Water Resources Management Plan 2024

Technical Appendix U – Climate Change

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Background and Introduction

This technical appendix describes the methods used to assess the impacts of climate change on our supply-demand balance. It includes consideration of the impact that different climate change projections suggest for our future supply capability, estimation of the impact that climate change may have on future demand for water and setting out how we have incorporated the uncertainty associated with climate change projections into our planning.

Human-driven climate change is already having an impact on the occurrence of extreme events across the world, including flood and drought events. It is important that we account for the potential impacts that climate change may have on the sufficiency of our supplies in order that appropriate investment is made, should it be necessary.

In the appendix we detail:

- Key guidance documents which set out how we should estimate the impacts of climate change on our supply-demand balance
- Salient changes between our climate change impact assessments for WRMP19 and WRMP24
- Methods that we have used to assess the impact of climate change on Deployable Output (DO) in our six Water Resource Zones (WRZs), and how we have incorporated climate change impacts into our supply forecast
- Methods that we have used to assess the impact of climate change on demand for water across our supply area
- Methods that we have used to incorporate uncertainty associated with climate change projections and impact assessment into our planning

Key Guidance and Methodology Documents

U.1 There are a number of key guidance documents which set out the methods that we should apply when assessing the impact of climate change on supply and demand for water.

U.2 The primary guidance documents referred to in our assessments are:

- Environment Agency, April 2022, Water Resources Planning Guideline: This document sets out key high-level requirements for our assessments of climate change
- Environment Agency, March 2021, Water Resources Planning Guideline Supplementary Guidance – Climate Change: This document sets out in more detail the methods that we should apply in supply-side climate change vulnerability and impact assessment
- Environment Agency, March 2021, Water Resources Planning Guideline supplementary guidance – 1 in 500: As set out in Appendix I, we are required to assess a '1 in 500-year' Baseline DO; this guidance includes detail of how we should incorporate the '1 in 500-year' requirement into climate change impact assessment
- Environment Agency, March 2021, Water Resources Planning Guideline supplementary guidance – Stochastics: The assessment of '1 in 500-year' Baseline Deployable Output (DO) has involved the use of 'stochastic' datasets. This guidance includes guidance regarding how we should incorporate climate change projections with stochastic datasets
- HR Wallingford, on behalf of Environment Agency, 2020, Review Report for Estimating the Impact of Climate Change on Water Supply
- Environment Agency, 2017, Estimating the Impact of Climate Change on Water Supply
- Environment Agency, 2013, Climate Change Approaches in Water Resource Planning: New Methods

U.3 Key datasets:

- UK Climate Projections 2018 (UKCP18): The datasets that have been applied in our supply-side climate change impact assessment are all from UKCP18. The UKCP18 Science Overview Report[1] provides an introduction to the datasets available
- UK Climate Projections 2009 (UKCP09): Our demand-side climate change impacts have been assessed using UKCP09 datasets, as explained in a later section

U.4 In addition to the Environment Agency (EA) guidance documents, other important method documents include:

- UKWIR, 2018, Climate Change Modelling and the WRMP
- UKWIR, 2021, Integrating UKCP18 With UKWIR Tools and Guidance: Review of Existing Methods
- UKWIR, 2013, Impact of Climate Change on Water Demand

U.5 In addition to the documents noted above there are several other recent publications on the impact of climate change on water resources in southeast England:

- Third UK Climate Change Risk Assessment (CCRA3): This assessment aims to understand climate risks and opportunities for the UK, highlighting vulnerabilities and

[1] Lowe et al., 2018, UKCP18 Science Overview Report, https://www.metoffice.gov.uk/pub/data/weather/uk/ukcp18/science-reports/UKCP18-Overview-report.pdf

adaptation measures that may be required. Linked to CCRA3 is a specific report on water availability[2].
- Enhanced Future Flows and Groundwater (eFLaG): This study delivered outputs after our WRMP24 climate change assessment was completed.

U.6 Considering the development of the water resource planning process, an important change between WRMP19 and WRMP24 has been the focus on regional groups. Thames Water is part of the Water Resources South East (WRSE) regional group. WRSE has developed datasets, methods and models which have been applied in the assessment of climate change impacts:

- WRSE, 2021, Method Statement: Climate Change – Supply Side Methods
- WRSE, 2021, Method Statement: Calculation of Deployable Output
- WRSE, 2021, Method Statement: Stochastic Datasets
- WRSE, 2021, Method Statement: Regional System Simulation Model

Key Features of Guidance

U.7 The Environment Agency's Water Resource Planning Guideline[3], Supplementary Guidance on Climate Change[4], and Supplementary Guidance on Stochastics[5] set out the requirement that we should assess the impact that climate change will have on our future water supply capability. The guidance sets out several initial key requirements:

- The analysis should be based on analysis of UKCP18[6] datasets
- A vulnerability assessment is required to establish the level of detail required in the analysis

U.8 Thames Water and WRSE's vulnerability assessment has identified that a 'Tier 3' assessment would be most appropriate for several of Thames Water's zones, and to ensure consistency of assessment across the WRSE region we have carried out a 'Tier 3' analysis across all Water Resources Zones (WRZ). Where a Tier 3 approach is required, the guidance further requires that we should:

- Consider the range uncertainty across different UKCP18 products
- Consider scenarios from the latest Met Office Model (Hadley Model 3), which are only available in the spatially coherent results from the Global or Regional projections
- Use rainfall-runoff/recharge/groundwater modelling and take outputs from these models through to water resource system modelling

U.9 Despite the implications that a great deal of modelling should be undertaken, the guidance also states that it may not be necessary to take large volume of scenarios through the full modelling chain. Pragmatically, insight gained from rainfall-runoff or recharge modelling, or analysis of climate data can be used to supplement results from water resource modelling. The guidance also states that there are no changes to the following aspects of guidance:

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[2] HR Wallingford, 2020, Updated Projections of Future Water Availability for the Third UK Climate Change Risk Assessment
[3] Environment Agency, 2022, Water Resources Planning Guideline
[4] Environment Agency, 2021, Water Resources Planning Guideline Supplementary Guidance – Climate Change
[5] Environment Agency, 2021, Water Resources Planning Guideline Supplementary Guidance - Stochastics
[6] Lowe et al., 2018, UKCP18 Science Overview Report Version 2.0, ukclimateprojections.metoffice.gov.uk

- Scaling - aside from a note on the potential for use of different baseline periods in UKCP18 data, guidance from 2017 still applies and is included as an appendix to 2021 guidance
- Method of assessing the impact of climate change for a given scenario, i.e. perturbation factors being applied to a baseline weather record, with perturbed records run through models and changes measured

U.10 Although the guidance sets out a number of points on data and methods, it does not set out specific instruction regarding the following:

- Which emissions scenario(s) should be the basis of the 'main' supply forecast, and which emissions scenario(s) should be considered in uncertainty analyses
- How to appropriately combine the requirement to determine a '1 in 500-year' DO with the requirement to assess the impact of climate change on DO

U.11 In addition to Environment Agency guidance on the assessment of climate change, Ofwat have released guidance on adaptive planning, and the development of long-term investment strategies[7]. This document sets out that the 50th percentile of results from RCP8.5 probabilistic projections would be considered by Ofwat to be a 'high' (severe) future, and that the 50th percentile of results from RCP2.6 probabilistic projections would be considered a 'low' (benign) future.

U.12 The CCRA3 report on water availability[8] highlights that, "in terms of overall catchment water availability at average low flows, no factor has a greater influence on the water available for the environment than the environmental flow policy". Climate change will impact the amount of water available for both public water supply and the environment, and the policy response to altered flow regimes will have significant impacts for the environment and public water supply. This factor is a significant driver for the National Framework for Water Resources' "Environmental Destination" scenarios, the impacts of which for our supplies are detailed in Section 5 of our WRMP. While this Appendix is focussed on determining the impacts of climate change directly on our supply system, climate change impacts are also seen in other chapters and appendices of our WRMP, for example through the indirect effects of climate change driving licence reductions (Section 5) and consideration of climate change risks in our environmental assessments (Section 9). The CCRA3 report highlights that the UK and England as a whole are currently in surplus, but that climate change is likely to change this picture drastically. The report also highlights that UK impacts are dominated by England, with the worst projected impacts forecast to be in the South East.

[7] Ofwat, 2022, PR24 and beyond: Final guidance on long-term delivery strategies, https://www.ofwat.gov.uk/wp-content/uploads/2022/04/PR24-and-beyond-Final-guidance-on-long-term-delivery-strategies_Pr24.pdf
[8] HR Wallingford, 2020, Updated Projections of Future Water Availability for the Third UK Climate Change Risk Assessment

Key Changes Between WRMP19 and WRMP24

U.13 While there are several changes which have taken place, it is important to note that there are several things which have remained constant between WRMP19 and WRMP24:

- High-level impacts suggested by UKCP18 as compared to UKCP09: The high-level messages from UKCP18 are that climate change is likely to lead to warmer, wetter winters, and hotter drier summers, but that there is a high degree of uncertainty associated with the future impacts that climate change may have. This is the same high-level message delivered by the UKCP09 projections
- The results of our WRMP24 impact assessments are not materially different to those previously carried out. While we have reassessed the impact of climate change on our supply capability using new datasets and methods, the results suggest that the possible and likely range of impacts are approximately the same as those found in WRMP19
- Method of assessment of climate change impact for a given climate projection and weather dataset: Application of 'perturbation factor' based approaches are still the prescribed method set out in EA guidance
- Guidance regarding scaling: no significant update has been made to guidance regarding scaling

U.14 While the high-level outcomes of our WRMP24 assessments are broadly consistent with WRMP19, there have been a number of changes that have taken place between WRMP19 and WRMP24. These include changes in guidance and new assessment methods.

Use of UKCP18 Projections

U.15 Our WRMP19 climate change assessment made use of UKCP09 climate change projections. Between WRMP19 and WRMP24 the UKCP09 projections have been superseded by UKCP18. UKCP18 provides the most up to date, comprehensive set of climate change projections available for the UK. UKCP18 is not a 'like-for-like' replacement for UKCP09, and there are several important differences between the two datasets which have driven changes in our assessment methodologies. Salient differences include:

- Emissions scenarios:
  - UKCP09 emissions scenarios were classified as 'low', 'medium', and 'high', based on socio-economic assessment of different emissions projections
  - UKCP18 emissions scenarios are classified on the basis of changes to radiative forcing rather than socio-economic assessment. These projections are named RCP2.6, RCP4.5, RCP6.0, and RCP8.5, where the value following 'RCP' is the radiative forcing in 2100 (in W/m^2). The 'medium' (SRESA1B) emissions scenario from UKCP09 was included in UKCP18 probabilistic projections to enable a point of comparison between UKCP09 and UKCP18
- Climate models used:
  - UKCP18 makes use of the latest General Circulation/Climate Models (GCMs) and Regional Climate Models (RCMs). These include models from the Coupled Model Intercomparison Project – Phase 5 (CMIP5) and Phase 6 (CMIP6), with CMIP6 models being the latest iteration of climate models
- Availability of projections under different emissions scenarios:
  - With the growing importance of regional water resources planning, spatial coherence of climate change projections is important. The spatially and temporally coherent projections from UKCP18 (those from GCMs and RCMs) were initially only

available under the highest emissions scenario (RCP8.5). Some companies' WRMP19 assessments included use of 'Future Flows' datasets; these datasets were based on spatially coherent UKCP09 projections from the 'medium' emissions scenario
- Projections from probabilistic projections were available at all emissions scenarios

DO Resilience Standard – 1 in 500-year

U.16 As summarised in Appendix I, the Water Resource Planning Guideline (WRPG) sets out the requirement that our baseline sources should be available such that our supply system has a 0.2% annual chance of failure caused by drought. Failure, in this circumstance, is defined as a need for emergency drought orders. As such, our Baseline DO assessment and the assessment of the impact of climate change on DO are focussed on the assessment of climate change impact on a '1 in 500-year' DO. This requirement led to our baseline DO assessment incorporating use of stochastic weather datasets, which we have also applied when determining the impact of climate change on DO.

U.17 Our WRMP19 climate change impact assessment was based on the assessment of the impact of climate change on 'Worst Historical' DO. This assessment involved perturbing the historical weather record using multiple climate change projections and assessing the reduction in supply capability suggested.

Calculation of Impact of Climate Change on Deployable Output

Vulnerability Assessment

U.18 EA Supplementary Guidance on Climate Change, and the EA commissioned report which reviews UKCP18 and approaches to climate change assessment, contain detailed guidance on vulnerability assessment. This vulnerability assessment is designed to guide the detail of further analysis that should be carried out, recognising that water companies have carried out detailed analysis of climate change impacts using UKCP09 data, and that the main indications are that UKCP18 and UKCP09 datasets are not materially different.

U.19 The first step in vulnerability assessment is to update the 'Basic Vulnerability Assessment'. This basic vulnerability assessment was undertaken using data from WRMP19 (impact of climate change at 2070). The results can be seen in Figure U-1.

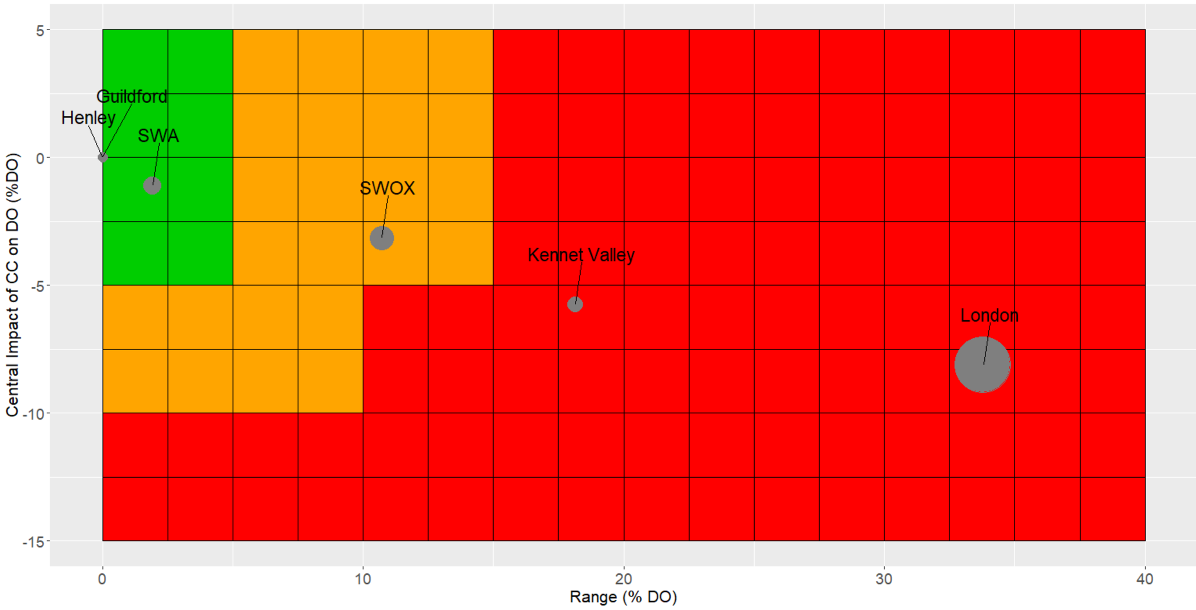


Figure U-1: Thames Water Basic Vulnerability Assessment – Climate Change

U.20 This shows that London and Kennet Valley WRZs are identified as high vulnerability, SWOX is identified as medium vulnerability and other WRZs are identified as low vulnerability.

U.21 EA supplementary guidance on climate change sets out that a second vulnerability assessment should then be undertaken in which the level of investment driven by climate change is assessed (Table U-1). Our WRMP19 suggested that no investment would be necessary in Kennet Valley to combat supply-demand balance issues, and so this vulnerability is deemed low. The impact of climate change for London drives a significant amount of investment across the planning period (with c.200 Ml/d of need driven by climate change), although there are several large drivers of investment and climate change is not the most significant. As for London, some investment is driven for the SWOX WRZ but climate change is not the main driver.

WRZ	Level of Investment Driven by Climate Change
London	High
SWOX	Medium
Henley	Low
Guildford	Low
Slough, Wycombe & Aylesbury	Low
Kennet Valley	Low

Table U-1: Impact of Climate Change on Investment

U.22 The results of this vulnerability assessment suggests that for London, a new climate change assessment using UKCP18, considering the full range of uncertainty within the projections, is required, i.e. a Tier 3 approach. This is also perhaps the case for the Kennet Valley, but that a Tier 2 approach would be satisfactory for the SWOX WRZ, while a Tier 1 approach would be acceptable for other zones.

U.23 In order to ensure consistency across our supply area, and indeed across the whole WRSE region, we have applied an approach whereby we have assessed the impact of climate change on all zones using the 28 spatially coherent projections from UKCP18. In addition, for London, we have then explored a significantly wider range of evidence.

UKCP18 Datasets Used

U.24 WRSE commissioned Atkins to undertake a project to assess the suitability of different UKCP18 products for use in Regional Planning. Atkins concluded that spatial coherence was important, and so recommended use of RCM and GCM projections. Atkins produced bias-corrected timeseries of rainfall and PET (from which change factors were also calculated) from the RCM projections, and calculated rainfall and temperature (from which PET was calculated) change factors from the 28 GCM projections.

U.25 Our initial Climate Change impact assessment was based on the use of perturbation factors from the 28 scenarios associated with the spatially coherent projections; these were the 12 RCM projections and 16 non-overlapping GCM projections (GCM results were used as boundary conditions for the RCM projections, and so the 12 RCM projections are a subset of the 28 GCM projections).

U.26 As will be described later, we have applied the UKCP18 probabilistic datasets in order to establish:

- The influence of emissions scenario on climate change impact
- The range of uncertainty present in the wider set of climate change projections in UKCP18
- Whether the spatially coherent projections present a different picture of climate change impacts to the probabilistic projections

U.27 With these aims in mind, we have made use of probabilistic projections for all RCPs and have investigated the impacts suggested by probabilistic projections at different points in time (2020-40; 2040-60; 2060-80; 2080-2100). As is described later, the scenarios considered within our WRMP24 supply forecast are representative of the full range of probabilistic scenarios in the UKCP18 dataset. While the scenarios modelled originate from the RCP8.5 emissions scenario, we have ensured through selection and factoring that the projections adopted are representative of all emissions scenarios.

U.28 In WRMP19 our main climate change assessment was based on UKCP09 probabilistic data, but due to constraints on the volume of data that we could take through the whole DO modelling chain we considered only 20 probabilistic projections for four scenarios (2080s medium emissions, 2080s high emissions, 2050s medium emissions, 2030s medium emissions). Due to the small number of scenarios considered, selection was important and so we employed Latin Hypercube Sampling (LHS) to ensure that we considered a range of climate projections (from extremely dry to very wet) with more dry scenarios considered than wet. Due to this biased selection we did not weight the impact of all scenarios equally. In this investigation we have made use of a larger number of probabilistic projections (200 per combination of timeslice and emissions scenario) and so have not adopted the same LHS approach; as such we have treated all probabilistic projections as being equally likely. In the absence of other information, we have also treated the 28 spatially coherent projections as equally likely.

Initial Assessment of Climate Change Impact on Deployable Output – London WRZ

U.29 In developing WRMP24, Thames Water has carried out two iterations of modelling to help determine the impact of climate change on DO. The first iteration was carried out during 2020 and 2021, and involved detailed hydrological, hydrogeological, and water resource modelling on 28 climate change projections. The second iteration carried out during 2021 and 2022 involved less detailed hydrological and water resource modelling (with no hydrogeological modelling) but included consideration of more than 3,000 climate change projections. This section describes the modelling carried out in the first iteration, before subsequently describing modelling carried out in the second iteration, and then explaining how results from the two modelling studies have been brought together. For both iterations, this document focuses on modelling carried out for our London WRZ. This WRZ was focussed on because it is our largest WRZ, and because it is the zone which, on a proportional basis, is the most impacted by climate change. Other similar methods to those applied in the first iteration of modelling have been applied for other WRZs.

U.30 The first iteration of modelling to investigate the impact of climate change on DO was carried out during 2020 and 2021, and was used to inform the 'Water Resources South East (WRSE) Emerging Regional Plan', published in January 2022. This modelling followed methods set out in the WRSE method statement[9], and involved use of the WRSE Regional Simulation Model (RSS)[10].

U.31 As a high-level description, this modelling involved detailed modelling of a limited number of scenarios and comprised the steps set out below.

Step 1: Generation of Climate-Perturbed Weather Record

U.32 This involved use of the 28 'spatially coherent' climate change projections from UKCP18, i.e. projections from the 12 RCMs and 28 GCMs. 40 projections were not considered because they are not all independent. Twelve of the GCMs are used to set boundary conditions for the 12 RCMs, and so the 12 are a subset of the 28, with the RCMs used in

[9] WRSE, 2021, Method Statement: Climate Change – Supply Side Methods, https://www.wrse.org.uk/media/4midbziv/method-statement-climate-change-august-2021.pdf
[10] WRSE, 2021, Method Statement: Regional System Simulation model, https://www.wrse.org.uk/media/pc2nxvzz/method-statement-regional-simulation-model-aug-2021.pdf

preference to the GCMs where they existed. At the time when our water resource modelling was being carried out, spatially coherent projections had only been produced under the highest emissions scenario considered in UKCP18, RCP8.5.

U.33 Atkins had produced bias-corrected timeseries of rainfall and potential evapotranspiration (PET) for the RCM projections, for sub catchments within the WRSE region. These bias corrected timeseries were used to derive monthly perturbation factors for rainfall and PET for 2070 (2060-2080), by comparing rainfall and PET timeseries from the baseline timeslice (1981-2000) with timeseries from the period 2060-2080. For the GCM projections, 'raw' (i.e. not bias corrected) timeseries of rainfall and temperature were used to derive rainfall and PET change factors. The change factors generated were based on the England and Wales projections, being the smallest area that encompassed the whole WRSE region. The result of this step was 28 sets of monthly perturbation factors for each of rainfall and PET, e.g. for a given climate change scenario we may have +10% rainfall in January, +25% PET in July.

