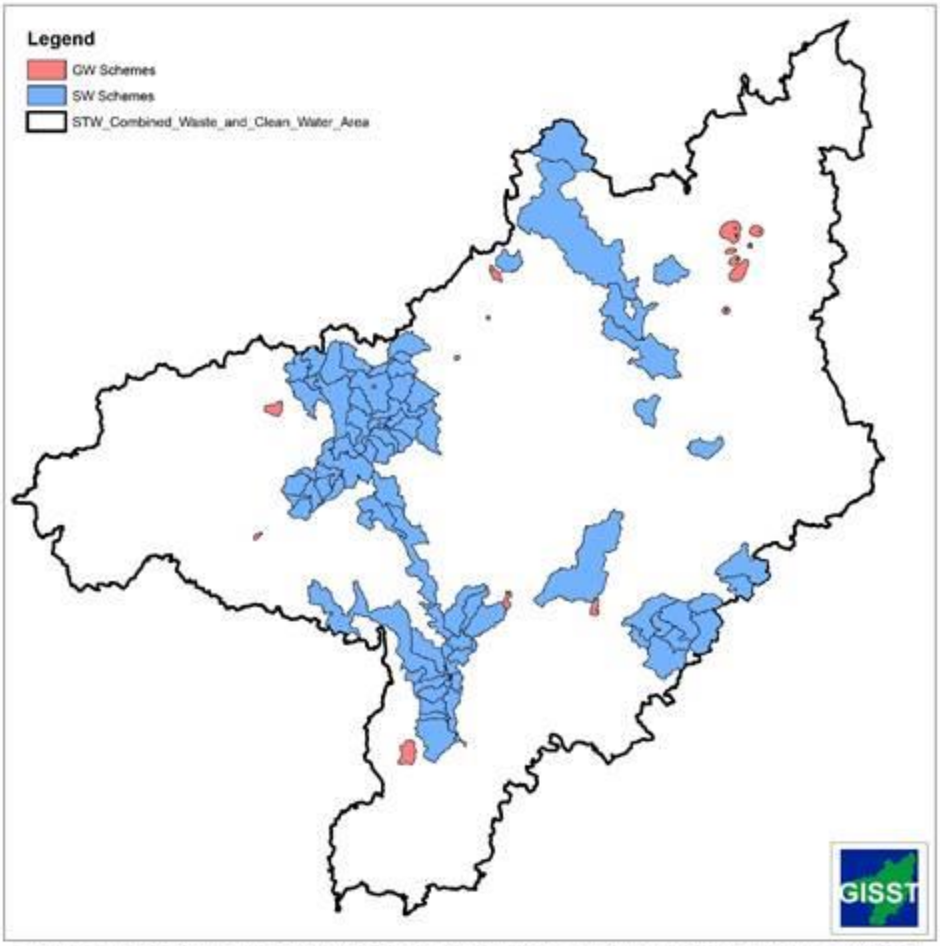
Over the last two AMPs our catchment management programme has been both ambitious (covering the whole of our region) and pioneering (one of the first such programmes in the country). Through our programme we undertake catchment investigations and schemes in both surface water and groundwater catchments. This programme of catchment management activities has allowed us to manage water quality risks in a sustainable and cost beneficial manner in accordance with regulatory requirements in Article 7 of the Water Framework Directive and Water Supply (Water Quality) Regulations.

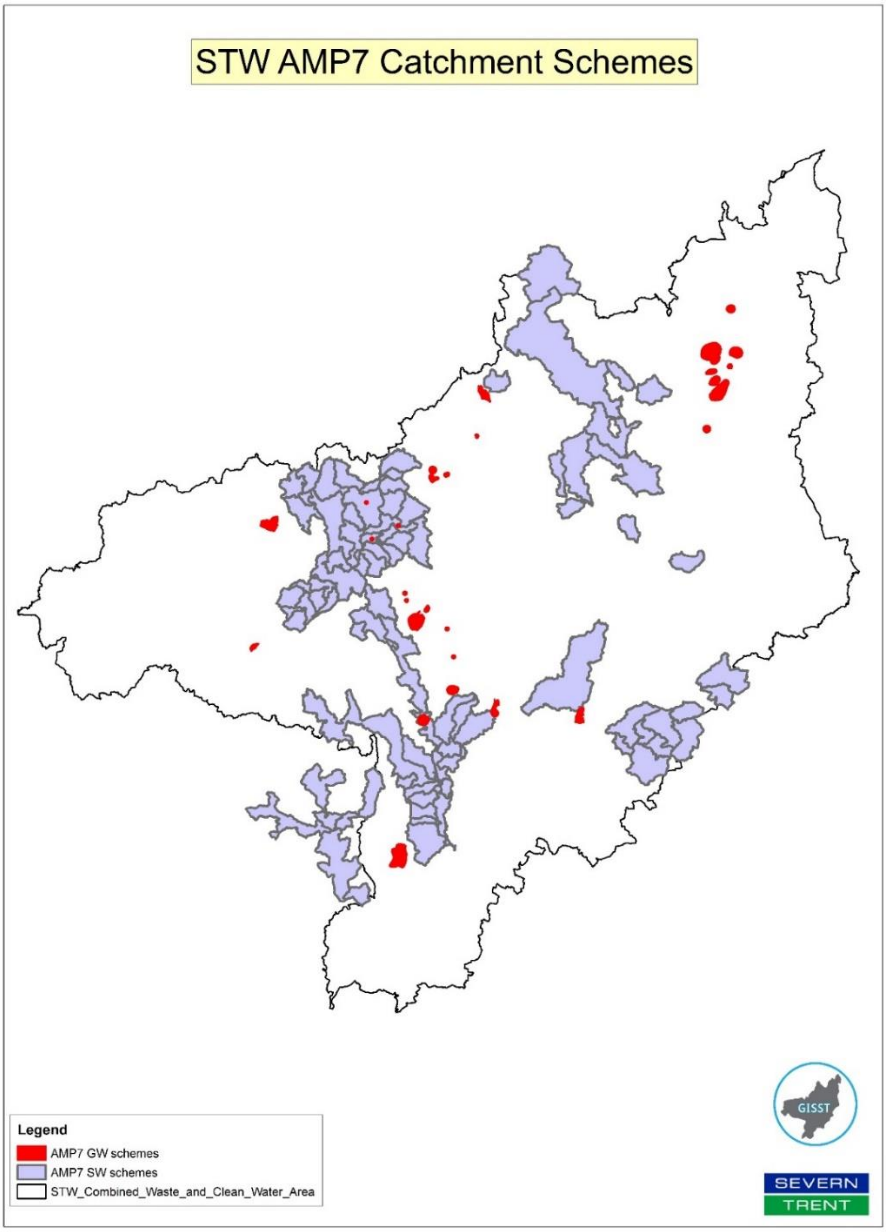
Our catchment management activities include investigations and catchment schemes. Investigations consider the potential for reducing pollution loading in drinking water sources in our region through catchment management. This work is typically undertaken as part of the Environment Agency's National Environment Programme (NEP). Outputs are fed into cost benefit assessments to consider the wider benefits and justification for proposing catchment management activities and other remedial actions. This supports our business planning process and helps to derive and prioritise a programme of interventions that we will carry out in the next AMP period. Catchment schemes are the delivery of programmes of catchment management activity on the ground. They involve the deployment of tools and staff to engage with landowners and stakeholders in order to proactively manage water quality risk in our catchments.

