Section 4

Current and future water supply

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Current and future water supply

- 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. The components of the term Water available for use (WAFU) are explained and the base year values for the year 2016/17, updated using the best available up-to-date information between draft and revised draft WRMP19 (referred to as AR17+ figures here), are shown.
- We describe the forecast of supply and the dual pressures affecting water supply of climate change and reductions in abstraction licence capacity to achieve for environmental improvements.
- We have included sustainability reductions in line with the Water Industry National Environment Programme (WINEP3) published by the Environment Agency (March 2018).
- We explain our involvement in the Water Resources in the South East (WRSE) Group and its examination of the potential for a regional water resources solution; and set out our bulk transfers with neighbouring water companies.

A. Introduction

4.1 The Thames basin is one of the most intensively used water resource systems in the world. Around 55% of effective rainfall is licensed for abstraction[1] and 82% of that is for public water supply (Figure 4-1).

4.2 Our baseline water supplies are derived mainly through surface water abstraction in London (supported by a series of large bunded storage reservoirs) and groundwater abstraction in the Thames Valley. The proportions of supply are as follows:

- **London:** 80% surface water and 20% groundwater
- **Thames Valley:** 30% surface water and 70% groundwater

4.3 In a dry year we supply 2,100 Ml/d of water in London and 780 Ml/d in the Thames Valley at peak times.

4.4 Our baseline water supplies are forecast to reduce over the planning period to 2100. The main cause is the impact of climate change (~134 Ml/d by 2044/45 increasing to ~241 Ml/d by

[1] Environment Agency, Thames Catchment Abstraction Management Strategy, May 2014, section 2, page 8

2099/00). A lesser cause is due to trading agreements expiring, which amount to 40 Ml/d over the period to 2099/00.

4.5 Together with growing demand as set out in Section 3: Current and future demand for water, this leaves us with a considerable challenge to balance supply and demand over the 80 year planning period in some zones, London in particular.

4.6 The remainder of this section is structured as follows:

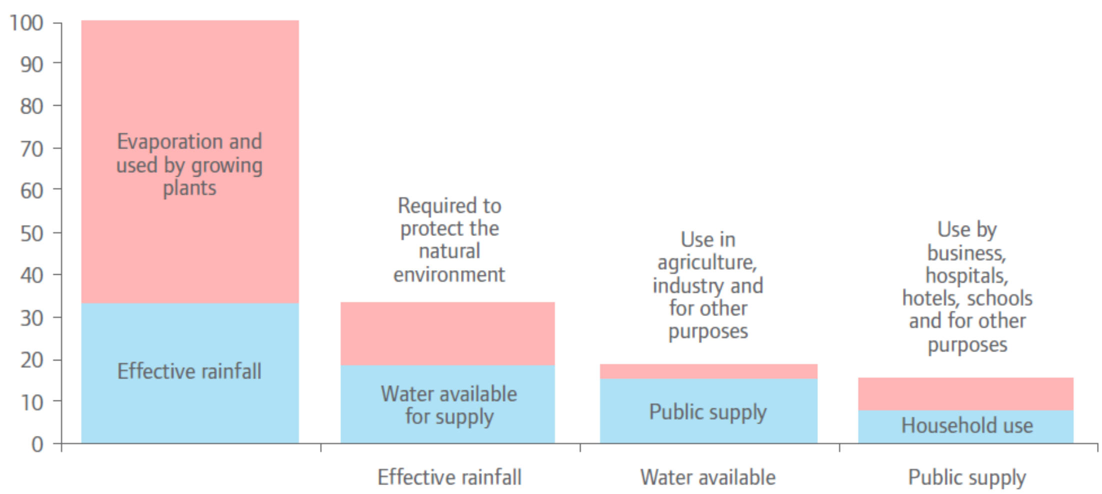
- Introduction
- Current WAFU
- Baseline supply forecast
- Sustainability reductions
- Climate change (further information in Section 5: Allowing for risk and uncertainty and Appendix U: Climate change)
- WRSE (further information in Section 7: Appraisal of water resource options).

The Thames basin

4.7 The Thames basin is the largest river basin in the south east of England. The average rainfall for the Thames catchment is 739mm[2] in a year, substantially less than the average for England and Wales, 919mm[3]. (Note this is derived from the records from 1883 to 2011.)

4.8 Of the rain that falls, two-thirds is either lost to evaporation or transpired by growing vegetation (Figure 4-1). Of the remaining one-third, which is 'effective' rainfall, approximately 55% is abstracted for use, making it one of the most intensively used river basins in the world. Of all the water abstracted, 82% is for public supply.

