Revised Draft Water Resources Management Plan 2024

Section 4 – Current and Future Water Supply

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Background and Introduction

Our water supplies are derived from a combination of surface water (from rivers) and groundwater (underground water holding rock formations, known as aquifers).

In this section we describe the amount of water which is currently available for water supply, Deployable Output (DO), and how this has been assessed. We also describe how we have made allowances for climate change and outage in assessing our Water Available For Use (WAFU).

The methods that we have used in assessing all components of the supply forecast are aligned with those used across Water Resources South East (WRSE).

Changes made between dWRMP24 and rdWRMP24:

- In order to ensure that our WRMP is based on up-to-date data, we have updated our supply forecast using data which aligns with the AR22 Annual Review submission for outage allowance, process losses, and source deployable outputs
- We have made improvements to the calculation of Deployable Output in the SWOX WRZ (Swindon and Oxfordshire Water Resource Zone) (Dry Year Critical Period (DYCP) scenario) and Kennet Valley (both Dry Year Annual Average (DYAA) and DYCP)
- We have provided an expanded description of the Deployable Output contribution of the Gateway desalination plant across the planning period
- 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

4.1 Water Resources planning is based around the calculation of a supply-demand balance. We calculate the amount of water that we could reliably supply during a drought and compare this against the demand for water that we anticipate, including a buffer between supply and demand to account for uncertainty, called Target Headroom. In this section, we describe how we have determined our supply capability during drought periods, and how we forecast our supply capability will change over time.

4.2 Our baseline supply capability (baseline referring to supply capability without new sources of water) is forecast to be diminished over time, with the main cause of reduction in supplies being climate change.

4.3 In this section we describe the calculation of each of the building blocks of our supply forecast. This begins with a description of the calculation of our supply capability under idealised conditions and excluding climate change impacts, known as Deployable Output (DO). We then detail how we have accounted for short-duration interruptions to source availability, known as outages, and how we have calculated an appropriate allowance to account for outage events. We then explain how we have calculated the losses of water that we expect to experience when treating water (for example, water we use for washing filters) during drought events. We then describe how we account for the impacts that climate change may have on our supply capability during drought events. We also detail the imports and exports from/to other companies and between our own water resource zones (WRZs) and constraints which prevent us from distributing water around our network (network constraints). We then use these building blocks to build a supply forecast, with Water Available For Use (WAFU) being the key output from this chapter. WAFU is calculated using the following formula:

WAFU = Deployable Output – Climate Change Impacts – Constraints – Outage – Exports + Imports

4.4 This section contains a summary explanation of the work undertaken in producing the supply forecast, with further detail presented in technical appendices I (Deployable Output), J (Outage), K (Treatment Capability and Process Losses), and U (Climate Change).

Where we get our Water Supplies

4.5 Our supply area is split into two main regions, London and the Thames Valley. London is supplied predominantly by surface water abstractions into large reservoirs in west and north London (around 70-80%) with groundwater sources in south east and north London also providing supply. The Thames Valley region is supplied mainly by groundwater sources (around 70%), with surface water abstractions in Reading, Guildford, and near Oxford also providing supply.

4.6 All of our supply area falls within the Thames Basin, the largest river basin in south east England. The annual average rainfall for the Thames Basin is 738 mm considering the period of record from 1883-2018. This is substantially less than the average for England and Wales of 919 mm (based on the period 1883-2012)[1]. Of the water that falls, around two thirds is lost to either evaporation or transpiration of plants, with around one third of precipitation remaining as ‘effective’ rainfall.

4.7 We have a total of six WRZs: London; Swindon and Oxfordshire (SWOX); Slough, Wycombe and Aylesbury (SWA); Kennet Valley (covering Reading, Newbury, Hungerford and Marlborough); Guildford; and Henley. In a dry year we supply around 2,000 Ml/d in the London WRZ, and 600 Ml/d across our other WRZs.

London

4.8 The London WRZ is a large, conjunctive use zone, involving both surface water and groundwater abstraction. The zone is supplied mainly by surface water resources, whereby water from the River Thames and River Lee is abstracted into large reservoirs in west London and north east London, respectively, before treatment at water treatment works (WTW) and subsequent distribution. There is around 165,000 Ml of storage in west London spread across 10 reservoirs, with the largest reservoir having a capacity of around 38,000 Ml and the smallest a capacity of around 2,000 Ml. Some of the water abstracted from the River Thames in west London is transferred to north east London via the ‘Thames-Lee Tunnel’ which can transfer up to 400 Ml/d from the Thames to the Lee Valley Reservoirs. There is approximately 37,000 Ml of storage in the Lee Valley Reservoirs,

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[1] Environment Agency, 2014, Average Temperature and Total Rainfall in England and Wales: 1845 to 2012, https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/141789/iwfg01-temp-rainfall-201301.csv/preview

spread across nine raw water reservoirs, the largest having a capacity of around 16,500 Ml and the smallest around 600 Ml.

4.9 Supply in south east London is dominated by groundwater sources. There are around 30 sources across this area, which together supply up to around 300 Ml/d, and which individually supply from less than 1 Ml/d to over 30 Ml/d.

4.10 In addition to these baseload sources, we also have several 'Drought' sources which are operated according to the Lower Thames Operating Agreement, detailed in the next section. The function of these drought sources is either to increase flows in the River Thames, i.e. the Environment Agency's West Berkshire Groundwater Scheme (WBGWS) or the New River, i.e. North London Artificial Recharge Scheme (NLARS), or to supplement supplies directly, e.g. Thames Gateway Desalination Plant, such that we do not draw down our surface water storage reservoirs as quickly.

4.11 The Thames Water Ring Main allows us to distribute water across London, making London a single WRZ. In general, water is transferred eastwards from west London, with more water being produced than is needed for supply in west London and less water being produced than is needed for supply in south east London.

Swindon and Oxfordshire (SWOX)

4.12 The SWOX WRZ is a conjunctive use zone, with approximately 60% of its supplies coming from groundwater sources and around 40% from surface water.

4.13 The zone can be split into three 'sub-zones' which have major transfers between them:

- South Oxfordshire (area stretching from Goring to Chinnor): groundwater only from mainly chalk aquifer sources; produces more water than is needed for local demand
- North Oxfordshire (Oxford, Banbury, Witney, Farringdon): surface water only – abstraction from the River Thames into Farmoor Reservoir, treated at Farmoor and Swinford WTWs; can produce more water than is needed for local demand, but during drought output is managed to conserve reservoir storage
- Swindon & Cotswolds: groundwater only, mainly from Cotswolds Oolitic Limestone sources and chalk sources; produces less water than is needed for local demand

4.14 In general, water is transferred northwards and westwards from South Oxfordshire, and northwards and westwards from Farmoor. The large transfers that are feasible between these sub-zones allow the zone to be considered a single WRZ.

Slough, Wycombe and Aylesbury

4.15 The water resources of the Slough, Wycombe and Aylesbury (SWA) zone are derived from twelve groundwater sources. There are no surface water sources in the SWA zone. The bulk of the abstraction in the WRZ is from sources located near to the River Thames, with significant reductions in abstraction licence having been made elsewhere in the Chilterns for the benefit of rivers such as the Wye and Chess. Water is transferred northwards from sources near the River Thames around Slough and Marlow, through the zone, to Wycombe and to Aylesbury.

Kennet Valley

4.16 The resources of the Kennet Valley WRZ are predominantly groundwater derived from confined and unconfined chalk aquifers; some of the groundwater sources in the zone have yields which are dependent on antecedent weather conditions. There is also a significant run-of-river (RoR) surface water abstraction from the River Kennet in Reading, which is potentially highly vulnerable to drought conditions.

Guildford

4.17 The Guildford WRZ is supplied by groundwater from the chalk and Lower Greensand aquifers and one surface water source which abstracts from both the River Wey and River Tillingbourne. The vast majority of the groundwater sources in the WRZ are assessed not to be drought sensitive.

Henley

4.18 The water resources of the Henley WRZ are derived from three groundwater sources abstracting from the unconfined chalk of the South West Chilterns and the lower River Loddon catchment. There is nitrate contamination of groundwater at the Sheeplands source which is managed by treatment as well as blending with groundwater from the Harpsden source under an aggregate abstraction licence.

4.19 There are no surface water sources in the Henley WRZ, and the yields of the groundwater sources in the zone are not deemed to be drought sensitive.

Key Guidance and Methodology Documents

4.20 The different components of our supply forecast are calculated according to prescribed methodologies.

4.21 The primary guidance documents referred to in the development of our supply forecast are:

- Environment Agency, April 2022, Water Resources Planning Guideline: This document sets out the key requirements for all aspects of the WRMP, including the development of our supply forecast
- Environment Agency, March 2021, Water Resources Planning Guideline supplementary guidance – 1 in 500: One of the key changes to guidance associated with the supply forecast is that water companies should ensure that we provide a '1 in 500-year' level of resilience to drought events by 2039. In order to do this, we need to determine what our supply capability is under '1 in 500-year' drought conditions. This document sets out supplementary guidance on how we should assess a '1 in 500-year' DO
- Environment Agency, March 2021, Water Resources Planning Guideline supplementary guidance – Stochastics: With key historical weather records being generally a hundred years or less in length, the determination of a '1 in 500-year' DO involves consideration of drought events which have not occurred during the historical record. This supplementary guidance note sets out how 'stochastic' datasets can be used to help define a '1 in 500-year' DO
- 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 – Outage: This supplementary guidance document sets out in more detail the methods that we should follow in outage calculation

4.22 In addition to Environment Agency (EA) guidance documents, there are other important documents that we use when assessing different components of our supply forecast. These are outlined in the technical appendices.

4.23 An important change between WRMP19 and WRMP24 has been the focus on regional groups in water resources planning. 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 calculation of different components of our supply forecast. These include:

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

Key Changes Between WRMP19 and WRMP24

4.24 There have been a number of changes that have taken place between the publication of our WRMP19 and WRMP24 which have influenced our approach to determining different components of our supply forecast. These include changes in guidance, new methods, and changes in our understanding/operation of existing sources.

Requirement to Determine a '1 in 500-year' Deployable Output

4.25 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. In this circumstance, 'failure' is defined as a need for emergency drought orders.

4.26 Water companies have historically assessed the capability of their sources subject to a 'worst historical' drought condition, i.e. the Source Deployable Output (SDO) or DO of a source/group of sources would have been calculated such that the yield of the source/group of sources is that which would have been feasible during the 'worst' drought on record. The benefit of a 'worst historical' assessment is that this involves the use of a measured record (i.e. a weather/flow/groundwater level record in which we can be fully confident), but the downside is that it limits assessment of supply capability to a small number of events, meaning that potential system vulnerabilities may be omitted from consideration). EA guidance accepts that the determination of a '1 in 500-year' DO figure involves a large amount of uncertainty, particularly considering the non-stationary climate that now exists due to the influence of greenhouse gas emissions, but that the aim of the '1 in 500-year' standard is to ensure that droughts that are significantly more severe than those experienced historically are considered.

4.27 The concept of a '1 in 500-year' (sometimes written 1:500) DO can be somewhat confusing. The '1 in 500' DO for a WRZ will be less than or equal to the '1 in 200' DO, which will in turn be less than the '1 in 100' DO. This is because the drought event being considered in the '1 in 500' condition will be more severe than that considered in the '1 in 200' condition, and so on.

Emphasis on 'System Response' in Calculation of Deployable Output

4.28 This is not an explicit change to requirements set out in the WRPG but is a significant change in emphasis. The WRPG supplementary guidance on 1 in 500 states:

> *"You should define your '1 in 500' supply deployable output using your system response. Your system should be defined at the water resources zone level"*

4.29 The 'system response' approach is specified to contrast against other approaches to determining extreme drought events, such as defining drought based on rainfall or similar. Using system response metrics is intended to better reflect the influence of drought events on outcomes (supply capability), rather than focussing on inputs (rainfall). In addition, the use of the word 'system' alongside response highlights a preference towards consideration of water resource systems, rather than a focus on individual sources. This is reflected in the approaches that we have applied.

Changes and Clarifications Regarding Inclusions and Exclusions in the Calculation of Deployable Output

4.30 The EA has clarified how specific factors should be included or excluded within the assessment of DO. Compared to WRMP19, the most significant clarification/change to reporting of DO is that the Baseline DO figure presented should not include contributions from any demand or supply drought measures. This means that our reported Baseline DO figure will exclude benefits associated with the imposition of Temporary Use Bans (TUBs), Non-Essential Use Bans (NEUBs), and media campaigns. Benefits from demand restrictions associated with our stated Levels of service will be included as options (i.e. they will be excluded from the Baseline supply-demand balance but will be included within our final supply-demand balance). Throughout this document, it is important to ensure that 'like-for-like' comparisons between WRMP19 and WRMP24 DO figures are made. We have not historically included supply-side drought permits or orders within baseline DO, reflecting the uncertainty in these permits and orders being granted, and so this aspect does not reflect a change for us.

4.31 In addition to the changes highlighted as being necessary by the Environment Agency, we have also decided to make one change to the presentation, but importantly not the calculation, of Deployable Output. We have an export from our London WRZ to Essex & Suffolk (E&S) Water – on average, up to 91 Ml/d of water is transferred from our Lee Valley Reservoirs to supply E&S Water's customers in Essex. A transfer as large as this has important 'system response' consequences, and so it is important that we include this transfer within our DO modelling. However, to facilitate transparency and understanding, we wish to explicitly highlight the volume of the transfer to E&S in our supply forecast, including the changes that will be made to this agreement over the course of the planning period.

UKCP18 Projections

4.32 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 and so we have used UKCP18 datasets in our WRMP24 supply forecast. 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. Further details can be found in Appendix U.

Treatment of Within-Region Transfers

4.33 For our WRMP19, we treated a number of transfers as part of our baseline. Notable examples included an inter-zonal transfer between our Slough, Wycombe and Aylesbury (SWA) and Swindon and Oxfordshire (SWOX) zones, and exports from our London WRZ to Affinity Water. The WRSE regional approach to planning allows WRSE to consider whether these transfers would be part of a 'Best Value Plan' (e.g. should Affinity be in a position of surplus, we may be able to cease the transfers to them during dry periods). As such, transfers within the WRSE region have not been considered as part of our baseline for WRMP24, and are instead considered as options. The WRSE model is able to assign minimum values for transfers in order that transfers with associated contracts can be properly considered.

WRSE-Aligned Methods for Outage Calculation

4.34 An aligned method for outage calculation has been developed through the WRSE regional group. This has resulted in the development of an aligned approach to the screening of outage events and subsequent calculation of outage allowance.

4.35 For WRMP19 we calculated an Outage Allowance figure for each WRZ and then applied these same figures in both DYAA and DYCP Planning scenarios. The figures calculated were more appropriate for use in the DYAA planning scenario and so, through the WRSE outage project, we have moved to consideration of an Outage Allowance to be used in the DYCP planning scenario.

Deployable Output

4.36 Deployable Output is a measure of the supply capability of a water resource system under specified (generally drought) conditions. The constraints considered in the calculation of DO are:

- Hydrological Yield
- Licensed Quantities
- Level of Service
- Treatment Constraints
- Water Quality
- The Environment, via Licence Constraints
- Pumping Assets and Raw Water Mains
- Abstraction Well, Borehole, Spring and Aquifer Characteristics

4.37 The water that we supply to our customers comes from a variety of different sources, including boreholes, wells, springs, ‘run-of-river’ (RoR) surface water abstractions, pumped surface water abstraction from rivers into reservoirs, and a desalination plant. DO can be calculated at the level of individual sources, leading to the calculation of source Deployable Output (SDO) values, or at the WRZ level. In some cases, groundwater and surface water sources operate within the same WRZ and, if operated in-combination, can bring about a larger WRZ DO than the sum of individual SDOs; such combined operation is known as conjunctive use. Deployable Output is calculated subject to prescribed methodologies, both at the source level, and at the WRZ level.

4.38 In WRMP19 our DO assessment was primarily based on an assessment of the supply capability that we would expect if the worst drought in the historical record were to happen again, otherwise known as a ‘worst historical’ DO assessment. We supplemented this with a ‘stochastic’ DO assessment for the London WRZ only, which investigated how our supply capability would be impacted by more extreme drought events. For WRZs other than London we carried out Extreme Value Analysis to investigate the potential impact of more extreme droughts.

4.39 The requirement to conduct analysis to determine a ‘1 in 500-year’ DO, the focus on ‘system response’ in the determination of this DO, and the increased focus on the WRSE Regional Group all necessitated significant change from our previous ‘worst historical’ DO analyses.

4.40 Our vulnerability assessment has highlighted that the London and SWOX zones are high risk and require the application of complex methods. Consequently, in order to ensure that we have applied appropriate methods in determining a ‘1 in 500-year’ DO for these complex zones, and to align with WRSE methods of DO assessment, our DO assessment is based on hydrological, hydrogeological and water resources modelling using ‘stochastic’ datasets.

Deployable Output

4.41 Figure 4-1 shows the modelling processes that we have followed when calculating DO. WRSE commissioned Atkins to produce 'Stochastic' weather datasets. These weather datasets were used as inputs to hydrological and hydrogeological models; these models produced river flows and timeseries of groundwater yields respectively. Timeseries of river flow and groundwater source yield were used as inputs to 'Pywr'[2] models developed for the different WRZs as part of the WRSE Regional Simulation Modelling project, along with non-weather dependent inputs, such as WTW capabilities and yields for GW sources deemed not to be drought sensitive. The WRSE Groundwater Framework was applied to determine which groundwater sources should be subject to modelling and which could reasonably be assumed to be represented as 'static' yields. This section includes descriptions of the generation of stochastic weather datasets and how water resource model outputs were converted into DO.

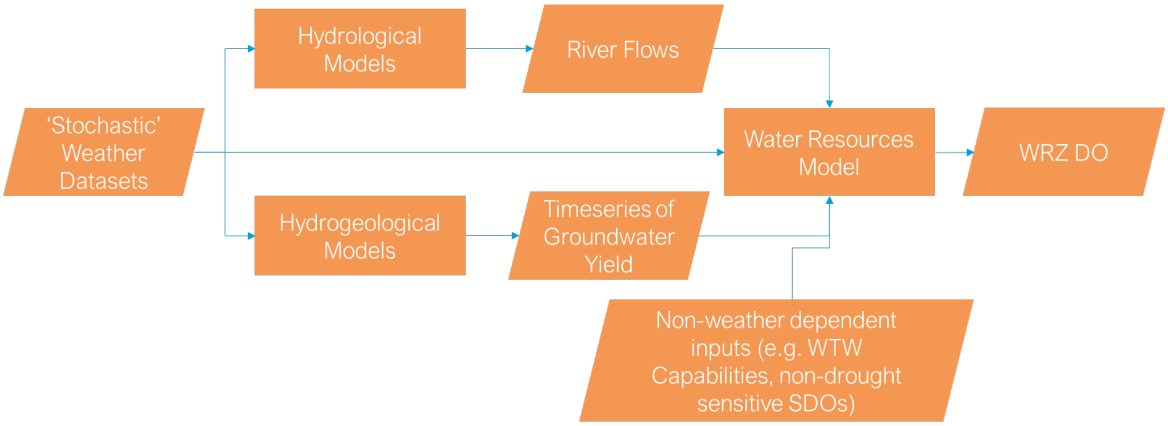

Figure 4-1: High-level Flow Chart of DO Calculation Process

Stochastic Weather Datasets

4.42 For more detail on stochastic weather datasets, please see Appendix I, the Atkins report for WRSE on the generation of stochastic weather datasets[3], and the WRSE method statement on stochastic datasets[4].