During AMP5, we successfully delivered one of the largest programmes of catchment management investigations in the industry. Our AMP5 catchment schemes were delivered through partnership agreement for example the Leam Strategic Partnership and partnership working with the Rivers Trust in the Tittesworth catchment. Our AMP5 investigations provided a justification for the development of 27 AMP6 catchment schemes. These schemes are currently being delivered following the appointment of seven Severn Trent agricultural advisors and a further four Severn Trent partnership funded advisors. The current AMP6 schemes offer advice, training, monitoring, events and grants to farmers in priority catchments in accordance with the water quality issues in that catchment.

Our plan for AMP7 and beyond includes the continuation of our 27 current catchment schemes plus eight new schemes that were recommended through our AMP6 NEP investigations. The location of these schemes is indicated in Figure A13.1. The proposed catchment schemes will help protect our current sources from water quality risks, ensure no deterioration, help improve the resilience of our assets, and generate wider environmental benefits.

Figure A13.1: Map showing locations of catchment schemes in AMP7



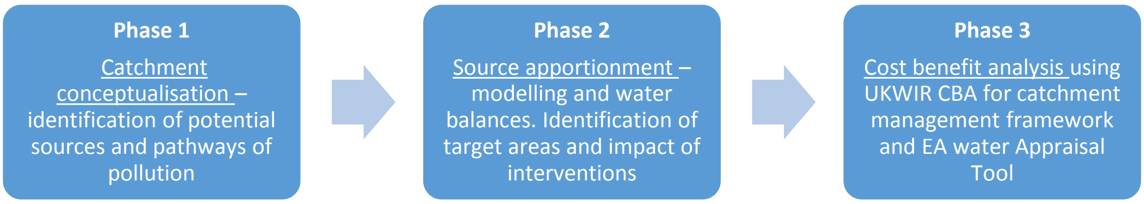

STW AMP7 Catchment Schemes
GISST
Legend
AMP7 GW schemes
AMP7 SW schemes
STW_Combined_Waste_and_Clean_Water_Area
SEVERN
TRENT

Our approach to catchment management activities has been formulated across many AMP periods. In AMP5 we made significant improvements in our catchment risk assessment processes. We have been able to verify the identified catchment risks through catchment walkovers, land use mapping and water quality data coupled with flow travel times. During AMP6 we built on these processes further to incorporate Research & Development (R&D) work that we carried out to improve our pesticide risk modelling (CatchIS) for groundwater catchments. This included enabling the potential to run the modelling software with a greater resolution (field scale through the use of our remote sensing data) into our business as usual procedures. Outputs from the Drinking Water Safety Plan (DWSP), coupled with water quality trending have also been used to help identify future water quality risks which need to be investigated or mitigated in future AMPs.

Catchment investigations and schemes provide cost beneficial solutions to water quality risks, addressing issues at source rather than relying on unsustainable and expensive end of pipe solutions. Article 7 of the Water Framework Directive requires water companies to move away from treatment options, utilising catchment approaches as the first and preferred option where possible. Minimising risks to water quality through proactive catchment management provides resilience in the face of uncertain future climates and growth, and with pressure to reduce abstraction in some area, there is even greater need to protect the quality of our remaining sources. Through catchment management, outages due to water quality issues can be reduced, and in some area, WFD benefits can be sought from water company catchment interventions.

As part of our WFD Article 7 obligations and through liaison with the Environment Agency we are tasked with developing a list of National Environment Programme (NEP) sites for which we are obligated to undertake investigations or deliver catchment schemes. Surface water investigations tend to be based on operational issues. Groundwater investigation sites are identified through a screening approach considering a range of environmental and operational targets. We have adopted a phased approach to the investigation as described in Figure A13.2. This approach was agreed in advance with the Environment Agency, with the development of signed scoping documents.

Figure A13.2: Phased approach to catchment investigation



A similar range of activities is undertaken for each catchment investigation. However groundwater catchments receive greater focus on building a conceptual understanding of the groundwater system and interactions with pollutant sources. For surface water catchments, we focus on understanding the existing activities amongst stakeholders that can influence management of water in the catchment. Catchment investigations enable us to prioritise activity on high risk fields / sub-catchments to ensure catchment interventions are delivered in the most influential parts of the catchment. The key deliverables of each catchment investigation are:

- The identification of potential sources of pollution and pathways to the source.
- A catchment model, either simple source apportionment or if the investigation requires more detailed scenario modelling.
- The identification of possible mitigation measures, including the evaluation of potential treatment options.
- A benefits assessment or cost benefit analysis.
- A catchment plan to be undertaken in the next AMP.