Figure 4-1: What happens to water in the Thames basin



[2] "Thames 12 Station average" data from the Environment Agency and averaged over 131 years
[3] Defra, Official Statistics for England and Wales

Source: Taken from GLA Securing London's Water Future - The Mayor's Water Strategy for London, 2011

Where we get our water supplies

Figure 4-2: Existing water resources in the Thames catchment

4.9 The amount of water we can put into supply (i.e. leaving our WTWs and into our distribution network), is called WAFU and is a function of many factors.

4.10 WAFU in the base year (2016/17) is evaluated according to the relationship below and describes the amount of water available to supply the demand for water:

WAFU = Deployable Output – Climate Change Impacts – Constraints – Outage +/− Bulk Supply Imports/Exports (including Inset Arrangements).

4.11 Each of these components is described further below.

4.12 We take into account increases and decreases to these components when forecasting WAFU over the 80 year planning period. Principally these are:

- The impact of climate change
- Changes as a result of trading agreements expiring
- New schemes coming online and
- Changes to abstraction licences in the period to 2019/20 (as discussed in Section 2: Water resources programme 2015-2020.

4.13 WAFU is then assessed against demand (Section 3: Current and future demand for water) plus Target Headroom (Section 5: Allowing for risk and uncertainty) to understand whether a WRZ is in surplus or deficit (Section 6: Baseline water supply demand position).

B. Current water available for use (2016/17)

4.14 The individual components to calculate the amount of WAFU are discussed briefly below.

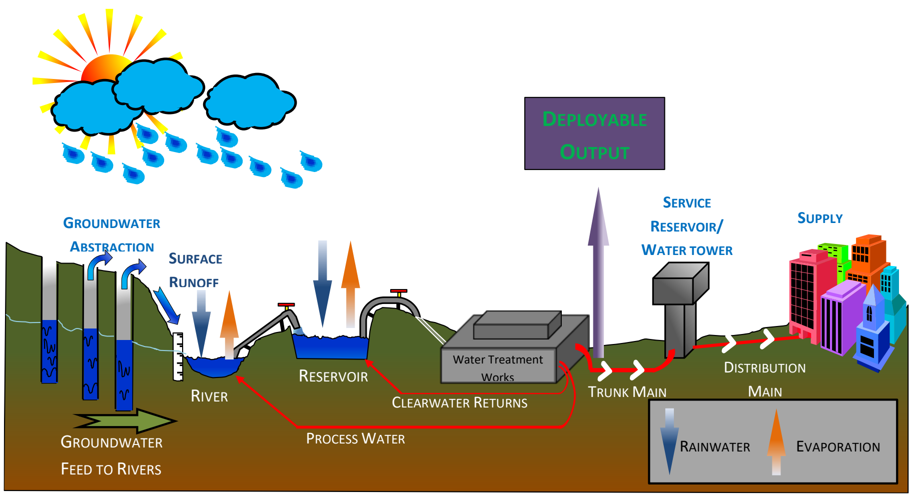
Deployable Output

4.15 DO is the building block on which the assessment of WAFU is based. It is defined as the output of a commissioned water source or group of sources or of a bulk supply for a given Level of Service as constrained by:

- Hydrological yield;
- Licensed quantities;
- Environment (through licence constraints);
- Pumping plant and/or well/aquifer properties;
- Raw water mains and/or aquifers;
- Transfer and/or output main;
- Treatment;
- Water quality.

4.16 This is shown in Figure 4-3 below:

Figure 4-3: Definition of DO



Source: Based on Water Resources Planning Tools 2012 Definitions and Environment Agency Guidelines May 2016

4.17 DO is calculated using prescribed methodologies for surface and groundwater sources.[4,5,6,7,8] The assessment of DO also follows the principles for DO derivation as outlined in the 2012 UKWIR/Environment Agency report on Water Resources Planning Tools[9].

4.18 We have a complex supply system where, in many areas, surface and groundwater are mixed and operated together to maintain yields over the year in reaction to antecedent weather and demand patterns. These are known as conjunctive use systems.

4.19 London's water comes from many sources but most is abstracted from the River Thames and stored in raw water reservoirs before being treated and put into supply. The raw water reservoirs provide a buffer for use in dry periods when abstraction from the River Thames is restricted. The quantities that can be abstracted from the river depend on the relationship between the quantities stored in the reservoirs, the need to ensure a residual freshwater flow in the River Thames over Teddington weir, and the time of year. This is governed by the formal operating agreement between Thames Water and the Environment Agency under Section 20 of the Water Resources Act 1991, called the Lower Thames Operating Agreement (LTOA).