4.43 The weather datasets used as inputs to hydrological, hydrogeological and water resources models are key in determining DO. With reliable, granular datasets for rainfall and potential evapotranspiration (PET) needed for water resources modelling generally only available for no more than 100 years, the consideration of '1 in 500-year' drought events requires the application of statistical and/or modelling techniques.

4.44 The need to consider droughts more severe than those which have occurred historically has driven the UK water industry to broadly adopt a 'stochastic' weather generation process in drought risk assessment.

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[2] Tomlinson, J.E., Arnott, J.H. and Harou, J.J., 2020. A water resource simulator in Python. Environmental Modelling & Software. https://doi.org/10.1016/j.envsoft.2020.104635

3 Atkins, 2020, Regional Climate Data Tools, https://www.wrse.org.uk/media/ok1mtsoq/wrse_file_1338_regional-climate-data-tools.pdf

4 WRSE, 2021, Method Statement: Stochastic Climate Datasets

4.45 The use of the term 'stochastic' references the partially random nature of rainfall. Rainfall volumes cannot be predicted solely based on climate variables, but rainfall volumes are influenced by climate variables. The stochastic datasets that have been generated are intended to represent different versions of what historical weather timeseries 'could' have been, given the underlying climate drivers. A statistical model has been trained which links climate drivers to monthly rainfall volumes, considering random and non-random processes.

4.46 The stochastic datasets represent 400 different versions of what rainfall and PET could have been over a baseline period (1950-97[5]). The 400 'replicates' of 48 years give weather datasets which are deemed to represent a total of 19,200 years but this is not representative of a continuous 19,200-year sequence, rather it is 400 48-year sequences.

Groundwater Source Yield Assessment

4.47 Groundwater source yields are one of the key inputs in the calculation of Deployable Output. In previous WRMPs we have calculated single 'DYAA' and 'DYCP' SDO values for individual sources, based on observation and hindcasting of groundwater levels and application of groundwater level-yield relationships to establish DOs. Further detail on our groundwater source yield assessment methods can be found in Appendix I.

4.48 While the methods applied were advanced and gave robust DO values, they could not necessarily be used in isolation to determine '1 in 500-year' system-response DO values at the WRZ level. Additionally, in our water resources modelling we have historically used 'static' DO values when establishing our WRZ DOs, meaning that we have not previously considered the potentially dynamic response of groundwater source yields when determining DO. A more dynamic consideration of groundwater source yields was deemed a priority in the development of the WRSE DO modelling approach, and so the Groundwater Framework was developed to prioritise those sources for which dynamic modelling of groundwater source yield would be valuable. Hydrogeological modelling was then carried out for these sources in order to provide groundwater yield timeseries for inclusion in Pywr modelling.

4.49 The WRSE Groundwater Framework[6] proposed a standard assessment approach to characterise groundwater sources. It also suggested the most appropriate modelling approach for representation of groundwater source yield or DO in the Regional System Simulator (RSS, referred to as the WRSE Pywr model) developed in Pywr, taking into account need, data availability and timescale. Appendix I gives further details of our application of the WRSE groundwater framework and the methods used to provide inputs to the RSS.

4.50 Broadly, the Groundwater Framework identified that some of our sources should be represented as yield timeseries inputs, while for other sources DO values as used in WRMP19 would suffice. For those sources where a timeseries of yield had been derived, the yield timeseries was used as an input to the Pywr modelling. For those sources where yield timeseries had not been deemed necessary, the DO values calculated were used as inputs to the Pywr modelling.

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[5] Adopted in line with EA Guidance which references of a stationary precipitation record in Oxford until 2010, Sun et al., 2018 assessed stationarity in the Oxford precipitation record from 1767 to 2010.

[6] WRSE, 2021, Method Statement: Groundwater Framework, https://www.wrse.org.uk/media/zbmazk2c/method-statement-groundwater-framework-aug-2021-1.pdf

Hydrological Modelling

4.51 Flows are a key input when determining DO of a water resources system in which surface water abstractions are present.

4.52 At WRMP19 we used two water resources/hydrological modelling tools. The first of these, Thames Water's existing water resources model (WARMS2), takes several rainfall timeseries and PET timeseries as well as two observed flow timeseries as inputs, and contains rainfall-runoff models directly within the water resources model. The second model used for WRMP19 was Interactive River Aquifer Simulation model (IRAS) – this model was used only for London and used semi-naturalised flow inputs (flows in the River Thames which have had artificial influences between Windsor and Teddington removed) from a lumped parameter model for the Thames at Teddington as a direct input. If WARMS2 was fast enough to be used with stochastic weather datasets, we would use this model as our only water resources model due to its detail, its semi-distributed hydrological modelling approach, and the model's ability to dynamically consider the impact of abstractions and discharges.

4.53 The WRSE Pywr Model does not directly contain rainfall-runoff models due to the model speed penalty that this would entail and the requirement for the model to be used with around 20,000 years' worth of input data. As such, hydrological modelling has been done outside our water resources model, with timeseries of flow used as inputs to our water resources model. New models and approaches were used to provide the hydrological inputs required, further details of which can be found in Appendix I.

Water Resources Modelling

4.54 When producing WRMP19, we made use of two water resources models:

- WARMS2, built in Aquator – a detailed model of the whole River Thames catchment incorporating rainfall-runoff models. This model is reliable and detailed, but does not run quickly enough for us to use it to conduct 'full stochastic' DO analyses, as is required in the calculation of a '1 in 500-year' DO.
- IRAS – a heavily simplified model of the London supply system, not incorporating the rest of the River Thames catchment. Rainfall-runoff models were not included (i.e. flows were an input to this model). This model is fast but is not detailed and the lumped nature of the hydrological inputs meant that its calibration was not sufficiently good for results from IRAS to be used in isolation.

4.55 In producing WRMP24 we have made use of newly developed Pywr models, which were developed as part of the WRSE Regional Simulation Modelling project. For TW, the aim of these models is that they would bridge the gap between WARMS2 and IRAS, being sufficiently detailed, sufficiently fast and that they could be used to determine a '1 in 500-year' DO.

4.56 The 'WRSE Regional Simulation Model' (another name for the WRSE Pywr model) is not a single model, but rather a collection of sub-models which can be coupled and run as larger 'sub-regional' models (Figure 4-2). For example, a sub-model exists for the Henley WRZ which can be run on its own, but this can be coupled with other TW models (and Affinity sub-models) to give a model for the River Thames catchment as a whole. The ability to consider sub-regional or whole regional solutions was considered important given the increased standing of Regional Groups in the WRMP process, and for TW in particular due to the large multi-zonal and multi-company solutions being considered by the company (e.g. Severn-Thames Transfer, South East Strategic Reservoir Option, Thames to Southern Transfer, Thames to Affinity Transfer).

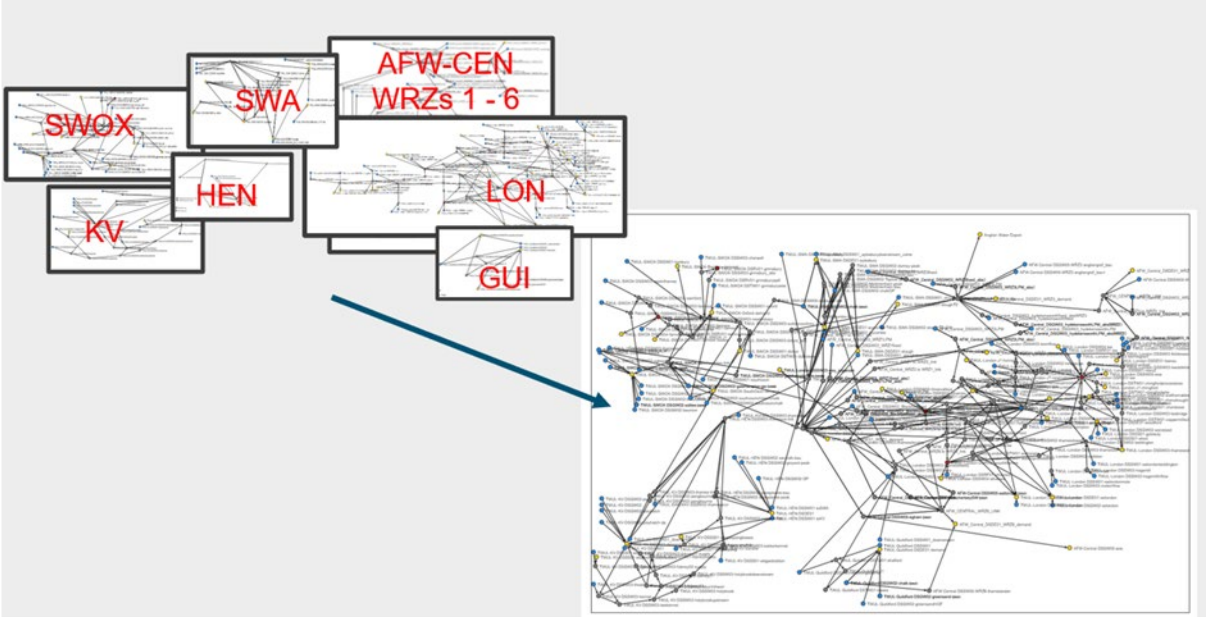

Figure 4-2: WRSE North Pywr Model Schematic

4.57 The Thames Water sub-models were built as relatively detailed simplifications of the representation of the TW supply system, providing a moderately simplified version of the WARMS2 model. As an example of the level of simplification included, the SWOX system is represented in WARMS2 as having 10 demand centres (Banbury, Oxford, Faringdon, Witney, Wantage, South Oxon, Watlington, Cotswolds, Swindon, Marlborough), but in Pywr these demand centres have been aggregated to four (Marlborough / Swindon / Cotswolds, Oxford/Faringdon/Witney, Banbury, South Oxfordshire /Watlington/Wantage). A fully simplified model, such as that built for the National System Simulation Model Project (Water Resource England and Wales, WREW), would represent SWOX as a single demand centre. Similarly, groundwater sources have been aggregated at fewer nodes than in WARMS2, but not generally aggregated to a single node per WRZ. The approach taken in Pywr was to include significant within-WRZ infrastructure in order to ensure that our future plans would 'work' at a sub-WRZ level.

4.58 Validation of the Pywr models involved a stepped process, considering the different changes that have been made between WRMP19 and WRMP24. For example, we validated the models using hydrological timeseries simulated by WARMS2, before then validating the model using hydrological timeseries from our newly developed hydrological models. Further detail on the validation of our water resources models can be found in Appendix I.

4.59 In WRMP19 we conducted water resources modelling of only the London and SWOX WRZs when determining WRZ DO, with other zones' DOs being calculated as an aggregated of individual source DOs. In producing WRMP24 we have conducted water resources modelling of all our WRZs, in order to capture any conjunctive use aspects that may exist.

Lower Thames Control Diagram

4.60 The amount of water that we can abstract from the Lower Thames is governed by the Lower Thames Operating Agreement (LTOA). The LTOA is an agreement made between the Environment Agency and Thames Water under Section 20 of the Water Resources Act 1991. The LTOA contains a control diagram on which the total storage volume in the Thames Water London reservoirs is plotted on a daily basis. Explicit in the LTOA is the need to maintain a prescribed flow over Teddington Weir. When storage is relatively healthy for the time of year, a minimum flow of 800 Ml/d must be maintained over Teddington Weir, the point at which the River Thames becomes tidally influenced. As London reservoir levels fall, the minimum flow over Teddington Weir, the Teddington Target Flow (TTF) may be reduced in defined bands down to a minimum flow of 300 Ml/d. In conjunction with the changing flow constraint, as storage declines the company must apply progressively more intensive demand management measures and restrictions on water use by customers in order to both preserve available storage and mitigate against over-abstraction from the River Thames and consequent environmental damage. As storage declines, we may/should also trigger the aforementioned drought sources as defined control curves are crossed.

4.61 Between WRMP14 and WRMP19 the Lower Thames Control Diagram (LTCD) shown in Figure 4-3, the control diagram governing the LTOA, was optimised to maximise the supply capability of London while reducing the environmental impacts of abstraction in the Lower Thames compared to the previous LTCD. This optimisation exercise was done in close collaboration with the EA, and a 6-week public consultation was undertaken. The LTCD has not been re-optimised between WRMP19 and WRMP24.

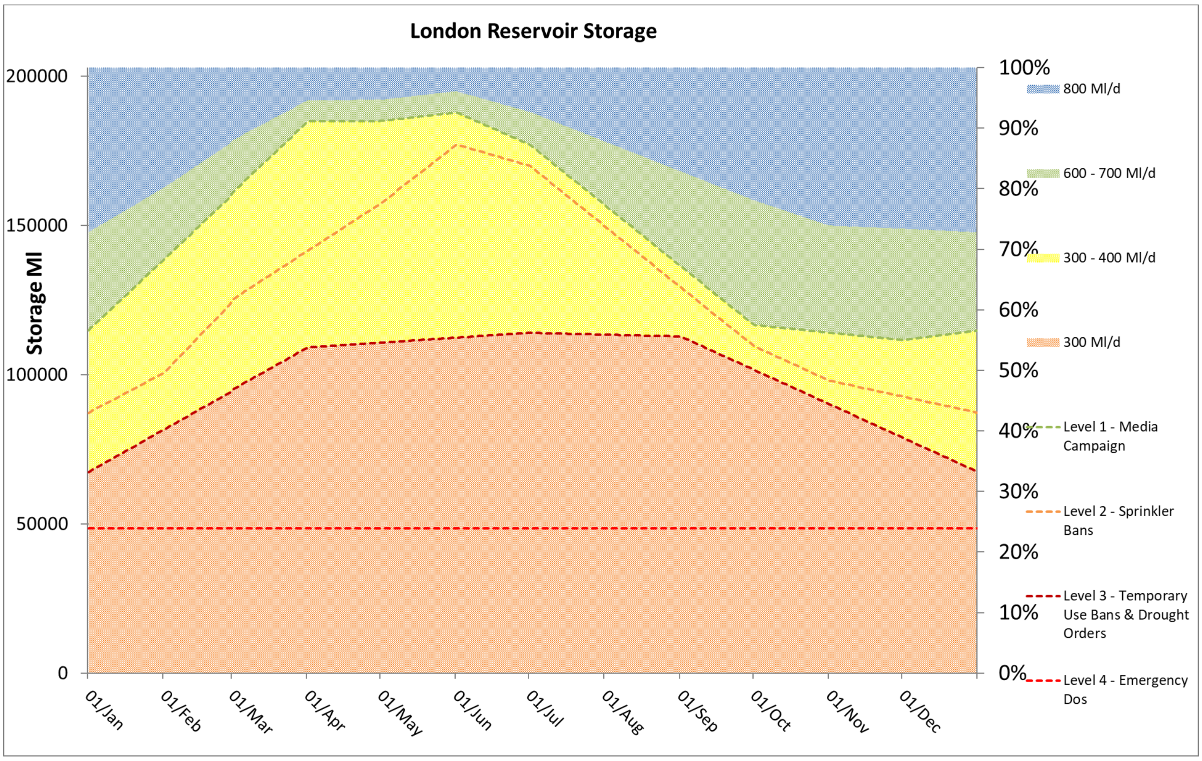

Figure 4-3: Lower Thames Control Diagram

4.62 The paragraphs below describe how the LTCD is used to trigger various actions. In practice the drought management actions are taken considering forecasts of many factors, such as groundwater levels, rivers flows and reservoir storage, but in our water resources modelling these actions are assumed to be triggered by the LTCD and, in some case, by flow at Teddington on a given day. The operational protocol governing our drought response can be read in more detail in our Drought Plan.

4.63 When storage is in the LTCD blue band (see Figure 4-3), no demand restrictions are required and only 'base' sources should be used. The Gateway Desalination Plant, East London Groundwater Sources (known as ELReD) and an abstraction near Stratford are all triggered when London storage moves from the blue band into the green band. At the same time less water needs to be left to go over Teddington Weir, either 600 Ml/d or 700 Ml/d depending on the time of year.

4.64 If storage reduces further and storage moves into the yellow band, we should trigger an enhanced media campaign (Level 1 demand restrictions) and the TTF reduces to either 300 Ml/d or 400 Ml/d, again depending on the time of year. In addition, at this point NLARS can be triggered. Within the yellow band is a line which triggers 'Level 2' demand restrictions, i.e. TUBs. At this point, the WBGWS is also triggered.

4.65 If storage declines into the orange band, Non-essential Use Bans (Level 3 demand restrictions) are triggered with the TTF reduced to 300 Ml/d. The horizontal dotted line at approximately 25% of London's storage is our 'Level 4' trigger; this is the point at which we assume that we would impose emergency drought orders. As such, the definition of '1 in 500' failure for us involves determining the highest level of demand at which we would not cross the 'Level 4' line on the LTCD more often than once every 500 years.

4.66 The emergency storage volume in London is calculated as 30 days of emergency storage.

4.67 For all WRZs, our assumption is that media campaigns, TUBs, and NEUBs would be triggered by London reservoir storage volumes, i.e., we do not have individual triggers for media campaigns, TUBs and NEUBs for each WRZ.

Methods Used in Calculation of WRZ DO

4.68 The stochastic weather datasets were run through hydrological and hydrogeological models as described in preceding sections. The resultant timeseries of flow and groundwater source yield were then used as inputs to the relevant Pywr models. The Pywr models contain 'demand' nodes, which represent demand for water, as well as nodes and links which represent rivers, reservoirs, and other water supply infrastructure. The model can also represent constraints which can either be relatively simple (e.g. pipe capacity) or more complex, e.g. determining the minimum flow that must be left to flow over Teddington Weir subject to the LTOA. The models can be used to conduct 'what-if' scenario-based investigations, for example determining minimum reservoir storage when applying different levels of customer demand.

4.69 As previously described, we plan to progressively increase the Level of Service (LoS) that we offer to customers. Currently, our stated LoS is that we would not impose emergency restrictions more often than once every 100 years; this will increase to not more often than once every 200 years by the early 2030s, and not more often than once every 500 years before the 2040s. As such, it was necessary for us to determine not just the '1 in 500-year' DO for each WRZ, but also the '1 in 100-year' and '1 in 200-year' DO figures.

4.70 In calculating DO figures, the key model variables to track are those which determine whether emergency restrictions would be required. For London and SWOX this involves tracking whether reservoir storage falls below the 'Level 4' control curve on the LTCD or

Farmoor Storage diagram respectively, as well as tracking whether all demand centres had their demands satisfied. For all other zones, which don't have reservoir storage, it involves tracking whether demands being applied are met (i.e. tracking deficits).

4.71 We calculate DO alongside demand, and the supply-demand balance for two different scenarios – Dry Year Annual Average (DYAA, also known as Average or ADO) and Dry Year Critical Period (DYCP, also known as Peak or PDO). The Annual Average DO calculation involved observation and counting of 'Level 4' events at any point during the year. The Critical Period DO calculation involved counting only 'Level 4' events that occurred during a specified period. TW considered the 'Peak' period to be July and August.

4.72 For each WRZ individually, many levels of demand were applied in the Pywr models, and outcomes were observed. In DO runs, due to the long timeseries used and requirement for model speed to allow DO runs to be completed in a reasonable timeframe, only those variables which were absolutely necessary for the calculation of DO were stored. Had large numbers of variables been stored a great deal of storage space would have been necessary, and models would have run more slowly. In a given model run, the variable captured was an indication of whether, for the WRZ of interest, in any given year at a given level of demand, Level 4 restrictions would have been required; April to March was used to define a year as drought events often span into January.

4.73 For each LoS of interest, the DO figure was determined as the highest level of demand that could be applied before emergency restrictions would need to be applied more often than the LoS states. In practice, this means that the DO is the highest level of demand that can be applied before the number of 'Level 4' events exceeds the value as prescribed by the Level of Service (Table 4-1).