In AMP6 we delivered 27 catchment schemes and 13 investigations under the NEP programme. The AMP6 investigations have been utilised to shape eight new catchment schemes for AMP7. In addition to a further 13 new investigations, these schemes form our NEP obligations for AMP7. We will also continue to deliver our AMP6 schemes across 27 catchments, even though these are no longer NEP obligations.

A large number of our current catchment schemes seek to address multiple water quality parameters, covering issues such as multiple pesticides, cryptosporidium, nitrate, colour/sediment and metaldehyde. Moving into AMP7 our catchment approach will be extended to include biodiversity, flooding and managing Phosphorus (P) inputs upstream of sewage works.

In order to further protect drinking water from pollution and the need for more treatment at our water treatment works (WTWs) the Environment Agency have designated Safeguard Zones (SGZs). These zones are areas where land use is causing pollution of the raw water. Action is targeted in these zones to address pollution so that extra treatment of raw water can be avoided. SGZs are a joint initiative between the EA, water companies and other key stakeholders in a catchment and are one of the main tools for delivering the drinking water protection objectives of the WFD. A total of 19 of our catchments are designated as SGZs, requiring us to undertake catchments schemes and deliver mitigation measures upstream of our WTWs.

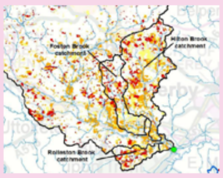
A13.3 Our future catchment management schemes

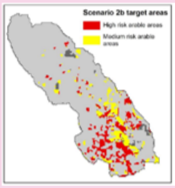
Our future plan includes the continuation of current 27 catchment schemes plus eight new catchments recommended through our AMP6 NEP investigations. Figure A13.3 provides an indicative overview of our proposed new catchment schemes. These catchment schemes will help protect our current sources from water quality risks, ensure no deterioration of the water body and help towards improving the resilience of our assets. As well as the catchments indicated, we are supportive of catchment activities being carried out by other organisations and partnerships. An example of which is the Sherbourne catchment where we fully support the West Midlands Wildlife Trusts and we look forward to understanding the outcome of the recent Water Environment Grant bid made for that catchment.

Figure A13.3: New catchment schemes for AMP7

Surface water

Dove	Ogston	Mitcheldean
Metaldehyde scheme on arable land in the Hilton Brook, Foston Brook and Rolleston Brook sub-catchments of the River Dove catchment supporting continued work in Staunton Harold catchment.	Metaldehyde scheme on high and medium risk areas of arable land within the Ogston Reservoir natural catchment. Also addressing nutrients and grassland herbicides.	Metaldehdye scheme on arable land within the three Mitcheldean sub catchments – shown in orange below.





Groundwater water

Astley	Bellington	Copley	Hilton
• Strong CBA justification for advisory scheme • Light touch advisory scheme would address uncertainty in trend – sensitive analysis envelope around trend takes baseline just above target concentration for site	• Light touch advisory scheme recommended to address changes in the catchment observed during walkovers e.g. increase in veg growing • Scheme would address short term start up spikes	• Light touch advisory scheme to address uncertainty in trend and start up spikes – potential to combined under Hilton scheme – located close by	• CBA justification for light touch advisory scheme to address uncertainty in model and mitigate any significant change in the catchment

The scope of our future drinking water catchment management activities includes the following:

- STEPS (Severn Trent Environmental Protection Scheme)
- Payment for Ecosystem Services – 'Farm to Tap' previously known as 'Farmers as Producers of Clean Water' (FaPCW)
- Advice and Training

In addition to the above, during 2018 we trialled a new scheme called 'Cash for Catchments' which aimed to deliver funding to support a range of important causes including:

- Preservation of our region's biodiversity
- Control of invasive non-native species
- Natural flood management
- River restoration and improving river water quality

The success and benefits of the Cash for Catchments fund will be analysed with the results and recommendations directing our approach to continuing to run the fund annually in future.

STEPS (Severn Trent Environmental Protection Scheme)

STEPS is a competitive scheme run across all priority catchments in our region. We recognise that there has been high uptake of the STEPS scheme and that it has been popular with farmers. Under our STEPS scheme we offer capital grants to farmers to undertake works which will help reduce diffuse pollution, for example through the installation of biobeds/biofilters. Within our current STEPs grants we also offer a number of options which help support improved soil biodiversity for example low input grasslands and arable reversion. There are grant options for water retention such as farm wetlands, grass swales and sedimentation ponds. More information can be found about these items at https://www.stwater.co.uk/about-us/environment/farming-for-water/steps1/. The capital grants window is open annually from January to March. The scheme commenced in 2015 and will continue until 2020.

Since 2015 we have undertaken three rounds of grant applications and have received over 600 applications for funding. Applications have ranged from improved pesticide handling facilities to water course fencing to rainwater harvesting equipment. More innovative ideas have been welcomed through a unique 'farmer innovation' option where farmers present their own ideas for improving water quality.

We recognise that we need to communicate the benefits and outcomes of these schemes more widely to promote their benefits and drive wider confidence in these programmes and similar new products / practices elsewhere. This is something we are currently looking to address and we will continue to explore ways of strengthening communication links with the farming networks across our region.

Payment for Ecosystem Services – Farm to Tap

Our Farm to Tap scheme, previously known as Farmers as Producers of Clean Water (FaPCW), commenced in September 2016 and runs annually between September and December each year (during the highest risk metaldehyde period). This scheme pays farmers for producing clean run-off from their land and therefore contributing to improvements in drinking water quality within their local sub-catchments. The scheme encompasses the principles of PES (Paid Ecosystem Services) with the overall aim of changing farmer behaviour and promoting ownership of the river(s) within their catchments. It is envisaged that this approach will help drive long lasting behavioural change and sustainable improvements in water quality.