4.20 DO for the London conjunctive use zone (CUZ) is calculated using a simulation model entitled WARMS2, which is an enhancement of the original WARMS used for our Water Resources Management Plan 2014 (WRMP14). The LTOA is fundamental to the calculation of DO because it determines the relationship between the flow in the River Thames and the amount of water available to abstract for given levels of raw water storage in the London water storage reservoirs. This in turn defines how the abstractions from the Lower Thames are managed and therefore determines the supply capability for London. Due to the interconnectivity across London it also influences the operation of other strategic sources. Key to the LTOA is the Lower Thames control diagram (LTCD), which sets the rules by which the level of flow over Teddington weir is set, known as the Teddington Target Flow. It also provides River Thames flow / London raw reservoir storage trigger levels which place actions on us that are aimed at reducing demands and providing a DO benefit, for example a media campaign or hosepipe ban and supporting yields by operating strategic schemes, including, as an example, the WBGWS, during a dry year as detailed within Appendix I: Deployable output.

4.21 Following the re-development of the WARMS2 an update of London's DO was calculated for the Annual Review 2016 (AR16). The calculation assumes the preferred version of the optimised LTCD and the Teddington Target Flow matrix (TTFM), agreed with the Environment Agency. The re-development of WARMS and the introduction of an optimised LTCD resulted in a significant change in London's DO as seen in Table 4-1. The updated optimised LTCD is shown in Figure 4-4, with details in Appendix I: Deployable Output.

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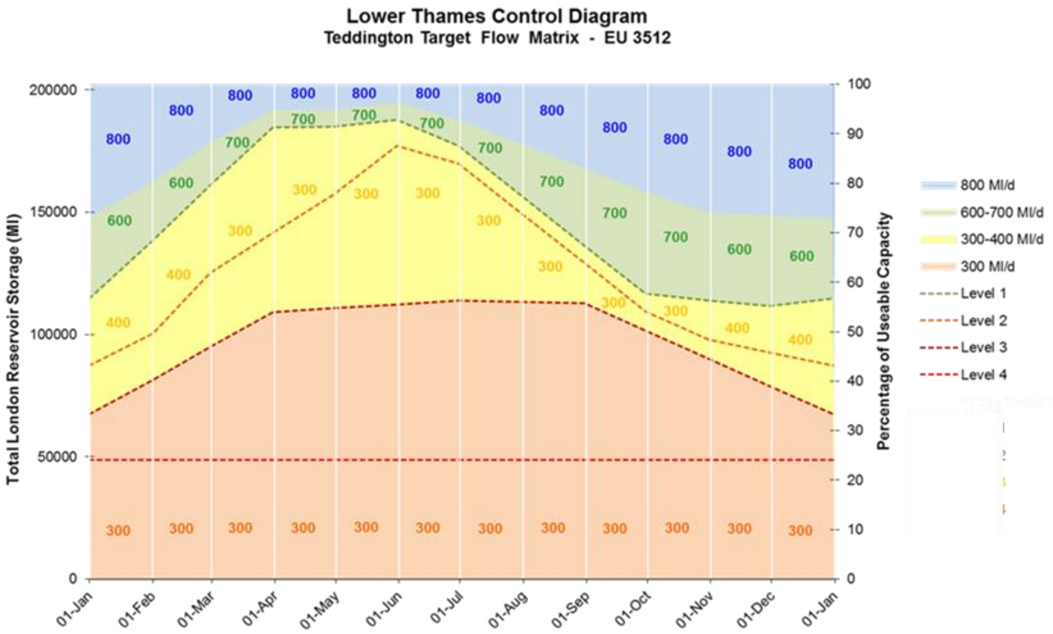
[4] Drayton and Lambert ,1995, Surface Water Yield Assessment
[5] Environment Agency, 1997, Reassessment of Water Company Yields
[6] Beeson, van Wonderen and Mistear, 1995, Assessing the Reliable Outputs of Groundwater Sources
[7] UKWIR and Environment Agency, 2000, A Unified Methodology for the Determination of Deployable Outputs from Water Sources
[8] UKWIR, 2014, Handbook of Source Yield Methodologies
[9] UKWIR and Environment Agency, 2012, Water WR-27 Water Resources Planning Tools

4.22 With regard to the future operation of the WBGWS, we will await the Environment Agency's national review of their environmental augmentation schemes, to be completed by March 2019, which will address their longer term availability, including that of the WBGWS. This will be followed up by discussion of the scheme ownership and operation beyond 2031. To assess the potential future water supply impact for the London and Kennet Valley WRZs, the WBGWS has been included within the Economics of Balancing Supply and Demand (EBSD) model as a 'what-if' scenario as part of programme appraisal as detailed in Section 10: Programme appraisal and scenario testing.