Level of Service (Level 4)	Number of allowed 'Level 4' events across 19,200 years (400 x 48 years)
1 in 100-year	192
1 in 200-year	96
1 in 500-year	38
1 in 2-year	9600

Table 4-1: Levels of Service and Number of Allowable Level 4 Events Across Stochastic Record

Results

4.74 In this section, for each WRZ and planning scenario, calculated WRMP24 DO figures are presented alongside WRMP19 DO figures with a high-level summary of the main drivers of variance given. In each case the WRMP19 values presented are those stated in WRMP19 and so, due to the accounting changes mentioned previously and/or changes in underlying source assessment, do not necessarily give a 'like-for-like' comparison (for example, the London DO stated for WRMP19 would include the benefit associated with TUBs and NEUBs, and would already account for the large export to Essex and Suffolk Water, while the WRMP24 DO would exclude both of these factors). For a more detailed comparison between WRMP19 and WRMP24 calculated DO figures, including comparison between WRMP19 re-accounted DO figures with WRMP24, please see Appendix I. Section 6 of our WRMP gives a detailed breakdown of the supply-demand balance variance between WRMP19 and WRMP24 at the beginning of the planning period.

London

4.75 Only a DYAA DO run was undertaken for London. We do not undertake a DYCP assessment for London due to the presence of the Thames Water Ring Main and other strategic mains enabling treated water transfer around London.

Scenario	DO (Ml/d)	WRMP19 DO (Ml/d)
1 in 100 DYAA DO	2335	2302
1 in 200 DYAA DO	2219	2162
1 in 500 DYAA DO	2076	2052

Table 4-2: London DYAA DO Figures

4.76 Major causes of variance between WRMP19 and WRMP24 DO values for London are:

- Changes in accounting practices, i.e. removal of benefits of TUBs and NEUBs, and removal of export to Essex and Suffolk from baseline DO
- Amendments to SDO of individual sources, most notably the Thames Gateway desalination plant, the capability of which has been reassessed as 100 Ml/d, compared to 150 Ml/d assessed in WRMP19
- A change to our stated LoS related to the imposition of TUBs (1 in 10 LoS for WRMP24, compared to 1 in 20 LoS for WRMP19)
- Newly developed stochastic weather datasets, hydrological modelling, and water resources models

Thames Gateway Desalination Plant

4.77 In our baseline deployable output modelling, a 100 Ml/d capability was assumed for the Thames Gateway desalination plant. As described in the ‘Outage’ section of this document, the plant has faced a number of outage issues over recent years and has been unavailable throughout 2022 due to a planned maintenance upgrade. In the WRMP24 we committed to providing an update on the success of our programme of work which aims to restore the capability of Gateway WTW. A summary of progress in AMP7 to date is:

- Recovery projects works completed October 2021 (Phase 1) – remedial and re-commissioning works to successfully test up to 100 Ml/d
- AMP7 Phase 2 (fast track) key items for Health & Safety and resilience to enable the return of the site up to 50 Ml/d peak by spring 2023 – this was delayed further to July 2023 due to national shortage of carbon dioxide, required to operate the re-mineralisation plant before the water is placed into supply.)

4.78 Our focus for the remainder of AMP7 is to ensure a reliable 50 Ml/d output is achievable. A summary of the AMP7 Phase 2 (non-fast track) programme of works to ensure a reliable 50 Ml/d capability by 2025 is:

- Improved RO racks leak collection and drainage
- Improved undercroft drainage and floor surface upgrades
- Design and procurement activities for chemical improvement works below
- Completion of the Regulation 31 water quality testing of all RO membranes as required by the DWi.

4.79 Funding has been included in our PR24 business plan for scope to make the desalination plant more resilient and to replace life-expired components. We have also commissioned a peer review to validate our proposed scope of renewals. A summary of the notional programme of works for AMP8 to achieve a reliable 75 Ml/d output by 2030 (subject to change based on actual performance/risk and the peer review of proposed scope) is:

- New chemical clean-in-place (CIP) system for the existing ultrafiltration (UF) membranes (requires main building extension)
- New bulk chemical storage and transfer systems for the CIP system and for the chemically enhanced backwash (CEB) of the existing UF membranes
- Enhance existing chemical systems
- Replace/refurbish water cooled MCCs
- Replace chemical dosing lines
- Install biofoul prevention
- Assessment on lime hardening extension based on performance in AMP7

4.80 In order to reflect planned work and to present a sufficiently conservative view to ensure a robust plan, the baseline supply forecast incorporates a reduction in the DO of the Gateway plant, with a 50 Ml/d capability up to 2029-30, increasing to 75 Ml/d from 2030-31 onwards. There is an interaction between deployable output and outage allowance, meaning that the Water Available for Use (WAFU) contribution of the site varies across the early part of the planning period (discussed in the Outage section of this document). Accounting for this DO variation within our WRMP tables has been done by making amendments to reflect prolonged outage, stated in 7.4BL, with resultant amendments to outage allowance featuring in 9BL. The “Deployable Output before forecast changes” (6BL) for the London WRZ assumes a 100 Ml/d site capability throughout to reflect our modelled baseline condition.

SWOX

4.81 Multiple changes were made in WRMP24 in producing a SWOX DO, most notably:

- Changes in accounting practices, i.e. removal of benefits of TUBs and NEUBs from baseline DO
- SDO updates, including sustainability reductions totalling around 12 Ml/d at Axford, Ogbourne and Childrey Warren
- New stochastic datasets, including use of a different underlying rainfall dataset
- New hydrological input data and use of WRSE Pywr model
- Inclusion of time-variant groundwater yields, which will likely increase SWOX DO due to conservative SDO figures for sources having been used previously
- Modelling of conjunctive use system for whole of SWOX; in WARMS2, South Oxfordshire is considered separately with groundwater assumed to be a fixed import
- Update of demand splits across the SWOX WRZ (from using 2014-15 data to 2019-20) and associated changes in effluent returns

Scenario	DO (Ml/d)	WRMP19 DO (Ml/d)
1 in 100 DYAA DO	321.7	329.2
1 in 200 DYAA DO	310.6	323.8
1 in 500 DYAA DO	297.2	306.8

Table 4-3: SWOX DYAA DO Figures

4.82 Our approach to the calculation of SWOX’s DYCP DO has changed between WRMP19 and WRMP24. The calculation for WRMP19 involved factoring the calculated DYAA DO figure and ensuring that this did not exceed the treatment capability of the zone. For

WRMP24 we have produced a modelled ‘system response’ DYCP DO. In addition, the approach to considering severe and extreme drought has been improved significantly; the river flow impacts found for the DYAA scenario were scaled to produce DYCP impacts for SWOX at WRMP19, whereas a modelled ‘system response’ DO was found for each DO return period in WRMP24.

4.83 Between dWRMP and rdWRMP we reviewed the modelling that had been undertaken and noted that the SWOX DYCP assessment had omitted EDO implementation due to emergency restrictions being in place during the peak period.

Scenario	DO (Ml/d)	WRMP19 DO (Ml/d)
1 in 100 DYCP DO	345.1	385.4
1 in 200 DYCP DO	332.6	379.1
1 in 500 DYCP DO	319.4	359.2

Table 4-4: SWOX DYCP DO Figures

SWA

4.84 The main changes in SWA DO figures are DO reductions due to sustainability reductions made during AMP7. Note that the WRZ DO does not account for the Hawridge sustainability reduction, which is anticipated to be made before the end of AMP7.

Scenario	DO (Ml/d)	WRMP19 DO (Ml/d)
1 in 100 DYAA DO	183.4	185.1
1 in 200 DYAA DO	183.2	184.6
1 in 500 DYAA DO	183.2	184.4

Table 4-5: SWA DYAA DO Figures

Scenario	DO (Ml/d)	WRMP19 DO (Ml/d)
1 in 100 DYCP DO	199.7	214.4
1 in 200 DYCP DO	199.7	213.9
1 in 500 DYCP DO	199.7	213.7

Table 4-6: SWA DYCP DO Figures

Kennet Valley

4.85 A thorough investigation into the DO of the Kennet Valley WRZ was undertaken for WRMP24, focussing on the 1 in 500-year DO for the Fobney run-of-river source. This is detailed in Appendix I, with the result being a significant reduction in DO assumed for 1 in 200-year and 1 in 500-year events compared to initial estimates and WRMP19 calculations. In our dWRMP24, post-modelling amendments were made to DO in the Kennet Valley WRZ to account for the insight gained from investigations. Between dWRMP and rdWRMP, we incorporated the insight gained from the investigation into our modelling directly.

Scenario	DO (Ml/d)	WRMP19 DO (Ml/d)
1 in 100 DYAA DO	152.7	143.7
1 in 200 DYAA DO	138.3	140.9
1 in 500 DYAA DO	116.4	139.6

Table 4-7: Kennet Valley DYAA DO Figures

Scenario	DO (Ml/d)	WRMP19 DO (Ml/d)
1 in 100 DYCP DO	158.6	155.2
1 in 200 DYCP DO	156.6	151.8
1 in 500 DYCP DO	140.4	140.9

Table 4-8: Kennet Valley DYCO DO Figures

Guildford

4.86 There are minimal changes in the Guildford DO calculations or inputs compared to WRMP19.

Scenario	DO (Ml/d)	WRMP19 DO (Ml/d)
1 in 100 DYAA DO	68.87	65.82
1 in 200 DYAA DO	68.87	65.82
1 in 500 DYAA DO	68.87	65.82

Table 4-9: Guildford DYAA DO Figures

Scenario	DO (Ml/d)	WRMP19 DO (Ml/d)
1 in 100 DYCP DO	74.28	71.7
1 in 200 DYCP DO	74.28	71.7
1 in 500 DYCP DO	74.28	71.7

Table 4-10: Guildford DYCP DO Figures

Henley

4.87 The only change in the Henley DO calculation is an amendment to an SDO to account for a long-term outage.

Scenario	DO (Ml/d)	WRMP19 DO (Ml/d)
1 in 100 DYAA DO	21.55	25.65
1 in 200 DYAA DO	21.55	25.65
1 in 500 DYAA DO	21.55	25.65

Table 4-11: Henley DYAA DO Figures

Scenario	DO (Ml/d)	WRMP19 DO (Ml/d)
1 in 100 DYCP DO	21.7	25.9
1 in 200 DYCP DO	21.7	25.9
1 in 500 DYCP DO	21.7	25.9

Table 4-12: Henley DYCP DO Figures

Outage

4.88 Outage is a temporary, short-term loss in supply capability. At the Water Resource Zone (WRZ) level, we include an outage allowance in our supply-demand balance. This accounts for the risk to customers' supplies that is posed by planned and unplanned outage events that impact Deployable Output. This is done in order that our stated 'Water Available for Use' appropriately accounts for sources which could become unavailable during drought due to outage events.

4.89 It is important to note that our outage allowance is not a forecast of outage, nor does it describe the impact of planned outages. Instead, it is an allowance that we make to be prudent when determining our supply-demand balance. Our goal is always to have supply sources available, and we do not aim to have a prescribed level of outage. Our aim in calculating outage allowance is to ensure that we leave a prudent gap between supply and demand.

Approach to Outage Allowance Calculation

4.90 The WRSE regional group has undertaken a project to align methods used in the calculation of outage allowance across WRSE companies. This project resulted in the development of an aligned approach to the screening of outage events and subsequent calculation of outage allowance. This has led to an aligned approach across WRSE companies.

4.91 This section summarises the data and methods used in outage allowance calculation. For further details, please see Appendix J.

4.92 Our approach to outage allowance calculation uses methods which are broadly similar to those used in WRMP19, based on collecting historical data on outage events, screening those events, and conducting mathematical modelling, using Monte Carlo sampling, to derive a reasonable allowance. Some aspects of our approach have changed from WRMP19, most notably:

- Some aspects of sampling techniques and distributions used in Monte Carlo sampling
- Consideration of an allowance for the DYCP planning scenario, where for WRMP19 we calculated a single (DYAA) outage allowance that was applied to both the DYAA and DYCP scenarios
- Removal of 'generic' outages from our outage modelling due to lack of evidence that the generic forms of outage included presented risk

4.93 Figure 4-4 is a flow chart showing the processes that we go through to calculate outage allowance for each WRZ.

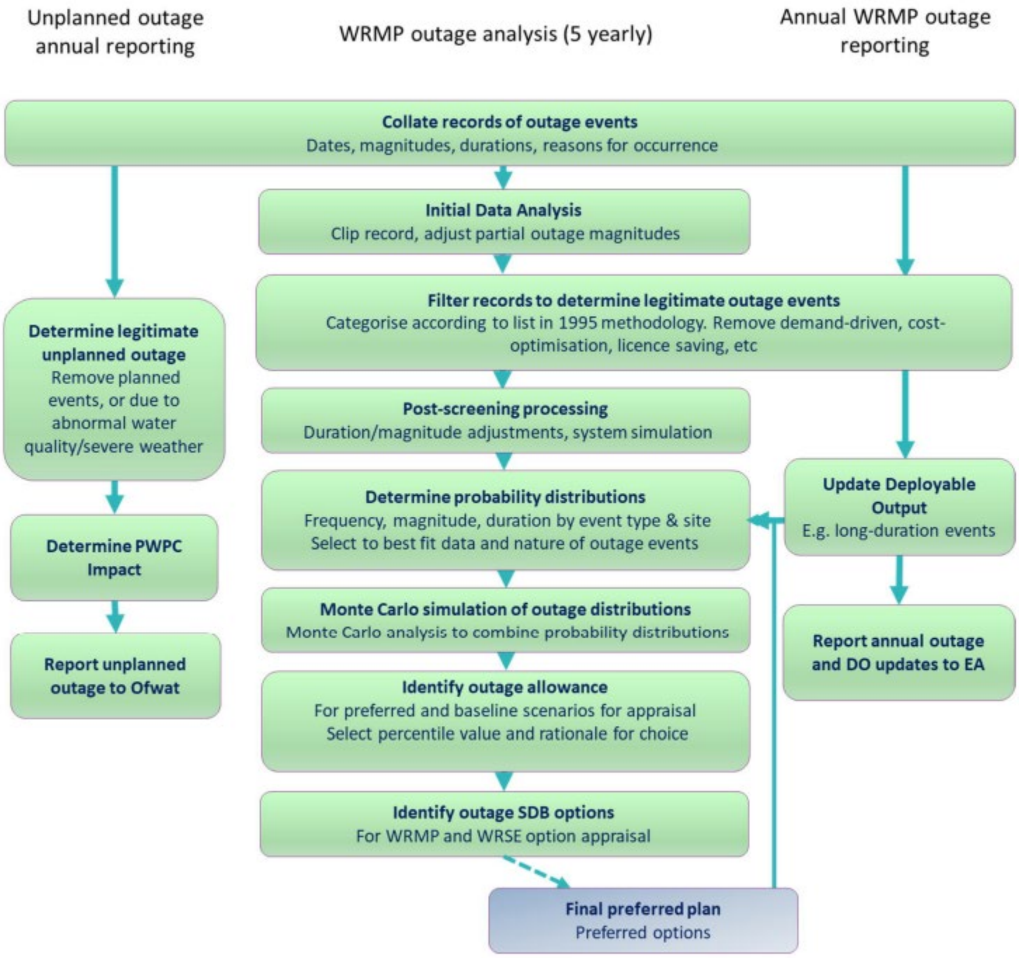

Figure 4-4: Approach to Outage Allowance Calculation – Taken from WRSE Outage Method Statement

Data Collection

4.94 EA Supplementary Guidance sets out the requirement that our outage allowance is based on recent, relevant data on 'actual' outages that have occurred.

4.95 The outage dataset is aligned with that used in the derivation of unplanned outage (Ofwat Performance Commitment). However, as water source availability is assessed against different performance metrics for outage allowance (DO) and unplanned outage (Peak Week Production Capacity), the dataset is assessed carefully to ensure outage events are identified. In addition, subsequent screening steps differ between unplanned outage and outage allowance.

4.96 Information regarding outages that have occurred is collected throughout the regulatory reporting year, using different corporate data sources. The outage event information is collated into outage recording forms for London and the Thames Valley areas. Data collected includes the source/sourceworks affected, the start and end dates for potential outage events and, to establish the magnitude of the impact, the source/sourceworks output during the outage event. We include partial outages in our outage assessment.

4.97 As DO values for water supply sources are the baseline numbers against which the magnitude of outage events are compared, these are reviewed and updated to current or forecast values as appropriate.

Screening of Events

4.98 As part of the data collection process, data regarding the cause of outage events is collected. This data is used to classify outage events. EA Supplementary Guidance sets out the requirement that we differentiate between planned and unplanned outage events, with classification of the type of unplanned outage as follows:

- Pollution of source
- Turbidity
- Nitrate
- Algae
- Power failure
- System/asset failure
- Cryptosporidium failure
- Other

4.99 All screened outage events are input to the Outage Modelling Tool.

Processing of Outage Events

4.100 Outage events identified through data collection and screening are processed to ensure an appropriate consideration within outage allowance calculation. For instance, on some occasions it is found that operating philosophy, rather than an asset outage, is the reason for reduced output at a source, and so inclusion with outage allowance would not be appropriate. Processing steps include consideration of:

- Whether a given outage poses risk to ‘DYAA’ and/or ‘DYCP’ supply capability
- Where investment has been made to reduce/eliminate specific outage risks
- Likelihood of coincidence of outage event cause with drought events (e.g. flooding)
- Potential mitigation of outage events via supply system operation

4.101 After events have been processed, we are left with a comprehensive list of outage events that have occurred at different sourceworks, categorised by cause, and processed such that they are ready for outage allowance modelling. The database of outage events is held within the Outage Modelling Tool, which is then used to derive outage allowance.

Outage Modelling

4.102 An Outage Modelling Tool exists for each Water Resource Zone. The Outage Modelling Tool processes outage events such that distributions for frequency, magnitude and duration are defined for each combination of source/sourceworks and outage category. On occasion these distributions are edited using expert judgement.

4.103 The Outage Modelling Tool for each WRZ is then used to conduct Monte Carlo simulation, sampling from the distributions of frequency, magnitude, and duration to ascertain the outage risk that is posed to each WRZ. In a given Monte Carlo iteration, for each combination of source and outage category the distributions are sampled to produce a data-informed outage in Ml/d that may be experienced in a year; all sampled outage values are summed to give a total WRZ outage value for that iteration. Multiple (3,000+) Monte Carlo iterations are carried out, and total WRZ outage values are stored; the 95th percentile of the values calculated is selected as the Outage Allowance value to be taken forward to the supply-demand balance. The Outage Modelling Tool calculates values for DYAA and DYCP outage separately.

Outage Allowance

4.104 The methodology outlined was followed and applied using data up to the AR21 reporting period. The outage allowance values produced are:

Zone	WRMP19 DYAA Outage Allowance (Ml/d)	rdWRMP24 DYAA Outage Allowance (Ml/d)
London	99.76	107.44*
SWOX	17.23	6.69
Slough, Wycombe and Aylesbury	9.46	15.49
Kennet Valley	2.49	1.95
Guildford	1.40	1.55
Henley	0.36	1.15

Table 4-1: rdWRMP24 DYAA Outage Allowance Values

*Note: This outage allowance figure includes calculations which reflect the recent outage history of the Gateway desalination plant, but also assumes a site capability of 100 Ml/d. As is described below, amendments made to reflect reductions in the site's capability reduce the necessary allowance for outage events, and so our baseline outage allowance varies across the planning period.