U.34 Due to the computational burden involved, it was not feasible to run hydrological/hydrogeological models using multiple climate-perturbed versions of the 'full stochastic' weather record that was used in the determination of baseline Deployable Output. Instead, of the 400 replicates (representing different versions of what 'could' have happened during the period 1950-97), 21 replicates were selected for climate change impact modelling. Based on hydrological/hydrogeological analysis of the stochastic weather record, these replicates were selected by determining those which contained severe drought periods which impacted different parts of the WRSE region This targeted selection meant that the replicates were not deemed to be representative of the whole stochastic sequence, with a higher likelihood of severe and extreme drought events being present in the selected replicates than in the wider stochastic record.

U.35 The perturbation factors were applied to the rainfall and PET records of the selected replicates. For example, if the perturbation factor was +10% rainfall in January, then all rainfall values in January of any year within all 21 replicates were increased by 10%. This gave 28 climate-perturbed versions of the weather data in each of the 21 selected replicates, a total of 28,224 years' worth of data.

Step 2: Hydrological and Hydrogeological Modelling

U.36 Hydrological and hydrogeological models were run for each of the 28 climate change scenarios, for each of the 21 selected replicates. The models used and the methods applied were exactly the same as those used in the derivation of baseline DO.

U.37 The outputs from this step were climate-perturbed versions of the river flow and groundwater source yield timeseries which were used as inputs to the WRSE Pywr model. The inputs to the Pywr model were, therefore, in exactly the same format as those used in the baseline DO modelling.

Step 3: Water Resources Modelling

U.38 The WRSE Pywr model was run at many levels of demand, for each of the climate change scenarios, and for each of the 21 selected replicates. 'Level 4' failures were recorded for London.

U.39 The baseline DO assessment was carried out by considering the full stochastic record. The method used was to consider that baseline DO was the highest level of demand that could be applied before emergency restrictions would need to be imposed more often than once every five hundred years. In practice, this meant determining the highest level of demand that could be applied before 39 ‘Level 4’ events were observed across the stochastic record; the stochastic record includes a total of 48 x 400 = 19,200 years, and 19,200/500 = 38.4.

U.40 Since the climate-perturbed records being modelled were not representative of the whole stochastic record, the same methods were not applied. Instead, a ‘Baseline Yield’ was calculated for each of the 21 replicates (note that there is a subtle difference between ‘Yield’ and ‘DO’ – yield being a value which can be calculated for each year or subset of a given stochastic/historical record and DO being calculated for the whole record); this involved running the Pywr model at different levels of demand and determining the highest level of demand that could be applied without requiring ‘Level 4’ restrictions in that replicate. For each of the 21 replicates, a climate-perturbed ‘Yield’ value was then calculated for each of the 28 climate change scenarios, by applying the same method, i.e. determining the highest level of demand that could be applied without requiring ‘Level 4’ restrictions in each climate-perturbed version of that replicate.

U.41 The output from this step was a 29 x 21 grid (28 climate change scenarios, plus the non-climate-perturbed baseline), where each cell in the grid was a climate-perturbed Yield value for a given replicate. This also allowed for the calculation of the impact of climate change on the Yield in that replicate. In addition, the Yield value calculated for each replicate was compared to the outputs from the ‘full stochastic’ Baseline DO modelling, in order to estimate the return period of the worst drought event contained within that replicate. For example, if the 1 in 200-year DO calculated from modelling of a WRZ were 250 Ml/d, and the non-CC-perturbed ‘Yield’ calculated for a given replicate was 250 Ml/d then that replicate would be assigned a Baseline Return Period of 200 years. Consequently, a portion of these grids could have looked as follows in Table U-2 and Table U-3, noting that all values are illustrative only:

Baseline	CC01	CC02	CC03	…
2100	1950	2050	2120	…
2200	2000	2130	2230	…
2050	1870	2020	2040	…
…	…	…	…	…

Table U-2: Illustrative Yield Values from the Baseline and Climate Change Runs – all values in Ml/d

Baseline	Baseline Return Period of Worst Drought in Replicate (Years)	CC01 Impact	CC02 Impact	CC03 Impact	…
2100	520	-150	-50	+20	…
2200	430	-200	-70	+30	…
2050	650	-180	-30	-10	…
…	…	…	…	…	…

Table U-3: Illustrative Values for Impact of CC on Yield, and Baseline Return Period of Worst Drought – all values in Ml/d

Step 4: Derivation of DO Impact

U.42 The table of climate change impact results was used to estimate the impact of climate change on ‘1 in 100-year’, ‘1 in 200-year’, and ‘1 in 500-year’ DO.

U.43 For a given climate change scenario, the 21 DO impacts found were plotted, with the value on the x-axis being the baseline return period of the worst drought in the replicate, and the value on the y-axis being the impact of the climate change scenario on the yield in that replicate. The impact of the climate change scenario on 1:100, 1:200, and 1:500-year DO was then estimated considering all of the points plotted, either by fitting a line to link return period to yield impact (Figure U-2, taken from the WRSE Method Statement on Climate Change, shows this graphically), or by calculating an average of the yield impacts of replicates with return periods close to the return period of interest.

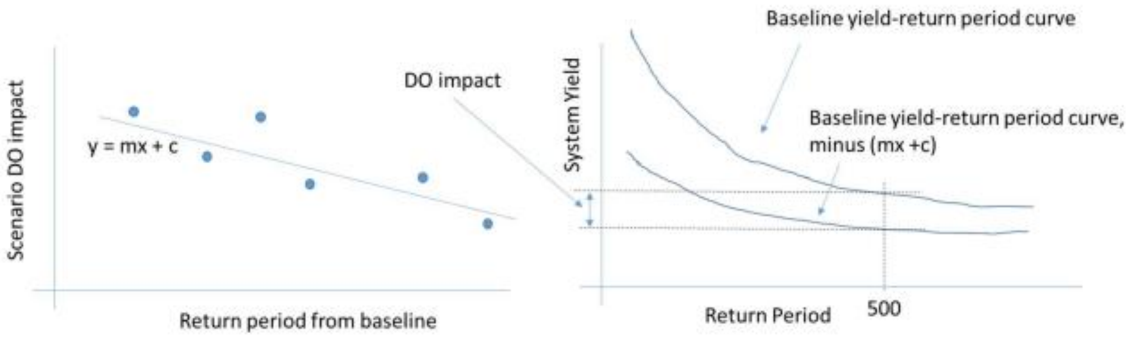


Figure U-2: Climate Change DO Impact Derivation (from WRSE Method Statement)

U.44 The output from this analysis was the impact of each of the 28 climate change projections on 1:100, 1:200, and 1:500 DO values. The median value of the 28 1:500 DO values was taken as the impact of climate change on DO in 2070, and the DO impact was scaled to this point.

Results and Discussion

U.45 The 28 values for the impact of climate change on the London WRZ DO can be seen in Figure U-3. This shows that there is a wide range of possible impacts of climate change on London's DO, ranging from a reduction of over 15% of London's current DO to a 5% increase in DO, even though this modelling considers only a single emissions scenario (RCP8.5). Climate change scenarios 1 to 15 are all from the newest (as of March 2021) version of the Met Office's Hadley Model (HadGEM3-GC3.05); the results from this model suggest a more severe impact of climate change on London's DO than the results from other models (scenarios 16-28).

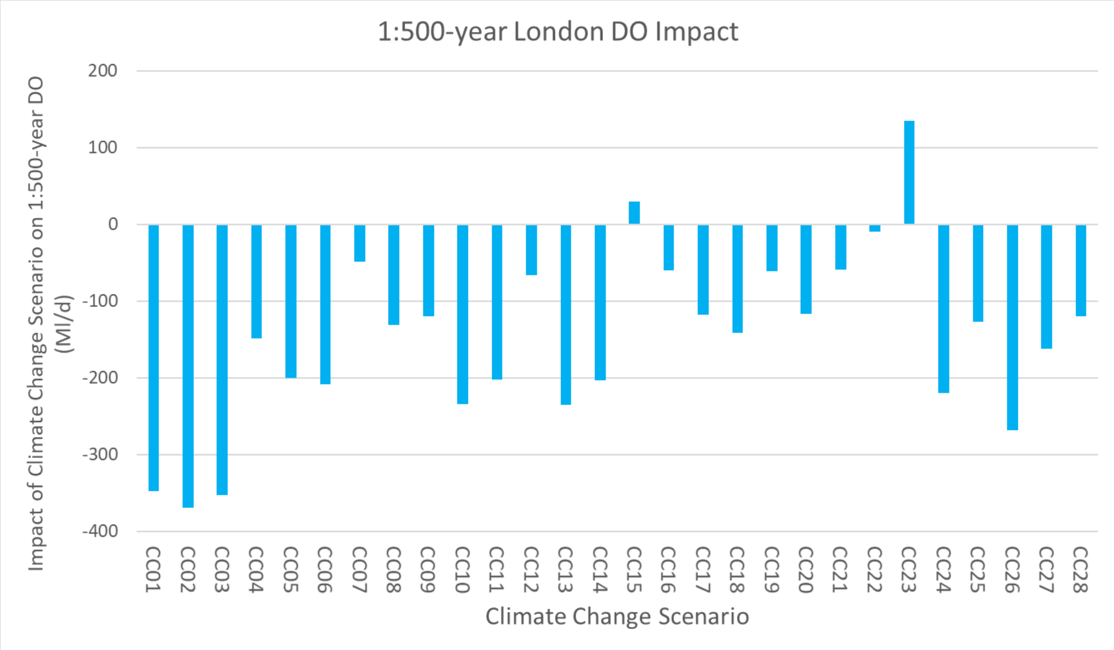


Figure U-3: London DO Impact of Climate Change from 28 RCM and GCM scenarios, RCP8.5

U.46 The median of the 28 calculated values, -136.7 Ml/d, was taken as the central impact of climate change in 2070. Other calculated DO impacts were used in Target Headroom modelling.

U.47 The key questions left due to the limitations of the modelling carried out in the first iteration were:

- Did the method used to derive the impact of climate change on 1 in 500-year DO give a robust estimate of the impact of climate change on 1:500-year DO, despite only considering a limited sub-set of the data?
- How do the DO results from modelling involving the spatially coherent projections at RCP8.5 compare with DO results that would be obtained from modelling involving probabilistic projections at RCP8.5?
- How would DO results from modelling an RCP8.5 emissions scenario compare with results from other emissions scenarios?

U.48 The output from this analysis was the impact of each of the 28 climate change projections on 1:100, 1:200, and 1:500 DO values. The methods described were applied for each of our WRZs, except for Henley WRZ due to the lack of drought-vulnerable sources in the zone.

Supplementary Assessment of Climate Change Impact on Deployable Output – London WRZ

U.49 In order to answer some of the outstanding questions, a second iteration of climate change impact modelling was undertaken. In this phase of modelling a more simplified approach was applied but investigating a wider range of future climate scenarios. The increased speed of a simplified modelling approach allowing for a large volume of scenarios to be explored. The London WRZ was again the focus of this investigation.

Step 1: Development of Simplified Hydrological and Water Resource Models

U.50 The main reason for limiting the modelling volume to consideration of 28 future climate scenarios and 21 of 400 replicates was that extensive modelling using our semi-distributed, and multi-staged, hydrological and hydrogeological models, and indeed subsequent modelling in our relatively detailed water resources model, would have resulted in many years' worth of computational processing time. To drive speed in this iteration of the investigation new models were developed, with simplicity and speed being the main aims. With the aim of this investigation being centred more around comparison of results using different datasets and methods, the 'absolute' DO values are not expected to be used.

U.51 The water resources model which was developed was a heavily simplified version of the London sub-model from the WRSE Pywr model. Key aspects of its simplification were:

- Non-time variant groundwater yield: In the main Pywr model, time-variant groundwater yields in South East London were included. While these are valuable in assessing DO, climate change does not tend to impact our groundwater yields as much as river flows. Using 'static' groundwater yields means a reduced amount of modelling to produce inputs
- Inclusion of only two hydrological input timeseries: the only hydrological input series were 'semi-naturalised' river flows for the River Thames and River Lee. This loses the granularity of river flows joining the Lower Thames by excluding the nuance associated with inflows from the Colne, Wey, Mole, and Hogsmill. It also means that this is a model of our London WRZ only, whereas the model used for calculation of baseline DO was a model that incorporated the whole Thames catchment
- Removal of all 'custom parameters': These can slow Pywr models and so the following were excluded from this simplified model:
  - Averaging of flows and delays of 10 days before turning on/off different 'strategic schemes', e.g. Thames Gateway WTW, North London Aquifer Recharge Scheme (NLARS), meaning that their operation is triggered by the Lower Thames Control Diagram (LTCD) without delays
  - NLARS and West Berkshire Groundwater Scheme (WBGWS) profiles of declining yields throughout their period of use were removed. Instead, NLARS' output is assumed to be 170 Ml/d, and WBGWS' output is assumed to be 100 Ml/d
- West London WTWs were aggregated to a single WTW node
- All London reservoirs were aggregated to a single reservoir node
- All London demands were aggregated to a single demand node

U.52 The hydrological models used were GR6J models. The model used for the River Thames was that used in the first step of producing the flows used in the Thames Water baseline DO assessment. A GR6J model for the River Lee was calibrated using autocalibration over the period 1920-1997; Modified Kling-Gupta Efficiency (KGE2) was the target criterion used and calibrated with a KGE2 of 0. 87 and a Nash-Sutcliffe Efficiency (NSE) of 0.74. The parameters for the two models were:

Parameter	Teddington Model	Lee Model
X1, Production Store Capacity (mm/d)	275.5714	281.3522
X2, Intercatchment exchange coefficient (mm/d)	-0.3904	-0.4863
X3, Routing store capacity (mm)	48.8592	11.3846
X4, Unit hydrograph time constant (d)	3.2346	1.8507
X5, Intercatchment exchanges threshold (dimensionless)	0.3105	0.4125

Parameter	Teddington Model	Lee Model
X6 (exponential store depletion coefficient)	28.3350	24.4771
Area (km^2)	9948	1036

Table U-4: River Lee at Feildes Weir GR6J Model Parameters

U.53 Stochastic timeseries were run through the model to establish whether 1:100-year, 1:200-year, and 1:500-year DO results were comparable to those from the main baseline DO runs. Noting that both DO figures include an export to Essex & Suffolk Water and so do not align with the DO results presented in the baseline DO assessment, the results were as follows:

DO Return Period (years)	Full Model DO (model used in baseline DO assessment) – Ml/d	Simplified Model DO (model developed and used for this investigation) – Ml/d
100	2236	2189
200	2119	2059
500	1970	1851
Difference between 1:100 and 1:500 DO	266	338
Difference between 1:200 and 1:500 DO	149	208

Table U-5: Comparison Between DO Figures Calculated Using 'Full' and 'Simplified' Pywr Models for London

U.54 These results suggest that DO figures from the simplified model should not be taken at face value, but comparisons between DO impacts are likely to give reasonable insight. As such, results in this investigation will generally be compared against one another, rather than being compared to results from modelling carried out using the more detailed Pywr/hydrological models used to determine our baseline DO.

Step 2: Generation of Perturbed Weather Record

U.55 Very similar methods were used in the second iteration for generation of perturbed weather records. Perturbation factors for rainfall and temperature were downloaded from the UKCP18 user interface for many different combinations of timeslice and emissions scenario. Perturbation factors were gathered for 2020-40 (2030), 2040-60 (2050), 2060-80 (2070), and 2080-2100 (2090), for probabilistic projections under RCP2.6, RCP4.5, RCP6.0, and RCP8.5. Temperature perturbation factors were then converted into PET perturbation factors, using the same methods as used in the derivation of PET factors to be applied to GCM projections.

U.56 Perturbation factors were applied to the whole stochastic baseline weather dataset.

Step 3: Hydrological Modelling

U.57 Perturbed weather records for each climate change projection were run through the GR6J models that had been calibrated.

U.58 Hydrological modelling was undertaken for at least 200 projections from each combination of probabilistic projection and timeslice. This meant that a total of 200 projections x 4 emissions scenarios x 4 timeslices x 19,200 years = 61.4 million years' worth of flows were simulated. For each emissions scenario, for each timeslice, a total of 3000 probabilistic projections are available from UKCP18.

Step 4: Water Resource Modelling - Testing Methods and Models Against Already Modelled Climate Change Projections

U.59 To further verify that the models developed would give reasonable results, analysis was carried out in which the same methods were applied to the climate change projections investigated in the first iteration of modelling, i.e. runs were undertaken for the 28 spatially coherent projections (RCP8.5). The outputs from these runs were analysed using the same 'line fitting' method as was used in the first iteration of modelling, considering only 21 of the 400 replicates and performing 'Yield Assessments' on individual replicates.

U.60 Please note that in this section and beyond the 'Simple' model refers to the simplified hydrological (GR6J) and water resource models (Pywr, London only, more simplified than WRSE Pywr model) developed for this investigation, while the 'Full' model refers to the models used in the assessment of baseline DO (hydrological models being GR6J and WARMS2 and water resources model being WRSE Pywr model), which were also used in the first iteration of climate change analysis.

U.61 Figure U-4 shows a comparison between 1:500-year DO impact figures calculated using the 'Full' Model and 'Simple' Model, for each of the 28 climate change scenarios. This figure shows that the simpler model gives 1:500-year CC DO impacts which are close to those calculated using the 'Full' model. The r^2 value when comparing DO impact values calculated using the two model is 0.79, indicating a strong correlation. When fitting a regression model (y=mx + 0) between the 'Full Model' and 'Simple Model' results, the gradient coefficient (m) was 0.84, indicating that the 'Full Model' gives DO impacts around 16% smaller in magnitude than the 'Simple Model'. Similar results were obtained when conducting this analysis on 1:100-year DO (r^2 =0.905, and m = 0.92) and 1:200-year DO (r^2 = 0.877, m = 0.90).

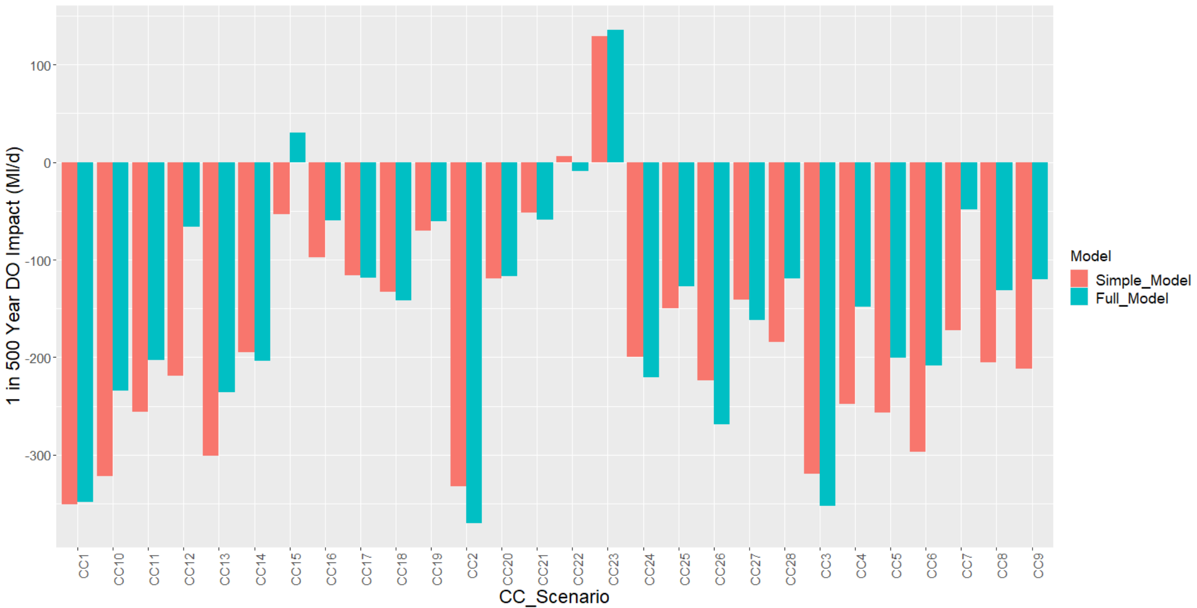


Figure U-4: Comparison Between 1:500-year DO Impacts Found Using Simple Model (Used in this Investigation) and Full Model (Used in Baseline DO Modelling), when using 'Line Fitting' Method of Analysis

U.62 Following this analysis, results from the same 28 spatially coherent projections were analysed, but the DO was calculated considering outputs from the 'Simple' model using all 400 replicates and a 'full stochastic' method of assessment, i.e. determining 1:500-

year DO by calculating the highest level of demand that could be applied before 39 years required Level 4 restrictions, rather than conducting yield assessments on individual replicates.

U.63 A graph of results taken from the 'Simple Model', comparing DO impacts calculated using a 'Full Stochastic' method and the 'Line Fitting' method can be seen in Figure U-5. This chart shows a high level of correlation between the results (r^2 = 0.966), but also shows that the 'Full Stochastic' assessment gives a greater magnitude of 1:500-year DO reduction in almost all cases (m=0.79). This compares to 1:100-year and 1:200-year results which suggest similar correlations between DO impacts calculated using 'Full Stochastic' and 'Line Fitting' methods (r^2 = 0.989 and 0.981, for 1:100 and 1:200-year DO results, respectively; m = 1.00 and 0.832, for 1:100 and 1:200-year DO results, respectively). These results imply that the use of the 'line fitting' methodology is likely to result in an underestimate of the DO impact of climate change for extreme (1:200 and 1:500) drought events, when compared to a 'full stochastic' assessment based on the same climate change projection.

U.64 This may be because some droughts which are less severe in a 'baseline' (non-CC) situation become relatively more severe in a 'perturbed' (with CC) situation. The 'full stochastic' method reassesses the DO considering the full stochastic dataset, and so this 'reordering' is picked up implicitly in the data analysis, but the method underlying the 'line fitting' approach in which 'Baseline Return Period' is used assumes that climate change does not influence the relative severity of different droughts. This issue may not impact 1:100 DO to the same degree as 1:200 and 1:500 due to the larger number of 1:100-year events within the stochastic dataset, c.200, as opposed to c.50 for 1:500-year events.