Figure 4-4: Lower Thames control diagram



4.23 The groundwater source DO (SDO) numbers that contribute to the current WAFU for the Water Resources Management Plan 2019 (WRMP19) and input to WARMS2 are those reported in the Annual Review 2017 (AR17) as adjusted for the impact of updates to groundwater SDOs (following an internal review of constraints) and revised treatment works throughput capabilities and treatment works loss figures (using our WTW Process Models). The 2016/17 values within the WRMP19 are therefore referred to within this document as AR17+ figures.

4.24 The calculation of these groundwater SDOs is in accordance with good practice, ensuring consistency in their assessment and enabling a coherent assessment of our DO. In particular, the approach defines source DOs for a single drought year for all sources in each WRZ. In addition, the groundwater source DOs are arrived at by defining: a Dry Year Critical Peak (DYCP) DO that reflects a demand driven peak DO for Average Day Peak Week (ADPW) at the time of peak summer demand in July/August; a Dry Year Annual Average (DYAA) DO that reflects an average over 12 months; as well as a minimum DO that accounts for the lowest groundwater levels in the drought year.

4.25 The Swindon and Oxfordshire (SWOX) WRZ is the other CUZ within the Thames Water area where the DO is also modelled using WARMS2. The current assessment for SWOX WRZ DO follows best practice (WRPG) because WARMS2 models the Upper Thames strategic reservoir/groundwater source conjunctive use system, with the South Oxfordshire (SOX) source DOs and transfers to the Upper Thames added as a post-processing step to calculate the WRZ DO.

4.26 The remaining four zones of Kennet Valley, Henley, Guildford and Slough, Wycombe and Aylesbury (SWA) derive raw water supplies predominantly from groundwater sources, although Kennet Valley and Guildford have significant run of river surface water sources at Fobney and Shalford, respectively. The Kennet Valley and Guildford WRZs have not been assessed as CUZs because they do not have any strategic reservoir storage; rather they are served by a combination of run of river sources and groundwater sources.

4.27 The DO calculation for run-of-river surface water sources with no raw water storage (Fobney, Kennet Valley WRZ and Shalford, Guildford WRZ) follows the approach outlined in the UKWIR Handbook of Source Yield Methodologies (2014). This relies on flow data provided by the Environment Agency, rather than model outputs.

4.28 The mechanism by which demand restrictions are triggered in the Thames Valley WRZs is set out in detail in our draft Drought Plan 2017. Drought management decisions must start with a consideration of the impact the drought is having on the supply capability within each WRZ and the approach taken in formulating the drought management protocol is dependent upon the nature of the water resources system within each WRZ. Because of the dominant nature of the London WRZ, it will generally be the case that the water use restrictions introduced in the London WRZ will also be applied to the rest of our supply area. Nonetheless, the Drought Plan recognises that there may be situations in which more local measures may need to be introduced for the other WRZs. Consequently, protocols have also been developed for these zones. The protocol for each zone is included in further detail in Appendix I: Deployable Output.

4.29 Further information and discussion on the methodology for calculating DO, DO sensitivity analysis and the impacts of Levels of Service, including the DO benefit of demand restrictions and strategic schemes and details of how these drought actions are triggered, is provided in Appendix I: Deployable Output.

4.30 The DYAA and DYCP DOs for 2015/16 (AR16) and 2016/17 (AR17), which are included in the Annual Review to the Environment Agency, are shown in Table 4-1 below as are the values at WRMP14 based on Annual Review 2013 (AR13) data; 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. Changes to the DOs between reporting years are explained as part of the Annual Review reporting process. Further details of our Annual Review process can be found on our website. The AR17+ figures are also shown in Table 4-1. These figures reflect the best information available at the time of producing the WRMP19 between AR17 and AR18.

Table 4-1: DO WRMP14, 2015/16 (AR16) and 2016/17 (AR17+).

WRZ	Deployable Output (Ml/d)							
	DYAA WRMP14	DYAA AR16	DYAA AR17	DYAA AR17+**	DYCP WRMP14	DYCP AR16	DYAA AR17	DYCP AR17+**
London*	2144	2305	2305	2302	--	--	--	--
SWOX	319.5	319.2	329.2	329.2	373.9	373.7	385.4	385.4
Kennet Valley	137.1	133.1	135.8	143.9	160.1	155.1	157.8	155.4
Henley	25.7	25.7	25.7	25.7	26.3	26.3	25.9	25.9
SWA	186.3	186.3	183.3	185.1	215.1	216.2	213.3	214.4
Guildford	65.0	65.4	65.4	65.8	71.2	72.9	71.3	71.7
Total	2877.6	3034.7	3044.4	3051.7	846.6	844.2	853.7	852.9

**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.*

***Note A17+ figures have been used in the WRMP19. These are the AR17 figures adjusted to take account of the impact of updates to SDOs (following internal review of constraints) and revised treatment works capabilities and treatment works loss figures (using our WTW Process model).*

4.31 AR18 DOs are consistent with the AR17+ DOs with the exception of SWOX which is +1 Ml/d DYAA and +1.19 Ml/d DYCP due to a refinement to the Chingford WTW capability.