The scheme provides landowners with information on what activities can help reduce metaldehyde losses (Figure A13.4). However, it does not stipulate that they must undertake these activities, but instead it allows the farmer to choose management options that suit their farm business. Farmers can receive up to £8/ha for improvements or no deterioration downstream in water quality.

Figure A13.4: Farm to Tap practices to reduce Metaldehyde losses in water

In order to measure the success of Farm to Tap in addition to water quality monitoring within the catchment, all participants are required to complete a survey at the end of each year detailing what mitigation actions have been taken to help reduce metaldehyde losses during the monitoring period.

Advice and Training

In addition to our schemes we also offer the following support to farmers:

- Pesticide sprayer testing.
- Pesticide application training.
- Metaldehyde spreader calibration.

We are the first water company to partner with Natural England's (NE's) Farm Advice Framework (FAF) contract and are funding farm advice visits through this established framework of approved technical expert contractors. The framework is also being used to deliver DEFRA's current countryside stewardship programme. Partnering with NE on their FAF contract has provided us with the opportunity to use well-established, respected contractors to undertake farm advice visits to farmers and landowners. Visit types include;

- Machinery testing and calibration (fertiliser/manure spreaders).
- Soil and Nutrient Management Plan.
- On-farm review of pathways for and sources of faecal contamination of water courses.
- Pesticide Handling and Application and Bio-bed and Pesticide Facilities Design.

In addition to these measures, since 2014 we have also funded a pesticide amnesty to reduce the amount of unwanted pesticides within catchments. To date a total of 13 tonnes of pesticides have been removed from our catchments.

Alongside our training, visits and advice activities, we also strongly advocate the new Farming Rules for Water. We have a number of Agricultural Advisors that provide advice and guidance on legislative requirements when carrying out farm visits. Our schemes are voluntary and are designed to enable farmers to go above and beyond good agricultural practice rather than specifically to meet regulatory requirements. Where there is evidence that voluntary measures are insufficient to meet these requirements and all voluntary measures have been exhausted then we will liaise with the appropriate Regulators.

Success to Date

Over the last 3 years since starting our STEPS schemes, much has been achieved across our catchments. Figure A13.5 highlights some of our key successes to date. Our Catchment Team has engaged with 1,704 farmers/agronomists covering 1,512 farms across 27 catchments (data up to 19/09/2017). We have received over 600 applications for funding towards on farm improvement works under our STEPS grants and 428 farms signed up to our metaldehyde schemes for autumn 2018.

Figure A13.5: AMP6 catchment scheme success

Our catchment schemes have also resulted in:

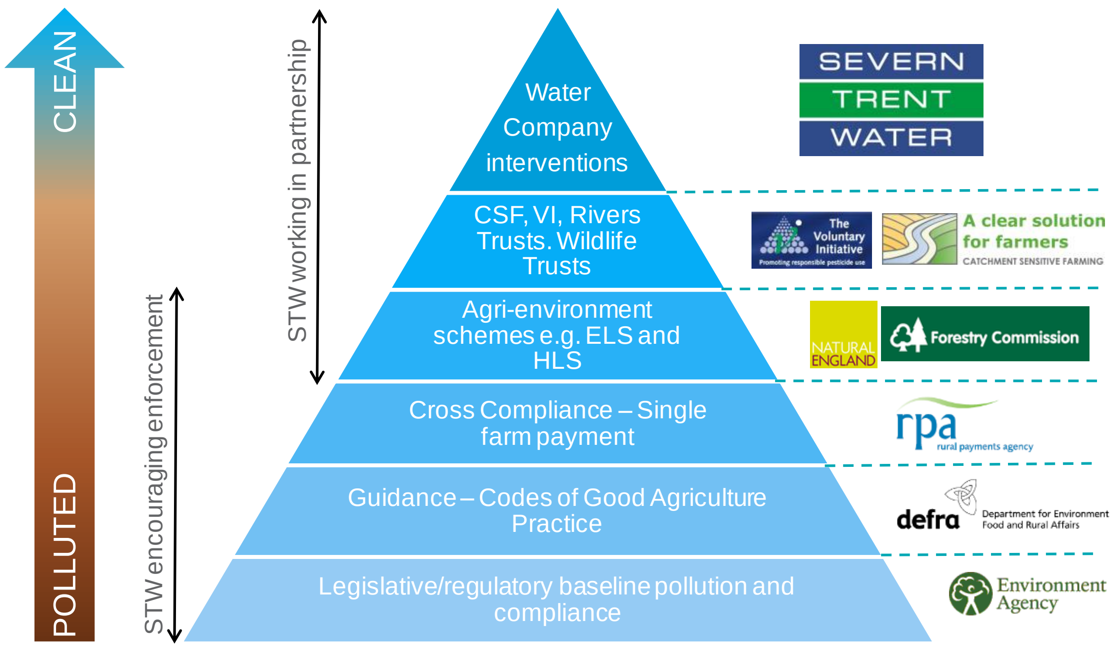
- A 50% reduction in metaldehyde exceedances of PCV at our Water Treatment Works (WTWs).
- A 50% reduction in pesticide peaks at Site L WTW, avoiding the need for the installation of a Granular Activated Carbon (GAC) plant to treat water for pesticides.
- The cancellation of our planned capital investment (plus ongoing opex) in a nitrate removal plant in Worcestershire. This was achieved through better understanding of agricultural practices in the area and a partnership approach with local landowners about changing practices.

Stakeholder Engagement

Stakeholder engagement is essential for the implementation of a catchment management strategy. We see the Catchment Based Approach (CaBA) partnerships as key in aiding the delivery of our strategy. However, our advice only catchment management work has shown that in some catchments, stakeholder engagement, good agricultural practice and advice alone will not bring about sufficient water quality improvements. In these catchments or high risk areas, enhanced and targeted catchment measures are needed to meet drinking water standards (DWS) or target water quality concentrations. It is in these areas where we see water company intervention as being key to managing catchment risk and where we place our catchment schemes in our tiered approach to catchment management activities as shown in Figure A13.6.