4.105 It can be seen that DYAA outage allowance for most WRZs had not materially changed since WRMP19. SWOX's outage allowance has reduced, mainly due to the removal of 'generic' outage events from the record as there is little evidence of a risk being posed from them, especially as, in some cases, actual outages have been identified within these generic categories. As a result, an element of double counting of outages has been removed.

Zone	WRMP19 DYCP Outage Allowance (Ml/d)	rdWRMP24 DYCP Outage Allowance (Ml/d)
London	N/A	N/A
SWOX	17.23	3.06
Slough, Wycombe and Aylesbury	9.46	3.26
Kennet Valley	2.49	0.99
Guildford	1.40	0.38
Henley	0.36	0.17

Table 4-2: rdWRMP24 DYCP Outage Allowance Values

4.106 The DYCP outage allowance for all WRZs has reduced due to the explicit calculation of DYCP outage allowance. In WRMP19, DYCP outage allowance was assumed to be the same as DYAA outage allowance, but it appears that relatively fewer outage events occur during our peak demand period.

Thames Gateway Desalination Plant

4.107 The modelling carried out to inform our baseline DO and our outage allowance was based on the assumption that our desalination plant has a deployable output contribution of 100 Ml/d.

4.108 The desalination plant is complex and has faced a number of reliability issues during recent years. It has only been intermittently available over the period 2017-21 but was tested at an output of 100 Ml/d (though water produced during this test was not put into supply) for a short period in June 2021. However, it has been unavailable throughout 2022 due to a planned maintenance upgrade. In this section we address the issues that have been experienced at the desalination plant, how they impact our supply forecast and our plan for improving the reliability of the Gateway plant, and in Section 10 and Section 11 of the WRMP we demonstrate the robustness of our plan.

4.109 The programme of works to restore a reliable capability at the Gateway desalination plant is described in the “Deployable Output” section of this document.

4.110 There is an interaction between the deployable output of a source and the amount of outage allowance contribution, whereby the larger the DO of a source, the larger the impact of an outage at a source on outage allowance. As is described earlier in this section, the contribution to deployable output assumed for the Gateway desalination plant in our WRMP varies over the planning period due to allowances to reflect prolonged outage at the site.

4.111 We have run our outage model to determine the outage allowance reduction that would result from a reduced DO assumption for the Gateway plant. This shows that reducing the site’s DO by 50 Ml/d would reduce the London WRZ’s outage allowance by 33.55 Ml/d, while reducing the site’s DO by 100 Ml/d (i.e., if we were to assume that the site were to be unavailable) would reduce the outage allowance by over 50 Ml/d.

4.112 The impact on WAFU is shown in the WAFU section below, but in summary this means that the assumption of DO being reduced by 50 Ml/d during the period 2022/23 – 2029/30 reduces WAFU by (50 – 33.55 =) 16.45 Ml/d. The aim of our AMP8 maintenance programme is to improve the reliability of the desalination plant, with the intention that the plant achieves a reliable 75 Ml/d capability. It is therefore assumed that the original WAFU contribution would be reasonable to assume for the long-term, and so in the supply forecast London WRZ’s DO is reduced by 25 Ml/d compared to the base-year position from 2031 onwards, and London WRZ’s outage allowance is also reduced by 25 Ml/d from the base-year position, leading to a net-neutral impact on WAFU.

4.113 To explore this further, in Section 10 of our plan, investment model sensitivity runs have been undertaken to explore the consequences for our plan of a reduced output from our desalination plant over the long-term, to ensure that the plan is robust.

Treatment Losses

4.114 Having sufficient and appropriate water treatment in place is fundamental in providing a water supply to our customers that is wholesome, with its quality needing to meet the regulatory standards for drinking water. It follows, therefore, that it is necessary to assess and monitor the water quality hazards and contaminants in the water that passes through our water treatment works (WTW). This includes hazards associated with the raw groundwater and river water resources from which we abstract, as well as hazards that can arise within our storage reservoirs.

4.115 In addition to ensuring we have treatment in place that is appropriate to remove contaminants to concentrations or values required by drinking water regulations and our own internal risk assessment processes, we need to account for the capability of the WTW. Specifically, we need to quantify how much water our WTW can treat under different raw water quality challenges and account for this capability in calculating the Deployable Output (DO) of our individual water sources and our WRZ.

4.116 At any WTW, even very simple plants, for every litre of water that is abstracted from the environment and treated before passing into the distribution network, a small fraction of the water will be unsuitable for supply. This fraction of water is known as the waste stream. The water that comprises the waste stream contains any separated raw water contaminants that can arise from plant cleaning and maintenance and also for health and safety reasons, such as eye baths or showers required in the event of chemical spillages.

4.117 The sum of all the waste streams is generally referred to as the process loss for a WTW. Generally, the more complex a WTW, which can have multiple treatment processes, the greater the process losses. Although WTWs are designed to limit the amount of process losses, such losses do occur. Some of the waste streams are treated and discharged to rivers directly, while others may be discharged to a sewer and returned to the environment via a wastewater treatment plant.

4.118 As a result of the variable complexity of water treatment process, it is important to understand and quantify WTW capability and process losses. Similarly, it is important to understand where process losses are returned to the environment and, as a result, can contribute again as a raw water resource for abstraction or environmental benefit.

4.119 We undertake modelling to assess the capability of our WTWs, and process losses that may be anticipated. In some cases, these capabilities and process losses are included in our water resources modelling to ensure we have an accurate picture of our system response.

Methods and Water Resources Modelling

4.120 To enable us to have an appropriate level of understanding and quantification of WTW capability and process losses, we have developed and maintained a series of Mass Balance models, with a model being available for each of our operational WTWs. These models implement a mass balance calculation in which water flow and contaminant loadings on the treatment processes are established, providing a means of simulating the capability of a WTW for a given raw water condition.

4.121 By including design limits and water quality standards, e.g. disinfection policy, potable water requirements, on each treatment process stage and that the output of each process is controlled within these limits, the quality of the treated water is always preserved. This reflects the practice of needing to operate our WTWs to ensure they do not fail and that they provide wholesome water to our customers.

4.122 The models also account for factors such as asset capability, e.g. pump and filtration capability, as well as process operation. The representation in the models of processes such as Rapid Gravity Filtration (RGF) and Slow Sand Filtration (SSF), for example, include filter run times, cleaning triggers and durations as well as process water use.

4.123 Through the use of our WTW Mass Balance models, we can quantify WTW capability and process losses. As a result, the models provide key inputs to the assessment of DO, identification of potential constraints on DO, as well as enabling an assessment of raw water quality hazards to treatment capability and ultimately DO. We consider appropriate scenarios of different water quality challenge, particularly relating to algae, when determining treatment capability and process losses that we should assume.

4.124 The WTW Mass Balance models are reviewed and updated to reflect changes in treatment work assets, water quality standards and operating practices, being carried out as part of our business-as-usual process.

4.125 In our WRMP19 methodology, SDOs were reported net of process losses but for WRMP24 process losses are required to be identified more explicitly. As a result, process losses associated with each WTW are identified and are subtracted from the supply capability when calculating WAFU. Further details of modelling carried out to determine treatment capability and process losses is included in Appendix K.

4.126 Treatment capability and process loss figures for our large surface WTW assumed in our water resources modelling are detailed in Table 4-15. Process losses at Fobney and particularly Shalford WTW are generally higher than other works because the water that they treat comes straight from rivers (meaning they are 'run-of-river' WTW), whereas water at our other WTW comes from raw water reservoirs. Our large raw water reservoirs play an important part in the treatment process at our large works, allowing for larger solids to settle out.

WRZ	WTW	Treatment Capability (Ml/d)	Process Loss (%)
London	Ashford Common	690.0	1.94
	Hampton	749.0	2.32
	Kempton Park	167.5	1.13
	Walton	132.0	5.44
	Coppermills	537.5	6.67
	Hornsey	39.6	1.09
	Chingford	38.7	0.82
SWOX	Farmoor & Swinford (amalgamated)	174.0	2.28
Kennet Valley	Fobney	63.7	11.5
Guildford	Shalford	27.8	7.91

Table 4-1: Treatment Capabilities and Process Losses for Surface WTW

Process Losses and Treatment Capabilities Included in Water Resources Modelling

4.127 All of the WTWs that treat river and reservoir raw water are represented explicitly as individual WTWs. This means that the Hampton, Ashford, Kempton, Walton, Coppermills, Hornsey and Chingford WTW are represented explicitly in the London Pywr model, as are the process losses from each of the WTW. This is also the case for Farmoor and Swinford WTW in the SWOX Pywr model, Fobney WTW in the Kennet Pywr model and Shalford in the Guildford Pywr model.

4.128 While individual WTW process losses might seem significant, their discharge may be supporting downstream abstraction as well as having environmental benefit through increased river flows. It is necessary however, to operate wastewater treatment processes to ensure that their discharges protect the quality of any receiving watercourse and so meet Environment Agency requirements.

4.129 All of the process losses from those LPPs (Large Process Plants) in west London are discharged back into the River Thames and, as a result, can generally be reabstracted at intakes further downstream. From Coppermills WTW process water that is not recycled back into the Lee Valley reservoirs goes into the River Lee below any abstraction intakes. For the Chingford and Hornsey WTWs, the process losses are very small and their potential return as inflows to Chingford WTW and Coppermills WTW not accounted for explicitly in the Pywr system model.

4.130 Conceptually therefore, the significant WTW process losses are represented in the Pywr model to be consistent with their permitted discharges back into the water environment and are aligned with their representation in the WARMS2 model.

Implications of raw water quality challenges and climate change

4.131 In the event that the water quality challenge experienced at a WTW in a given year is greater than that assumed in the calculated representative values, the actual process losses may be higher than the values calculated. This potential challenge from raw water quality results in a risk that WTW process losses could increase and, as a result, capabilities decrease; this is particularly the case for the LPPs fed from raw water reservoirs.

4.132 In particular, during times of algal blooms in the reservoirs that are more severe than those accounted for in its calculated representative capability and process loss, the recycling of process water is likely to be reduced. This would mean that less of the process losses would be treated to water quality standards acceptable for discharge back into the reservoirs and, consequently, more would be discharged back into the environment and not recycled. Overall therefore, algae can affect the treatability of reservoir water and increase the cost of treatment and production of drinking water.

4.133 To capture the risk of poorer raw water quality in reservoirs, we have included new components in our Target Headroom modelling for WRMP24 (Section 6).

4.134 It is evident that our WTW outputs and water supply, particularly the LPPs which are dependent on reservoir storage, can be vulnerable to seasonal raw water quality, especially algal blooms. A UKWIR study on climate change implications for water treatment identified algae could become more problematic for water supply as process losses are likely to increase further and WTW capability reduce.

4.135 By looking at the resilience of our raw water storage and supply network we have found that the change in algal bloom severity and duration is dependent on individual reservoir characteristics, including their physical structure and management. For example, deeper reservoirs have better control measures to manage the raw water quality and therefore are more resilient to the impacts of climate change.

4.136 Nevertheless, as well as future raw water resource availability, the water quality challenge and how this may change in future climates is an important factor to account for in planning. Evidence indicates that the impact of climate change is increasing the range of species of algae that can cause a bloom event in our reservoirs and also increasing the period of year for which our reservoirs are at risk of algal bloom. We have an ongoing programme working with subject matter experts to develop decision support tools to assess potential raw water quality behaviours, with algal impacts on LPP performance being a focus.

4.137 Our aim continues to be to better inform our evaluation of system resilience and to be able to base judgements on sound quantitative modelling. Following assessment of these results and establishing their significance in terms of risk to our existing supply demand balance, we will continue our programme of investigation to establish the magnitude of impact to assist in making more informed decisions and to target investment to improve system resilience.

Results

4.138 Treatment capability is considered a constraint in the DO calculation process, and so is not presented as a component of WAFU. The calculation of process losses at our WTW, incorporating the influence of process loss returns upstream of abstraction points in our water resources modelling and whether process loss reductions would lead to an increase in WAFU, results in the following WAFU impacts, which are assumed constant across the planning period:

WRZ	DYAA WAFU Impact, -ve (Ml/d)	DYCP WAFU Impact, -ve (Ml/d)
London	8.42	N/A
SWOX	3.58	4.09
SWA	0.49	0.49
Kennet Valley	8.53	8.51
Guildford	3.58	1.86
Henley	0.00	0.00

Table 4-2: Treatment Works Losses

Climate Change

4.139 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.

4.140 Updated climate change projection data, provided through the UK Climate Projections 18 (UKCP18) project[7], has been incorporated into our supply forecast. UKCP18 provides a vast amount of information on the potential future impacts that climate change may have.

4.141 Estimating the impact of climate change on our supply capability during extreme drought events poses a significant challenge. As described previously, determining our supply capability under '1 in 500-year' drought events poses significant uncertainty. Attempting to calculate the impact that climate change will have on our supply capability during extreme drought events adds another layer of uncertainty into this process.

4.142 While the platitude of 'wetter winters, drier summers' suggests that climate change may not have a large overall impact on the occurrence of drought events, the reality is that increased temperatures throughout the year, along with more variable precipitation patterns are likely to increase drought risk in the River Thames catchment, by placing greater reliance on a shorter recharge period. The impact of climate change on drought risk is, however, very complex, and highly uncertain, and so we have undertaken extensive modelling to assess the impact of climate change on our supply capability under different future climate scenarios.

4.143 This section presents a summary of the work undertaken in our assessment of climate change impacts on supply capability. Further detail is presented in Appendix U.

Guidance on Climate Change Impact Assessment

4.144 The Environment Agency's Water Resource Planning Guideline[8], Supplementary Guidance on Climate Change[9], and Supplementary Guidance on Stochastics[10] 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[11] datasets
- A vulnerability assessment is required to establish the level of detail required in the analysis

4.145 Thames Water and WRSE's vulnerability assessment (detailed in the next section) 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 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

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[7] Met Office Hadley Centre, 2018, UKCP18 Probabilistic Climate Projections. Centre for Environmental Data Analysis

[8] Environment Agency, 2022, Water Resources Planning Guideline

[9] Environment Agency, 2021, Water Resources Planning Guideline Supplementary Guidance – Climate Change

[10] Environment Agency, 2021, Water Resources Planning Guideline Supplementary Guidance - Stochastics

[11] Lowe et al., 2018, UKCP18 Science Overview Report Version 2.0, ukclimateprojections.metoffice.gov.uk

- 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

4.146 Despite the implications that a great deal of modelling should be undertaken, the guidance also states that it may not be necessary to take a 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:

- 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

4.147 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

4.148 In addition to Environment Agency guidance on the assessment of climate change, Ofwat has released guidance on adaptive planning, and the development of long-term investment strategies[12]. 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.

Vulnerability Assessment

4.149 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.

4.150 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 4-5.

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[12] 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

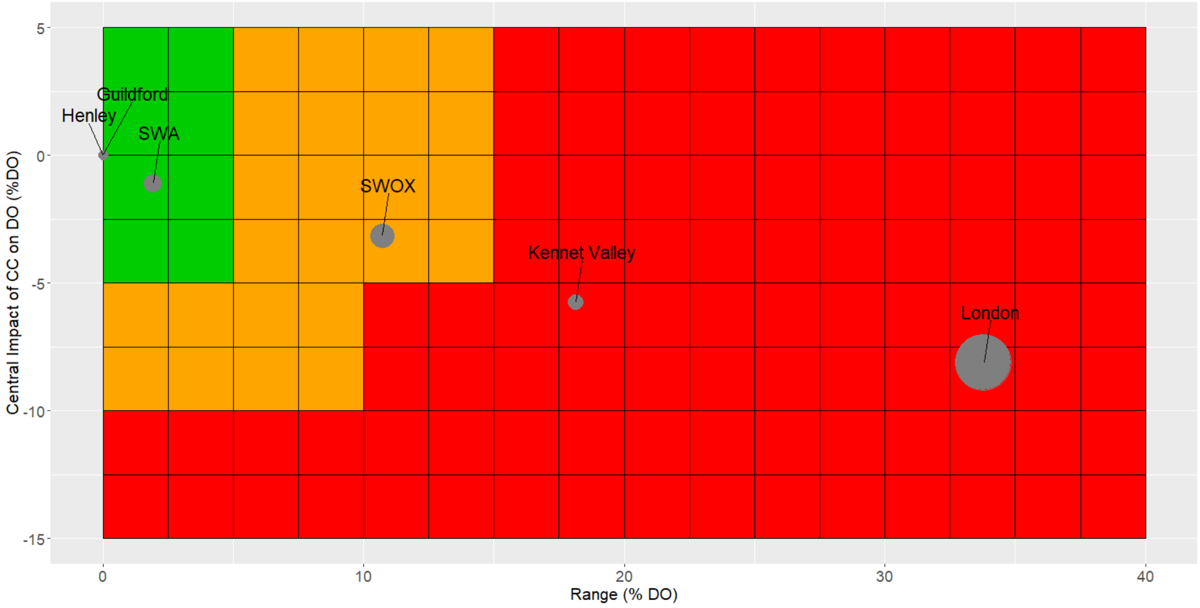

Figure 4-5: Thames Water Basic Vulnerability Assessment – Climate Change

4.151 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.

4.152 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 4-17).

4.153 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 4-1: Impact of Climate Change on Investment

4.154 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.

4.155 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

4.156 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. Further detail is provided in Appendix U.

4.157 Due to the importance of spatial coherent in assessing climate impacts for the Regional Plan, our initial Climate Change impact assessment was based on the use of perturbation factors from the 28 scenarios associated with the spatially coherent projections from RCP8.5 (RCP2.6 spatially coherent projections were not available at the time of this assessment).

4.158 As will be described later, we have applied the UKCP18 probabilistic datasets in the London WRZ 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

4.159 We have ensured, through selection and factoring, that the climate change impact scenarios which we have adopted in our supply forecast and adaptive planning scenarios are representative of the full range of data available in the UKCP18 projections, rather than being biased towards 'severe' climate change futures.

4.160 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 well as having used the 28 spatially coherent projections available for RCP8.5.

Assessment of Climate Change Impact on Deployable Output

4.161 In developing towards 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 the 28 spatially coherent RCP8.5 climate change projections for all WRZs. The second iteration carried out during 2021 and 2022 involved less detailed hydrological and water resource modelling (with no hydrogeological modelling), for the London WRZ only, but included consideration of more than 3,000 climate change projections.

4.162 Appendix U contains a greater amount of detail regarding both investigations. Here, a summary of work undertaken is described and results are presented.

4.163 Both investigations incorporated the same overall steps in assessing the impact of climate change on DO for a given climate change projection, but differed in the methods and/or models used in each step:

- Step 1 - Generation of a climate-perturbed weather record: following EA guidance, we perturb weather records by factors derived from UKCP18 climate change projections
  - In the 'low volume, high complexity' study (iteration 1), a subset of the stochastic sequence, focussed on drought events, is selected and perturbed
  - In the 'high volume, low complexity' study (iteration 2), the whole 19,200-year stochastic weather sequence is perturbed
- Step 2 - Hydrological and hydrogeological modelling: using the perturbed weather sequences generated in the first step, we run hydrological and/or hydrogeological models in order to provide inputs for our water resources models
  - In the 'low volume, high complexity' study (iteration 1), exactly the same hydrological and hydrogeological models are used as for the baseline DO run
  - In the 'high volume, low complexity' study (iteration 2), lumped parameter hydrological models are used. No hydrogeological modelling was undertaken in this step. These models are used because they are faster than the more detailed hydrological models used in our DO calculations
- Step 3 - Water resources modelling: we undertake water resources modelling to understand the system response impacts of climate change
  - In the 'low volume, high complexity' study (iteration 1), the WRSE Pywr models were used, as per our baseline DO assessment
  - In the 'high volume, low complexity' study (iteration 2), a simplified Pywr model for the London WRZ only is used
- Step 4 - Derivation of DO Impact: we determine a 'climate-impacted DO' and find the difference between our baseline DO and this DO figure to determine the impact that climate change has had on DO
  - In the 'low volume, high complexity' study (iteration 1), the use of a subset of the stochastic record resulted in the need to estimate the impact of climate change on 1 in 500-year DO using regression or averaging
  - In the 'high volume, low complexity' study (iteration 2), having used the whole stochastic record meant that a 'full stochastic' DO assessment, as per our baseline DO calculation, could be undertaken

4.164 As can be surmised from the description above, the first iteration of modelling used the same models as our baseline DO and, due to the volume of data and modelling involved in a single DO run using these models, needed to use modified methods in calculating DO. The second iteration of modelling on the other hand used simplified models compared to our baseline DO modelling, but was able to use a 'full stochastic' DO calculation methodology.