Treatment works losses

4.32 An important element in the calculation of DO is the amount of water used at treatment works. Abstracted water is treated within a WTW before disinfection and being put into the supply network. There is inevitably a loss of water in this process.

4.33 Many groundwater sources are good quality and may need only a simple treatment process with negligible waste. However, the large surface WTWs that treat water from our London raw water reservoirs necessitate the employment of a variety of treatment processes. Treatment processes and WTWs also require additional 'process water' for cleaning and maintaining the plant.

4.34 The process for treating water means that there are potential losses of process water to the system unless there is an opportunity to re-cycle the water.

4.35 This 'process water' contains contaminants and is either treated and discharged to the river, or discharged to a sewer or, where possible, further treated and re-cycled back to the "head of the works" for re-use.

4.36 The route for disposal of process water depends upon the nature of the WTW, the source and quality of the raw water.

4.37 The opportunity to recycle process water can be achieved by a number of routes:

- Directly, as at the Coppermills WTW, which recovers the majority of process water by treatment and recycling
- Indirectly via discharge into a watercourse or river, where it contributes to the flow available for abstraction or the “hands off flows”, as on the Lower Thames
- Indirectly via a sewage treatment works, which in turn may support downstream water available for abstraction or the “hands off flows”, as on the Lower Thames

4.38 Process losses are included in WARMS2 and therefore included in the calculation of DO.

4.39 The modelling of the water resources system through WARMS2 assumes that a percentage of additional water is needed to deliver a specific quantity into supply. For example to put 100 Ml/d into supply with a 10% process water requirement means that 110 Ml/d would need to be transferred to the WTWs and results in a 10 Ml/d process water loss (calculated in WARMS2 as 10% of 100 Ml/d output from the WTW into supply).

4.40 As noted the percentage of process water losses differs between works due to varying raw water quality and treatment processes.

4.41 Note the Coppermills WTW has the facility to transfer 35 Ml/d of process water back upstream of the process plant for re-use.

4.42 The process water losses percentages assumed for each WTW in WARMS2 for AR17 and for AR17+, the figures used in the WRMP19 and consistent with AR18, are shown in Table 4-2.

4.43 AR17 process losses at the large surface WTW have been reviewed since submission of the draft WRMP19. This review has used our WTW Process Models. The AR17+ process losses now range from around 1% up to almost 16%, but with most being less than 7%. At the treatment works with losses of almost 16%, i.e. Coppermills WTW, facilities exist for recycling some of the process water as noted about, which reduces net process losses to 7.4%. The updated AR17+ process losses used for WRMP19 are documented in Table 4-2 and these are consistent with the figures used for AR18. The analysis and calculation for the key WTW in each WRZ discussed in Appendix K: Process losses.

Table 4-2: Process water losses assumptions in WARMS2

WRZ	WTWs	Process water losses (%)	
		AR17	AR17+
London	Ashford Common	3.0	2.3
	Hampton	6.1	3.4
	Kempton Park	7.2	1.1
	Walton	14.2	6.7
	Coppermills	8.0	7.4
	Hornsey	3.0	4.6
	Chingford	3.5	0.7
SWOX	Farmoor	8.4	6.9
	Swinford	3.3	5.7
Kennet Valley	Fobney	7.0	5.9
Guildford	Shalford	12.0	5.3

4.44 We will continue to examine the potential for reducing process water losses at our WTW sites as part of our maintenance plans and our efforts to continuously improve our processes, reducing waste and enhancing water supply benefit from our WTWs.

Constraints

4.45 Constraints occur where existing infrastructure is not capable of distributing or treating all of the raw water that can be produced at a site. In AMP5 several schemes were completed to remove a number of identified network constraints leaving just a few limitations where schemes are being pursued. The remaining constraints have been assessed to ascertain whether it is cost effective to implement schemes to remove them. Most network constraints are associated with small rural sources on the edge of our distribution network, feeding areas of local demand. All constraints within the existing supply system have been examined for their potential to increase water availability, and therefore to be taken forward to programme appraisal as scheme options, however these will decrease as demand increases and water is used locally.

4.46 Network constraints are deductions from DO (in the same way as outage is deducted) and are not included as an integral part of the DO assessment, as was the case for the WRMP14.

4.47 A summary of constraints for 2015/16 (AR16) and 2016/17 (AR17 and AR17+) is shown in Table 4-3 below. AR17+ figures have been used in the WRMP19 and these figures are consistent with AR17 and AR18. A review of constraints was undertaken for AR17, which shows marginal reductions in the constraints from AR16 due to variation in demand.