Our partnerships with River Trusts, Wildlife Trusts and other organisations that have complementary objectives for our catchments (such as Wye & Usk Foundation, Trent Rivers Trust, Severn Rivers Trust, Catchment Sensitive Farming and Nottinghamshire Wildlife Trust) are key to helping us deliver our AMP6 catchment ambitions and we expect this to continue into the future. In addition to these organisations, we have also established a recent partnerships with the West Midlands Wildlife Trusts. We fully recognise and appreciate the cost effective, reliable and extensive expertise these partnerships bring to our current catchment programme. We will also aim to further utilise our partnerships with Wildlife and Rivers Trusts along with Catchment Based Approach (CaBA) groups to explore large integrated catchment management approaches.

Figure A13.6: Tiered approach to catchment management initiatives and stakeholder engagement



We need to be clear both internally and externally about the principles of catchment management in these areas. To this end, we have established high level principles for engagement which will underpin activities and communication in this area.

In AMP7 we will follow these principles:

- We will use scientific evidence and/or expert opinion to support the need for any cost beneficial changes in catchment management.
- We will work with stakeholders (including farmers and landowners) to bring about catchment management improvements voluntarily.
- We will use local expertise and insight to deliver our schemes efficiently through partnerships with Rivers Trusts, Wildlife Trust and other organisations with complementary objectives for our catchments.
- We will seek to facilitate management changes in the source catchment areas by bringing together interested parties and/or external funding streams into the catchment area to improve resource protection.
- Where farmers are asked to go above and beyond good agricultural practice we may part fund improvements or offer incentives to farmers to encourage changes in practices, for example through product substitution.
- We expect farmers to meet good agricultural practice through existing legislation, regulation and guidance. Where farmers do not adhere to the Code of Good Agricultural Practice (COGAP) through voluntary means we will look to the Environment Agency to enforce good practice.
- We will actively seek to have catchment areas designated as Safeguard Zones to promote voluntary activity.
- We will only resort to regulatory tools such as Water Protection Zones as a last option.
- We will seek to influence regional and national research needs, policy and delivery mechanisms where we identify gaps through our catchment engagement and R&D work.

A13.4 Water quality and new supply-side options

For our WRMP we have identified 119 different feasible options for increasing deployable output. These options include increasing water treatment works outputs, further optimising treatment works processes and increasing our strategic distribution capabilities. Further information on how we derived our feasible options is provided in Appendix D. The individual components of each solution has been considered in terms of:

- The source of raw water abstraction.
- The treatment works and treatment processes.
- The means of distributing the treated water.
- The distribution service reservoirs impacted by the new source.

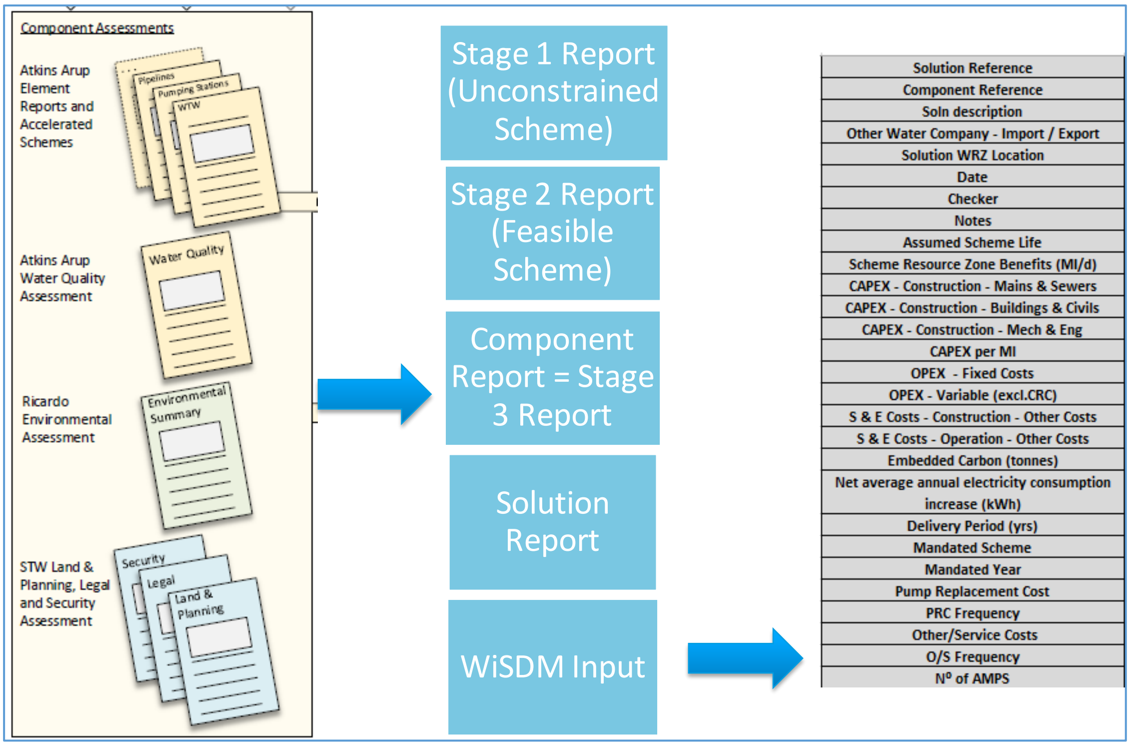
The design and scope of each option has been assessed using a 'bottom up' approach, and water quality is explicitly one of the elements we have considered when developing our supply-side options. Figure A13.7 outlines the option development process and shows how water quality considerations were integrated into the assessment alongside other factors such as environmental impact and planning requirements.

We followed an option screening process to refine our list of potential options and to screen out any options that would not be considered feasible. Technical expert screening workshops were held to:

- Appraise each option.
- Understand whether any identified constraints could be resolved.
- Assess any wider opportunities or potential benefits offered by each option.
- Remove any unfeasible options from further subsequent development stages.

This screening process is described in greater detail in Appendix D.