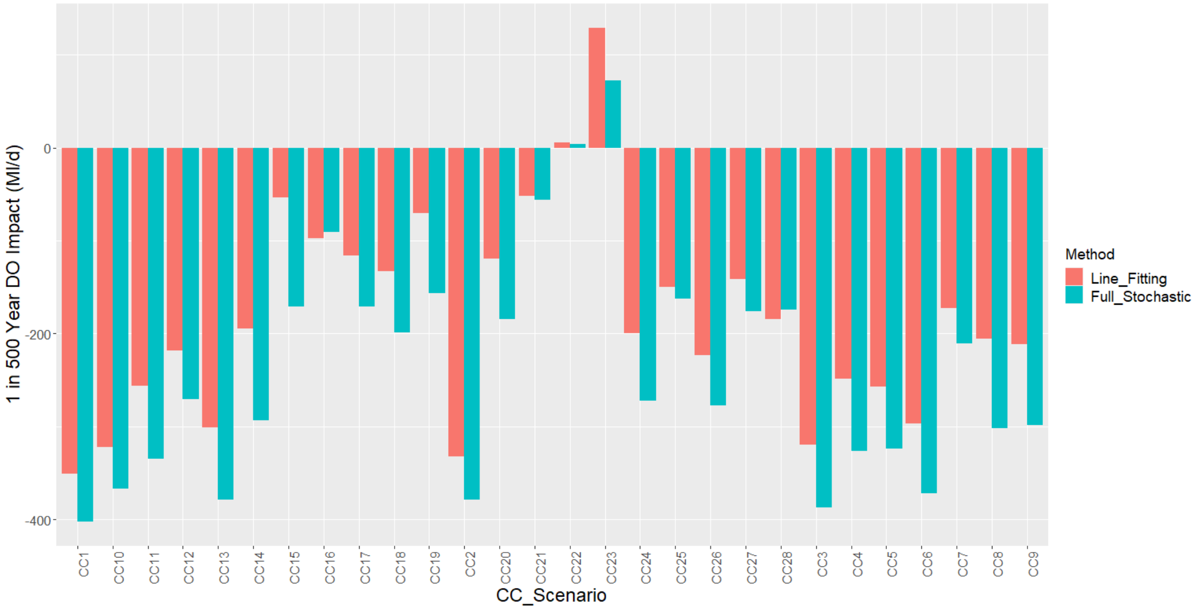


Figure U-5: Comparison Between 1:500-year DO Impacts from the 'Simple Model', found using the 'Line Fitting' and 'Full Stochastic' analysis methods

U.65 The median 1:500-year DO impact from the 28 spatially coherent projections is a reduction of 197 Ml/d if using the 'Simple' Model and a 'Line Fitting' method, but a reduction of 271 Ml/d if using the 'Simple' Model and 'Full Stochastic' method of analysis.

U.66 This analysis helps to answer the first of the three outstanding questions from the first iteration of modelling:

- Did the method used to derive the impact of climate change on 1 in 500-year DO give a robust estimate of the impact of climate change on 1:500-year DO, despite only considering a limited sub-set of the data?

U.67 This analysis suggests that, while the model and methods used give a reasonable estimate of the impact of climate change on DO, the 1:500-year DO impact found is likely to be an underestimate of around 20-30%. The underestimate of 20% results if considering the gradient of a linear regression between the two datasets, with 30% being the underestimate if considering the difference between the median impact calculated using the two methods. As a result, it is recommended that climate change impacts are scaled to reflect the likely underestimate from the application of the 'line fitting' method. The factors applied to DOs of different return period to account for this were based on comparison of the median impacts as calculated by 'full stochastic' and 'line fitting' methods using the 'Simple' model. These factors are:

	1 in 500	1 in 200	1 in 100
Median Impact – Full Stochastic (Ml/d)	271	314	293
Median Impact – Line Fitting (Ml/d)	197	249	271
Scaling factor to apply (dimensionless)	271/197=1.38	1.29	1.08

Table U-6: Scaling Factor Calculation 1

Step 5: Water Resource Modelling – Analysis of Probabilistic Projections

U.68 The flow timeseries generated from hydrological modelling of the perturbed weather sequences produced using the probabilistic climate projections were used in the 'Simple' water resources model, and the results were analysed. This involved 'full stochastic' DO analysis of 200 climate projections from each of the combinations of timeslice and emissions scenario. In addition, flows produced using perturbation factors for different timeslices of the GCM projections were also used as model inputs.

U.69 The results from this step were approximately 3,300 DO impact estimates, i.e. 200 x 4 x 4 = 3,200 from probabilistic projections and DO impacts from the 28 GCM projections at 4 different timeslices, with DO impacts being estimated for different return periods.

U.70 The summary of all results can be seen in Figure U-6. Results from common emissions scenarios can be identified by colour and results from common timeslices can be identified by pattern.

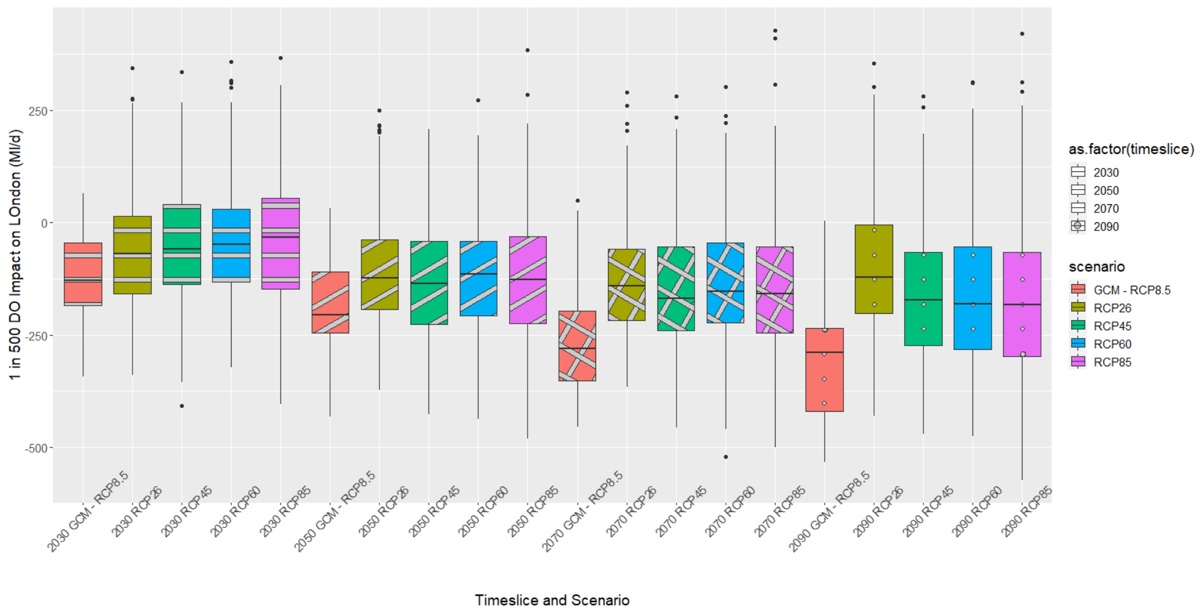


Figure U-6: Summary of All Results from 'Full Stochastic' Climate Change Analysis

U.71 In order to highlight the key results, other graphs have been plotted from this data. Figure U-7 shows the median DO impact found for each combination of emissions scenario and timeslice. The important results that Figure U-7 highlights are:

- There is relatively little difference between the impacts calculated for different emissions scenarios from the probabilistic projections at the same timeslice. For example, at 2070, the median impact of RCP8.5 probabilistic projections is a reduction in DO of 160 Ml/d while the median impact of RCP2.6 projections is a reduction of 140 Ml/d, i.e. there is only a 20 Ml/d difference between the median impacts from these different emissions scenarios
- There is a very significant difference between the results obtained from analysis of the spatially coherent projections (GCM – RCP8.5) and all other projections, including probabilistic projections at RCP8.5. For example, the median impact calculated from the spatially coherent projection at RCP8.5 in 2070 is a reduction in DO of 289 Ml/d while the median impact from the probabilistic projections at RCP8.5 in 2070 is a reduction of 160 Ml/d
- The use of linear scaling from 1990 through to 2100 does not appear to be a bad assumption, although it does appear that climate change impacts are likely to take effect during the period 2030-2050, and then perhaps level off after 2070

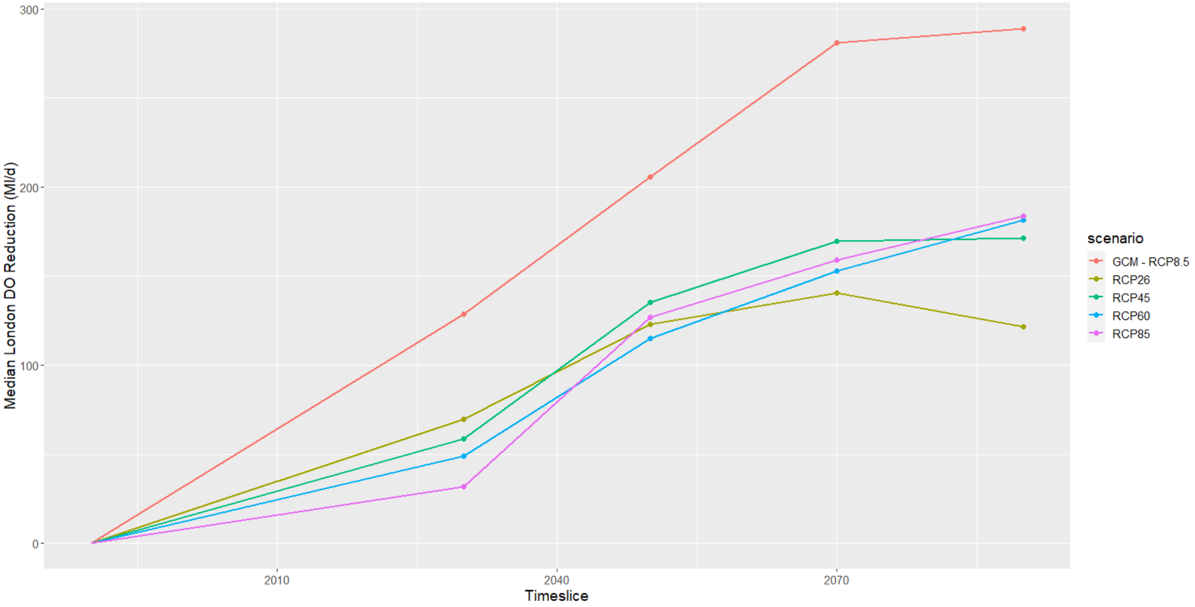


Figure U-7: Median 1:500 London DO Impacts from Each Combination of Timeslice and Emissions Scenario

U.72 The results indicate that the first iteration of modelling is likely to suggest a greater magnitude of DO reduction than would be suggested if considering the whole range of UKCP18 projections. The spatially coherent projections, however, include projections from the newest iteration of the Hadley model, while the probabilistic projections include projections from the previous iteration of the Hadley model. In which case, it may be that the newer iteration is more reliable.

U.73 Figure U-8 shows insight from Figure U-6 and Figure U-7 overlaid. The dots on this chart are the median DO impacts from different emissions scenarios, while the boxplots show DO impacts from a single emissions scenario (RCP8.5, although results from other emissions scenarios look very similar). This graph shows that there is significant uncertainty associated with how climate change will impact drought risk, regardless of the emissions scenario, as there is a wide range of DO impacts calculated from a single emissions scenario. The uncertainty in DO impact of climate change associated with a single emissions scenario is significantly larger than the difference between the median impacts calculated from different emissions scenarios. The interquartile range for RCP8.5 probabilistic projections at 2070 is around 200 Ml/d, whereas the difference between the median impact for the RCP2.6 and RCP8.5 scenarios is around 20 Ml/d.

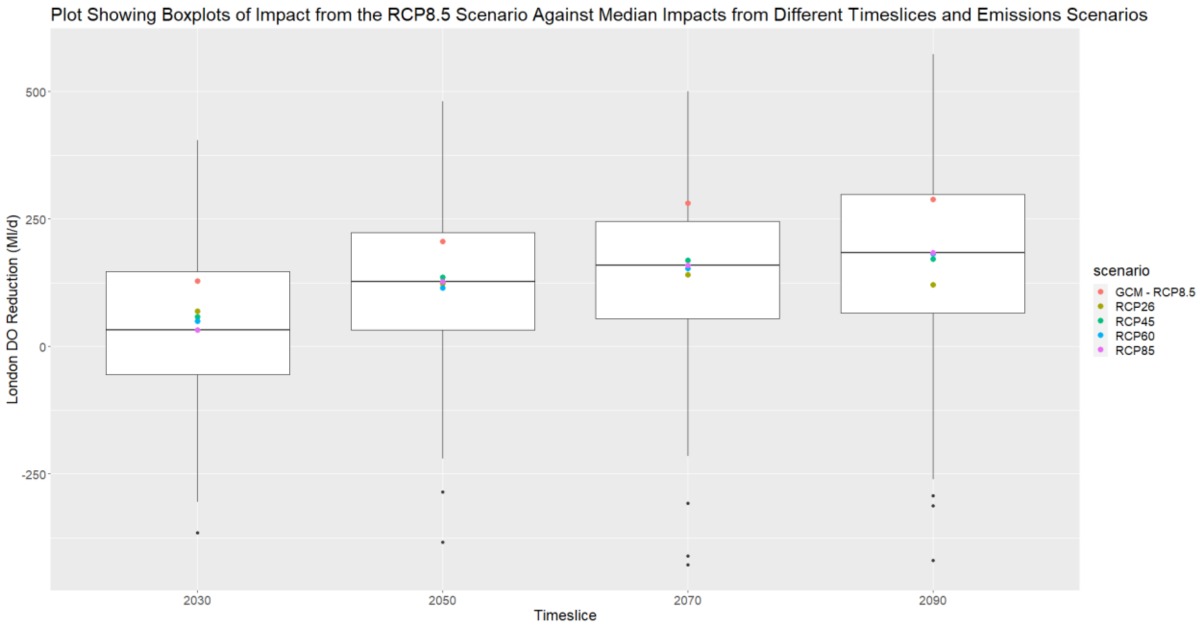


Figure U-8: Overlaying Median London DO Impact Projections from Different Emissions Scenarios with Boxplot of DO Impacts from a Single Emissions Scenario

U.74 Regarding answers to the key outstanding questions highlighted earlier:

- How do the DO results from modelling involving the spatially coherent projections at RCP8.5 compare with DO results that would be obtained from modelling involving probabilistic projections at RCP8.5?

U.75 Model results from the spatially coherent projections suggest a significantly more severe impact of climate change than results from probabilistic projections, even for the same emissions scenario. The models underlying the spatially coherent projections are different to those from the probabilistic projections, and it is not known whether the spatially coherent or probabilistic projections provide a more robust basis for decision making. To bring the median of the spatially coherent projections in line with the median of the probabilistic projections, the following factors have been applied:

	1 in 500	1 in 200	1 in 100
Median Impact – RCP8.5 Probabilistic (Full Stochastic Method, Simple Model) – Ml/d	159	182	171
Median Impact – RCP8.5 Spatially Coherent (Full Stochastic Method, Simple Model) – Ml/d	271	314	293
Scaling factor to apply - dimensionless	0.59	0.58	0.58

Table U-7: Scaling Factor Calculation 2

- How would DO results from modelling an RCP8.5 emissions scenario compare to results from other emissions scenarios?

U.76 Results from RCP8.5 probabilistic projections do not suggest more severe impacts of climate change than results from probabilistic projections for other emissions scenarios. As an example, the 25th percentile of 2070 RCP2.6 results is -58 Ml/d, the 75th percentile of 2070 RCP2.6 results is -217 Ml/d and the 50th percentile of the 2070 RCP2.6 results is

-140 Ml/d, while the 50th percentile of 2070 RCP8.5 results is -160 Ml/d. The interquartile range of results from RCP2.6 probabilistic projections is significantly greater than the difference between the medians from RCP2.6 and RCP8.5 projections.

U.77 While results from analysis of the GCM projections are significantly different to those from the probabilistic projections, the range of results present in the GCM projections does cover much of the range present in the probabilistic projections, and so adaptation of existing results, rather than wholesale replacement, is likely to suffice.

U.78 The results from this investigation show that consideration of RCP2.6 50th percentile as a 'benign' climate future and RCP8.5 50th percentile as a 'severe' climate future would not cover a reasonable range of uncertainty present in the wider probabilistic projections. Thames Water, aligned with the WRSE Regional Group, have considered a 'median' climate change scenario as the central forecast, and have considered the 6th and 7th (CC06 and CC07) of the 28 spatially coherent projections as 'High' and 'Low' climate change impact scenarios respectively. Figure U-3 shows that these scenarios sit at the upper and lower end of the scenarios considered, but that neither scenario is the most extreme in the set of scenarios modelled.

U.79 Figure U-9 demonstrates why the projections that we have adopted are appropriate. The black line on this chart is a probability density plot of all climate change impacts modelled for the 2070 timeslice for all 828 scenarios modelled (that is, 200 scenarios from RCP2.6 probabilistic data, 200 scenarios from RCP4.5 probabilistic data, 200 scenarios from RCP6.0 probabilistic data, 200 scenarios from RCP8.5 probabilistic data, and 28 scenarios from RCP8.5 spatially coherent data). This demonstrates that, when considering all of the UKCP18 data which exist, there is clearly a wide range of uncertainty surrounding the impact that climate change will have on our supplies. Of the 828 scenarios modelled, 691 (83%) indicate that climate change will result in a net decrease in our supply capability while 137 (17%) indicate that climate change will result in a net increase in our supply capability. The vertical lines on this figure are salient scenarios:

- The pink dashed vertical line shows the climate change impact in 2070 of the 'High' scenario (CC06 from the spatially coherent projections) used in our plan.
- The green dashed vertical line shows the climate change impact in 2070 of the 'Low' scenario (CC07 from the spatially coherent projections) used in our plan.
- The blue dashed line is the 50th percentile of all 2070 impacts modelled using RCP2.6 probabilistic projection data.
- The red dashed line is the 50th percentile of all 2070 impacts modelled using RCP8.5 probabilistic projection data.

U.80 This chart shows that, if we were only to consider those scenarios which Ofwat have suggested in their Long-Term Delivery Strategy (LTDS) guidance[11], there would be a high likelihood (nearly 50%) that our plan would not be resilient to potential climate change impacts when considering all available UKCP18 data.

U.81 This chart also shows that the 'High' and 'Low' scenarios used in our plan are not 'extreme high' and 'extreme low' scenarios, and are instead very plausible climate change impact scenarios when considering all data from the UKCP18 projections.

[11] Ofwat, 2022, PR24 and beyond: Final guidance on long-term delivery strategies, https://www.ofwat.gov.uk/wp-content/uploads/2022/04/PR24-and-beyond-Final-guidance-on-long-term-delivery-strategies_Pr24.pdf

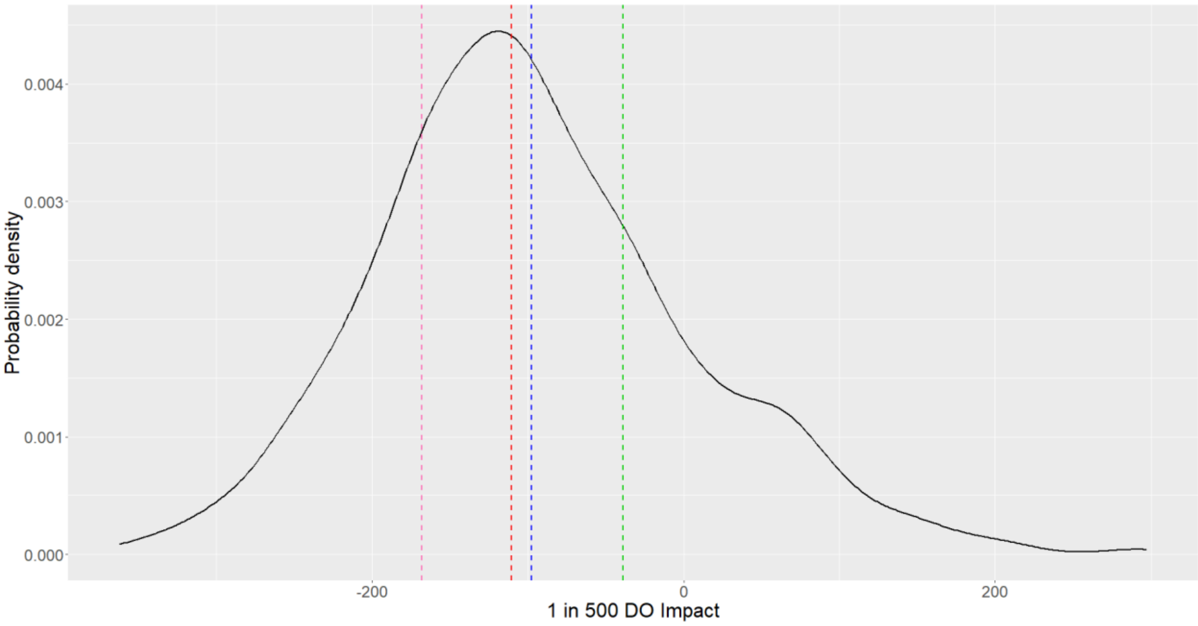


Figure U-9: 2070 Climate Change DO Impacts for London (Ml/d). Black line is a probability density plot of impacts from all 828 scenarios modelled for this timeslice; green vertical line is our 'low' scenario; pink vertical line our 'high' scenario; blue vertical link is the 50th percentile of RCP2.6 results; red vertical line is the 50th percentile of RCP8.5 results

U.82 A similar result can be seen using the raw precipitation anomaly outputs from UKCP18 (Figure U-10). This chart shows a probability density plot for summer precipitation anomalies under the RCP2.6 and RCP8.5 scenarios. Using the data underlying this plot, the median summer precipitation anomaly indicated in the RCP2.6 emissions scenario is -15.5% while the median summer precipitation anomaly indicated in the RCP8.5 emissions scenario is -24.2%. A -24.2% anomaly is approximately a 70th percentile impact under the RCP2.6 scenario, i.e., under an RCP2.6 emissions scenario there is a 30% chance that the summer precipitation anomaly will be more extreme than -24.2%. Using the 50th percentile value from different emissions scenarios is an inadequate way of considering the risks and uncertainty that climate change poses. We consider that there is a need to move past the reductive narrative that high emissions scenarios are the same as high impact scenarios and we ask our regulators to acknowledge this. Representations from our regulators on our dWRMP focussed on the use of data from the RCP8.5 scenario and highlighted a need to justify using data from a high emissions scenario due to the risk of planning for an overly extreme scenario. As we have shown, using data from a high emissions scenario does not mean that we are planning for a extreme scenario.