Table 4-3: Constraints by WRZ

WRZ	Constraints (Ml/d)					
	DYAA AR16	DYAA AR17	DYAA AR17+**	DYCP AR16	DYCP AR17	DYCP AR17+**
London*	0	0	0	N/A	N/A	N/A
SWOX	0.30	0.28	0.28	1.23	1.19	1.19
Kennet Valley	0	0	0	0	0	0
Henley	0	0	0	0	0	0
SWA	5.2	2.0	2.0	5.2	2.0	2.0
Guildford	0	0	0	0	0	0

**Constraints data for London WRZ under DYCP is blank as the London WRZ is assessed for DYAA only due to both London's reservoirs and ring main providing a buffer during peak periods.*

***Note A17+ figures have been used in the WRMP19 these figures are consistent with AR17 and AR18.*

Outage

4.48 Outages are temporary reductions in DO, which can be caused by factors such as mechanical failure or pollution events. The methodology used for evaluating the Outage Allowance is compatible with and computationally identical to the latest UKWIR methodology used for assessing Headroom Uncertainty - see Appendix V: Risk and uncertainty. The method enables an assessment of the uncertainty surrounding outage within the supply demand balance, with a range of probabilities and confidence limits. This calculation is based on the analysis of historical events, updated annually in light of new data and information, and reported as part of the Annual Review to the Environment Agency. The Outage Allowance is calculated in accordance with the original UKWIR methodology (1995), which is consistent with more recent guidance updates, including the Risk Based Planning Methods (UKWIR, 2016), which states that the 1995 methodology remains acceptable.

4.49 Our outage model concentrates on the 'critical month' in each WRZ, with this month having the highest calculated Outage Allowance. As a result, 'residual outages' could be considered to exist outside the 'critical month', but they do not contribute to the Outage Allowance unless the month they occur in later became the 'critical month'. As the existing outage methodology is conservative, insofar as the 'worst' month for outage is selected to reflect the Outage Allowance for each WRZ, the exclusion of any 'residual outages' in other months would not underestimate outage.

4.50 Table 4-4 summarises our Outage Allowances by WRZ for 2015/16, 2016/17 and the values at WRMP14 based on AR13 data, as well as the baseline for the WRMP19, i.e. AR17+. Changes to the Outage Allowance between reporting years are explained as part of the Annual Review reporting process, but it can be seen that the latest Outage Allowance shows a significant increase from that of WRMP14. This is as a result of the assessment of the historical outage record undertaken as part of the AR16. As part of the review we noted that our Outage Allowance is biased downwards by data gaps within the earlier records from which it is calculated; an important element in the calculation of the frequency of events. On reviewing the results it shows that using the more recent record gives a better reflection of recent events and the level of actual outage.

4.51 Following detailed discussions with the Environment Agency, and after reviewing our approach and datasets against those of other water companies, we concluded that our Outage Allowance would be more representative of the current day if we were to reduce the length of historic data used in the assessment from 15 years (2001/02 to 2015/16) to nine years (2007/08 to 2015/16). We agreed this adjustment with the Environment Agency in 2016 and so now are also considering outages from 2016/17 as well as 2017/18. Although shortening the historical outage record has resulted in increased confidence in the calculated Outage Allowance, to avoid the calculated value being overly skewed to very recent outages, particular attention was given to reservoir and raw water tunnel outages. This relates to a number of London reservoir outages that occurred recently following the failure of a raw water tunnel connected to a storage reservoir. Several other tunnels were of similar design, and so these were relined, resulting in outages during construction works. This resulted in the reservoir Outage Allowance being skewed towards very recent outages, when there had been no other such outages over the previous 30 years. To reflect this historical position and mitigate an overly skewed Outage Allowance, the outage record was lengthened from 10 to 30 years. The programme of raw water tunnel relining is coming to an end and will be completed in the next few years. We have, accordingly, removed some of the reservoir and raw water tunnel outages found in the historical record, and will remove all of these outages when the programme is finished to reflect the reduction in risk as a result of asset investment.