Results – First Investigation for London WRZ

4.165 The 28 values for the impact of climate change on the London WRZ DO found in the first modelling iteration (low volume, high complexity) can be seen in Figure 4-6. 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).

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

4.167 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?

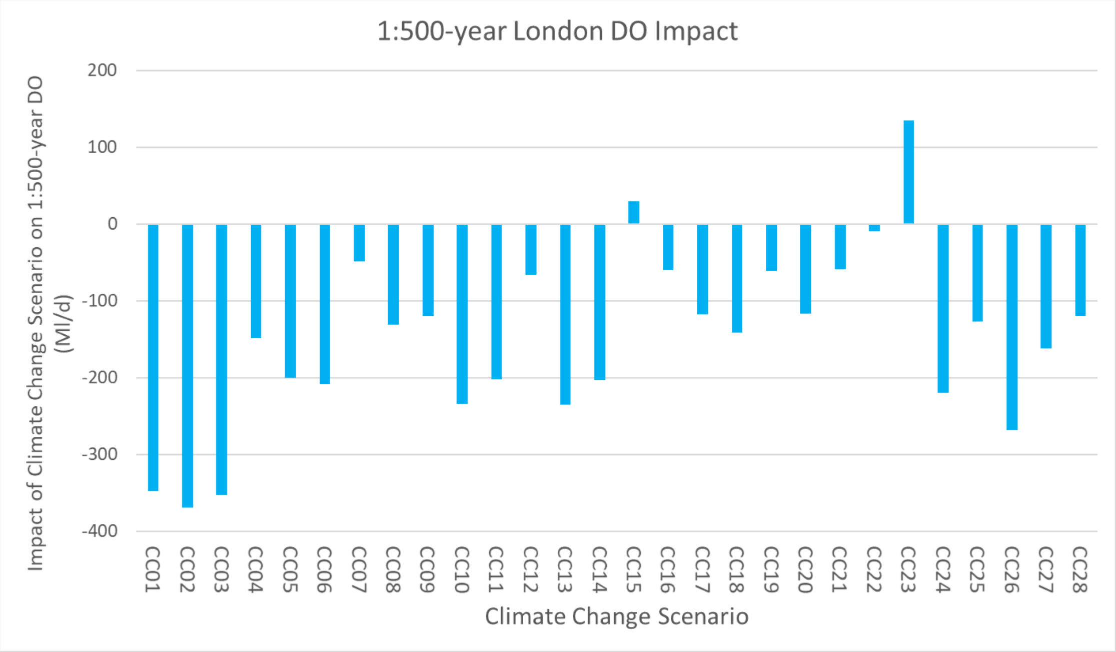

Figure 4-6: London DO Impact of Climate Change from 28 RCM and GCM scenarios, RCP8.5

Results – Second Investigation for London WRZ

4.168 Following the validation of simplified models (details in Appendix U), results from the 28 spatially coherent projections were analysed, but the DO was calculated considering outputs from the 'low complexity' model using all 400 replicates and a 'full stochastic' method of assessment. Analysis and results of this step can be seen in Appendix U. The analysis helped 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?

4.169 The analysis suggests that, while the model and methods used in our first iteration of modelling give a reasonable estimate of the impact of climate change on DO, and are able to accurately distinguish between climate scenarios that would have severe and less severe impacts (there being a very high correlation between results found from both methods), the 1:500-year DO impact found is likely to be an underestimate of around 20-30%. 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 same conclusion was drawn to a significantly smaller degree when establishing the impact of climate change on 1 in 100-year DO, being less than a 10%, likely due to the larger number of '1 in 100-year' droughts within a subsample than '1 in 500-year droughts'.

4.170 In the next stage of analysis, focussed on the probabilistic projections, the flow timeseries generated from hydrological modelling of the perturbed weather sequences produced using the probabilistic climate projections were used in the 'low complexity' 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.

4.171 The results from this step were approximately 3300 DO impact estimates, i.e. 200 x 4 x 4 = 3200 from probabilistic projections and DO impacts from the 28 GCM projections at four different timeslices, with DO impacts being estimated for different return periods.

4.172 The summary of all results can be seen in Figure 4-7. Results from common emissions scenarios can be identified by colour and results from common timeslices can be identified by pattern.

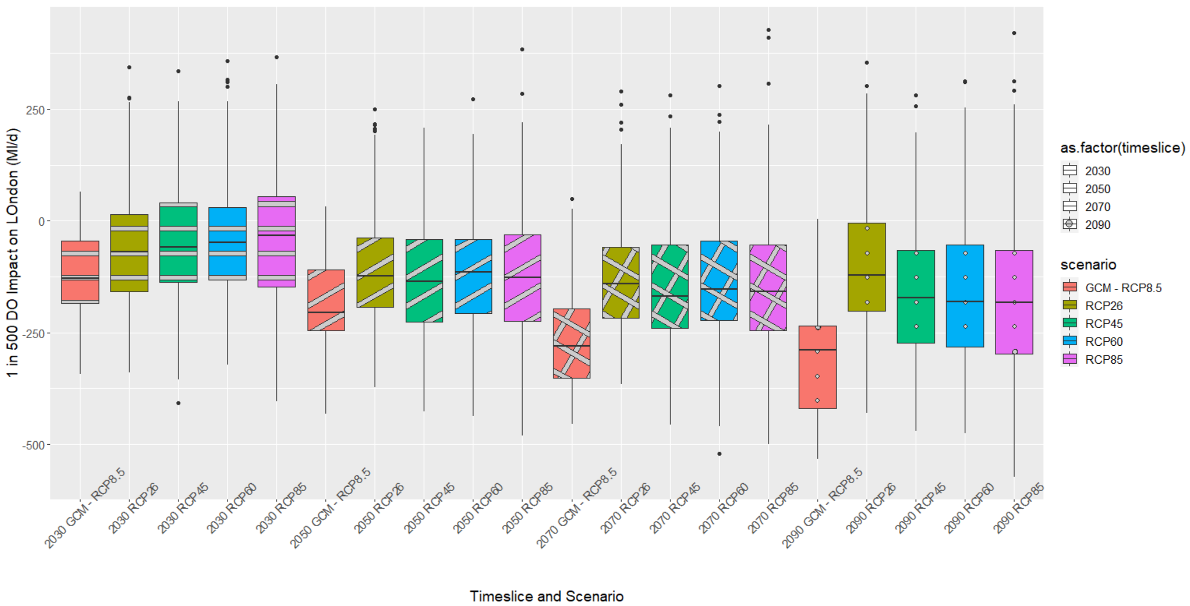

Figure 4-7: Summary of All Results from 'Full Stochastic' Climate Change Analysis

4.173 This figure shows that, at each timeslice, DO impacts from the four emissions scenarios for which probabilistic projections were analysed (RCP2.6, yellow; RCP4.5, green; RCP6.0, blue; and RCP8.5, purple) have similar median impacts and a similar range of impacts. This Figure also shows that the RCP8.5 spatially coherent projections appear to suggest more severe impacts of climate change than any of the probabilistic projections would suggest.

4.174 In order to highlight key results, other graphs have been plotted from this data. Figure 4-8 shows the median DO impact found for each combination of emissions scenario and timeslice. The important results that Figure 4-8 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 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. It may be that the newer iteration is more reliable.

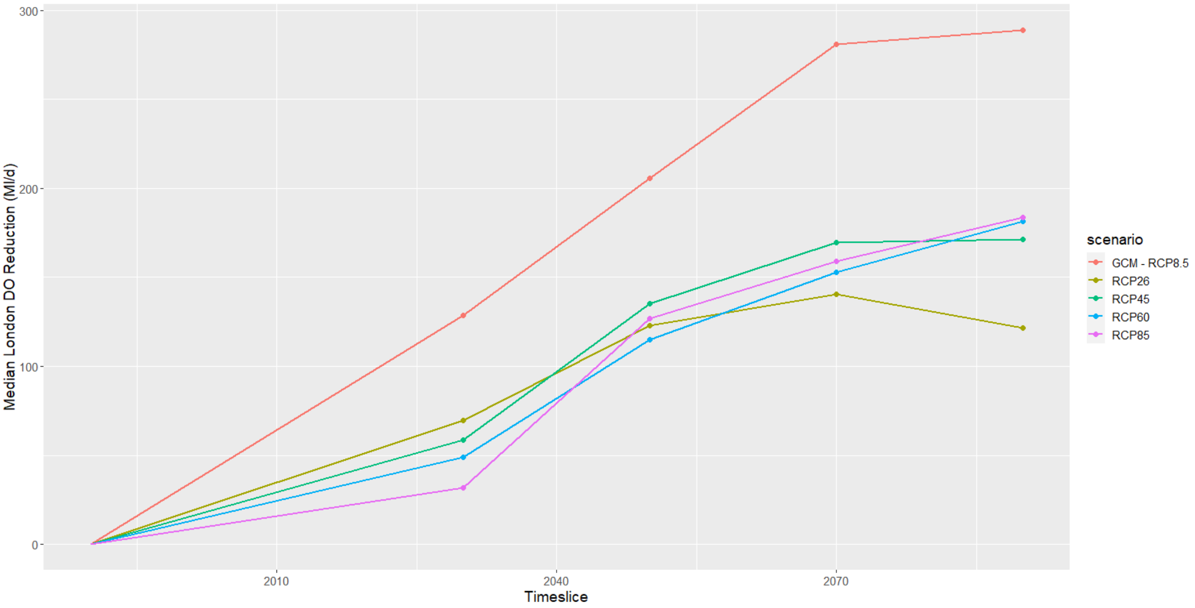

Figure 4-8: Median 1:500 London Do Impacts from Each Combination of Timeslice and Emissions Scenario

4.175 Figure 4-9 shows insight from Figure 4-7 and Figure 4-8 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 probabilistic projections, 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. This is the same finding as we found when investigating the difference in climate change impacts between different scenarios as part of producing our WRMP19.

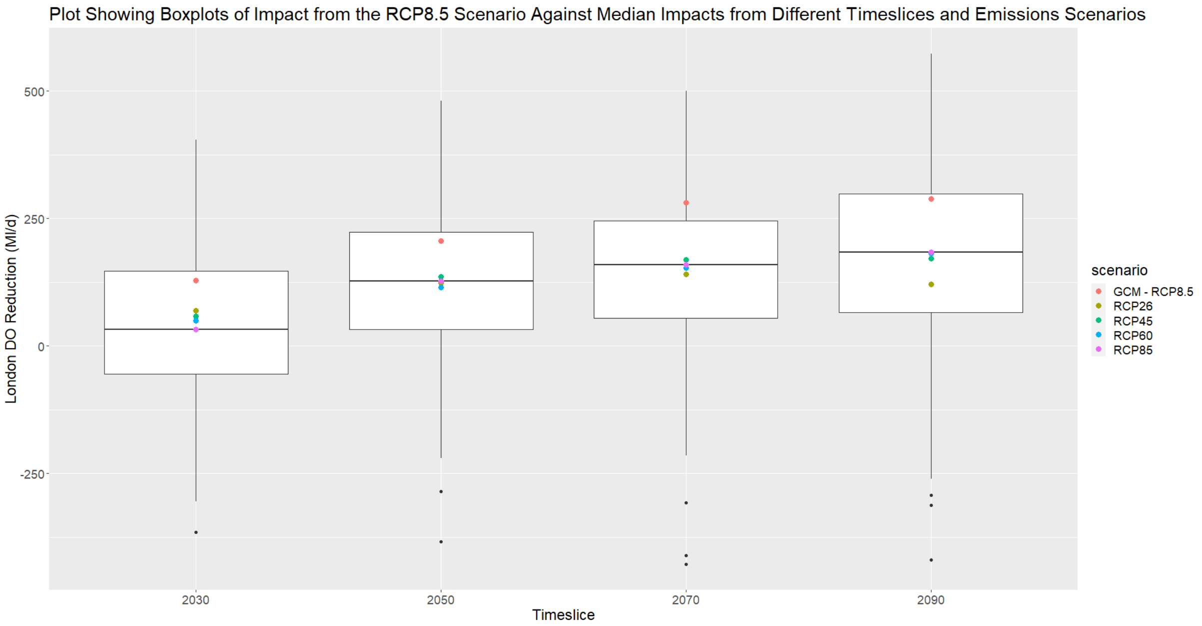

Figure 4-9: Overlaying Median London DO Impact Projections from Different Emissions Scenarios with Boxplot of DO Impacts from a Single Emissions Scenario

4.176 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?

4.177 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.

4.178 We have decided to scale back the results found in the first iteration of work such that the median result is representative of the median result found when investigating the probabilistic projections. This is in order that our investment plan is not skewed by the high climate change impacts found when using the small sample of spatially coherent model outputs.

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

4.179 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.

Adaptive Planning

4.180 Ofwat's guidance on long-term delivery strategies[13] sets out guidance that within our adaptive planning we should consider a 'low' future scenario based on the 50th percentile of RCP2.6 probabilistic projections, and a 'high' future scenario based on the 50th percentile of RCP8.5 probabilistic projections.

4.181 Results from the second iteration of modelling carried out suggest that, for the London WRZ, using a 50th percentile of RCP2.6 probabilistic projections as a 'low' scenario and a 50th percentile of RCP8.5 probabilistic projections as a 'high' scenario would mean that we are not considering the full range of uncertainty that is present in the UKCP18 projections, and that our plan would not be robust/efficient to severe or benign future climate scenarios. As such, it is our consideration that the scenarios defined in Ofwat's guidance are inappropriate for our planning.

4.182 Thames Water, aligned with the WRSE Regional Group, has 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. As mentioned, we have scaled back our climate change impact results to align with the probabilistic projections, and have scaled up our climate change impact results to account for likely underestimation of DO impacts in our first iteration of modelling. We have applied both scaling factors to high, median, and low scenarios.

4.183 Figure 4-10 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 exists, 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

4.184 This chart shows that, if we were only to consider those scenarios which Ofwat have suggested in their Long-Term Delivery Strategy (LTDS) guidance[14], there would be a high

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[13] 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

[14] 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

likelihood (nearly 50%) that our plan would not be resilient to potential climate change impacts when considering all available UKCP18 data.

4.185 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. Appendix U of our rdWRMP24 presents additional evidence to demonstrate that consideration of 50th percentile values from different emissions scenarios is an inadequate way to consider the risks that climate change poses.

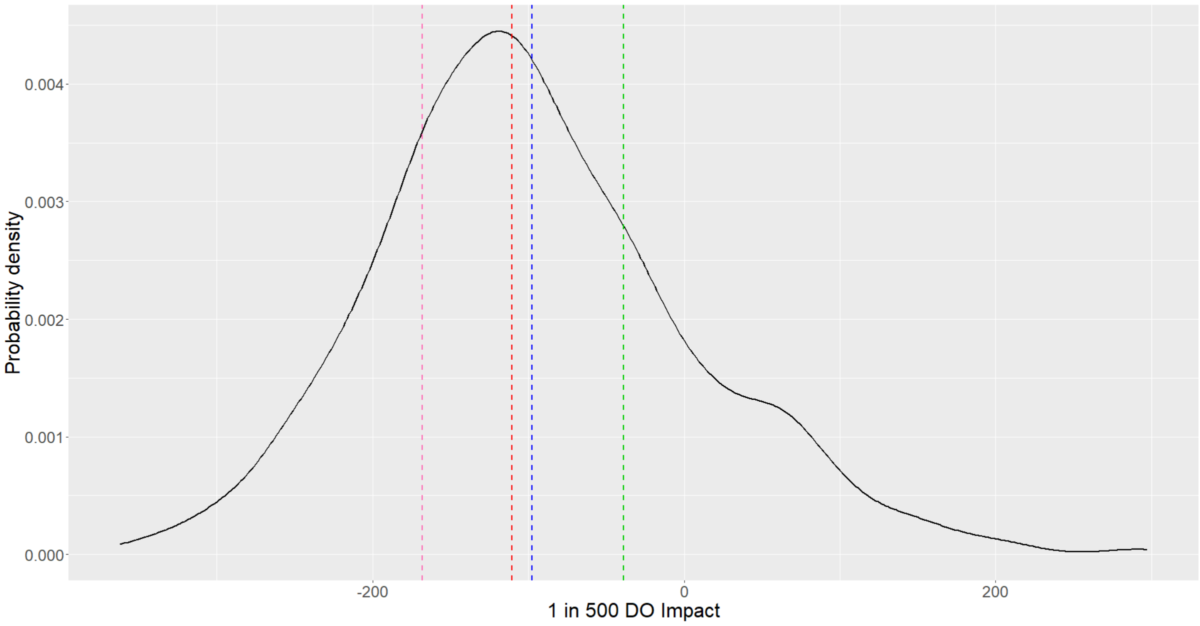

Figure 4-10: 2027 Climate Change DO Impacts for London (Ml/d). Black line is a probability density plot of impacts from all 828 scenarios modelled for this timeslice; green vertical line is our 'low' scenario; pink vertical line our 'high' scenario; blue vertical link is the 50th percentile of RCP2.6 results; red vertical line is the 50th percentile of RCP8.5 results

Scaling of Climate Change Impacts

4.186 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 4-11. 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.

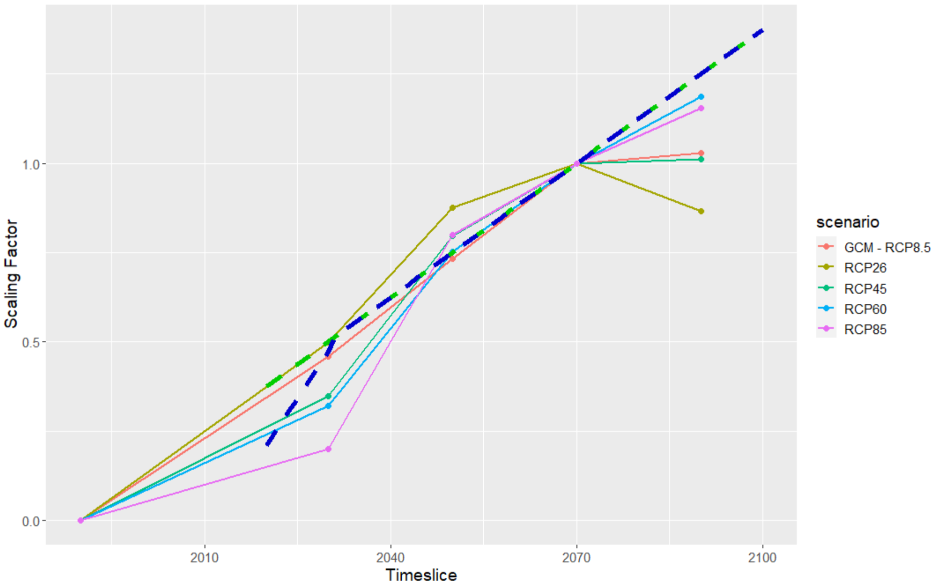

Figure 4-11: Scaling Factor as Calculated From Projections (Solid Lines), Compared to the 'Modified EA Standard' (Scaling linearly from 1990-2070, Green Dotted) and "Alternative EA Scaling" (Blue Dotted)

Results

London and SWOX – 2070 Impacts

4.187 Results from the two iterations of analysis which focus on the London WRZ have been incorporated into the London WRZ and SWOX WRZ supply forecasts. The DO for the London WRZ and SWOX WRZs 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, and the DYCP DO for the SWOX WRZ are either impacted by climate change to a significantly smaller extent or are dependent on other (non-hydrological) constraints.