Figure A13.7: Assessing water supply options



Qualitative assessment was followed up (where applicable) with quantitative assessment. Where necessary, this technical expert screening included consultation with our water treatment process design and engineering team for water quality and treatment specific considerations. As a summary, our screening considered the generic questions shown in Table A13.1 :

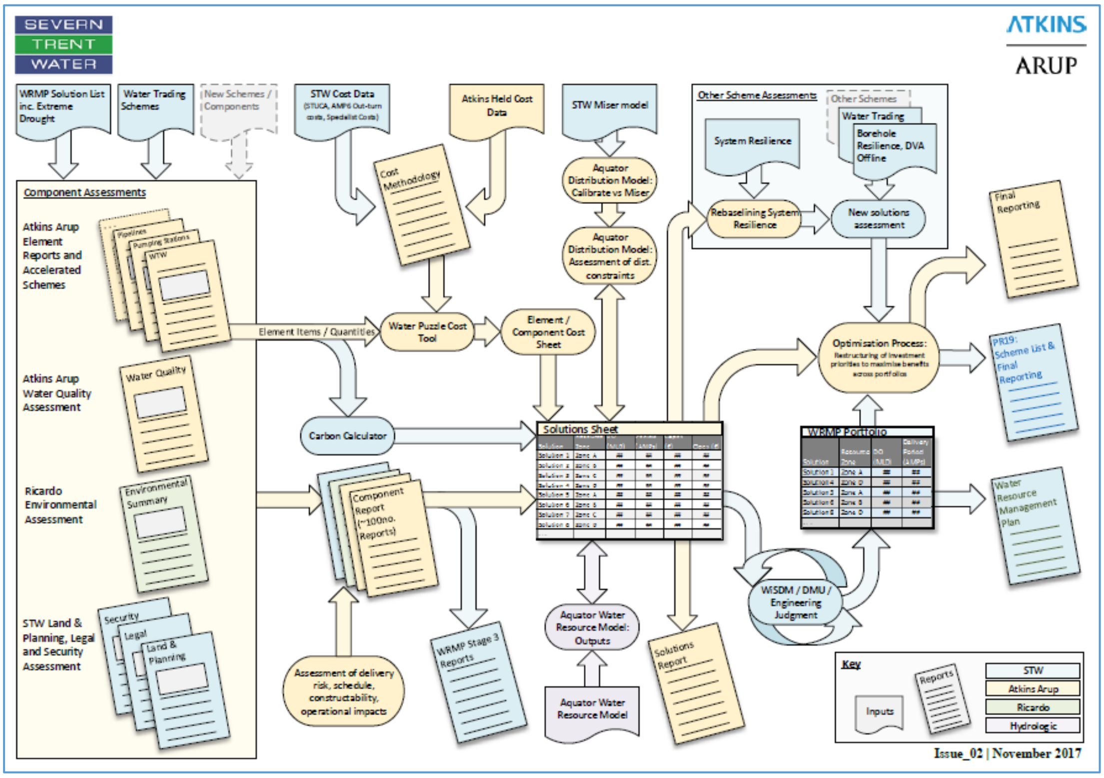
Table A13.1 Option screening considerations – Water Quality Factors

Item	Screening Considerations
Raw water provision and treatment	- Can we abstract any additional raw water required without environmental damage and, if required, what are the mitigation measures?
	- What is the quality of the raw water and is additional treatment required? - Do we need new / upsized or additional (under new DWI regs) treatment works? - If new treatment is required, is there physical space on existing sites for treatment or do we need to purchase land and establish a new site?
	- Can a range of deployable output values be specified for different circumstances?
Distributing water to our customers	- If the option involves increasing capacity of an existing site do we need to upsize our assets?
	- Does the distribution network have the capacity for the extra water? - Do we need to improve/upgrade our existing assets or do we need new ones (for example additional pipelines or pumping stations)?
	- Does the distribution system rely on a current water quality blend and how would the new supply impact on that? What could we do to mitigate blending / quality impacts?
	- Do we know if there are any other interventions that are being delivered in AMP6 or being proposed for AMP7 implementation that may impact on the option? This is to avoid abortive spend or duplication of work/cost.

Item	Screening Considerations
For option specific considerations, we explored the following questions.	<u>New groundwater source</u> - Where will this be located and what is the Catchment Abstraction Management Strategy (CAMS) status of the source? - What are the Water Framework Directive implications – both for groundwater and surface water bodies? - Will the new source be near any Water Dependant Terrestrial sites or Sites of Special Scientific Interest (SSSIs) or Special Areas of Conservation (SACs)? - Do we own the land already? - At what depth should the borehole be drilled? What aquifer is it sourcing from? How many boreholes are required? - What is the theoretical yield of the site? - What is the predicted water quality of the new water source? Do we need treatment at the site? - How will the new source be connected to our network? <u>Existing groundwater source</u> - What is the condition of the existing asset? Is it near or reaching the end of its asset life within the 25 year planning period? - Will we need to incorporate the costs for borehole rehabilitation and/or re-drill to ensure operation across the entire planning period? Has the expected rehabilitation technique been attempted before? - Are there any known issues with water quality? Can raw water from the source be treated using the existing assets or with conventional treatment methods?

These different screening elements have formed an important element of our overall WRMP supply-side options appraisal process. The overall process is summarised in Figure A13.8 and described in more detail in Appendix D.

Figure A13.8: The WRMP options development and appraisal process



A14 Critical period

The WRMP guidance requires that we report a Dry Year Annual Average (DYAA) supply / demand scenario as a minimum. The guidance also gives the option of reporting under the critical period scenario if relevant.

As an improvement to our 2014 WRMP, we have reviewed how a critical period scenario would affect each of our water resource zones. Our conclusions are that:

- A critical period, peak week scenario is relevant for our water resource zones that are entirely supplied from groundwater sources because these zones are not affected by reservoir storage levels or fluctuations in available river flows. The peak deployable output limiting factors are abstraction licence or the physical treatment, pumping or distribution capacity.
- A critical period, peak month scenario is relevant for zones which are supplied conjunctively from groundwater and river sources. The peak deployable output limiting factors are abstraction licence or physical treatment, pumping or distribution capacity combined with available river flows.
- A critical period scenario is not relevant to our zones supplied from raw water storage reservoirs.