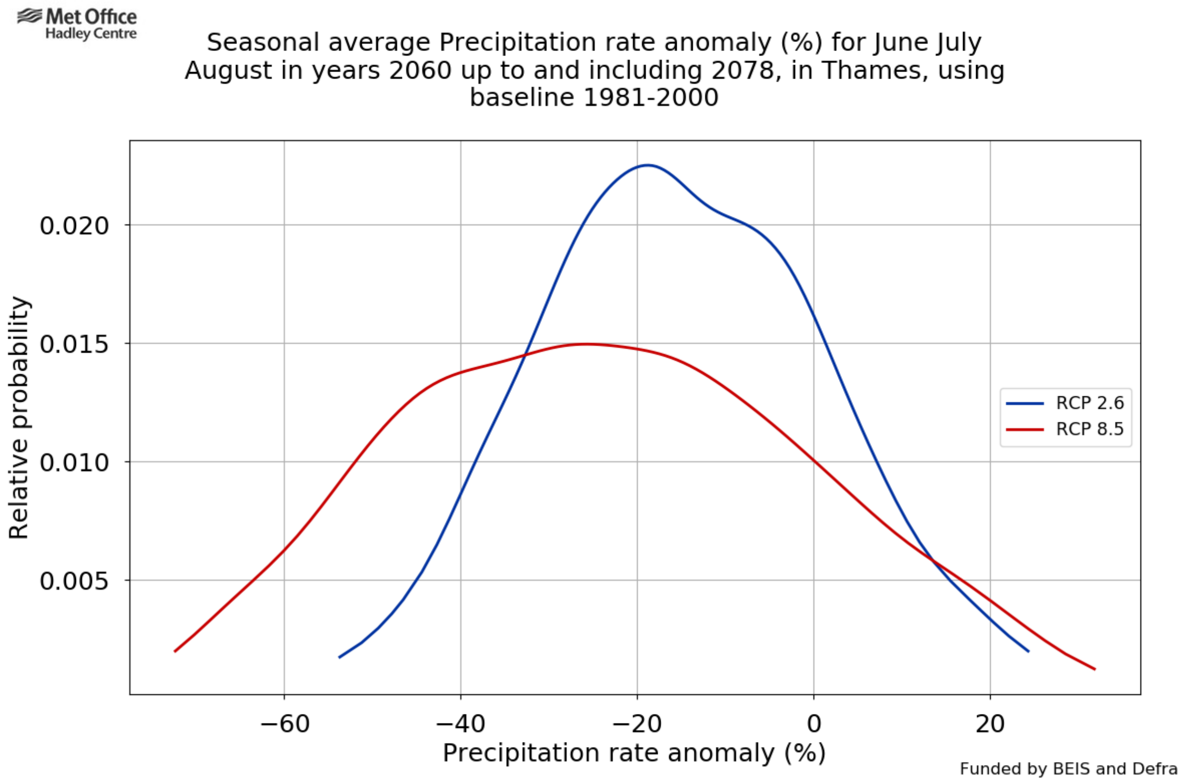


Figure U-10: Precipitation rate anomaly (%) for the summer season for the 2060-79 timeslice in the Thames catchment, compared to a 1981-2000 baseline[12]

Scaling of Climate Change Impacts

U.83 It is notable that impact assessments conducted, both for WRMP24 and for WRMP19, suggest that temperature-based scaling approaches would not be appropriate for scaling the impact of climate change on London's deployable output.

U.84 When normalised by the median DO impact calculated for each scenario in 2070, the resultant scaling of median climate change impacts through the planning period can be seen in Figure U-11. This indicates that climate change impacts are likely to accelerate through the period 2030 to 2050, but that a linear scaling from 1990 to 2070 gives a reasonable climate change impact scaling approach.

[12] Met Office Hadley Centre (2018): UKCP18 Probabilistic Climate Projections. Centre for Environmental Data Analysis. Chart produced by UKCP18 User Interface.

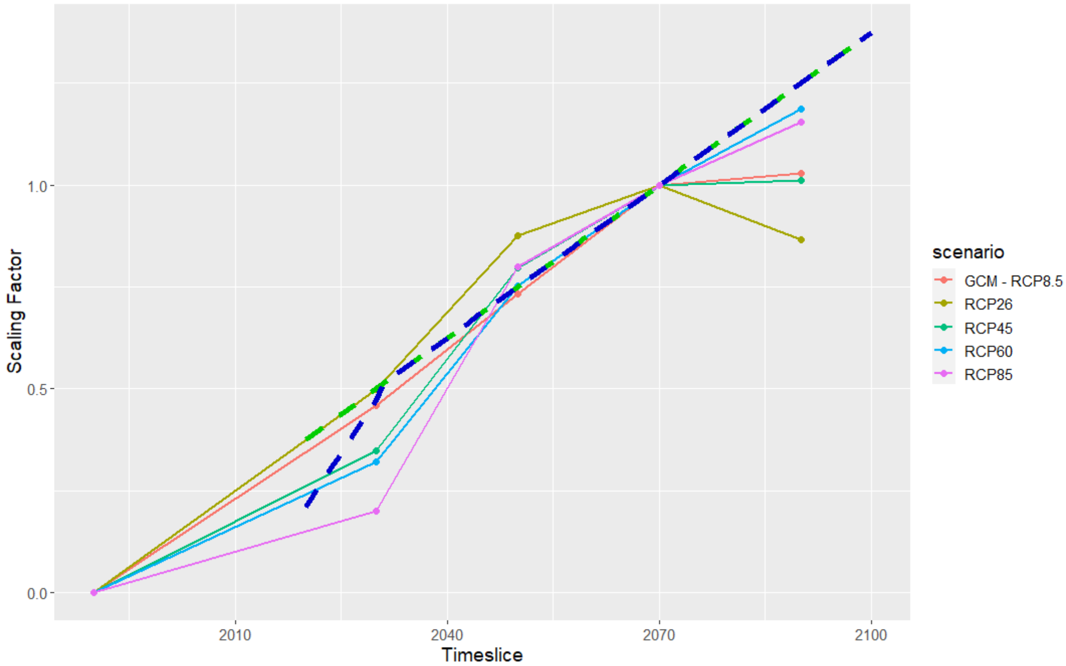


Figure U-11: Scaling Factor as Calculated From Projections (Solid Lines), Compared to the 'Modified EA Standard' (Scaling linearly from 1990-2070, Green Dotted) and "Alternative EA Scaling" (Blue Dotted)

Central Impact Assessment and Inclusion Within Target Headroom

London WRZ and SWOX WRZ

U.85 Results from the two iterations of analysis which focus on the London WRZ have been incorporated into the London WRZ supply forecast and the supply forecast for the SWOX WRZ forecast. The DO for the London WRZ and the SWOX WRZ are both hydrologically constrained and both zones contain relatively large reservoirs, and so we assume it reasonable to extend findings from investigations into our London WRZ DO to our SWOX WRZ DO. The DOs for other WRZs are either impacted by climate change to a significantly smaller extent, are dependent on other (non-hydrological) constraints, or are dependent on different (extreme low flow) hydrological responses.

U.86 For SWOX, the same methods as described in the 'initial' modelling phase for London were used. The results from the further investigation of the impact of climate change on London's DO were then applied to the results of the 'initial' SWOX climate change impact investigation. In our dWRMP, we considered different climate change impacts for the SWOX DYAA and DYCP scenarios. As is described in Appendix I, we have amended our DO calculation approach for the SWOX DYCP scenario after having reviewed water resources (WRSE Pywr) model outputs in more detail. This revised approach has led us to adopt the same climate change impact values for the SWOX DYCP scenario as for the DYAA scenario.

U.87 Results from the second iteration of modelling for the London WRZ suggest that manipulation of the 28 DO impact values calculated using the spatially coherent projections is likely to cover much of the range of uncertainty present in the wider set of projections, but that the spatially coherent projections (if left unamended) would present a significantly more severe view of climate change impact than the probabilistic projections. Results also suggest that the method of analysis applied (line fitting method) is likely to have underestimated the impact of climate change on DO, particularly for more extreme drought scenarios.

U.88 In the supply forecast, the 28 climate change DO impact values have been multiplied by two scaling factors, as set out below (Table U-8). The scaling factors represent the likely underestimation of DO impact from the line fitting method (Scaling Factor 1, Table U-6), and a reduction in DO impact considered to bring the spatially coherent projections in line with the probabilistic projections (Scaling Factor 2, Table U-7).

	1:500 DO	1:200 DO	1:100 DO
Scaling Factor 1	1.38	1.29	1.08
Scaling Factor 2	0.59	0.58	0.58
Overall Scaling Factor	0.81	0.73	0.63

Table U-8: Calculation of Overall Scaling Factors Applied to Climate Change Impacts in Supply Forecasts

U.89 The DO impact of the 28 climate change projections for the 2060-2080 timeslice considered within the supply forecast, when scaled as described above, can be seen in Figure U-12 (London WRZ) and Figure U-13 (SWOX WRZ DYAA and DYCP). There is a wide range of DO impacts of climate change present in these outputs, with a range of over 400 Ml/d for London WRZ (c.20% of London's baseline DO) and over 20 Ml/d for SWOX WRZ (c.7% of SWOX's baseline DO). Many of the results, however, sit within a range of 100-200 Ml/d DO reduction by 2070. The median impact of climate change on 1 in 500-year DO for the 2060-80 timeslice used in the supply forecast is -110 Ml/d for London. This impact is smaller than the median impact of climate change calculated for 1 in 100-year and 1 in 200-year DO, -160 Ml/d and -152 Ml/d respectively. The impact of climate change on 1 in 500-year DO may be smaller because the 1 in 500-year scenarios will consider extremely dry conditions already, with there being less water to lose to climate change impacts.

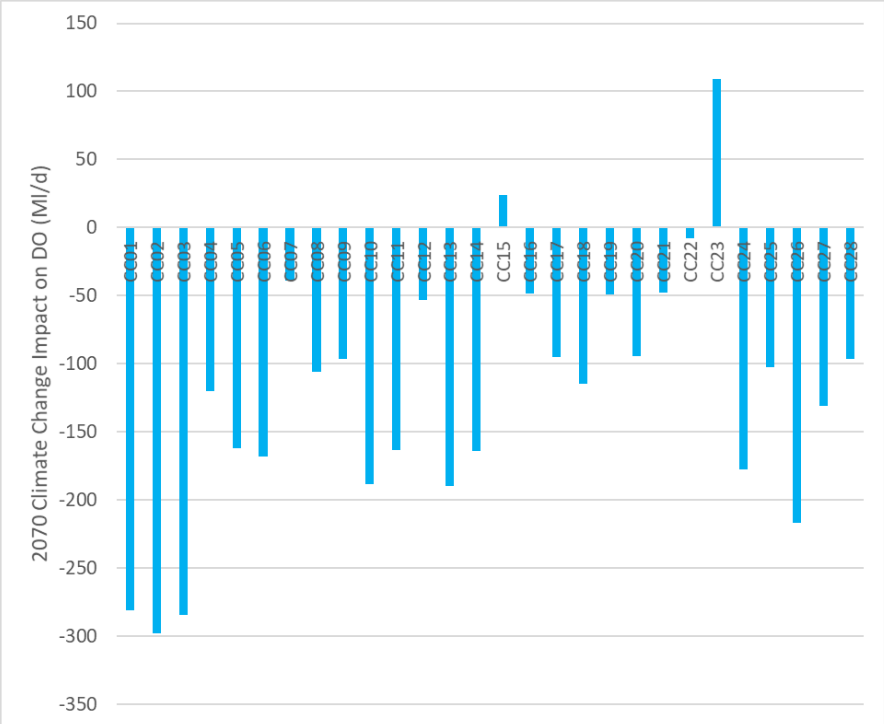


Figure U-12: Impact of 28 Climate Change Projections on London DO in 2070

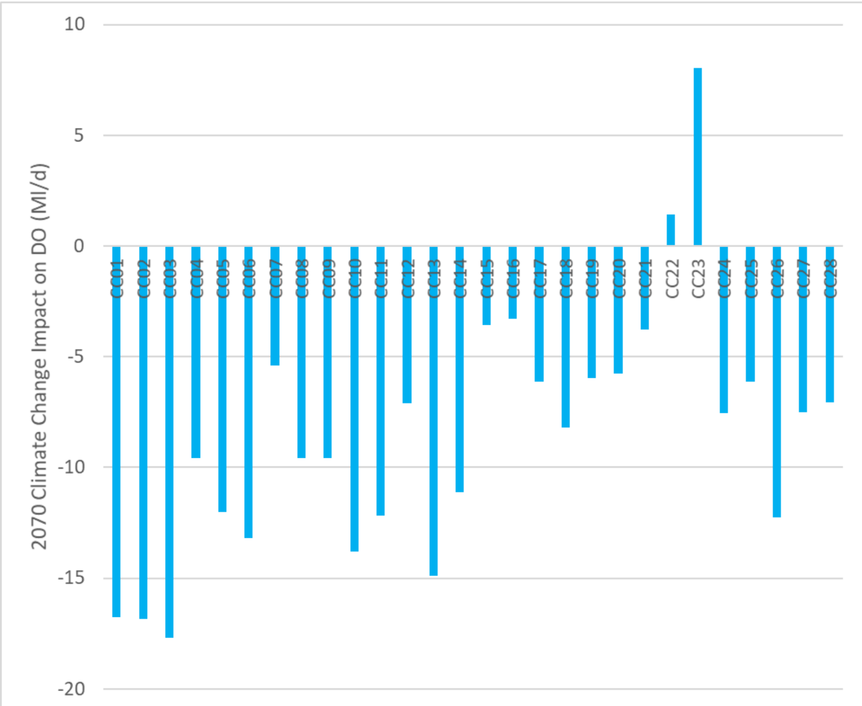


Figure U-13: Impact of 28 Climate Change Projections on SWOX DO in 2070

U.90 Target Headroom modelling (Section 6) for both the London WRZ and SWOX WRZ's DYAA scenario has considered the original, unfactored DO impacts calculated in the 'initial' phase of modelling, in order to ensure that the full range of uncertainty present in the UKCP18 projections is considered by not 'watering down' the uncertainty in climate change impact forecasts.

U.91 The variance around the median DO impact associated with each of the 28 climate change projections, which is included in our Target Headroom modelling, can be seen in Figure U-14 (London DYAA) and Figure U - 13 (SWOX WRZ DYAA).

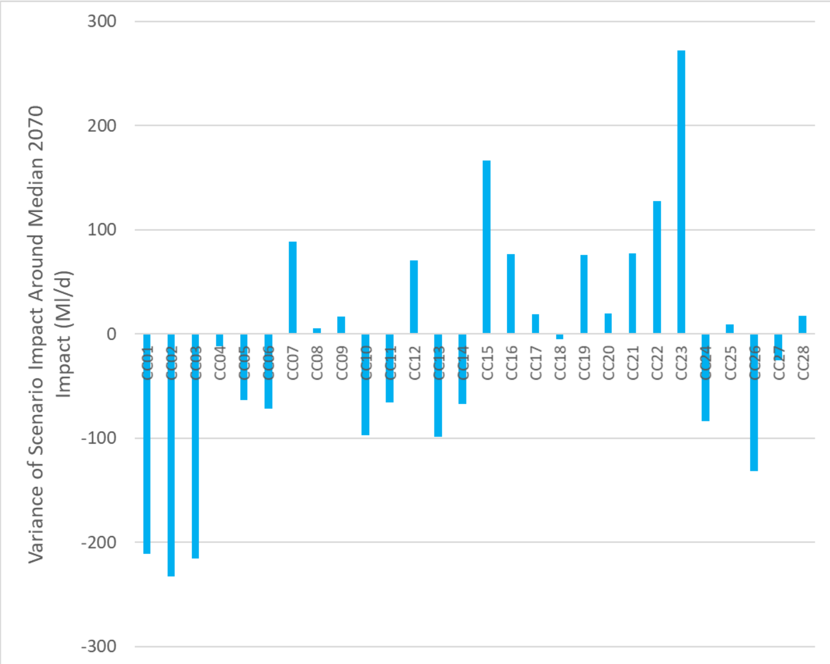


Figure U-14: Variance of London Climate Change DO Impacts Around Median Impact

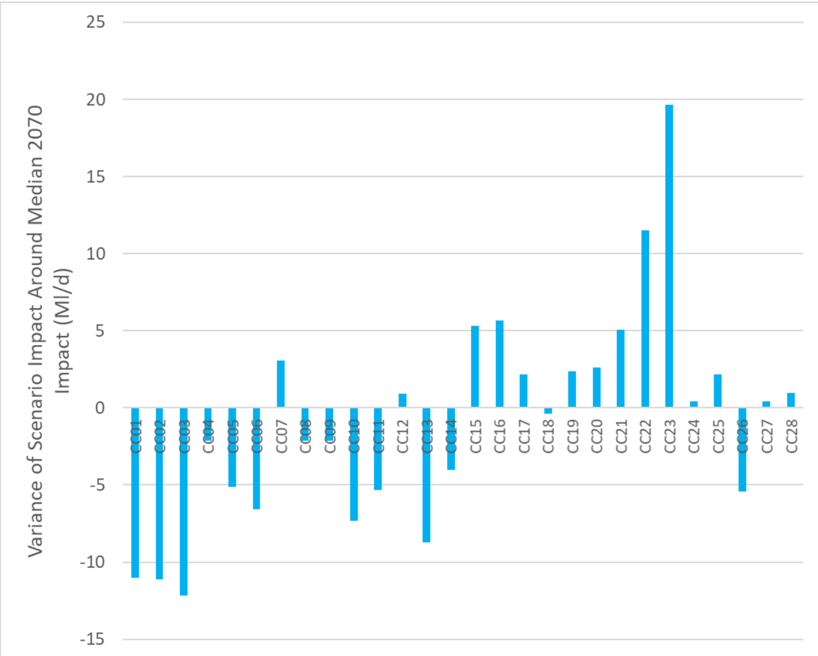


Figure U-15: Variance of SWOX DYAA Climate Change DO Impacts Around Median Impact

Slough, Wycombe and Aylesbury WRZ, Kennet Valley WRZ, and Guildford WRZ

U.92 The methods described as the 'initial' investigation for the London WRZ, i.e. use of hydrological and hydrogeological models to determine the impact of the 28 spatially coherent UKCP18 projections on WRZ DO in 2070, considering 21 replicates selected for the WRSE region, were applied to determine the impact on the DYAA and DYCP DO for the SWA, Kennet Valley and Guildford WRZs.

U.93 For these zones and scenarios, the DO impact of climate change was either relatively small, or is considered to be driven by factors other than hydrological variability, or critical DO constraints are considered very different to SWOX and London WRZs where there are large reservoirs (e.g., Kennet Valley, where the primary constraint is extreme but short-duration low flow conditions), and so scaling back the impacts of climate change was deemed either not to be needed, or necessarily correct.

U.94 For the Guildford WRZ, the impact of climate change on DO for both the DYAA and DYCP scenarios was modelled, and found to be zero for all 28 climate change projections.

U.95 The impact of the 28 climate change projections on SWA's DYAA and DYCP DO can be seen in Figure U-16. The variance around the median impact, i.e. the DO impacts considered in our Target Headroom modelling, can be seen in Figure U-17. The climate change DO impacts found for the SWA WRZ are significantly smaller than impacts found in WRMP19, because two sources which were found to be vulnerable to climate change in our WRMP19 climate change assessment, Pann Mill and Hawridge, either have been or are to be subject to licence reductions in AMP7.