4.188 The DO impact of the 28 climate change projections for the 2060-80 timeslice considered within the supply forecast, when scaled as described above, can be seen in Figure 4-12 (London WRZ) and Figure 4-13 (SWOX WRZ).

4.189 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.

4.190 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 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.

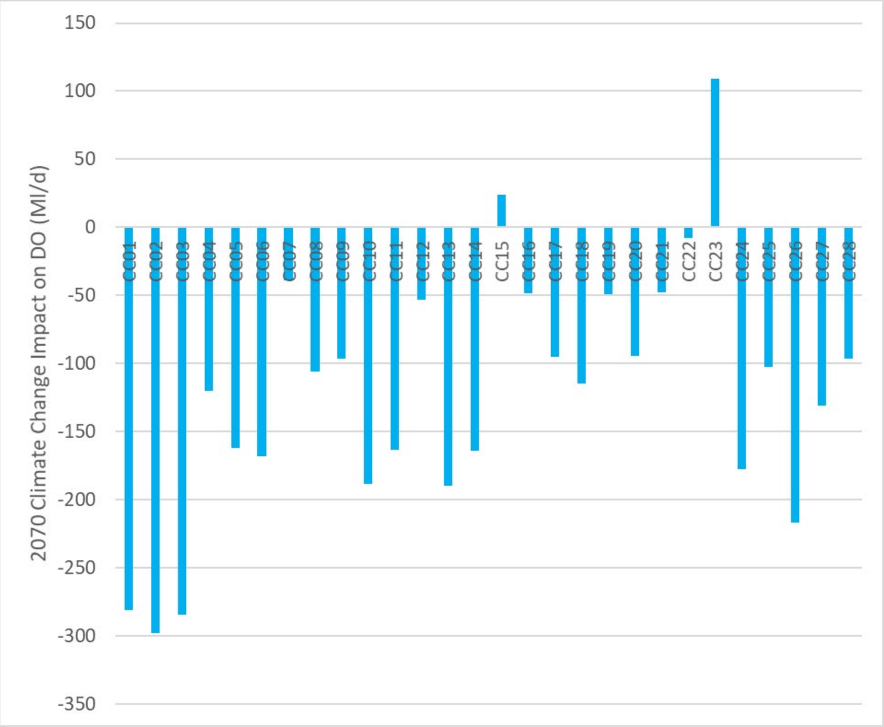

Figure 4-12: Impact of 28 Climate Change Projections on London DO in 2070

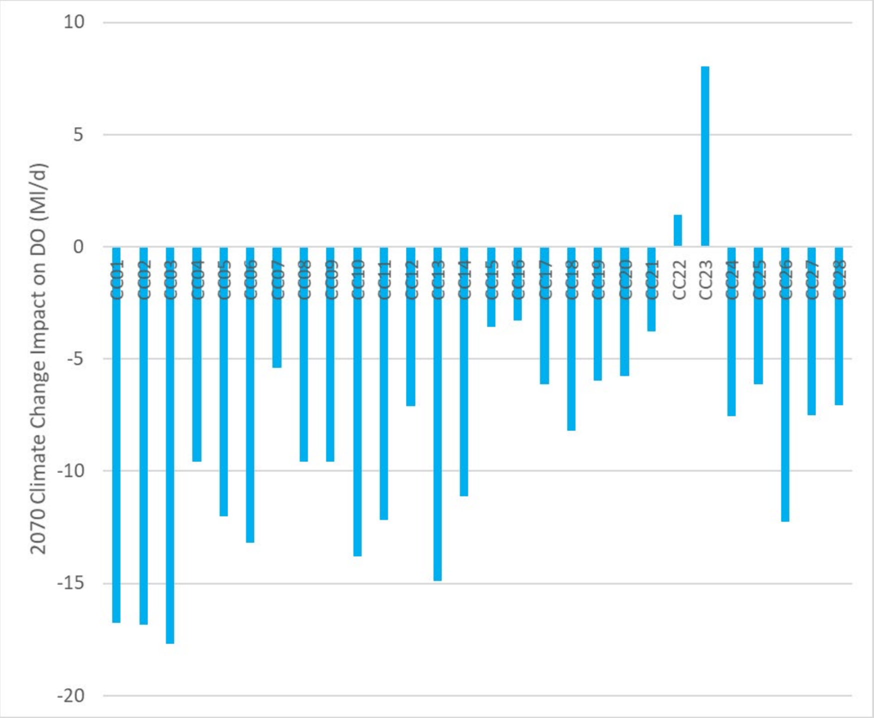

Figure 4-13: Impact of 28 Climate Change Projections on SWOX DO in 2070

Slough, Wycombe and Aylesbury WRZ, Kennet Valley WRZ, and Guildford WRZ – 2070 Impacts

4.191 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 of DO on the DYAA and DYCP DO for the SWA, Kennet Valley and Guildford WRZs.

4.192 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.

4.193 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

4.194 The scaling of climate change impacts is necessary to produce a possible trend in impact over the WRMP planning period. 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.

4.195 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.

4.196 The linear scaling equation suggested by the EA is as follows:

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

4.197 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)

4.198 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 4-14.

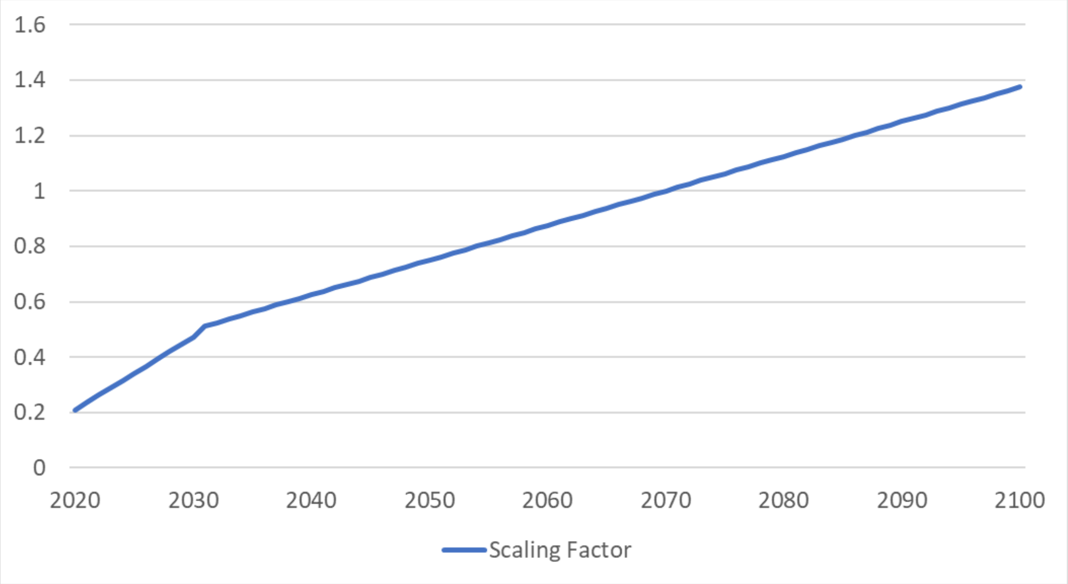

Figure 4-14: Climate Change Scaling Factors

4.199 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

4.200 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.

4.201 Presentation of the climate change impacts included within our WRMP24 supply forecast adaptive planning scenarios and comparison with values calculated in WRMP19 is presented in detail in Appendix U and is not repeated here. Climate change impacts included in our WRMP24 for the year 2070 are presented in Table 4-18 and Table 4-19.

	London	SWOX	SWA	Kennet Valley	Guildford	Henley
High Impact (Ml/d)	-168	-13.2	-0.4	-4.7	0.0	0.0
Medium Impact (Ml/d)	-110	-7.9	-0.2	-3.8	0.0	0.0
Low Impact (Ml/d)	-39	-5.4	-0.1	-3.1	0.0	0.0

Table 4-2: DYAA Climate Change Impacts – 2070

	London	SWOX	SWA	Kennet Valley	Guildford	Henley
High Impact (Ml/d)	N/A	-13.2	-0.5	-11.4	0.0	0.0
Medium Impact (Ml/d)	N/A	-7.9	-0.2	-10.0	0.0	0.0
Low Impact (Ml/d)	N/A	-5.4	0	-3.8	0.0	0.0

Table 4-3: DYCP Climate Change Impacts – 2070

4.202 Alongside the ‘central’ impact of climate change that is included in our supply forecast, we also make an allowance for uncertainty associated with climate change within Target Headroom. This is detailed in Appendix U and Section 6.

Bulk Supplies

4.203 Transfers allow for efficient use of water, with WRZs where there is a surplus of supply being able to transfer water to zones with a deficit. Bulk supplies can involve transfer of either raw or potable water.

4.204 We have a number of existing bulk supply agreements with neighbouring water companies. These can be for temporary support in an emergency situation, or available as permanent supplies, or a mixture of the two (e.g. a small transfer permanently, with an ability to increase transfers in an emergency).

4.205 We also have a number of inset appointments, otherwise known as New Appointments or Variations (NAVs). NAVs are where a company replaces the incumbent statutory supplier within a given area. Within the River Thames catchment, several NAVs exist whereby a different water supplier is responsible for supplying water that originates at our sources, and so we account for these NAVs as bulk supplies within our supply-demand balance.

4.206 Most of the bulk supply agreements that we have are long-standing and exist in perpetuity, terminable only by mutual consent. Variation of these agreements is possible through negotiation.

4.207 Some bulk transfers involve contracts which allow for amendments (either increases or decreases) during periods of drought. In the WRMP we are most concerned with transfers that would be made during a drought situation.

4.208 We consulted all of our neighbouring companies during the pre-consultation stage of WRMP24 to ensure that we are making aligned assumptions in our WRMPs.

4.209 While there are some minor bulk supplies in the Thames Valley area, London is the only WRZ where bulk supplies are a significant factor in the supply-demand balance.

4.210 Where we have transfers, the associated water quality is considered in our Drinking Water Safety Plans.

Changes from WRMP19

4.211 As described in the introductory section of this chapter, in our WRMP19, we treated a number of transfers as part of our baseline. The WRSE regional approach to planning allows WRSE to consider whether these transfers would be part of a ‘Best Value Plan’ (i.e. existing transfers may become unnecessary in the future). As such, transfers within the WRSE region have not been considered as part of our baseline for WRMP24, and are instead considered as options. The WRSE investment model is able to assign minimum values for transfers in order that transfers with associated contracts can be properly considered.

4.212 We have changed the way that we account for a raw water export that we make to Essex and Suffolk Water. This transfer is sufficiently large that it is important that we model its impact within our water resources modelling, as it has ‘system response’ impacts (drawing down storage in north east London, requiring use of the Thames-Lee Tunnel).

4.213 We have not altered the impact of the Essex and Suffolk transfer on our WAFU forecast, but have altered the way that it has been accounted for within our supply forecast.

4.214 In WRMP19 we conducted our DO modelling with the transfer operating dynamically within the model. The DO that we reported was the amount of water that we could reliably supply, assuming that the Essex and Suffolk transfer was operating. We then reported a 0 Ml/d transfer to Essex and Suffolk Water.

4.215 In WRMP24 we have again conducted our DO modelling with the transfer operating dynamically within the model and have again initially calculated the amount of water that we could reliably supply, assuming that the Essex and Suffolk transfer was operating. We have then worked out the additional water that we could supply to London (i.e. the DO benefit) were the transfer to be turned off. When reporting our Deployable Output, we have reported London’s DO as the modelled DO with the transfer turned on, plus the DO benefit associated with turning the transfer off. We have then reported an export equal to the DO disbenefit associated with turning the transfer on.

4.216 The table below shows the difference in our accounting for the impact of this transfer. In this example, the DO calculated with the transfer turned on is X, and the DO impact of turning the transfer off is Y.

Component	WRMP19	WRMP24
Calculated DO	X	X
Reported DO	X	X + Y
Export	0	Y
WAFU	X	X

Table 4-1: Difference in accounting

Bulk Supplies Included Within Baseline Supply-Demand Balance

Essex and Suffolk Water

4.217 Our largest bulk supply export agreement covers the raw water transfer of up to 91 Ml/d on average and up to 118.2 Ml/d, to Northumbrian Water’s Essex and Suffolk area from our Lee Valley reservoirs.

4.218 We have reached several variation agreements with Essex and Suffolk Water regarding this transfer. A variation is currently in place which allows us to request that Essex and Suffolk Water reduce their export by an average of 20 Ml/d (modelled DO impact of 23 Ml/d); this agreement ends in 2035. For the AR20 reporting period, we negotiated a reduction of 25 Ml/d on transferred volumes during drought periods (modelled DO impact of 28 Ml/d).

Affinity Water

4.219 There are four existing exports to Affinity Water, known as Wraysbury (raw export from Wraysbury reservoir), Fortis Green (treated export from London WRZ), Hampstead Lane (treated export from London WRZ), and Ladymead (treated export from Guildford WRZ). The three treated water exports have been considered as “options” within the WRSE’s investment modelling, rather than being part of the baseline. This is because an overall regional best value plan may not include the continuation of these transfers (e.g., it may be better for Affinity Water to develop new sources of water and stop using the transfers rather than continuing the transfer if Thames Water need to develop new resources). The Wraysbury export is incorporated within our baseline, as this transfer is there to provide raw water quality risk mitigation (and it is thus not reasonable to consider that it would be stopped).

Inset Appointments

4.220 Our supply area has a number of Inset Appointments that supply customers in different WRZs. The exports to NAVs have been uplifted from 'measured' to 'dry year' using uplift factors. NAV exports are accounted for in the baseline supply-demand balance, with growth accounted for within demand forecasts.

Summary of Transfers Included in Baseline Supply-Demand Balance

4.221 Table 4-21 details the transfers included in our baseline supply-demand balance for the planning period 2026 onwards.

WRZ	Imports	Exports	DYAA Total (Ml/d)	DYCP Total (Ml/d)
London	None	Essex and Suffolk Water raw water export from King George V/ William Girling Reservoirs: 62 Ml/d in 2020 67 Ml/d from 2021-2035 90 Ml/d from 2036 onwards Inset of 5.46 Ml/d, assumed constant across planning period	-67.46 (2019/20); -72.46 (2020/21 – 2034/35); -95.46 (2035/36-2099/2100)	N/A
SWOX	None	Inset of 2.24 Ml/d (DYAA), 2.67 Ml/d (DYCP)	-2.24	-2.67
SWA	None	Inset of 1.57 Ml/d (DYAA), 1.87 Ml/d (DYCP)	-1.57	-1.87
Kennet Valley	None	Inset of 0.30 Ml/d (DYAA), 0.35 Ml/d (DYCP)	-0.30	-0.35
Guildford	None	None	0	0
Henley	None	None	0	0

Table 4-2: Summary in Baseline Supply-Demand Balance

Network Constraints

4.222 Network constraints occur where existing infrastructure is not capable of distributing or treating all of the raw water that could be produced at a site. Most network constraints are associated with small, rural sources on the edge of our distribution network, feeding areas of local demand. Network constraints are deducted from a WRZ's DO.

4.223 Table 4-22 details the Network Constraints accounted for in our supply forecast.

WRZ	DYAA Constraint (Ml/d)	DYCP Constraint (Ml/d)
London	0	N/A
SWOX	0.23	1.08
SWA	2	2
Kennet Valley	0	0
Guildford	0	0
Henley	0	0

Table 4-3: Network Constraints Included in Supply Forecast

Water Available for Use – Baseline Supply Forecast

4.224 Having determined the individual components of our supply forecast we are able to produce a forecast of WAFU for each WRZ.

4.225 The average and peak WAFU for the first year of the WRMP24 planning period (2025-26) are shown in Table 4-23 and Table 4-24 respectively.

WRZ	DO*	-	Climate Change Impact	-	Network Constraint	-	Outage	-	Treatment Losses	+/-	Bulk Supplies	=	WAFU
London	2253.8	-	58.8	-	0.00	-	73.89	-	8.42	-	72.46	=	2040.2
SWOX	321.66	-	4.15	-	0.23	-	6.69	-	3.58	-	2.24	=	304.77
SWA	184.66	-	0.09	-	2.00	-	15.49	-	0.49	-	1.57	=	165.02
Kennet Valley	152.72	-	5.90	-	0.00	-	1.96	-	8.53	-	0.30	=	136.03
Guildford	68.87	-	0.00	-	0.00	-	1.55	-	1.89	+	0.00	=	65.43
Henley	21.55	-	0.00	-	0.00	-	1.15	-	0.00	+	0.00	=	20.40

Table 4-1: DYAA WAFU 2025-26 (values in Ml/d)

* Note: DO Values stated here are 2025/26 DOs, incorporating sustainability reductions assumed up to this point, accounting for the Level of Service at this point in time

WRZ	DO*	-	Climate Change Impact	-	Network Constraint	-	Outage	-	Treatment Losses	+/-	Bulk Supplies	=	WAFU
London**													
SWOX	345.06	-	4.15	-	1.08	-	3.06	-	4.08	-	2.67	=	330.02
SWA	204.51	-	0.08	-	2.00	-	3.26	-	0.49	-	1.87	=	196.81
Kennet Valley	158.6	-	2.30	-	0.00	-	0.99	-	8.51	-	0.35	=	146.45
Guildford	74.28	-	0.00	-	0.00	-	0.38	-	1.86	+	0.00	=	72.04
Henley	21.70	-	0.00	-	0.00	-	0.17	-	0.00	+	0.00	=	21.53

Table 4-2: DYCP WAFU 2025-26 (values in Ml/d)

* Note: DO Values stated here are 2025-26 DOs, incorporating sustainability reductions assumed up to this point, accounting for the Level of Service at this point in time

** Note: The DO for our London WRZ is assessed for DYAA only due to both London's reservoirs and ring main providing a buffer during peak periods

4.226 In the following sections, the WAFU forecast is presented for each WRZ, with key features described.

4.227 Please note that WAFU is shown here (and above) excluding sustainability reductions, except for those which are confirmed for AMP7.

London

4.228 The London WAFU forecast (Figure 4-15) shows a gradual decline, due to climate change impacts, punctuated with sharper drops in WAFU. The sharper drops in WAFU are associated with:

- 2024-25 and 2025-26: Sustainability reductions confirmed for AMP7, and end to current licence trading agreement.
- 2032-33: Move to 1 in 200-year resilience
- 2035-36: End of variation to Essex and Suffolk Export
- 2040-41: Move to 1 in 500-year resilience

4.229 WAFU in London by the end of the planning period is a little over 20% lower than at the beginning of the planning period.