Table 4-4: Outage Allowances by WRZ

WRZ	Outage (Ml/d)*			
	WRMP14	**AR16**	**AR17**	**AR17+****
London	46.27	81.72	84.55	99.76
SWOX	14.88	16.73	17.50	17.23
Kennet Valley	1.85	2.80	2.59	2.49
Henley	1.05	0.44	0.40	0.36
SWA	12.53	10.75	9.99	9.46
Guildford	0.81	1.25	1.33	1.40
Total	77.39	113.69	116.36	130.7

**Note figures are consistent for DYAA and DYCP*

***Note A17+ figures have been used in the WRMP19. These are AR17 figures updated with the best available outage information at the time of producing the WRMP19.*

4.52 The change in Outage Allowance between WRMP14 (77.39 Ml/d) and WRMP19 (130.7 Ml/d) is largely driven by changes in the London WRZ and the methodology noted above. This resulted in an increase in Outage Allowance from 46.27 Ml/d in WRMP14 to 81.72 Ml/d in AR16. In the draft WRMP19, the Outage Allowance was very similar at 84.55 Ml/d, increasing to 99.76 Ml/d in London for the WRMP19 as shown in Table 4-4. As part of a continual data improvement process, our AR18 Outage Allowance has decreased to around 93 Ml/d in London. This accounts for outages in strategic schemes, resulting for example from raw water quality and asset condition issues, while ensuring that where previous investment has improved asset performance, so addressing the outage root cause, these outages are removed from the historical record (see para 4.50). In future, it is likely that resolution of water quality constraints through installation of new or modified treatment processes will also result in the associated outages being removed from the historical record.

4.53 The Outage Allowance used in the baseline forecast is considered to remain constant across the 80 year planning period. Considering future Outage Allowance and the final preferred programme, none of the options have any implicit bias towards greater or smaller outages and so it is not practical to estimate with confidence the Outage Allowance for new schemes. As a result, we consider it is appropriate to use the base year Outage Allowance throughout the planning period, recognising that this generally implies an effective change in Outage Allowance as a proportion of WRZ supply capability.

4.54 The Outage Allowance is currently considered to be same for both the DYAA and DYCP condition. The Outage Allowance for each WRZ is calculated based on the analysis of actual outage data record. Historically, we have not recorded outages against peak DOs, with one of the key reasons being that a peak DO is not needed for the majority of the time, only at times of peak demand, so our WTWs do not need to be available to deliver peak DO at all times. As such, simply altering the 'outage against average DO' model to measure outage against peak DO at times of peak demand would not necessarily give an accurate reflection of peak period outage. To ensure that our outage modelling provides an appropriate assessment of peak supply impact, specifically in those WRZs where DYCP is the supply demand driver, we will be reviewing and updating our methodology, as necessary. We aim to build on our outage reporting approaches to include recording and analysis of WTW capability to meet peak demands when required, and include an assessment of 'peak period outage' for WRMP24.

4.55 To ensure future outage risk is reduced to a minimum, we are developing plans and programmes for returning water sources to optimum availability and maintaining that availability into the future. This includes identifying the issues causing the outages, the impact on DO, the actions being undertaken to address the outage, and the outcome of our actions. In the WRMP19 we consider the significance of more than 90 days outages on Outage Allowance and the supply demand balance and the consequences for our preferred programme. This analysis is presented as an EBSD ‘what if’ scenario as part of Section 10: Programme appraisal and scenario testing.

Bulk supplies

4.56 Efficient and effective use of water is vital in the south east of England and bulk supplies form a part of that need. Bulk supplies are transfers of either raw or treated water into or out of the company's supply area.

4.57 We have a number of bulk supply agreements with neighbouring water companies. These can be for temporary support in an emergency situation, or as a permanently available supply. It is the latter which are of importance to the WRMP. Inset appointments[10] granted to other companies means that we have formal arrangements to supply water in certain areas, which have to be accounted for in the supply demand balance.

4.58 Most of the bulk supply agreements are long-standing and are in perpetuity and terminable only by mutual consent. Variation is only possible through renegotiation. The supply of water is 'on demand', and up to the quantities specified in the agreements. A summary of the bulk supply arrangements and volumes which are consistent for AR17, AR17+ and AR18 is shown in Table 4-5.

4.59 We consulted all our neighbouring companies prior to the production of our draft WRMP19 and continued these discussions between the draft and revised draft WRMP19 in association with our response to the public consultation on our draft plan. Volumes for the bulk supplies have been agreed in the final plan for each year of the planning period under a dry year scenario.

4.60 While there are some minor bulk supply import/exports in the Thames Valley, London is the only WRZ where bulk supplies are a significant factor in the supply/demand balance. Where we have external imports or transfers between WRZs, the associated water quality is considered in our Drinking Water Safety Plans covering groundwater as well as surface water sources.

[10] Inset appointments are also known as New Appointments or Variations, or 'NAVs'. NAVs occur when one company replaces another as the statutory water and / or sewerage company for a specific geographic area.