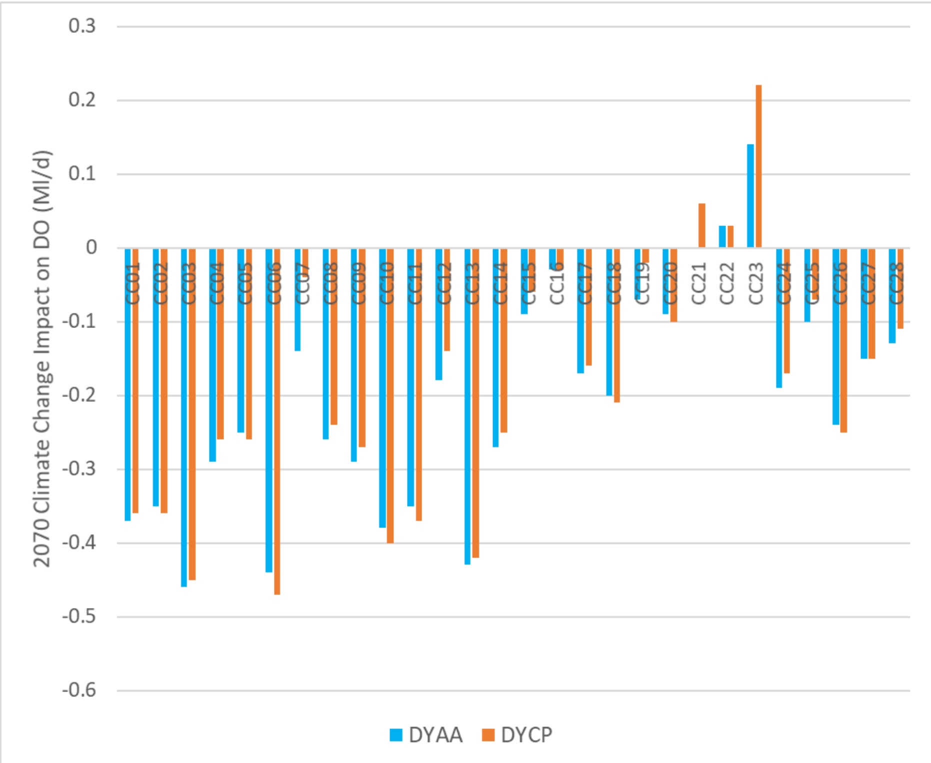


Figure U-16: Impact of 28 Climate Change Projections on SWA DO in 2070

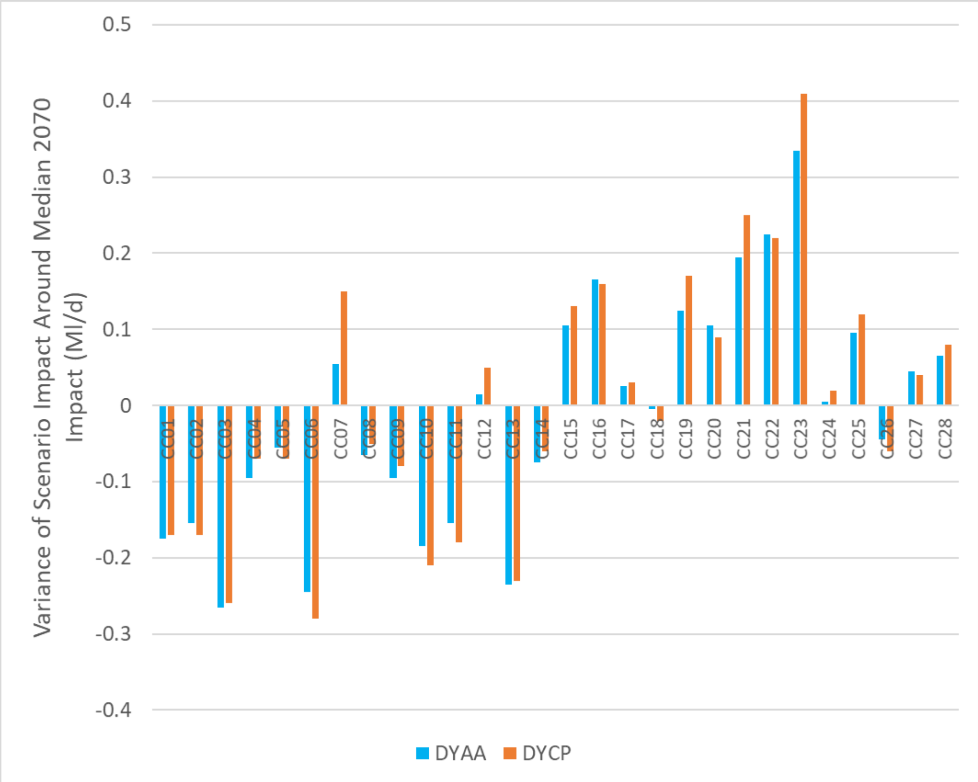


Figure U-17: Variance of SWA Climate Change Projection DO Impacts Around Median 2070 Impact

U.96 The impact of the 28 climate change projections on Kennet Valley's DYAA and DYCP DO can be seen in Figure U-18. The variance around the median impact, i.e. the DO impacts considered in our Target Headroom modelling, can be seen in Figure U-19.

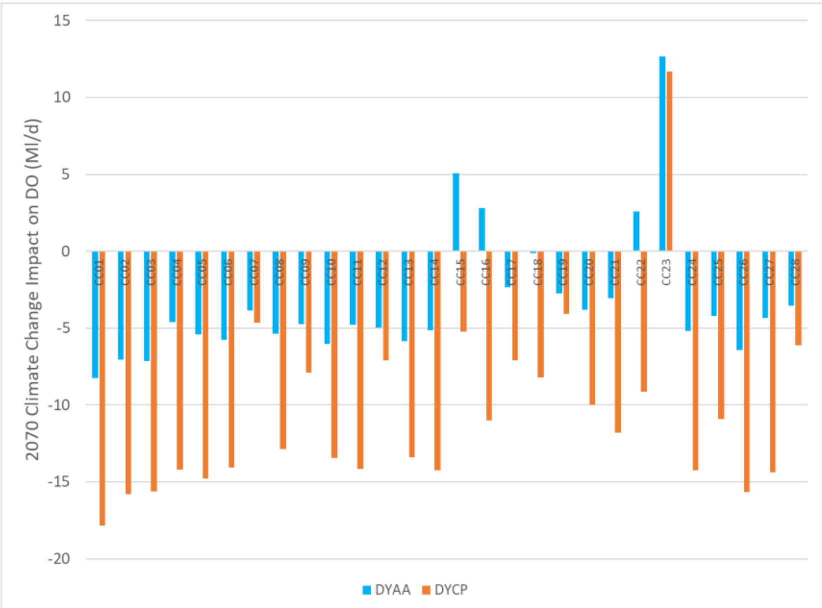


Figure U-18: Impact of 28 Climate Change Projections on Kennet Valley DO in 2070

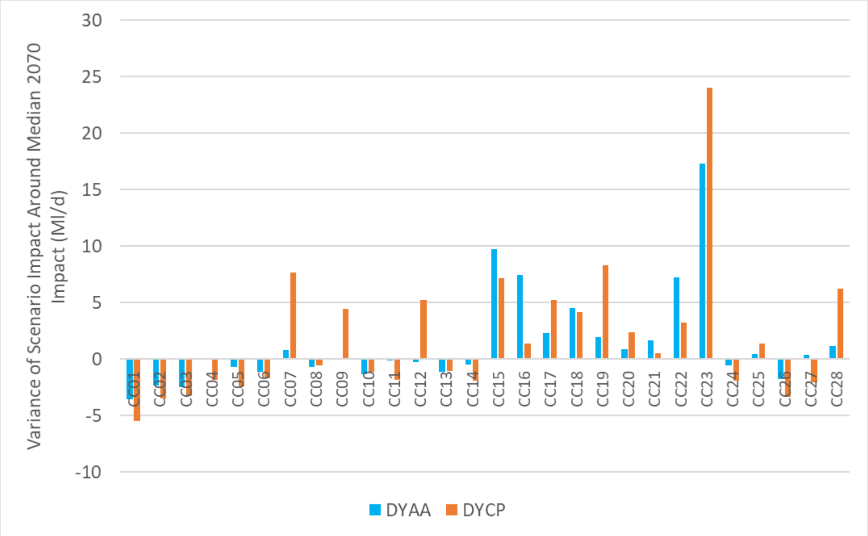


Figure U-19: Variance of Kennet Valley Climate Change Projection DO Impacts Around Median 2070 Impact

Henley WRZ

U.97 No climate change impact modelling was carried out the for the Henley WRZ. Application of the WRSE Groundwater Framework, as described in Appendix I, found that sources in the Henley WRZ, all of which are groundwater sources, are sufficiently resilient to drought events that consideration of the impact of stochastic sequences on their yield was not warranted, and so climate change modelling was also not carried out.

Scaling Climate Change Impacts

U.98 The scaling of climate change impacts is necessary to produce a possible trend in impact over the WRMP planning. It involves taking climate change impacts modelled to occur at a defined future point in time and projecting them backwards, and forwards as necessary, to establish the possible impact for each year of the planning period. As has been described earlier, WRMP24 guidance has not suggested a change to the scaling approach used in WRMP19.

U.99 A difference between our WRMP19 and WRMP24 assessments is that we have assessed climate change impacts in 2070 (2060-80 timeslice) in WRMP24, whereas impacts in 2085 (2070-2100 timeslice) were assessed in WRMP19. The reason for this is that the RCM spatially coherent projections used for WRMP24 only extend to 2080. Additionally, our WRMP19 and WRMP24 assessments used different baseline periods for climate change assessment. Our WRMP19 assessment used a baseline period of 1961-90 (the standard baseline period for UKCP19), while our WRMP24 assessment used a baseline period of 1981-2000, which is the earliest baseline for the RCM projections in UKCP18, due to the starting point for these projections being 1981.

U.100 The linear scaling equation suggested by the EA is as follows:

Scale factor = (Year-1975)/(2085-1975)

U.101 For the period in which we have adopted a linear scaling equation, we have used the following scaling factor formula to reflect the different baseline and projection forecast year:

Scale factor = (Year-1990)/(2070-1990)

U.102 For the first 5 years of the planning period we have kept the same scaling factors as we used in WRMP19. In WRMP14 and WRMP19 we scaled from zero climate change impact in 2012 to meet the linear scaling equation in 2032, in order to prevent a significant step-change in climate change allowance early in the planning period. When the scaling factors above meet the linear scaling equation, we follow the linear scaling equation as described above. The factors produced using this approach to scaling climate change impacts in all zones can be seen in Figure U-20.

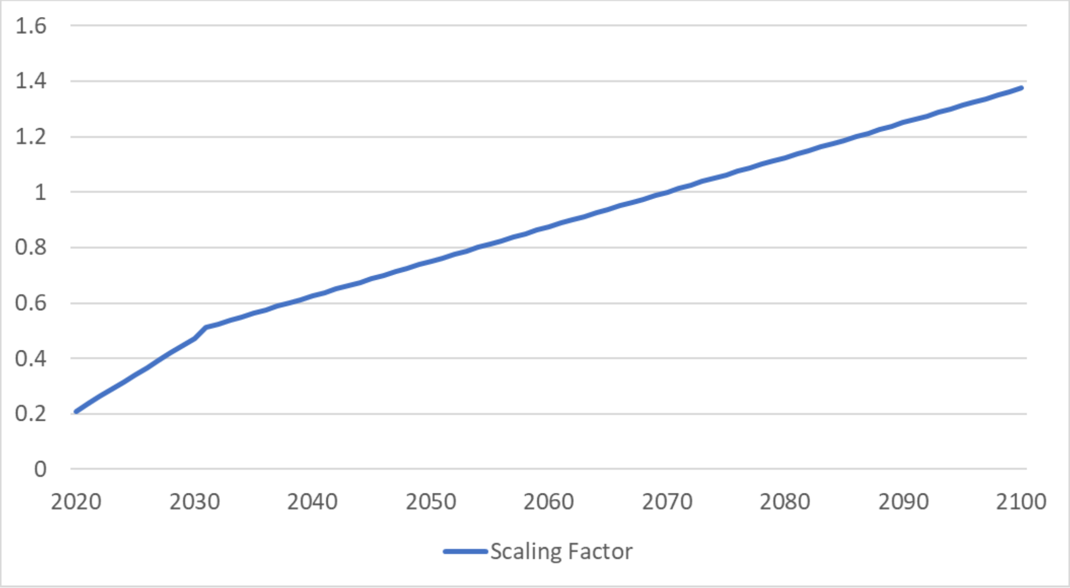


Figure U-20: Climate Change Scaling Factors

U.103 The same scaling factors have been applied in factoring the central impact of climate change on DO through the planning period, and in factoring the variances around median impacts that have been used in Target Headroom modelling.

Supply-Side Climate Change Impact Forecast

Central Impact Forecast

U.104 As is described in Section 6 (Uncertainty and Baseline Supply-Demand Balance) and Section 10 (Programme Appraisal), we have adopted adaptive planning techniques to ensure that our plan is robust and efficient under a wide range of future uncertainties. As a key uncertainty, we have considered different scenarios of climate change within our adaptive planning.

U.105 As such, for each of the WRZs and planning scenarios outlined below, we have shown the impact of the median climate change scenario (Central, scaled as necessary) across the whole planning period, as well as the CC06 (High) and CC07 (Low) scenarios (also scaled as necessary) from 2040 onwards, which have been adopted in our adaptive planning. We have also compared the impacts at 2070 considered in WRMP24 with the central impact considered in WRMP19.

U.106 For each WRZ we have calculated the impact of climate change on 1 in 100-year, 1 in 200-year, and 1 in 500-year DO. We have used climate change DO impact values for our Target Level of Service for each year of the planning period. This means that we have used the scaled 1 in 100-year climate change DO impacts in the period 2020-2030, the impact of climate change on 1 in 200-year DO in the period 2031-39, and the impact of climate change on 1 in 500-year DO in the period 2040 onwards. Figures in the sections that follow show step changes at points when our Target Level of Service changes as we have found that the impact of climate change on more severe drought events is smaller than on less severe events.

U.107 For each WRZ, in the Annex at the end of this chapter we have included tables and figures which show the Deployable Output Impact of each of the 28 climate change scenarios modelled.

London

U.108 The central allowance that we have determined for the London WRZ is initially very similar to the allowance calculated in WRMP19. Were we considering the impact of climate change on 1 in 100-year DO we would end up with an almost identical central climate change impact in the long term; our 2070 WRMP19 DO impact for London WRZ was 159.93 Ml/d and the 2070 WRMP24 1 in 100-year climate change DO impact for London WRZ is 160.02 Ml/d. However, as noted above, the impact of climate change on 1 in 500-year DO is smaller than the impact of climate change on both 1 in 100-year and 1 in 200-year DO. This explains the step in climate change impact in 2040 in Figure U-**21**, and so our central forecast is a reduction of 110 Ml/d by 2070. In our adaptive planning we have also considered ‘High’ and ‘Low’ scenarios, which reach impacts of 168 Ml/d and 39 Ml/d of DO reduction respectively by 2070.

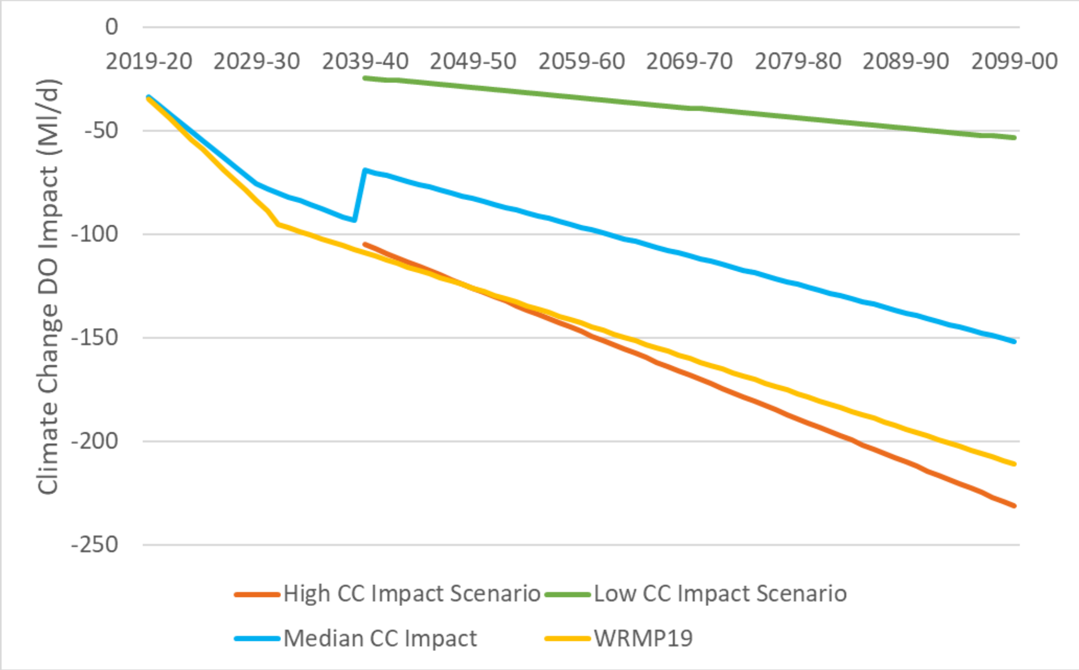


Figure U-21: London DYAA - Central Forecast of Climate Change Impact Through the Planning Period, alongside 'High' and 'Low' Climate Change Scenarios and WRMP19 Central Impact

SWOX

U.109 For the SWOX WRZ, the central impact of climate change on DYAA DO that we consider through the planning period is similar to that used in WRMP19 (Figure U-22). Again, we have considered 'High' and 'Low' climate change scenarios which cover a wider range of future potential impacts. The DYAA and DYCP climate change impact projections for SWOX have been considered as being the same for our rdWRMP24 and final WRMP24, a change from our dWRMP24.

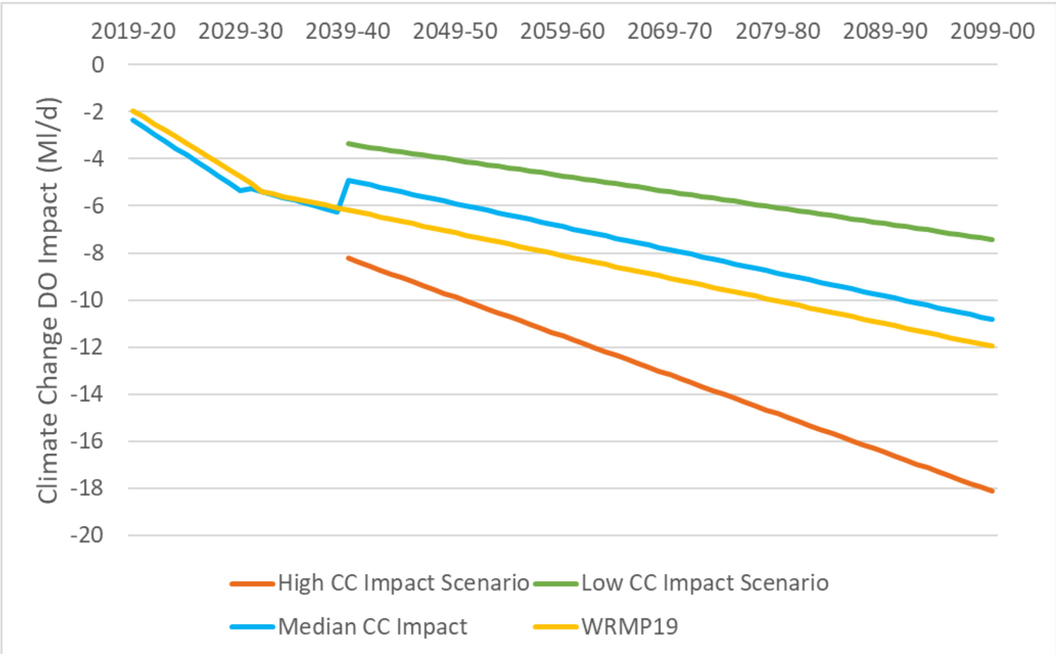


Figure U-22: SWOX DYAA - Central Forecast of Climate Change Impact Through the Planning Period, alongside 'High' and 'Low' Climate Change Scenarios and WRMP19 Central Impact

Slough, Wycombe and Aylesbury

U.110 Our WRMP19 climate change assessment found a fairly significant impact of climate change on our Hawridge and Pann Mill sources. Licence reductions at both of these sources mean that the impact of climate change on these sources is no longer an issue, and so the impact of climate change on the SWA WRZ in WRMP24 is significantly reduced compared to our WRMP19 assessment for both the DYAA (Figure U-23) and DYCP (Figure U-24) planning scenarios.

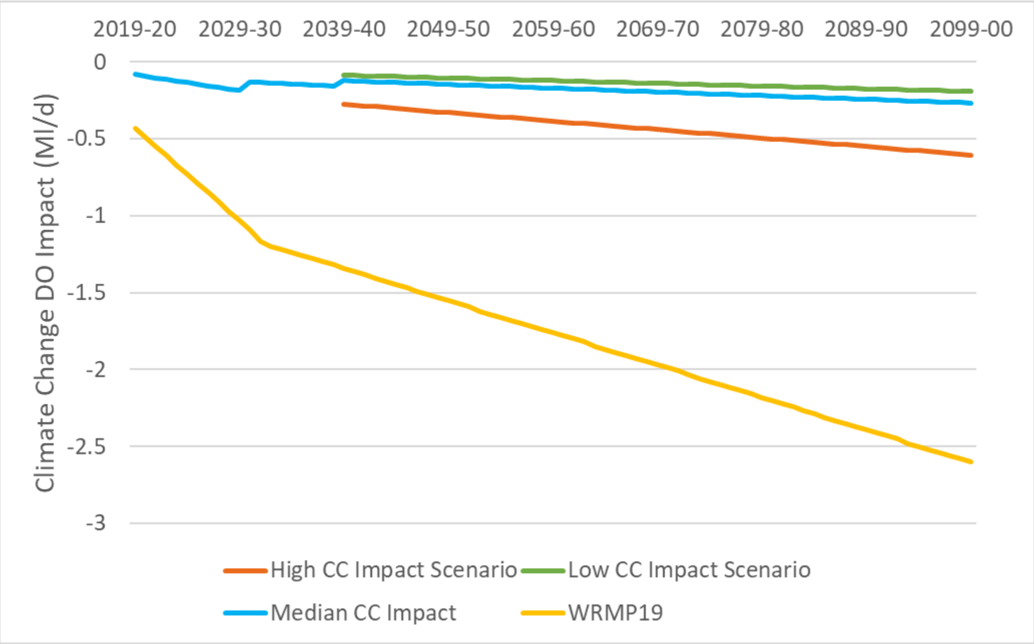


Figure U-23: SWA DYAA - Central Forecast of Climate Change Impact Through the Planning Period, Alongside 'High' and 'Low' Climate Change Scenarios and WRMP19 Central Impact

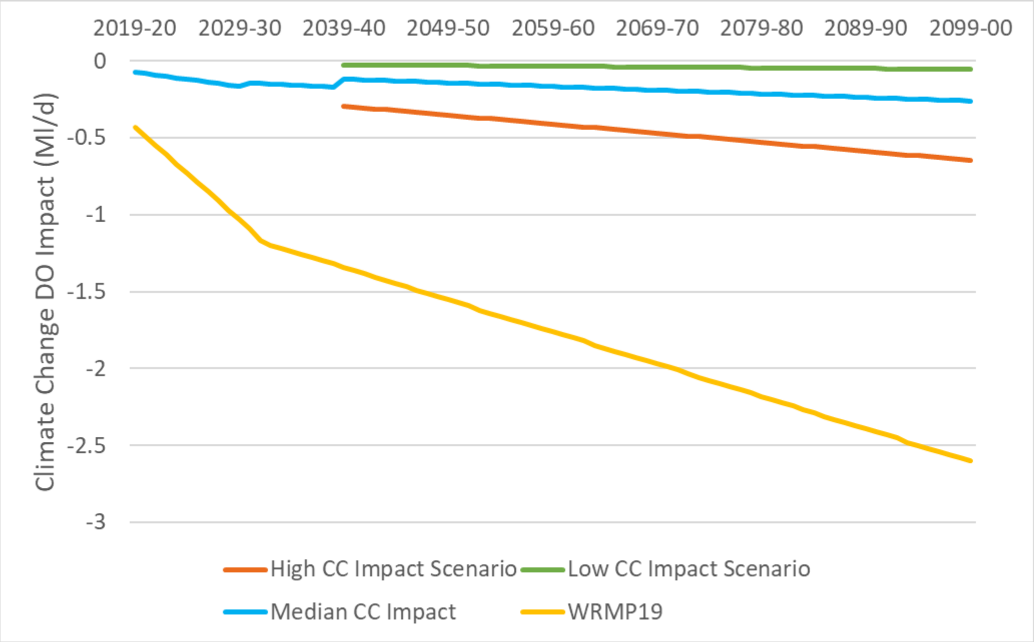


Figure U-24: SWA DYCP - Central Forecast of Climate Change Impact Through the Planning Period, Alongside 'High' and 'Low' Climate Change Scenarios and WRMP19 Central Impact

Kennet Valley

U.111 Figure U-25 shows the DYAA DO climate change impacts of scenarios used in our plan. This shows that initially the climate change impact is slightly higher than that used in WRMP19, but that it is lower in the long term. There are large step changes in climate change DO impact at the points when our planned resilience levels change. This is because the 1 in 500-year and 1 in 200-year baseline DO figures for the Kennet Valley WRZ are significantly lower than the 1 in 100-year DO, meaning that there is less DO to 'lose' from climate change when we will be planning for more severe droughts.