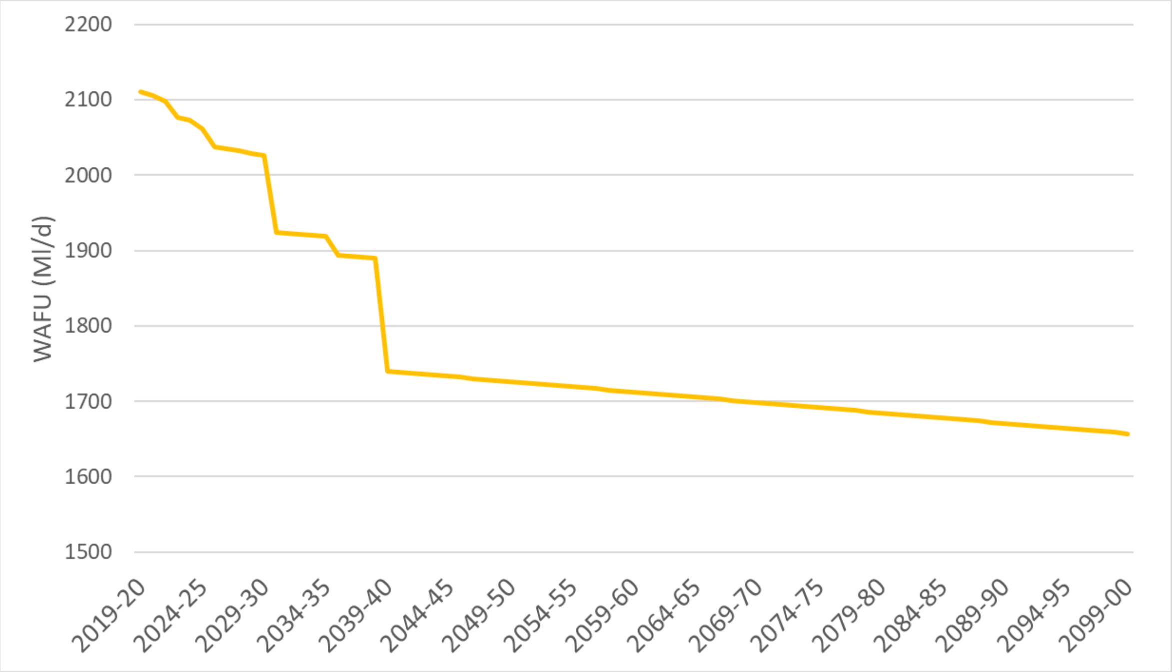

Figure 4-15: London DYAA WAFU Forecast

SWOX

4.230 The SWOX DYAA and DYCP WAFU forecasts (Figure 4-16) shows a similar pattern to the London WAFU forecast, with a gradual decline (again due to climate change impacts), punctuated with sharper drops due to changes in the level of resilience.

4.231 The SWOX DYAA and DYCP WAFU both reduce by around 10% across the planning period.

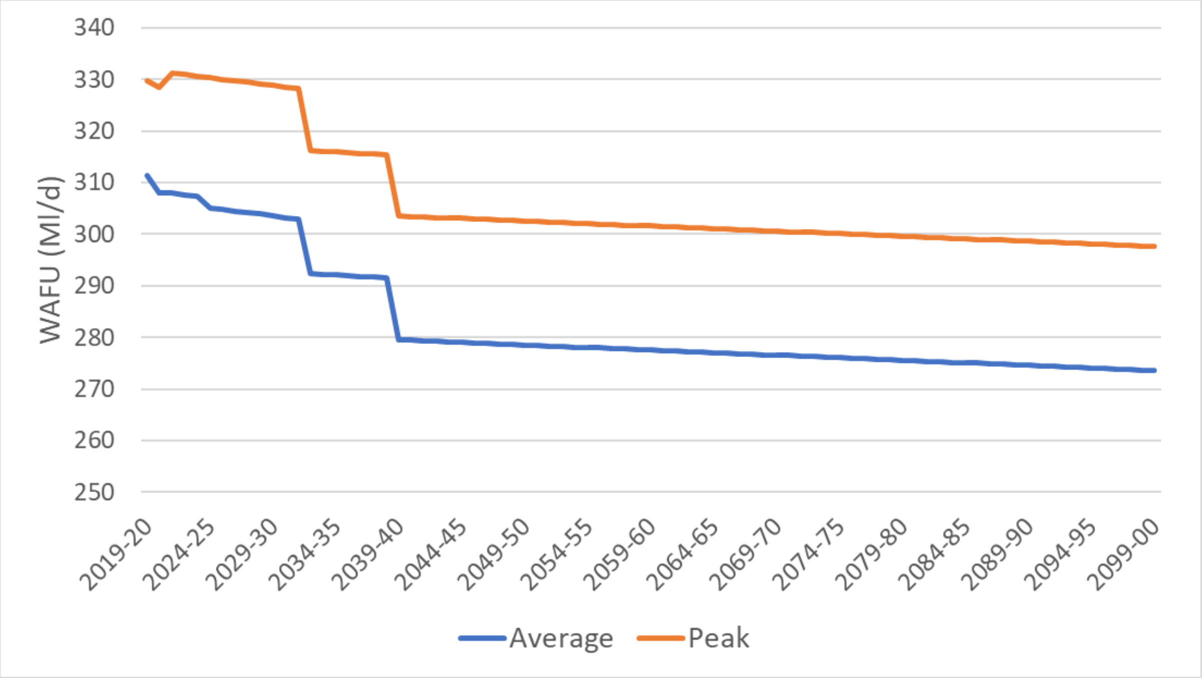

Figure 4-16: SWOX WAFU Forecast

Slough, Wycombe and Aylesbury

4.232 The Slough, Wycombe and Aylesbury WAFU forecasts (Figure 4-17) show some initial small changes (associated with DO changes in AMP7 and sustainability reductions that are confirmed for AMP7 or shortly after), before stable WAFU forecasts throughout the planning period. This reflects the negligible impact of climate change and resilience changes on the WAFU of the SWA zone.

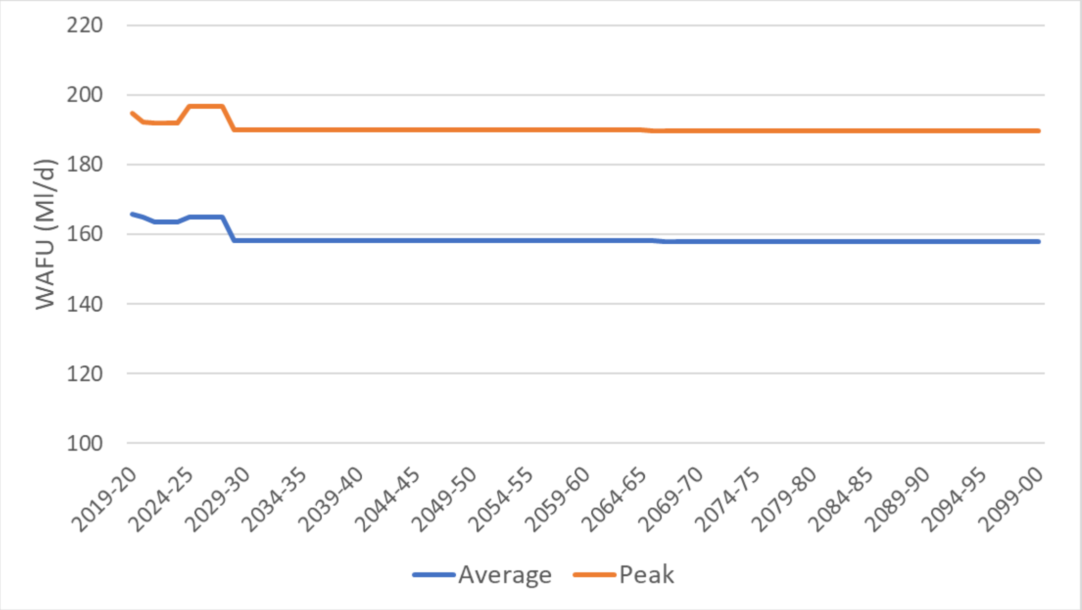

Figure 4-17: Slough, Wycombe & Aylesbury WAFU Forecast

Kennet Valley

4.233 The Kennet Valley WAFU forecasts (Figure 4-18) show that changes in resilience have a significant impact on both DYAA and DYCP WAFU, due to the vulnerability of the Fobney run-of-river source to extreme drought events. Aside from WAFU drops associated with changes in resilience, the WAFU forecasts are broadly stable across the planning period.

4.234 The Kennet Valley DYAA WAFU drops by around 30% across the planning period, while the DYCP WAFU forecast drops by around 20% across the planning period.

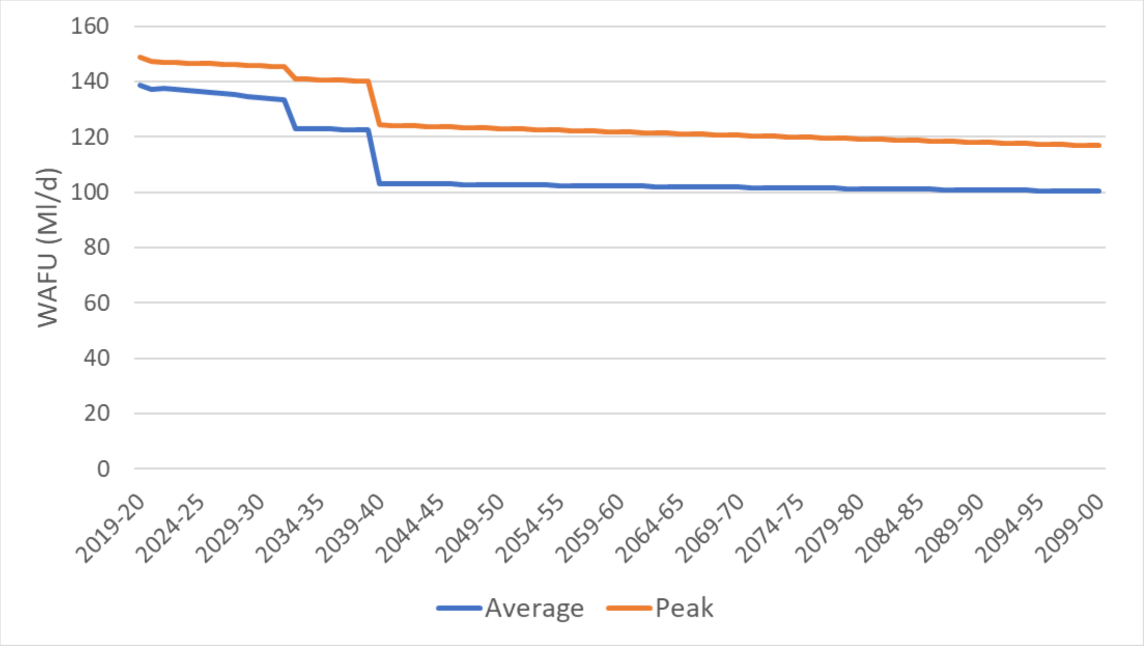

Figure 4-18: Kennet Valley WAFU Forecast

Guildford

4.235 The Guildford WAFU forecasts (Figure 4-19) show a broadly stable forecast throughout the planning period. The DYCP forecast shows an initial increase in 2025, due to the forecast delivery of a scheme at the end of AMP8.

4.236 Aside from initial changes in DO, there is no change to either WAFU forecast across the planning period, reflecting the resilience of the sources in the Guildford WRZ to drought conditions.

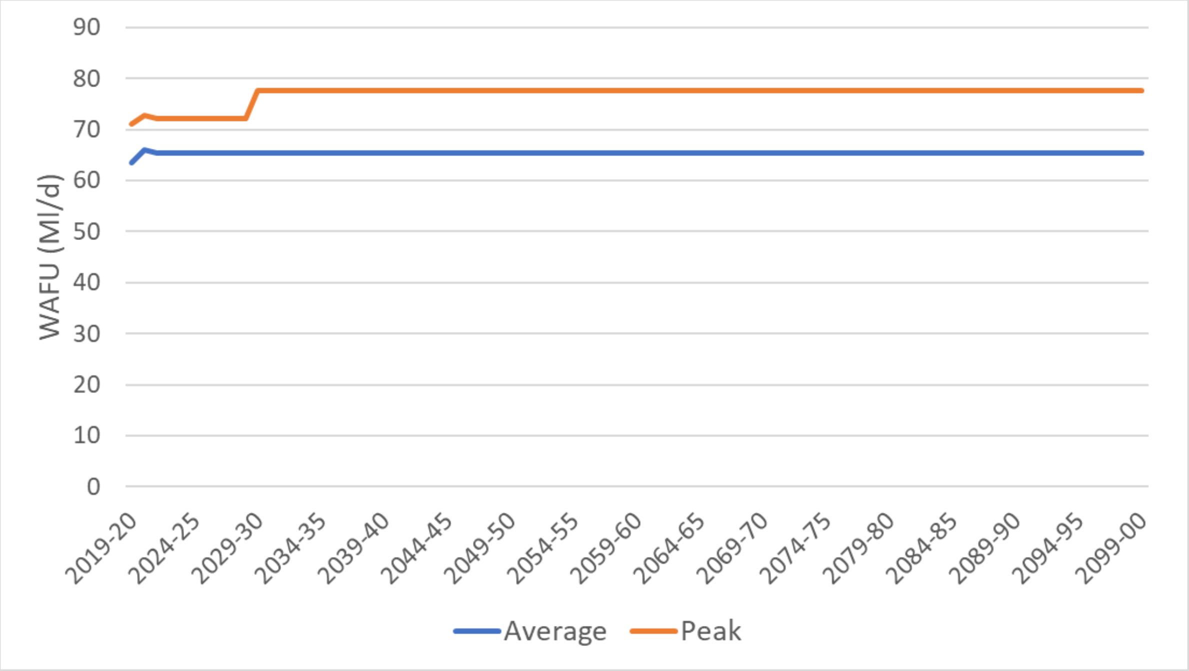

Figure 4-19: Guildford WAFU Forecast

Henley

4.237 The Henley WAFU forecasts (Figure 4-20) show an initial decrease in the zone's WAFU due to a reassessment of a source DO (Sheeplands) reflecting a long-term outage.

4.238 Aside from initial changes in DO, there is no change to either WAFU forecast across the planning period.

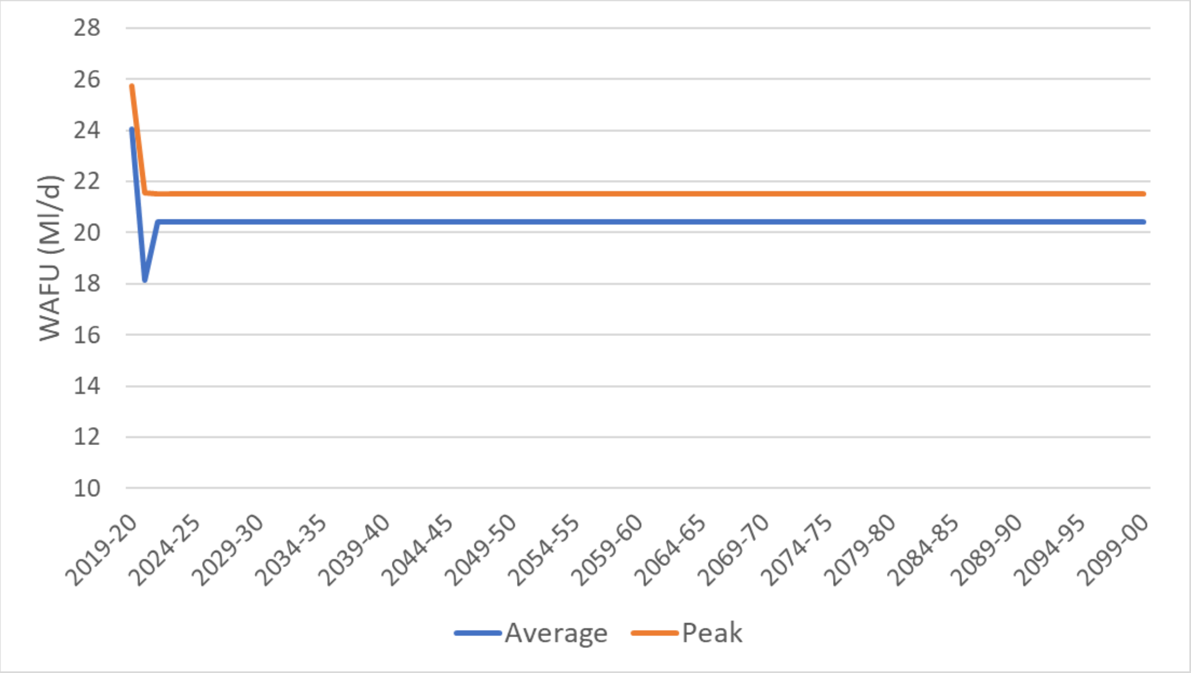

Figure 4-20: Henley WAFU Forecast

Drought Response Surfaces

4.239 As is required by the Water Resources Planning Guideline, Section 4.6, here we present Drought Response Surfaces according to the Drought Vulnerability Framework.

4.240 As part of the development of our Drought Plan 2022, we have undertaken an assessment of the risk of potential shortfall in water resources in severe droughts of different types using Drought Response Surfaces (DRS). We have not supplemented or amended the assessment that was carried out for the Drought Plan, and so for full details of work that was undertaken, we would encourage you to read Appendix N of our Drought Plan[15].

4.241 We have undertaken an assessment for each of our Water Resource Zones (WRZs) for our current baseline position but have not conducted assessments for future time periods or our final plan condition. We have used an appropriate method for each WRZ, dependant on the size and relative drought vulnerability of the WRZ and considering the best available data for each zone. It should be noted that there is a significant level of uncertainty associated with this type of assessment.

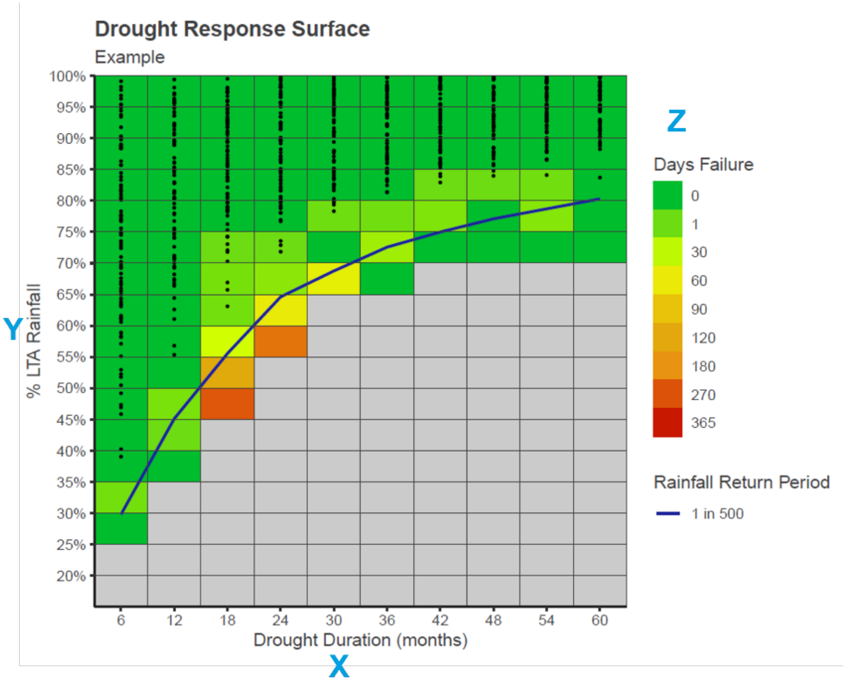

Figure 4-21: Example Drought Response Surface

4.242 The purpose of drought response surfaces is to visually present the potential risks of droughts of varying durations and severities. The plot is made up of a grid of cells, where each cell represents drought of a given different duration (in months on the X axis) and rainfall deficit (% of average rainfall on Y axis). The axes are such that extremely long and dry droughts appear in the bottom right of the grid, while short and less severe droughts appear in the top left of the grid.