Figure A14.1 illustrates an example of a conjunctive use zone affected by the critical period, peak month scenario. In this example, the zone is supplied from a combination of groundwater and river abstraction sources, and there is no reservoir storage within the zone.

Figure A14.1: A conjunctive river and groundwater abstraction zone

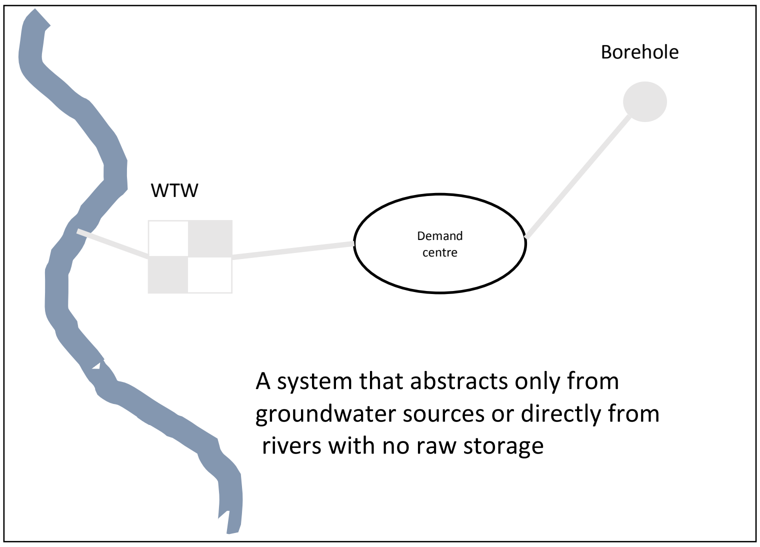
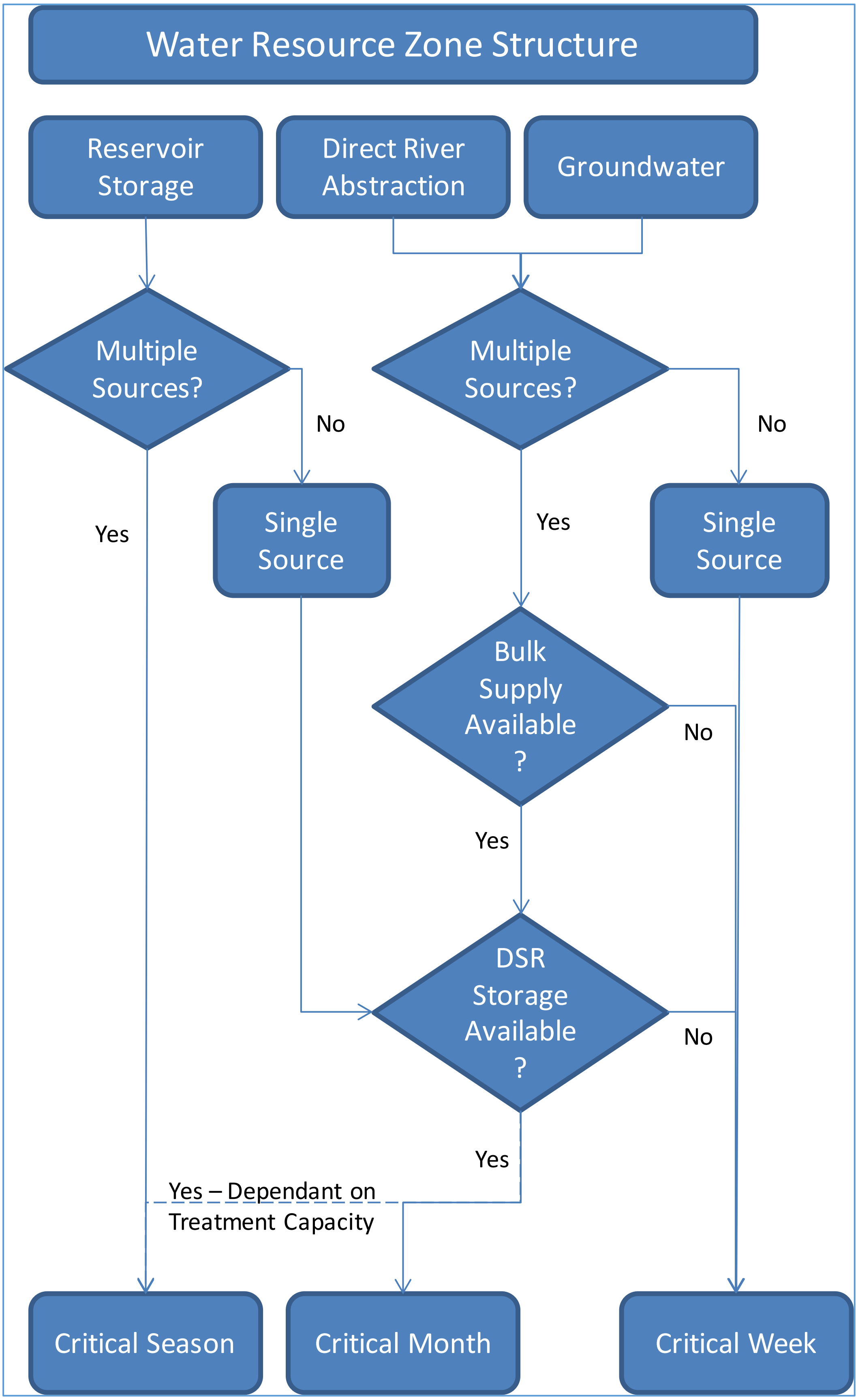


Figure A14.2 overleaf shows the criteria we have used to assess whether critical period conditions might apply to a zone.