U.112 Figure U-26 shows the DYCP DO climate change impact projections. This shows that the "High" and "Median" scenarios considered are more severe than the WRMP19 central projection, but that the "Low" scenario considered is less severe than the projection used in WRMP19.

U.113 The figures show that the impact of climate change on DYCP DO is larger than the impact on DYAA DO. This is because the baseline 1 in 500-year DYAA DO for the Fobney run of river source is already very low while the 1 in 500-year DYCP DO for the same source is relatively high; climate change appears to make it more likely that extremely low river flows will be seen during the peak period for this source (i.e., we are more likely to see extremely low flows in July and August, where flows are currently unlikely to recess to extreme low levels until the early Autumn).

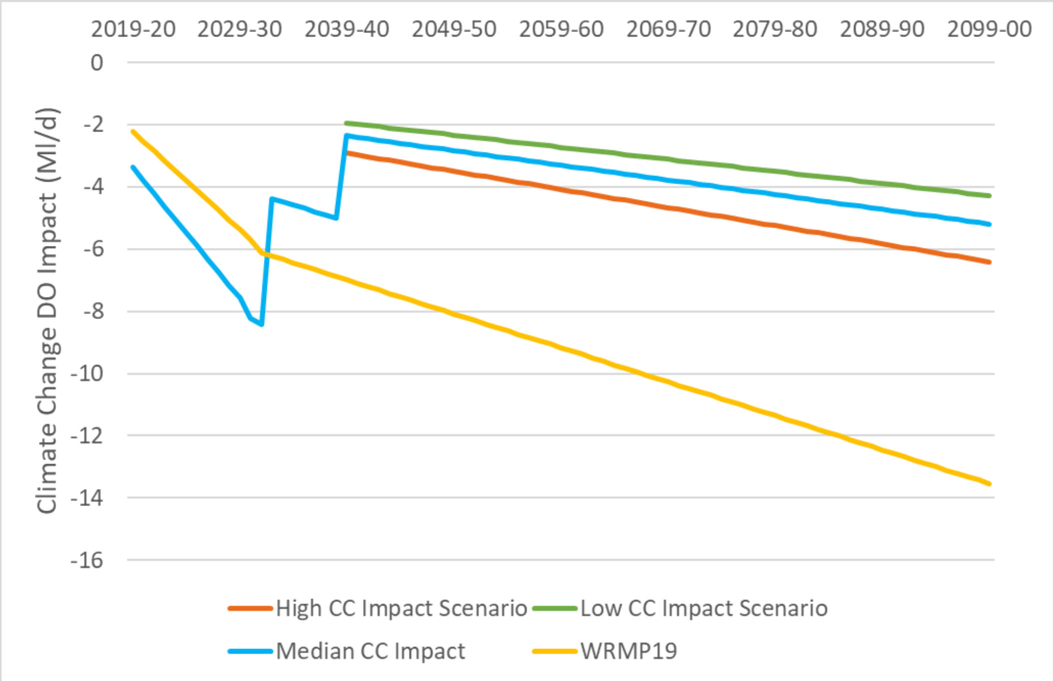


Figure U-25: Kennet Valley DYAA - Central Forecast of Climate Change Impact Through the Planning Period, Alongside 'High' and 'Low' Climate Change Scenarios and WRMP19 Central Impact

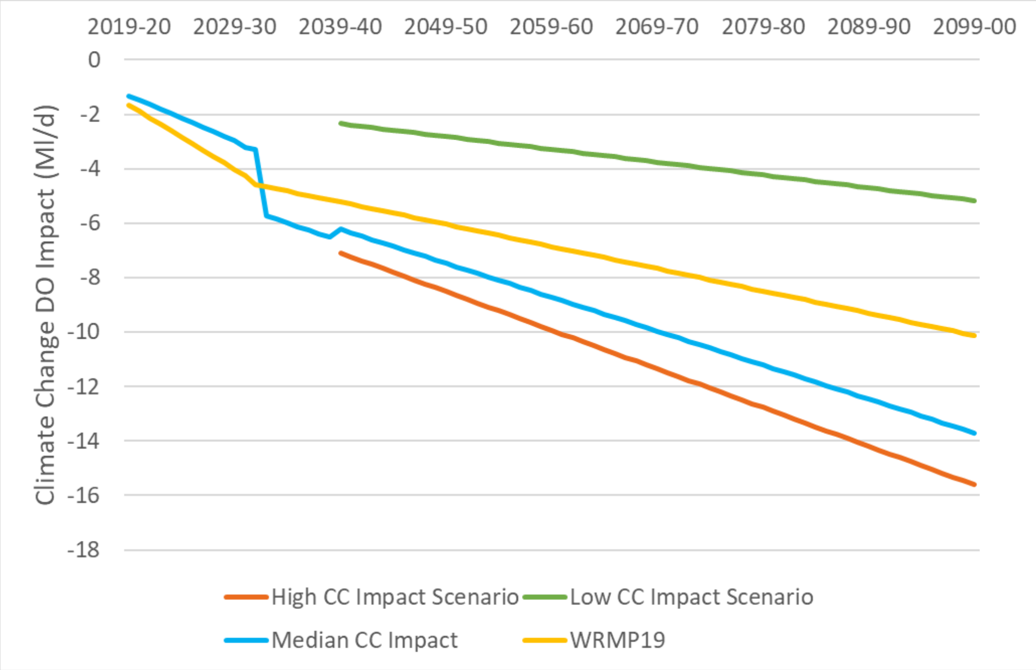


Figure U-26: Kennet Valley DYCP - Central Forecast of Climate Change Impact Through the Planning Period, Alongside 'High' and 'Low' Climate Change Scenarios and WRMP19 Central Impact

Guildford and Henley

U.114 As has been described above, the impact of climate change on Guildford's DO has been found to be zero, and the impact of climate change on Henley's DO has not needed assessment due to the resilience of the sources in the Henley WRZ.

Contribution to Target Headroom

U.115 The uncertainty around the median climate change forecast is included in Target Headroom. In our Target Headroom assessment, we have considered that each of the 28 scenarios that we have conducted detailed modelling for is equally likely, and so in our Monte Carlo sampling for Target Headroom, in each Monte Carlo iteration we randomly select one of the 28 climate change scenarios and include an allowance for the variance of the DO impact for that scenario compared to the median value. Further details of Target Headroom modelling can be found in Section 6.

U.116 For each WRZ and planning scenario, the influence of removing climate change uncertainty from Target Headroom has been calculated, in order to determine the contribution that climate change makes towards Target Headroom (Table U-9). Within our adaptive planning (see Section 6 and Section 10) we have considered different climate change impact forecasts from 2040 (2040 being the latest 'branch' point that we have considered), and so have not included a climate change Target Headroom allowance from this point onwards in order to avoid double counting climate change impacts.

WRZ and Scenario	2025	2030	2040 onwards
London DYAA	21.7	33.1	0
London DYCP	N/A	N/A	N/A
SWOX DYAA	0.03	0	0

WRZ and Scenario	2025	2030	2040 onwards
SWOX DYCP	0.62	0.29	0
SWA DYAA	0.0	0.0	0.0
SWA DYCP	0.0	0.0	0.0
Kennet Valley DYAA	0	0	0.0
Kennet Valley DYCP	1.5	2.7	0.0
Guildford DYAA	0.0	0.0	0.0
Guildford DYCP	0.0	0.0	0.0
Henley DYAA	0.0	0.0	0.0
Henley DYCP	0.0	0.0	0.0

Table U-9: Climate Change Contribution Towards Target Headroom (Ml/d)

Total Impact of Climate Change

U.117 Adding together the central impact of climate change on DO and the contribution of climate change towards target headroom, the total impact of climate change on our supply-demand balance can be found. Table U-10 shows the total impact of climate change on our supply-demand balance for the London DYAA scenario, the SWOX DYAA scenario, and the SWOX DYCP scenario. These scenarios have been selected as the London and SWOX WRZs are most vulnerable to climate change. A comparison is shown between the contribution in WRMP19 and the contribution in WRMP24. Where three rows are shown for WRMP24 values, this reflects the use of high, medium, and low scenarios in adaptive planning.

U.118 This table shows that we include a similar total allowance for climate change in both London and SWOX WRZs in the short term (up to 2040). The calculation of the impact of climate change on 1 in 500-year DO and the removal of climate change uncertainty from our Target Headroom calculations means that we have a smaller allowance for the impacts of climate change in the longer term than we did for WRMP19.

U.119 Climate change is a complex topic, and, as demonstrated in this chapter, significant uncertainty exists around climate change impacts on Deployable Output. We will continue to work with our regulators to improve the presentation and communication of climate change impacts and uncertainty.

Planning Scenario	2025	2030	2040	2050	2070
London WRMP19	99.4	131.1	152.8	163.5	197.5
London WRMP24	76.3	108.7	105.0 69.0 24.3	126.0 82.8 29.2	168.0 110.4 38.9
SWOX WRMP19, DYAA	6.3	8.0	9.2	9.9	11.8
SWOX WRMP24, DYAA	3.9	5.3	8.2 4.9 3.4	9.9 5.9 4.0	13.2 7.9 5.4
SWOX WRMP19, DYCP	7.6	9.7	11.2	11.8	14.0

Planning Scenario	2025	2030	2040	2050	2070
SWOX WRMP24, DYCP	4.5	5.6	8.2 4.9 3.4	9.9 5.9 4.0	13.2 7.9 5.4

Table U-10: Total Impact of Climate Change on Supply Forecast – all values in Ml/d

Demand-Side Climate Change Impacts

U.120 HR Wallingford were commissioned to carry out a study[13] to estimate the likely impacts of climate change upon household demand. No climate change effects are assumed for other components of demand based on the findings of the UKWIR report on the impacts of climate change on water demand[14].

U.121 HR Wallingford undertook a statistical analysis of available data in order to derive empirical relationships that describe how weather and other factors affect household demand for water in our supply area.

U.122 We provided the following data sets:

- DWUS (Domestic Water Use Study) unmeasured PCC by property type (2000-2010)
- PCC by property type for test DWUS[15] panel (2002-2004)
- Demand data (distribution input – minimum night line, 1998 onwards)
- Climate data (temperature, rainfall and sunshine hours, 1998 onwards)

U.123 The DWUS dataset is comprised of a panel of customers who have, voluntarily, had meters installed but are charged on an unmeasured basis. This dataset has monitored the consumption of customers for over 10 years, representative of our entire supply area. It also shows how usage changes with differing weather patterns and occupancy information is available for each member of the panel.

U.124 HR Wallingford used multiple linear regression to analyse data and to produce predictive equations.

U.125 Three climate variables were considered in the statistical analysis; temperature, rainfall and sunshine hours. However, sunshine hours were removed as it was found to be highly correlated with temperature, and temperature provided a stronger and better understood climate change signal which would increase confidence in the model. Including both sunshine hours and temperature could have resulted in instability within the model. For the DYAA model both rainfall and temperature were included. For the average day peak week scenario ADPW model only temperature was included as an explanatory variable, this was due to insufficient data as for most years there was no rainfall in the peak period.

U.126 To estimate the impacts of climate change, the full sample of 10,000 UKCP09 climate change projections for maximum temperature and rainfall in the Thames Valley basin in the 2030s medium emissions scenario, was used. These scenarios provide climate change factors that are applied to the regression models.

U.127 The climate change factors are reported as the change between the baseline period (1961-1990, mid-point 1975) and the future period (2021-2050, mid-point 2035). As the baseline for the WRMP14 was 2011 a scaling factor was calculated:

Scaling Factor = (2035-BaseYear)/(2035-1975)

U.128 These factors were then used with the regression relationships, described above, to provide estimates of PCC change due to climate change in the 2030s. The results of this gave 10,000 potential future PCC factors. The 10th, 50th and 90th percentiles of these

[13] HR Wallingford, 2003, EX6828, Thames Water Climate Change Impacts and Water Resource Planning. Thames Water Climate Change Impacts on Demand for the 2030s
[14] UKWIR, 2013, Impact of Climate Change on Water Demand 13/CL/04/12
[15] testDWUS – A temporary panel of unmeasured customers used to validate DWUS

factors were extracted to represent lower, mid and upper estimates of impact on PCC. The mid estimate was used in the demand forecasting models while the upper and lower estimates were used in headroom modelling (see Section 6: Allowing for Risk and uncertainty).

U.129 The climate change profiles for lower, mid and upper estimates are shown for the DYAA in Figure U-27 and the ADPW scenario in Figure U-28.

U.130 The impacts of climate change for the DYAA scenario are shown in Table U-11. These values are applied to all our WRZs.

	2020	2030	2050	2075	2100
Impact	0.00%	0.22%	0.66%	1.21%	1.77%

Table U-11: The Impacts of Climate Change for the DYAA Scenario

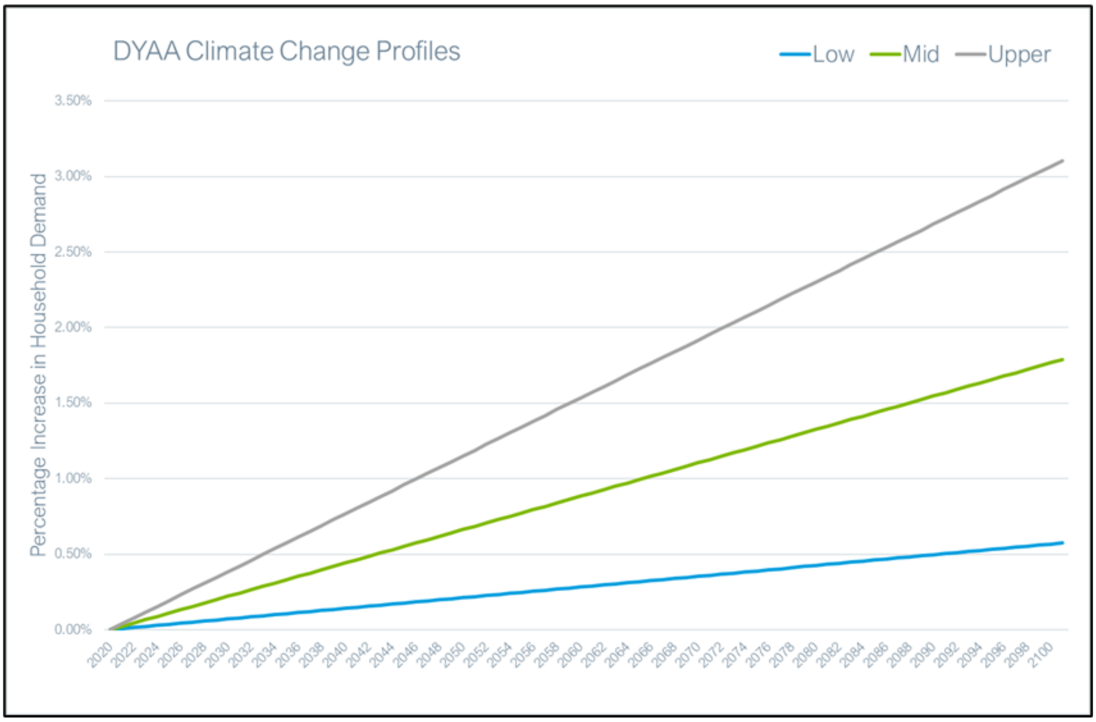


Figure U-27: Climate Change Impact on Demand Profile – Dry Year Annual Average (DYAA)

U.131 The impacts of climate change for the ADPW scenario are shown in Table U-12. These values are applied to all our Thames Valley WRZs.

	2020	2030	2050	2075	2100
Impact	0.00%	1.13%	3.38%	6.19%	9%

Table U-12: The Impacts of Climate Change for the ADPW Scenario

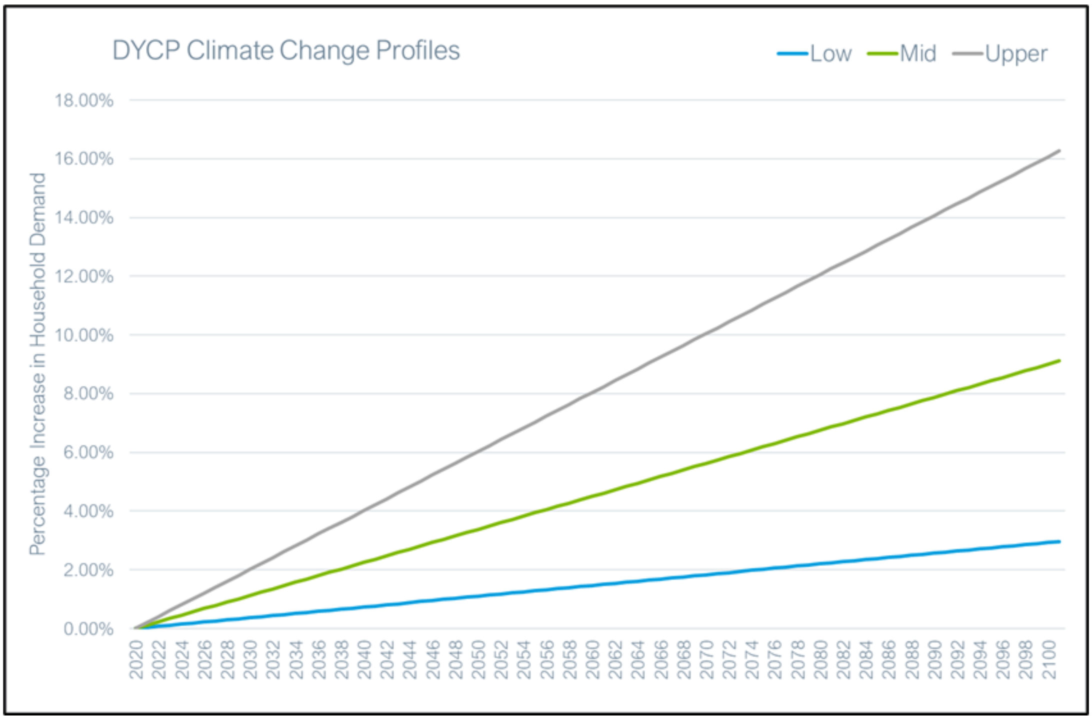


Figure U-28: Climate Change Impact on Demand Profile – Average Day Peak Week (ADPW)

U.132 How this information is used to produce household demand forecasts to 2100 is described within Section 3: Current and future demand for water. How the climate change forecasts are used in calculating demand uncertainty for Target Headroom is explained within Section 6 Uncertainty and Baseline Supply Demand Balance.

Annex 1: Climate Change Impacts for Scenarios Considered

U.133 In this Annex we have included more detailed information regarding the climate change impact values calculated for the 28 scenarios considered.