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[15] Thames Water, 2022, Final Drought Plan 2022 – Appendix N, https://www.thameswater.co.uk/media-library/home/about-us/regulation/drought-plan/appendices/thames-water-drought-plan-appendix-n.pdf

4.243 On the “Z” axis, the colours represent how severe the impact of the drought in that cell is - this can be represented using different metrics, but in our case, the colours show a number of days of “failure” i.e. the length of time, in days, that emergency restrictions will be required. Cells are green where the assessment does not indicate that emergency restrictions would be required, and red where the assessment indicates that emergency restrictions would be required for a long period of time. Droughts which are deemed unrealistic, or where our assessments do not give us an appropriate level of confidence, are shown in grey. Additional data is also presented for context: black points show events that have occurred using historic rainfall records, curved lines show the probability of a rainfall deficit of a given duration and severity occurring. Note that on the X axis, the duration scale is divided into discrete categories of 6-month intervals – for example, where a line crosses from 6 to 12 months, this is not indicating a drought of 9 months duration.

London

4.244 The DRS for London, Figure 4-22, uses results from the Pywr modelling carried out for WSRE regional plan and WRMP24 and was produced using Calculation Approach 1a in the UKWIR Drought Vulnerability Framework. This has involved use of the stochastic weather record that has been developed for WRSE & WRMP24, as per our DO assessment. Using this weather data, a number of days’ failure (a failure in London is defined as crossing Level 4 on the LTCD) was produced for each of the 19200 years in the stochastic record under an appropriate level of demand, with demand savings applied. The demand used reflects Base Year Demand + Target Headroom as per the EA Drought Vulnerability Framework guidance, as-well as an allowance for Bulk Supplies (in London specifically, this means that our export to Essex and Suffolk and exports to Affinity Water are included in the water resources model runs used to produce this drought response surface).

4.245 Each year of the record also has corresponding rainfall statistics (rainfall deficits over different periods) and storage level data. In order to match the rainfall deficits with the failure data for a given year, the timing of the drought was defined as ending when the minimum storage level was reached. The rainfall leading up to that date was then used to define where that event should be plotted. We then plotted the drought response surface using the mean of the numbers of days failure in each cell (many events may fall into a single cell on the DRS).

4.246 The DRS for London indicates that London is resilient to a range of droughts up to 1 in 200-year return period. The DRS indicates that London is most vulnerable to droughts between 1 and 3 years long, with average rainfall of less than 75%. For example, Figure 1 shows that for an 18-month drought of 45-50% rainfall, up to 6 months of emergency restrictions may be required. It should be noted that we believe that the 42-month event with 80-85% LTA rainfall showing potential risk of failure is likely an artefact of the methods used, rather than an indication of vulnerability.

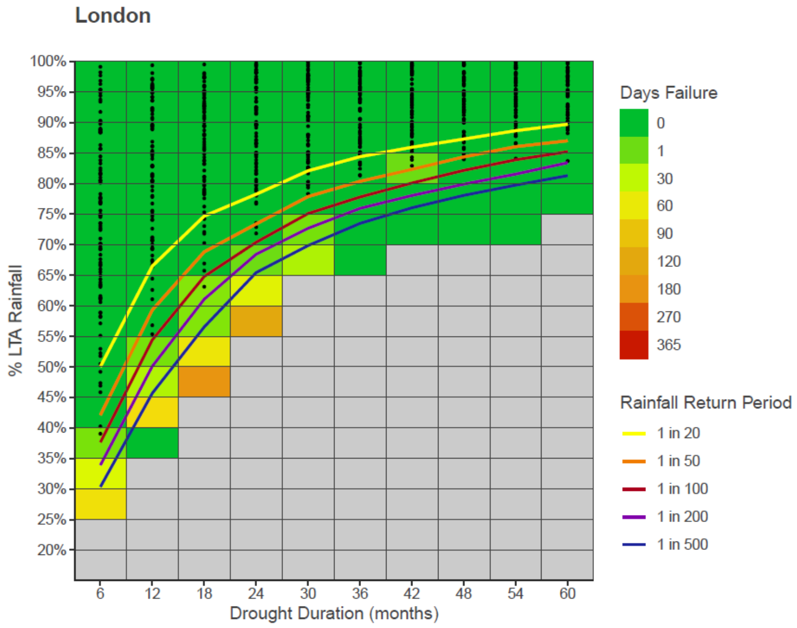

Figure 4-22: London Drought Response Surface

SWOX

4.247 The drought response surface, Figure 4-23, for SWOX uses the same methodology and Calculation Approach[1] as in London.

4.248 The drought response surface for SWOX, Figure 4-23, shows that we are broadly resilient to droughts up to 1 in 200-years, but for droughts of severity of 1 in 200-year or greater we are at risk of requiring emergency restrictions and so would be reliant on drought permits. This accords with our assessment of risk for SWOX which shows that we would be resilient to a drought similar to 1976 but that if it extended then we would be reliant on drought permits to ensure we did not need to impose emergency restrictions. The drought response surface for SWOX also provides a concordant view of the event type that SWOX is vulnerable to, insofar as SWOX is more vulnerable to 12 to 18-month drought events.

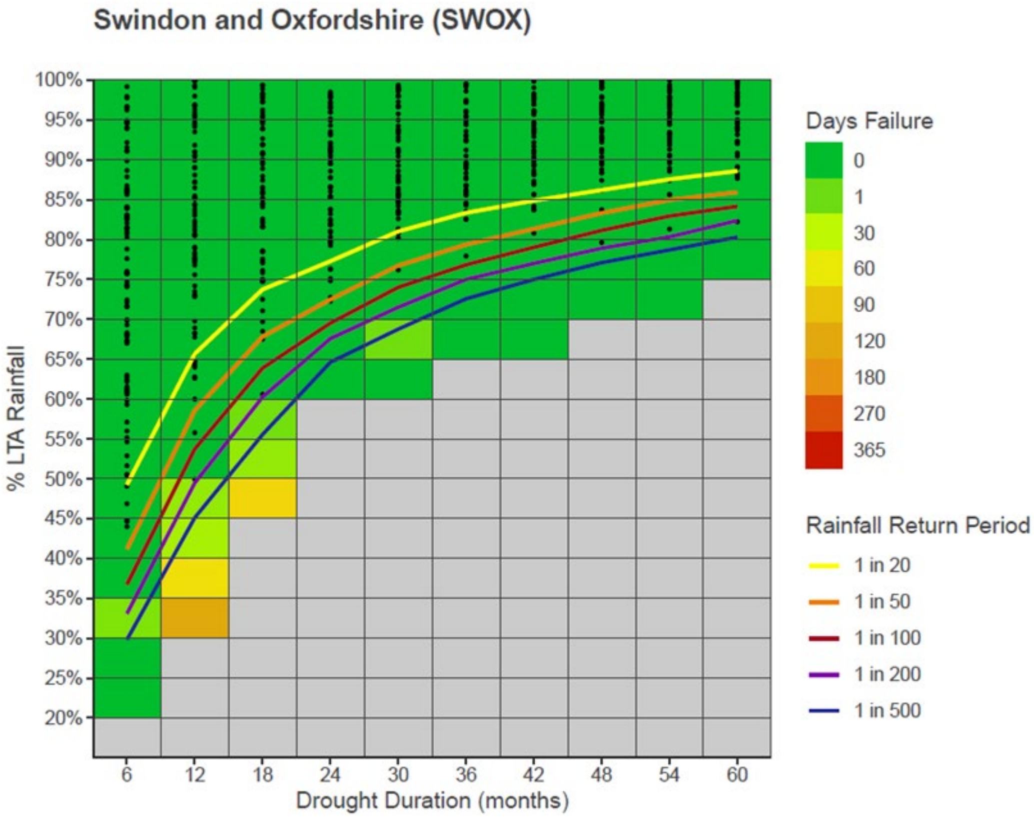

Figure 4-23: SWOX Drought Response Surface

Kennet Valley

4.249 The Kennet Valley DRS, Figure 4-24, uses a combination of methods following Calculation Approach 1b and 4b in the UKWIR Drought Vulnerability Framework[1]. The yield of our Fobney surface water source (run of river) was determined for each year in the stochastic series (using river flows from the same Pywr modelling used for the London and SWOX DRS analysis) and an appropriate stochastic rainfall dataset was used to classify years in the stochastic record to boxes on the DRS.

4.250 Approach 4b was applied for other sources within the Kennet Valley WRZ. This approach involves determining a statistical relationship between rainfall over a given duration and groundwater levels, and then applying these relationships to determine groundwater levels (and so yield) that may be anticipated for different drought durations and severities.

4.251 Our analysis using approaches 1b and 4b resulted in yields for each source being determined for each DRS cell. The sum of surface and groundwater yields were used to determine the total yield for the WRZ in each cell, which was compared against an appropriate demand figure (to give an indicative supply-demand balance for each DRS cell) and a calculation applied to determine if, and how long, emergency restrictions might be required for.

4.252 Two scenarios were considered in Kennet Valley regarding the availability of the West Berkshire Groundwater Scheme (WBGWS); within the Kennet Valley WRZ this influences only the Fobney run-of-river source. The first (a) was using the current trigger for WBGWS – London's reservoir storage falling below Level 2 on the LTCD.; the second scenario (b) assumes that WBGWS could be triggered by considering low flows in the River Kennet. The difference between these two figures indicates that there would be benefit for the

Kennet Valley WRZ in introducing a trigger for WBGWS which would be based on flows in the River Kennet; introducing such a trigger would require agreement by the Environment Agency.

4.253 The Kennet valley DRS shows that we are resilient to 1 in 500-year droughts of 2 years or more. But that we may be vulnerable to drought events of 1 in 100-year or worse severity lasting 1 to 1.5 years. Triggering of WBGWS, or use of other drought permits, may be required should such an event occur, although as with London this assessment is based on event severity being a function of rainfall, rather than river flows.

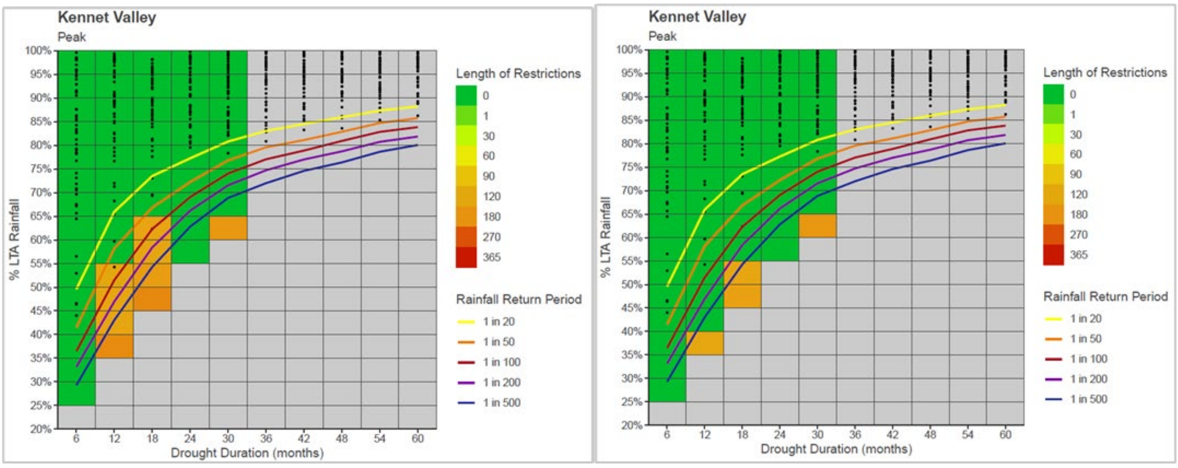

Figure 4-24: Kennet Valley Drought Response Surfaces, a (left), and b (right)

Slough, Wycombe and Aylesbury

4.254 The method used for producing the SWA DRS is similar to that of Kennet Valley – a combination of statistical estimations of groundwater levels and yields at a number of sites added to stochastic yield datasets for Dancers End and Radnage sources.

4.255 The DRS for SWA, Figure 4-25, shows resilience to droughts of up to 1 in 200-years but that beyond that there may be the requirement for drought permits during events of 30 to 36 months with less than 70% LTA rainfall. This reflects the potential vulnerability in the yields of a small number of sources, particularly Hawridge and Pann Mill. Sustainability reductions have been implemented at Pann Mill, therefore the yield is likely to be resilient to severe drought, and Hawridge is currently planned to be closed at the end of AMP7.

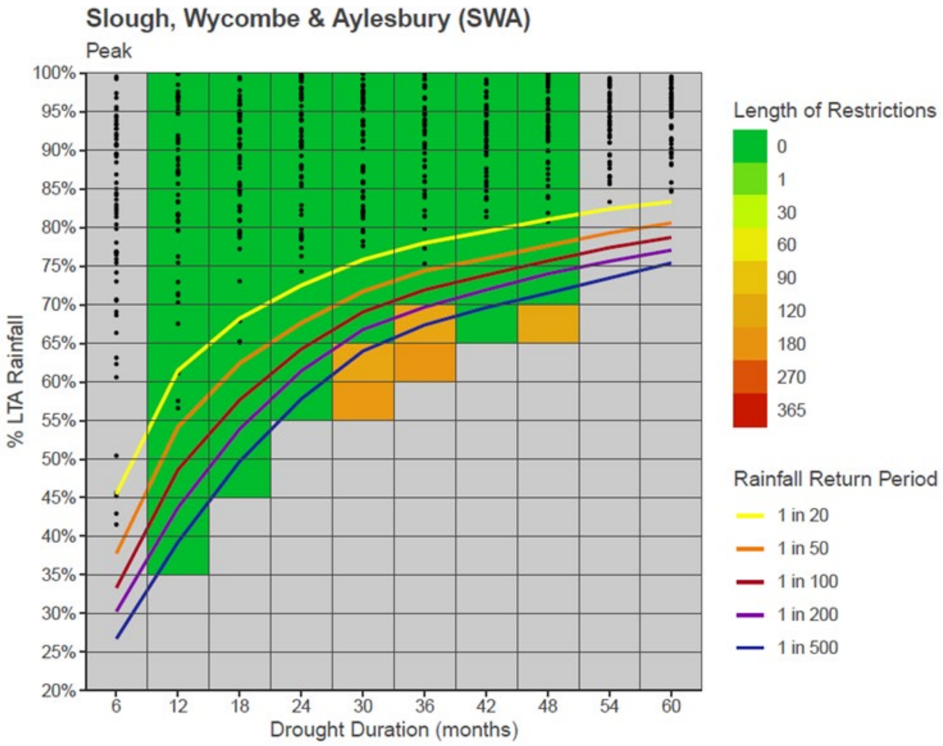

Figure 4-25: SWA Drought Response Surface

Guildford

4.256 The DRS, Figure 4-26, for Guildford shows resilience to droughts up to at least 1 in 500-year severity. At this level of drought severity there is a high level of uncertainty but this view accords with our assessment of the drought resilience of the Shalford source which is dependent upon flows in the River Wey being maintained at greater than 30 Ml/d.

4.257 The method used to produce this DRS are similar to those used for the SWA WRZ, whereby a combination of modelled flows using the stochastic record and statistically determined groundwater levels have been used to generate this surface.

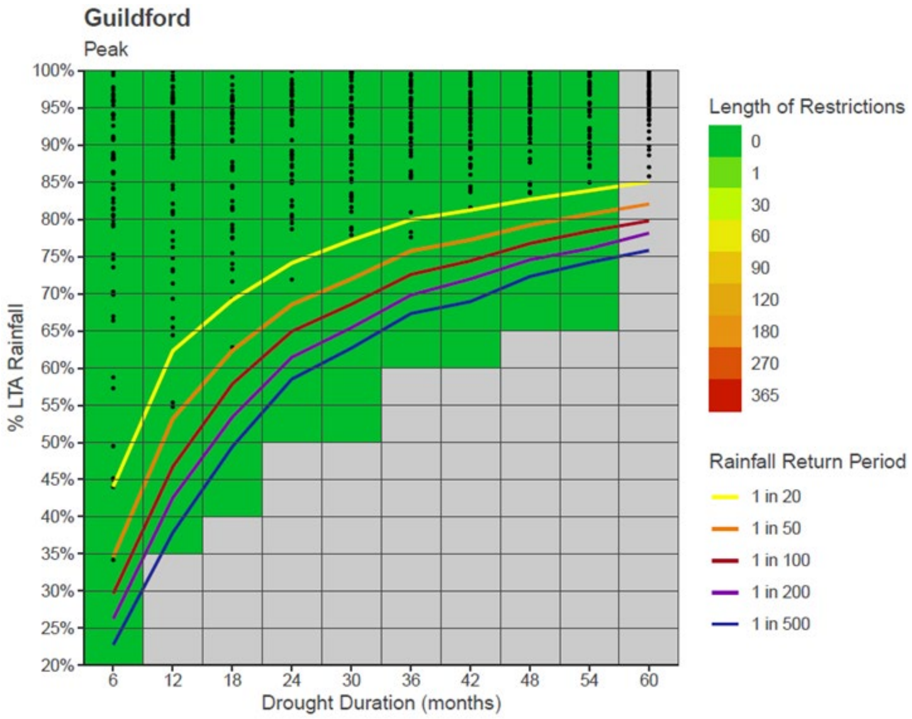

Figure 4-26: Guildford Drought Response Surface

Henley

4.258 The DRS for Henley, Figure 4-27, shows resilience to droughts up to at least 1 in 500-year severity. At this level of drought severity there is a high level of uncertainty but this view accords with what is known about our Henley sources in that they are Thames-side groundwater sources and so have a high level of drought resilience.

4.259 The Henley DRS was produced solely using statistical analysis of groundwater levels (method 4b) under low probability rainfall events.

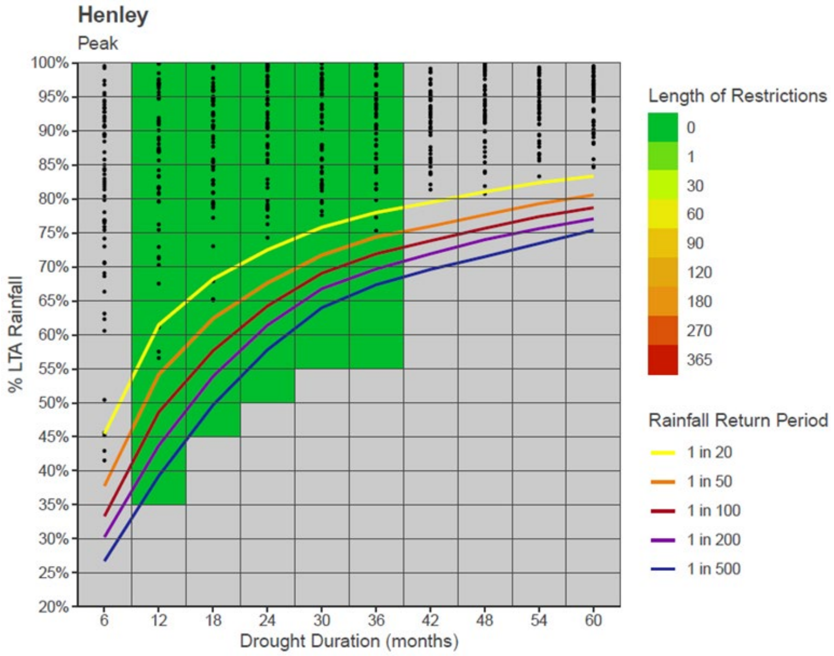

Figure 4-27: Henley Drought Response Surface


Thames
Water