Figure A14.2: Critical period assessment framework



The following section describes how we derive the peak demand and supply for this assessment.

Critical period demand

Critical Period demand factors are derived using 2006 regional demand data. We have used 2006 as a reference year for a peaking factor as it was during that year that we recorded our highest peak week demand event since 1995. We have calculated the ratio of peak week or peak month to the annual average demand in each County region, and mapped to our WRZs. The peak week or peak month factor is applied to the normal year annual average household demand forecast to give the Critical Period demand input to the Critical Period supply demand assessment.

Table A14.1 below sets out the critical period factors derived for each WRZ factors

Table A14.1: Critical period demand factors per water resource zone

WRZ	Critical Period	Peak factor
Bishops Castle	Peak week	1.22
Chester	Peak month	1.06
Forest and Stroud	Peak month	1.10
Kinsall	Peak week	1.22
Mardy	Peak week	1.22
Newark	Peak week	1.22
North Staffs	DYAA	n/a
Nottinghamshire	DYAA	n/a
Rutland	Peak week	1.13
Ruyton	Peak week	1.22
Shelton	Peak month	1.13
Stafford	Peak month	1.07
Strategic Grid	DYAA	n/a
Whitchurch and Wem	Peak week	1.22
Wolverhampton	Peak month	1.07

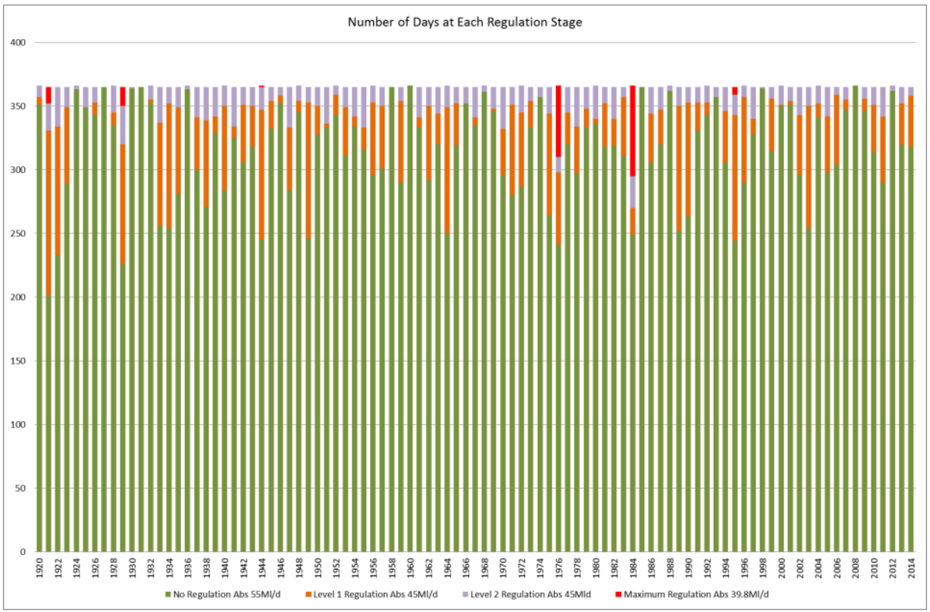
Critical period supply

Critical period supply deployable output (CPDO) has been assessed using two methods depending on the critical period of the zone. For those zones with a peak week critical period, the CPDO assessment has been based on the individual groundwater peak DO assessments for each groundwater source as described in section A2.1.

For zones with a peak month critical period. The available peak month CPDO has been assessed using outputs from the Aquator water resources model. The annual average DO for each zone was increased by the maximum monthly demand used in each year of the model run. This was calculated by combining the demand/demand factors for all demand centres in a water resource zone and finding the peak supply that was therefore required in the zone for that month from all sources combined. This gives the maximum monthly supply available based on the modelled outputs.

For the Forest and Stroud WRZ, which is constrained by a combination of the river source and spring sources in the zone, we have also looked at how often the river source is likely to be constrained at its lowest abstraction level. Figure A14.3 illustrates that this only occurs twice in our 95 year model run for prolonged periods. This helps to show that this zone is within our 3 in 100 temporary use bans level of service.

Figure A14.3 Number of days of restricted river abstraction levels at Site K WTW



Critical Period supply demand assessment

Table A14.2 below shows that the only zone with a projected deficit under the critical period analysis is the Forest and Stroud WRZ.

Table A14.2 Critical Period Balance of Supply and Demand

WRZ	Scenario	Supply / demand balance at 5 year steps (Ml/d)					
		2020	2025	2030	2035	2040	2044
Bishops Castle	CP – Peak Week	2.81	2.80	2.08	2.08	2.08	2.09
Chester	CP – Peak Month	See Appendix F2.4 for Chester profiled demand.					
Forest and Stroud	CP – Peak Month	5.17	4.62	-2.12	-2.25	-2.26	-2.34
Kinsall	CP – Peak Week	1.06	1.02	0.46	0.42	0.38	0.34
Mardy	CP – Peak Week	1.07	1.13	0.58	0.56	0.55	0.54
Newark	CP – Peak Week	6.19	6.19	1.06	0.97	0.87	0.87
Ruyton	CP – Peak Week	1.45	1.38	1.30	1.26	1.22	1.19
Shelton	CP – Peak Month	29.29	27.77	15.40	14.52	13.59	12.47
Stafford	CP – Peak Month	3.71	3.78	3.70	3.44	3.00	2.77
Whitchurch and Wem	CP – Peak Week	1.87	1.78	0.63	0.56	0.51	0.44
Wolverhampton	CP – Peak Week	15.75	15.68	15.03	14.57	13.96	13.51

The deficit in the Forest and Stroud WRZ is caused by the reduction of the available ground water sources as a result of the need to reduce unsustainable abstraction. The solution to this reduction in baseline deployable output is the same as described in Table 6 of the WRMP planning tables for this zone, and involves increased customer demand management and leakage reduction.

Because we are not projecting any wider critical period deficits, we have not produced a separate set of WRMP data tables.