Climate Change DO Impacts (Ml/d) for all Modelled Scenarios, London WRZ								
Year	2025	2030	2035	2040	2045	2050	2060	2075
CC1	-87.91	-121.72	-151.95	-175.63	-193.19	-210.75	-245.88	-298.56
CC2	-88.98	-123.20	-156.91	-186.43	-205.07	-223.71	-261.00	-316.93
CC3	-96.25	-133.28	-161.82	-177.88	-195.66	-213.45	-249.03	-302.39
CC4	-44.01	-60.94	-68.89	-74.93	-82.43	-89.92	-104.91	-127.39
CC5	-55.25	-76.50	-90.31	-101.15	-111.26	-121.37	-141.60	-171.95
CC6	-66.38	-91.91	-103.75	-104.98	-115.48	-125.98	-146.98	-178.47
CC7	-19.43	-26.90	-24.41	-24.33	-26.76	-29.20	-34.06	-41.36
CC8	-45.46	-62.95	-67.47	-66.37	-73.01	-79.65	-92.92	-112.84
CC9	-48.56	-67.23	-68.76	-60.48	-66.53	-72.58	-84.68	-102.82
CC10	-65.89	-91.23	-107.76	-117.92	-129.71	-141.50	-165.09	-200.46
CC11	-58.24	-80.64	-93.94	-102.25	-112.47	-122.69	-143.14	-173.82
CC12	-31.19	-43.18	-40.35	-33.32	-36.66	-39.99	-46.65	-56.65
CC13	-71.01	-98.32	-113.64	-118.83	-130.71	-142.59	-166.36	-202.00
CC14	-60.79	-84.17	-96.88	-102.71	-112.98	-123.25	-143.79	-174.61
CC15	-11.55	-15.99	-2.00	15.12	16.63	18.14	21.17	25.70
CC16	2.23	3.08	-7.94	-30.17	-33.18	-36.20	-42.23	-51.28
CC17	-28.34	-39.23	-46.46	-59.58	-65.54	-71.50	-83.41	-101.29
CC18	-31.32	-43.36	-53.92	-71.59	-78.74	-85.90	-100.22	-121.70
CC19	-23.35	-32.33	-30.90	-30.70	-33.76	-36.83	-42.97	-52.18
CC20	-26.51	-36.71	-44.28	-59.00	-64.90	-70.81	-82.61	-100.31
CC21	-4.15	-5.74	-9.72	-29.79	-32.77	-35.75	-41.71	-50.65
CC22	3.10	4.29	6.96	-4.74	-5.22	-5.69	-6.64	-8.06
CC23	21.96	30.41	53.07	68.22	75.04	81.86	95.51	115.98
CC24	-51.51	-71.32	-89.75	-111.13	-122.25	-133.36	-155.59	-188.93
CC25	-28.87	-39.98	-48.65	-64.14	-70.55	-76.97	-89.80	-109.04
CC26	-63.88	-88.45	-111.71	-135.38	-148.92	-162.46	-189.53	-230.15
CC27	-30.59	-42.36	-56.70	-81.74	-89.91	-98.09	-114.44	-138.96
CC28	-27.94	-38.69	-27.26	-60.32	-66.35	-72.39	-84.45	-102.55
Low (CC7)	-19.43	-26.90	-24.41	-24.33	-26.76	-29.20	-34.06	-41.36
Median	**-37.66**	**-52.15**	**-62.08**	-68.98	-75.88	-82.78	-96.57	-117.27
High (CC6)	-66.38	-91.91	-103.75	**-104.98**	**-115.48**	**-125.98**	**-146.98**	**-178.47**

Climate Change DO Impacts for all Modelled Scenarios, SWOX WRZ DYAA								
	2025	2030	2035	2040	2045	2050	2060	2075
CC1	-5.17	-7.16	-9.23	-10.49	-11.54	-12.58	-14.68	-17.83
CC2	-4.68	-6.49	-8.72	-10.52	-11.57	-12.62	-14.72	-17.88
CC3	-6.31	-8.74	-10.67	-11.05	-12.15	-13.26	-15.47	-18.78

CC4	-3.02	-4.18	-5.32	-5.99	-6.59	-7.19	-8.39	-10.19
CC5	-3.47	-4.80	-6.34	-7.51	-8.26	-9.01	-10.51	-12.76
CC6	-4.88	-6.76	-8.13	-8.24	-9.06	-9.89	-11.53	-14.00
CC7	-1.65	-2.28	-2.91	-3.37	-3.71	-4.05	-4.72	-5.74
CC8	-3.41	-4.72	-5.74	-5.99	-6.59	-7.19	-8.38	-10.18
CC9	-3.68	-5.10	-6.04	-5.99	-6.59	-7.19	-8.39	-10.19
CC10	-4.62	-6.40	-7.98	-8.62	-9.48	-10.34	-12.06	-14.65
CC11	-3.91	-5.41	-6.85	-7.61	-8.37	-9.13	-10.66	-12.94
CC12	-2.02	-2.80	-3.69	-4.44	-4.89	-5.33	-6.22	-7.56
CC13	-5.45	-7.55	-9.13	-9.31	-10.24	-11.17	-13.03	-15.82
CC14	-3.94	-5.45	-6.65	-6.95	-7.65	-8.34	-9.73	-11.82
CC15	-1.92	-2.66	-2.80	-2.22	-2.45	-2.67	-3.11	-3.78
CC16	-0.21	-0.30	-3.66	-2.05	-2.26	-2.46	-2.87	-3.49
CC17	-2.35	-3.25	-3.85	-3.82	-4.20	-4.58	-5.35	-6.49
CC18	-2.19	-3.03	-4.10	-5.12	-5.63	-6.14	-7.16	-8.70
CC19	-1.67	-2.31	-3.05	-3.73	-4.10	-4.47	-5.22	-6.34
CC20	-1.54	-2.13	-2.87	-3.60	-3.96	-4.32	-5.04	-6.11
CC21	-0.47	-0.65	-0.57	-2.37	-2.61	-2.85	-3.32	-4.03
CC22	1.04	1.44	0.57	0.88	0.97	1.06	1.24	1.50
CC23	0.67	0.93	2.10	5.01	5.51	6.01	7.01	8.52
CC24	-3.48	-4.82	-4.42	-4.72	-5.19	-5.66	-6.60	-8.02
CC25	-1.85	-2.56	-2.50	-3.82	-4.20	-4.58	-5.35	-6.49
CC26	-3.46	-4.80	-6.39	-7.65	-8.42	-9.18	-10.71	-13.01
CC27	-1.97	-2.73	-3.28	-4.70	-5.17	-5.64	-6.58	-7.99
CC28	-2.10	-2.91	-4.42	-4.42	-4.87	-5.31	-6.19	-7.52
Low (CC7)	-1.65	-2.28	-2.91	-3.37	-3.71	-4.05	-4.72	-5.74
Median	**-2.68**	**-3.72**	**-4.42**	-4.92	-5.41	-5.90	-6.88	-8.36
High (CC6)	-4.88	-6.76	-8.13	**-8.24**	**-9.06**	**-9.89**	**-11.53**	**-14.00**

Climate Change DO Impacts for all Modelled Scenarios, SWOX WRZ, DYCP Scenario								
	2025	2030	2035	2040	2045	2050	2060	2075
CC1	-5.17	-7.16	-9.23	-10.49	-11.54	-12.58	-14.68	-17.83
CC2	-4.68	-6.49	-8.72	-10.52	-11.57	-12.62	-14.72	-17.88
CC3	-6.31	-8.74	-10.67	-11.05	-12.15	-13.26	-15.47	-18.78
CC4	-3.02	-4.18	-5.32	-5.99	-6.59	-7.19	-8.39	-10.19
CC5	-3.47	-4.80	-6.34	-7.51	-8.26	-9.01	-10.51	-12.76
CC6	-4.88	-6.76	-8.13	-8.24	-9.06	-9.89	-11.53	-14.00
CC7	-1.65	-2.28	-2.91	-3.37	-3.71	-4.05	-4.72	-5.74
CC8	-3.41	-4.72	-5.74	-5.99	-6.59	-7.19	-8.38	-10.18
CC9	-3.68	-5.10	-6.04	-5.99	-6.59	-7.19	-8.39	-10.19
CC10	-4.62	-6.40	-7.98	-8.62	-9.48	-10.34	-12.06	-14.65
CC11	-3.91	-5.41	-6.85	-7.61	-8.37	-9.13	-10.66	-12.94
CC12	-2.02	-2.80	-3.69	-4.44	-4.89	-5.33	-6.22	-7.56
CC13	-5.45	-7.55	-9.13	-9.31	-10.24	-11.17	-13.03	-15.82

CC14	-3.94	-5.45	-6.65	-6.95	-7.65	-8.34	-9.73	-11.82
CC15	-1.92	-2.66	-2.80	-2.22	-2.45	-2.67	-3.11	-3.78
CC16	-0.21	-0.30	-3.66	-2.05	-2.26	-2.46	-2.87	-3.49
CC17	-2.35	-3.25	-3.85	-3.82	-4.20	-4.58	-5.35	-6.49
CC18	-2.19	-3.03	-4.10	-5.12	-5.63	-6.14	-7.16	-8.70
CC19	-1.67	-2.31	-3.05	-3.73	-4.10	-4.47	-5.22	-6.34
CC20	-1.54	-2.13	-2.87	-3.60	-3.96	-4.32	-5.04	-6.11
CC21	-0.47	-0.65	-0.57	-2.37	-2.61	-2.85	-3.32	-4.03
CC22	1.04	1.44	0.57	0.88	0.97	1.06	1.24	1.50
CC23	0.67	0.93	2.10	5.01	5.51	6.01	7.01	8.52
CC24	-3.48	-4.82	-4.42	-4.72	-5.19	-5.66	-6.60	-8.02
CC25	-1.85	-2.56	-2.50	-3.82	-4.20	-4.58	-5.35	-6.49
CC26	-3.46	-4.80	-6.39	-7.65	-8.42	-9.18	-10.71	-13.01
CC27	-1.97	-2.73	-3.28	-4.70	-5.17	-5.64	-6.58	-7.99
CC28	-2.10	-2.91	-4.42	-4.42	-4.87	-5.31	-6.19	-7.52
Low (CC7)	-1.65	-2.28	-2.91	-3.37	-3.71	-4.05	-4.72	-5.74
Median	**-2.68**	**-3.72**	**-4.42**	-4.92	-5.41	-5.90	-6.88	-8.36
High (CC6)	-4.88	-6.76	-8.13	**-8.24**	**-9.06**	**-9.89**	**-11.53**	**-14.00**

Climate Change DO Impacts for all Modelled Scenarios, KV WRZ DYAA								
Year	2025	2030	2035	2040	2045	2050	2060	2075
CC1	-2.38	-3.29	-5.74	-4.16	-4.58	-4.99	-5.83	-7.08
CC2	-2.40	-3.32	-5.17	-3.55	-3.91	-4.26	-4.97	-6.04
CC3	-2.15	-2.98	-5.29	-3.61	-3.97	-4.33	-5.06	-6.14
CC4	-1.76	-2.43	-4.24	-2.32	-2.56	-2.79	-3.25	-3.95
CC5	-1.76	-2.44	-4.57	-2.73	-3.00	-3.27	-3.82	-4.63
CC6	-1.93	-2.67	-4.51	-2.91	-3.21	-3.50	-4.08	-4.95
CC7	0.58	0.80	1.84	-1.94	-2.14	-2.33	-2.72	-3.31
CC8	-1.02	-1.41	-1.73	-2.70	-2.97	-3.25	-3.79	-4.60
CC9	-1.56	-2.16	-1.21	-2.40	-2.63	-2.87	-3.35	-4.07
CC10	-1.97	-2.73	-4.39	-3.03	-3.34	-3.64	-4.25	-5.15
CC11	-1.81	-2.51	-4.19	-2.40	-2.65	-2.89	-3.37	-4.09
CC12	-0.84	-1.16	-0.16	-2.51	-2.76	-3.01	-3.51	-4.26
CC13	-1.88	-2.60	-4.34	-2.94	-3.24	-3.53	-4.12	-5.00
CC14	-1.80	-2.49	-4.46	-2.59	-2.85	-3.11	-3.63	-4.40
CC15	1.20	1.66	5.81	2.55	2.81	3.06	3.57	4.34
CC16	3.37	4.67	-1.07	1.41	1.55	1.69	1.97	2.39
CC17	0.58	0.81	0.23	-1.18	-1.30	-1.42	-1.66	-2.01
CC18	-0.07	-0.10	-1.73	-0.07	-0.08	-0.09	-0.10	-0.12
CC19	0.31	0.42	2.55	-1.38	-1.51	-1.65	-1.93	-2.34
CC20	0.27	0.37	-1.31	-1.93	-2.12	-2.31	-2.70	-3.27
CC21	0.82	1.13	-2.40	-1.53	-1.69	-1.84	-2.15	-2.61
CC22	2.36	3.27	-0.83	1.30	1.42	1.55	1.81	2.20
CC23	5.65	7.83	9.65	6.39	7.02	7.66	8.94	10.86

CC24	-1.77	-2.45	-4.04	-2.62	-2.89	-3.15	-3.67	-4.46
CC25	-0.36	-0.50	-1.85	-2.12	-2.33	-2.54	-2.97	-3.60
CC26	-2.10	-2.90	-4.98	-3.23	-3.56	-3.88	-4.53	-5.50
CC27	-1.67	-2.32	-4.13	-2.18	-2.40	-2.62	-3.06	-3.71
CC28	0.02	0.03	0.50	-1.78	-1.96	-2.14	-2.49	-3.03
Low (CC7)	0.58	0.80	1.84	-1.94	-2.14	-2.33	-2.72	-3.31
Median	**-1.29**	**-1.78**	**-2.12**	-2.36	-2.60	-2.83	-3.30	-4.01
High (CC6)	-1.93	-2.67	-4.51	**-2.91**	**-3.21**	**-3.50**	**-4.08**	**-4.95**

Climate Change DO Impacts for all Modelled Scenarios, KV WRZ DYCP								
	2025	2030	2035	2040	2045	2050	2060	2075
CC1	-8.34	-11.55	-11.72	-9.00	-9.90	-10.79	-12.59	-15.29
CC2	-7.83	-10.85	-10.77	-7.98	-8.78	-9.58	-11.17	-13.57
CC3	-7.92	-10.96	-9.73	-7.89	-8.68	-9.47	-11.05	-13.41
CC4	-4.20	-5.81	-6.64	-7.16	-7.87	-8.59	-10.02	-12.17
CC5	-4.72	-6.53	-7.24	-7.46	-8.21	-8.95	-10.44	-12.68
CC6	-5.80	-8.02	-8.27	-7.09	-7.80	-8.51	-9.93	-12.06
CC7	-0.30	-0.42	-0.12	-2.35	-2.58	-2.82	-3.29	-3.99
CC8	-1.77	-2.45	-4.30	-6.50	-7.15	-7.80	-9.10	-11.05
CC9	-2.85	-3.95	-3.69	-3.99	-4.39	-4.79	-5.59	-6.78
CC10	-6.45	-8.93	-9.53	-6.78	-7.46	-8.13	-9.49	-11.52
CC11	-3.73	-5.17	-5.74	-7.14	-7.85	-8.57	-9.99	-12.13
CC12	-2.83	-3.91	-3.78	-3.58	-3.93	-4.29	-5.01	-6.08
CC13	-5.68	-7.86	-7.70	-6.76	-7.43	-8.11	-9.46	-11.49
CC14	-3.40	-4.71	-6.02	-7.18	-7.89	-8.61	-10.05	-12.20
CC15	0.10	0.14	2.13	-2.63	-2.89	-3.16	-3.68	-4.47
CC16	-3.40	-4.71	-4.43	-5.55	-6.10	-6.66	-7.77	-9.43
CC17	-2.08	-2.88	-3.23	-3.57	-3.93	-4.28	-5.00	-6.07
CC18	-3.50	-4.85	-4.57	-4.14	-4.56	-4.97	-5.80	-7.04
CC19	-1.00	-1.38	-1.79	-2.05	-2.26	-2.47	-2.88	-3.49
CC20	-2.85	-3.94	-3.65	-5.04	-5.55	-6.05	-7.06	-8.57
CC21	-3.38	-4.68	-5.81	-5.96	-6.55	-7.15	-8.34	-10.13
CC22	-2.23	-3.09	-2.50	-4.61	-5.07	-5.53	-6.46	-7.84
CC23	0.39	0.54	5.45	5.90	6.49	7.08	8.26	10.03
CC24	-4.10	-5.67	-7.35	-7.18	-7.90	-8.62	-10.05	-12.21
CC25	-2.55	-3.53	-5.47	-5.52	-6.07	-6.62	-7.72	-9.38
CC26	-6.14	-8.50	-8.66	-7.91	-8.70	-9.49	-11.08	-13.45
CC27	-4.78	-6.62	-7.81	-7.26	-7.98	-8.71	-10.16	-12.34
CC28	-1.98	-2.74	-3.82	-3.09	-3.40	-3.71	-4.33	-5.26
Low (CC7)	-0.30	-0.42	-0.12	-2.35	-2.58	-2.82	-3.29	-3.99
Median	**-3.40**	**-4.71**	**-5.61**	-6.23	-6.85	-7.47	-8.72	-10.59
High (CC6)	-5.80	-8.02	-8.27	**-7.09**	**-7.80**	**-8.51**	**-9.93**	**-12.06**

Climate Change DO Impacts for all Modelled Scenarios, SWA WRZ DYAA

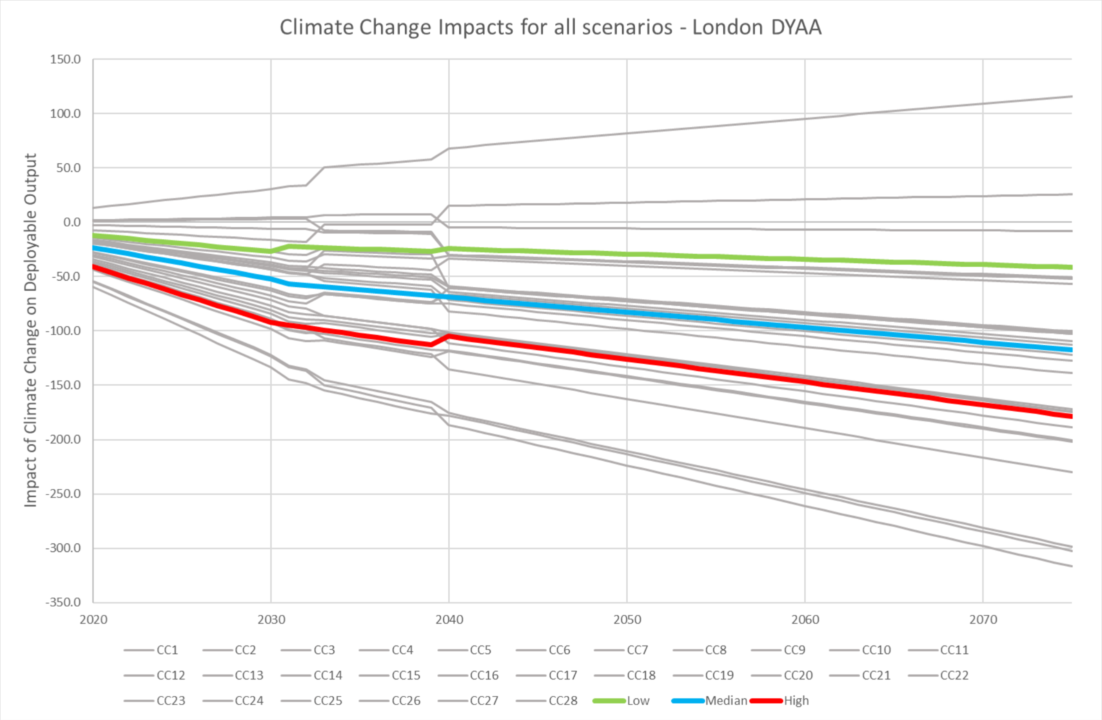
Year	2025	2030	2035	2040	2045	2050	2060	2075
CC1	-0.10	-0.13	-0.17	-0.19	-0.21	-0.22	-0.26	-0.32
CC2	-0.10	-0.14	-0.19	-0.18	-0.19	-0.21	-0.25	-0.30
CC3	-0.12	-0.17	-0.22	-0.23	-0.26	-0.28	-0.32	-0.39
CC4	-0.07	-0.10	-0.12	-0.15	-0.16	-0.18	-0.20	-0.25
CC5	-0.08	-0.11	-0.13	-0.13	-0.14	-0.15	-0.18	-0.21
CC6	-0.12	-0.17	-0.22	-0.22	-0.24	-0.27	-0.31	-0.38
CC7	-0.02	-0.03	-0.06	-0.07	-0.08	-0.08	-0.10	-0.12
CC8	-0.08	-0.11	-0.13	-0.13	-0.14	-0.16	-0.18	-0.22
CC9	-0.08	-0.11	-0.14	-0.15	-0.16	-0.18	-0.20	-0.25
CC10	-0.11	-0.15	-0.20	-0.19	-0.21	-0.23	-0.27	-0.33
CC11	-0.10	-0.14	-0.17	-0.18	-0.19	-0.21	-0.25	-0.30
CC12	-0.06	-0.08	-0.09	-0.09	-0.10	-0.11	-0.13	-0.15
CC13	-0.12	-0.16	-0.21	-0.22	-0.24	-0.26	-0.30	-0.37
CC14	-0.07	-0.10	-0.13	-0.14	-0.15	-0.16	-0.19	-0.23
CC15	-0.02	-0.03	-0.04	-0.05	-0.05	-0.05	-0.06	-0.08
CC16	0.01	0.01	0.03	-0.02	-0.02	-0.02	-0.02	-0.03
CC17	-0.03	-0.04	-0.07	-0.09	-0.09	-0.10	-0.12	-0.15
CC18	-0.04	-0.06	-0.08	-0.10	-0.11	-0.12	-0.14	-0.17
CC19	-0.01	-0.01	-0.02	-0.04	-0.04	-0.04	-0.05	-0.06
CC20	-0.03	-0.04	-0.05	-0.05	-0.05	-0.05	-0.06	-0.08
CC21	0.02	0.03	0.03	0.00	0.00	0.00	0.00	0.00
CC22	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03
CC23	0.03	0.04	0.06	0.07	0.08	0.08	0.10	0.12
CC24	-0.05	-0.07	-0.08	-0.10	-0.11	-0.12	-0.13	-0.16
CC25	-0.02	-0.03	-0.04	-0.05	-0.06	-0.06	-0.07	-0.09
CC26	-0.07	-0.09	-0.11	-0.12	-0.13	-0.15	-0.17	-0.21
CC27	-0.02	-0.03	-0.04	-0.08	-0.08	-0.09	-0.11	-0.13
CC28	-0.02	-0.03	-0.05	-0.07	-0.07	-0.08	-0.09	-0.11
Low (CC7)	-0.02	-0.03	-0.06	-0.07	-0.08	-0.08	-0.10	-0.12
Median	-0.05	-0.07	-0.09	-0.10	-0.11	-0.12	-0.14	-0.17
High (CC6)	-0.12	-0.17	-0.22	-0.22	-0.24	-0.27	-0.31	-0.38

Climate Change DO Impacts for all Modelled Scenarios, SWA WRZ DYCP								
	2025	2030	2035	2040	2045	2050	2060	2075
CC1	-0.09	-0.12	-0.13	-0.18	-0.20	-0.22	-0.25	-0.31
CC2	-0.10	-0.14	-0.14	-0.18	-0.20	-0.22	-0.25	-0.31
CC3	-0.13	-0.17	-0.19	-0.23	-0.25	-0.27	-0.32	-0.39
CC4	-0.07	-0.10	-0.09	-0.13	-0.14	-0.16	-0.18	-0.22
CC5	-0.07	-0.10	-0.12	-0.13	-0.14	-0.16	-0.18	-0.22
CC6	-0.12	-0.17	-0.18	-0.24	-0.26	-0.28	-0.33	-0.40
CC7	-0.01	-0.02	-0.03	-0.02	-0.02	-0.02	-0.03	-0.03
CC8	-0.07	-0.09	-0.08	-0.12	-0.13	-0.15	-0.17	-0.21
CC9	-0.07	-0.10	-0.09	-0.14	-0.15	-0.16	-0.19	-0.23
CC10	-0.10	-0.14	-0.15	-0.20	-0.22	-0.24	-0.28	-0.34

CC11	-0.10	-0.13	-0.14	-0.19	-0.21	-0.22	-0.26	-0.32
CC12	-0.03	-0.05	-0.07	-0.07	-0.08	-0.08	-0.10	-0.12
CC13	-0.11	-0.16	-0.17	-0.21	-0.23	-0.25	-0.30	-0.36
CC14	-0.07	-0.10	-0.09	-0.13	-0.14	-0.15	-0.18	-0.21
CC15	-0.02	-0.02	-0.05	-0.03	-0.03	-0.04	-0.04	-0.05
CC16	0.00	0.00	-0.02	-0.02	-0.02	-0.02	-0.02	-0.03
CC17	-0.05	-0.06	-0.10	-0.08	-0.09	-0.10	-0.11	-0.14
CC18	-0.06	-0.08	-0.13	-0.11	-0.12	-0.13	-0.15	-0.18
CC19	0.00	0.00	-0.02	-0.01	-0.01	-0.01	-0.01	-0.02
CC20	-0.03	-0.04	-0.07	-0.05	-0.06	-0.06	-0.07	-0.09
CC21	0.02	0.02	0.03	0.03	0.03	0.04	0.04	0.05
CC22	0.00	0.01	-0.01	0.02	0.02	0.02	0.02	0.03
CC23	0.02	0.03	0.08	0.11	0.12	0.13	0.16	0.19
CC24	-0.04	-0.06	-0.08	-0.09	-0.09	-0.10	-0.12	-0.15
CC25	-0.02	-0.02	-0.05	-0.04	-0.04	-0.04	-0.05	-0.06
CC26	-0.07	-0.09	-0.14	-0.13	-0.14	-0.15	-0.18	-0.21
CC27	-0.03	-0.04	-0.07	-0.08	-0.08	-0.09	-0.11	-0.13
CC28	-0.02	-0.03	-0.06	-0.06	-0.06	-0.07	-0.08	-0.09
Low (CC7)	-0.01	-0.02	-0.03	-0.02	-0.02	-0.02	-0.03	-0.03
Median	**-0.05**	**-0.07**	**-0.09**	-0.10	-0.11	-0.12	-0.13	-0.16
High (CC6)	-0.12	-0.17	-0.18	**-0.24**	**-0.26**	**-0.28**	**-0.33**	**-0.40**

U.134 The charts below show the same information, presented as timeseries on charts. Note that the grey lines are individual scenarios, the black line is the impact included in the preferred plan, and the coloured lines are the High, Median and Low scenarios.

U.135 The values are 1 in 100-year DO impacts until 2032, 1 in 200-year DO impacts from 2033 until 2039, and 1 in 500-year DO impacts from 2040 onwards.


Climate Change Impacts for all scenarios - London DYAA
Impact of Climate Change on Deployable Output
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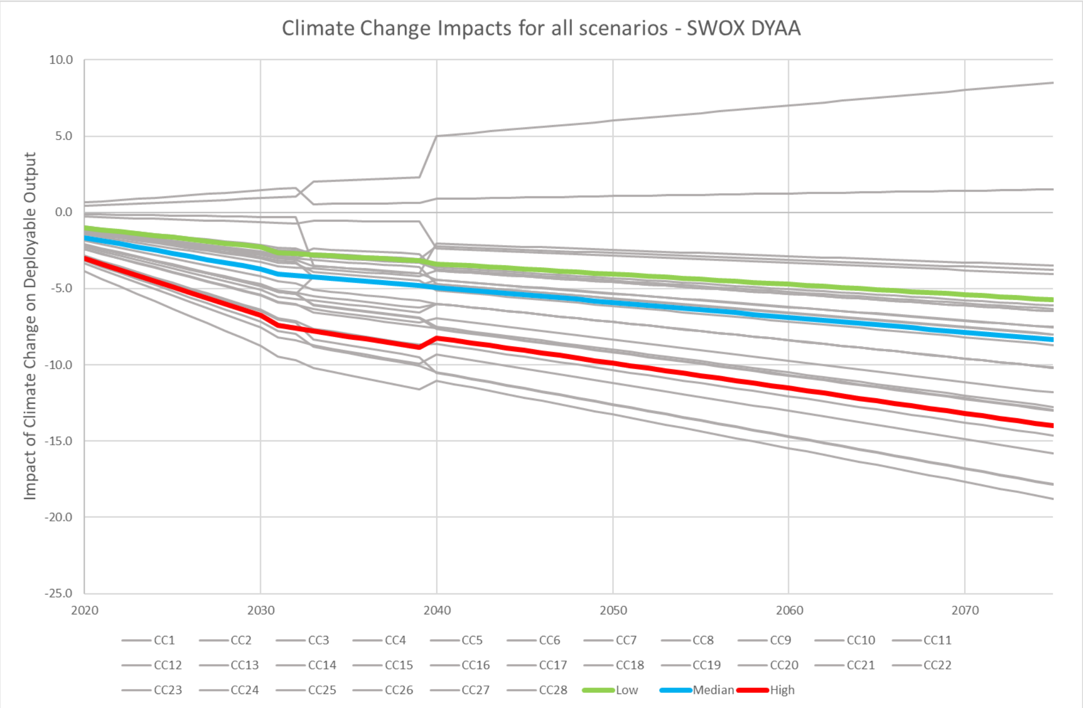
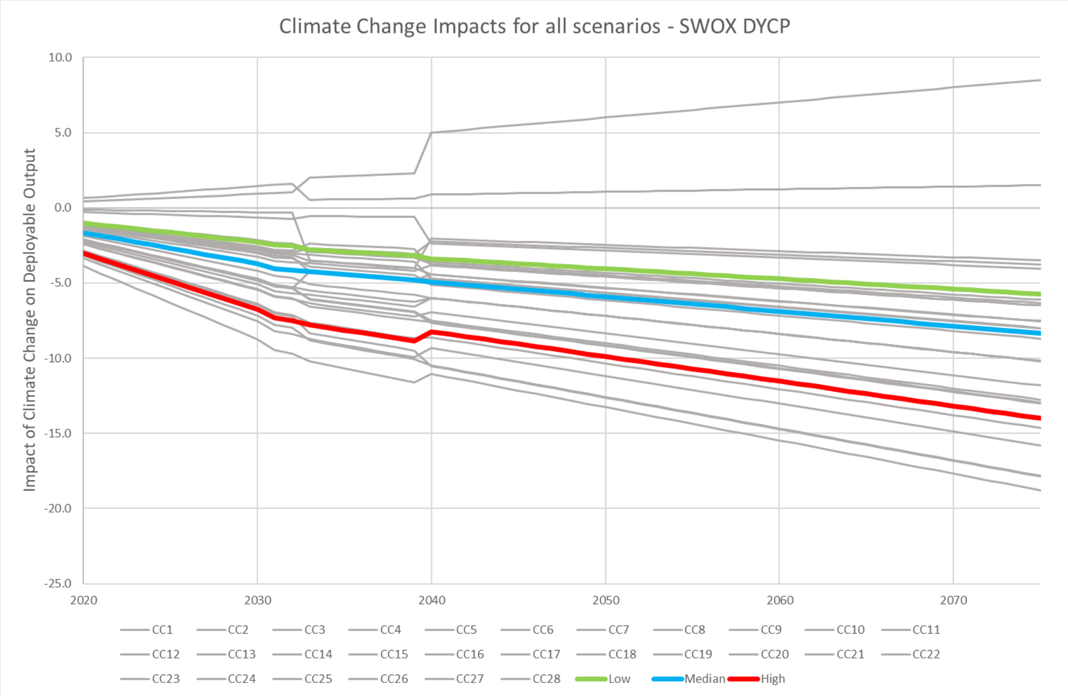
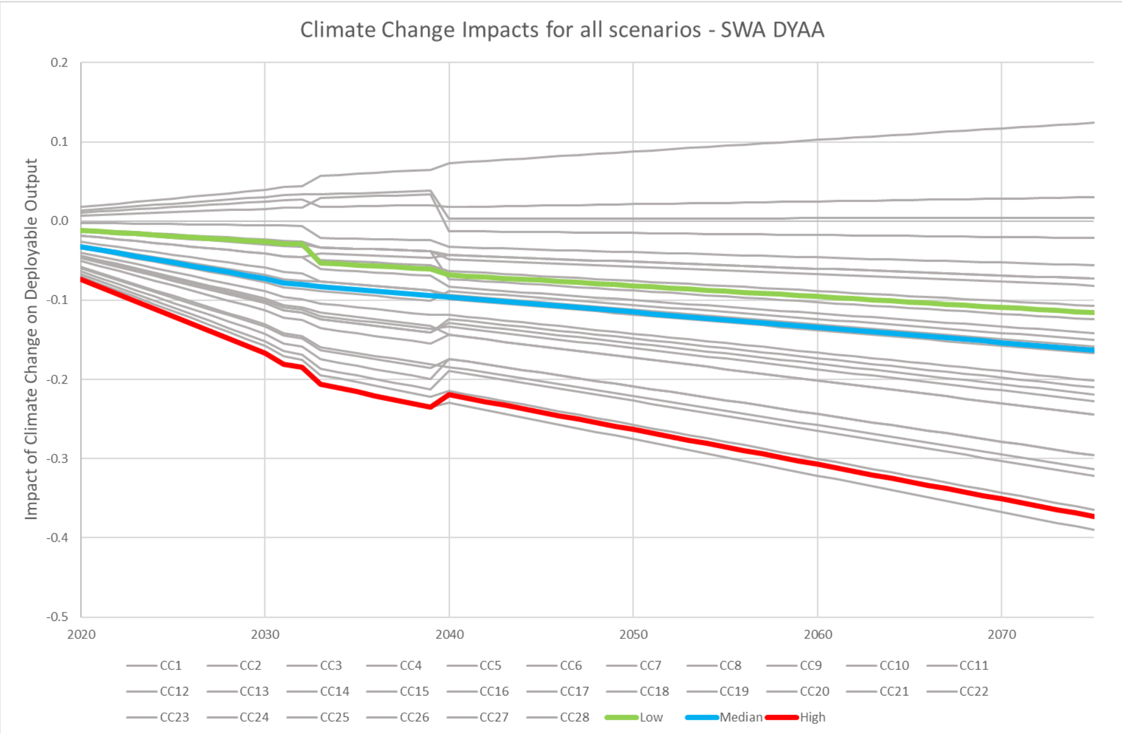
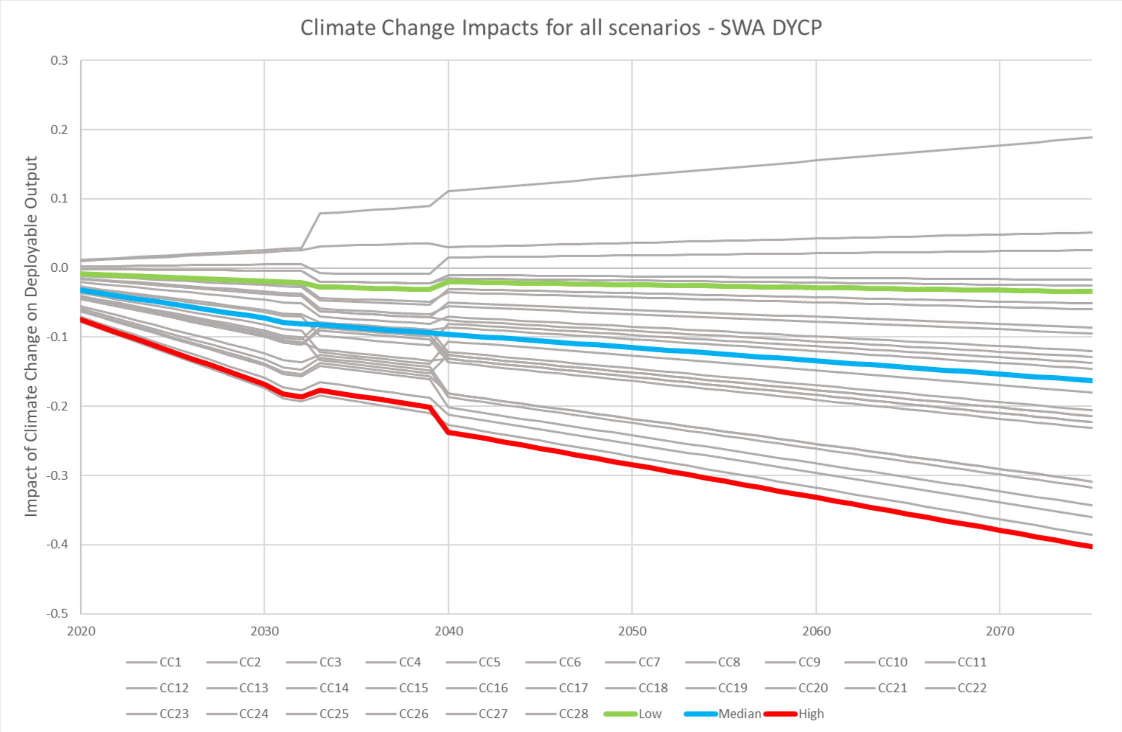
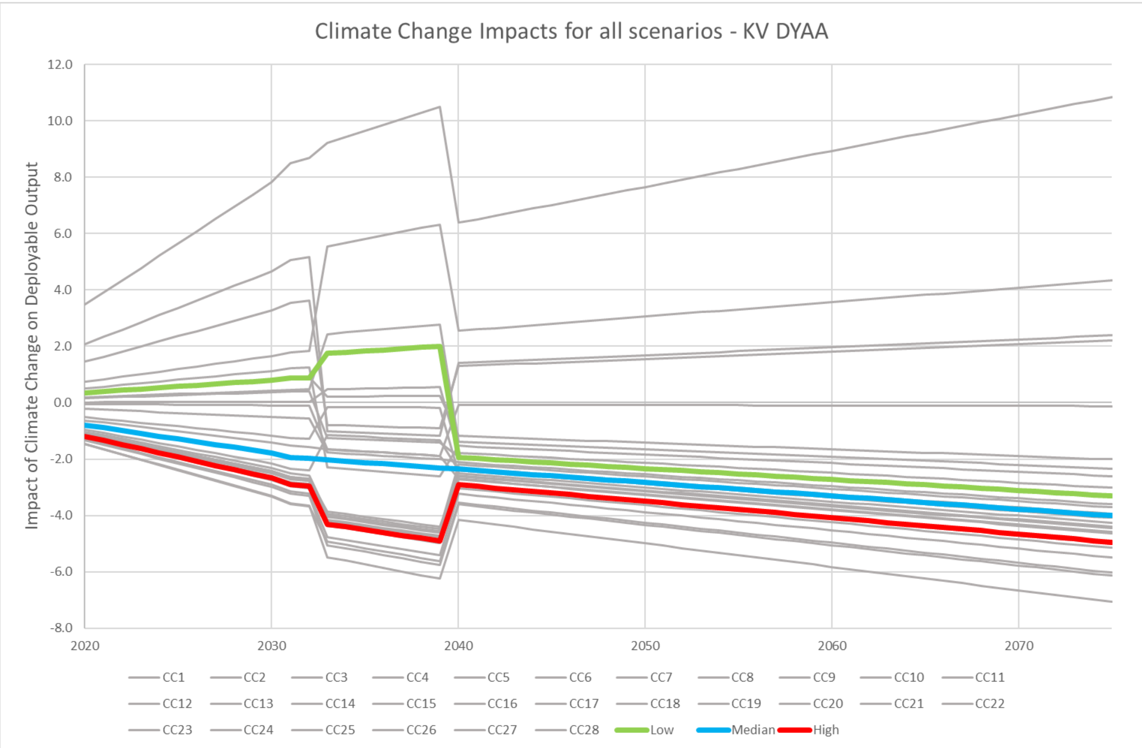
100.0
50.0
0.0
-50.0
-100.0
-150.0
-200.0
-250.0
-300.0
-350.0
2020
2030
2040
2050
2060
2070
CC1 CC2 CC3 CC4 CC5 CC6 CC7 CC8 CC9 CC10 CC11
CC12 CC13 CC14 CC15 CC16 CC17 CC18 CC19 CC20 CC21 CC22
CC23 CC24 CC25 CC26 CC27 CC28 Low Median High

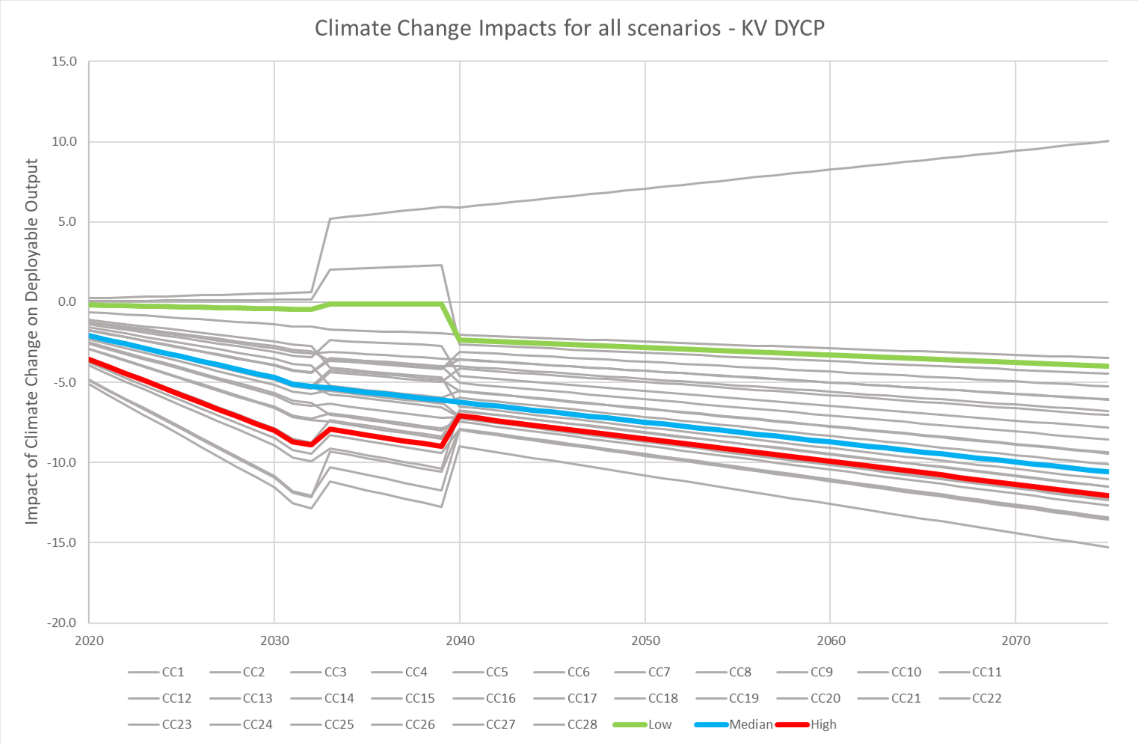

Climate Change Impacts for all scenarios - SWOX DYAA
Impact of Climate Change on Deployable Output
10.0
5.0
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
2020
2030
2040
2050
2060
2070
CC1 CC2 CC3 CC4 CC5 CC6 CC7 CC8 CC9 CC10 CC11
CC12 CC13 CC14 CC15 CC16 CC17 CC18 CC19 CC20 CC21 CC22
CC23 CC24 CC25 CC26 CC27 CC28 Low Median High


Climate Change Impacts for all scenarios - SWOX DYCP
Impact of Climate Change on Deployable Output
10.0
5.0
0.0
-5.0
-10.0
-15.0
-20.0
-25.0
2020
2030
2040
2050
2060
2070
CC1 CC2 CC3 CC4 CC5 CC6 CC7 CC8 CC9 CC10 CC11
CC12 CC13 CC14 CC15 CC16 CC17 CC18 CC19 CC20 CC21 CC22
CC23 CC24 CC25 CC26 CC27 CC28 Low Median High


Climate Change Impacts for all scenarios - SWA DYAA
Impact of Climate Change on Deployable Output
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
2020
2030
2040
2050
2060
2070
CC1 CC2 CC3 CC4 CC5 CC6 CC7 CC8 CC9 CC10 CC11
CC12 CC13 CC14 CC15 CC16 CC17 CC18 CC19 CC20 CC21 CC22
CC23 CC24 CC25 CC26 CC27 CC28 Low Median High


Climate Change Impacts for all scenarios - SWA DYCP
Impact of Climate Change on Deployable Output
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
2020
2030
2040
2050
2060
2070
CC1 CC2 CC3 CC4 CC5 CC6 CC7 CC8 CC9 CC10 CC11
CC12 CC13 CC14 CC15 CC16 CC17 CC18 CC19 CC20 CC21 CC22
CC23 CC24 CC25 CC26 CC27 CC28 Low Median High


Climate Change Impacts for all scenarios - KV DYAA
Impact of Climate Change on Deployable Output
12.0
10.0
8.0
6.0
4.0
2.0
0.0
-2.0
-4.0
-6.0
-8.0
2020
2030
2040
2050
2060
2070
CC1 CC2 CC3 CC4 CC5 CC6 CC7 CC8 CC9 CC10 CC11
CC12 CC13 CC14 CC15 CC16 CC17 CC18 CC19 CC20 CC21 CC22
CC23 CC24 CC25 CC26 CC27 CC28 Low Median High


Climate Change Impacts for all scenarios - KV DYCP
Impact of Climate Change on Deployable Output
15.0
10.0
5.0
0.0
-5.0
-10.0
-15.0
-20.0
2020
2030
2040
2050
2060
2070
CC1
CC2
CC3
CC4
CC5
CC6
CC7
CC8
CC9
CC10
CC11
CC12
CC13
CC14
CC15
CC16
CC17
CC18
CC19
CC20
CC21
CC22
CC23
CC24
CC25
CC26
CC27
CC28
Low
Median
High

Annex 2: Changes Between Plan Iterations

Changes between dWRMP24 and rdWRMP24:

- We have provided more detailed description of the scenarios adopted and how we have ensured that the full range of UKCP18 data is represented, in order to mitigate concerns that our plan is based on an overly pessimistic climate change scenario.
- We have provided an enhanced description of the way that climate change uncertainty has been considered
- We have considered the CCRA3 study on water availability
- We revised our Deployable Output modelling for the Kennet Valley WRZ (see Appendix I for details), and have aligned the climate change modelling for Kennet Valley WRZ with this revised approach
- We revised our Deployable Output modelling for the SWOX WRZ Dry Year Critical Period scenario, and have aligned the climate change impact forecast with this revised approach

Changes between rdWRMP24 and final WRMP24

- We have included further tabulated and graphed information in line with Environment Agency requests

Thames Water