Table 4-5: Bulk transfers (imports and exports) arrangements and volumes from base year 2016/17 and over the 80 year planning horizon

WRZ	Imports	Exports	DYAA Total (Ml/d)	DYCP Total (Ml/d)
London*	None	-2 Ml/d raw water to Affinity Water Central (Wraysbury to Sunnymeads) from 2016/17 -0.2 Ml/d treated water to Affinity Water Central at Hampstead Lane from 2016/17 -11.8 Ml/d treated water to Affinity Water Central at Fortis Green 2016/17 to 2018/19**. The bulk supply is set to increase over the planning period; From 2018/19 to -12.6 Ml/d From 2036/37 to -13.9 Ml/d From 2039/40 to -14.0 Ml/d	-14.0 (From 2016/17) to -16.2 (From 2039/40)	N/A
SWOX***	2.08 Ml/d from SWA (5 Ml/d on peak) 2016/17 onwards NB: internal transfer	None	+2.08 (From 2016/17)	+5 (From 2016/17)
SWA	None	-2.08 Ml/d to SWOX (-5 Ml/d on peak) from 2016/17 -NB- internal transfer	-2.08 (From 2016/17)	-5 (From 2016/17)
Kennet Valley	None	None	0 (From 2016/17)	0 (From 2016/17)
Guildford	None	-2.27 Ml/d treated water to Affinity Water Central (Ladymead)** from 2016/17 The peak bulk supply is set to increase over the planning period; in 2030/31 to -3.38 in 2031/32 to -4.7 Ml/d in 2032/33 -4.9 Ml/d in 2033/34 -5.0 Ml/d	-2.27 (From 2016/17) to -5.0 (From 2033/34)	-2.27 (From 2016/17) to -5.0 (From 2033/34)
Henley	None	None	0 (From 2016/17)	0 (From 2016/17)

**There is also a renegotiation of the export from London WRZ to Essex and Suffolk Water (Northumbrian Water South) 91 Ml/d on average (118.2 Ml/d on peak) and an import from Severn Trent Water to SWOX WRZ 0.1 Ml/d on average and peak, both from 2016/17 onwards. These are included within the WARMS2 modelling and taken into account in the calculation of DO and hence not included in the WRMP19 tables as a bulk supply.*
***We acknowledge a minor variation in the reporting of the Fortis Green and Ladymead bulk supply transfers between Thames Water and Affinity in our respective WRMP19 baseline supply-demand balances. The differences in the reporting are associated with the companies completing the development of their plans at different times in 2018/19. The correction required to the figures in Table 4-5 for Fortis Green London DYAA are -0.61Ml/d up to 2035/36, -1.87Ml/d 2036/37 to 2038/39 and -2.02 2039/40 onwards and for Ladymead Guildford DYCP -1.11 Ml/d 2030/31, -2.39 Ml/d 2031/32, -2.63 Ml/d 2032/33 and -2.70 Ml/d 2033/34 onwards. We have undertaken sensitivity analysis on the differences to our WRMP19 preferred plan and conclude they are not material. ***There is an additional export from SWOX WRZ to Wessex Water 0.01 Ml/d on average (-0.06 Ml/d on peak) which is lost in rounding error and therefore not included in the WRMP19 tables.*

4.61 Accounting for both the bulk supply volumes presented in Table 4-5 and the bulk transfers included within the DO calculation (the export to Essex and Suffolk and the import from Severn Trent Water) we are a net exporter of water.

Transfers to Essex and Suffolk Water

4.62 The largest bulk supply export agreement covers the raw water transfer of up to 91 Ml/d average and 118.2 Ml/d peak, to Northumbrian Water's Essex and Suffolk area from our Lee Valley reservoirs. This export is included within the WARMS2 modelling and is taken into account in the calculation of DO and hence is not included in Table 4-5 as a bulk supply.

4.63 As highlighted at WRMP14 there was an option to improve supplies in the London area with agreement to reduce the quantity to be transferred to Essex and Suffolk during a dry year. A first Trading Agreement was reached with Essex and Suffolk at AR15 that benefitted London's resources by 17 Ml/d. Since then a further opportunity arose to reduce the amount transferred, increase the benefit to London by 6 Ml/d at AR17. The reduction in the bulk supply with Essex and Suffolk ceases in 2035 (31 March 2035) where it then reverts to the original agreement.

Transfers to Affinity Water Central

4.64 There are three existing treated water bulk supply exports to Affinity Water Central:

1) from a supply point in the London Borough of Haringey, London WRZ (initially 11.8 Ml/d), known as Fortis Green;
2) from a supply point in the London Borough of Haringey, London WRZ known as Hampstead Lane (0.2 Ml/d); and
3) from a groundwater source in the Guildford WRZ via Ladymead WTW (2.27 Ml/d average 5.0 Ml/d peak).

4.65 The Fortis Green agreement allows for 27 Ml/d, although historically the amount agreed for water resources planning purpose has been 10 Ml/d. This has now increased to 11.8 Ml/d and will increase to 14.0 Ml/d by 2039 in agreement with Affinity Water (Affinity). Affinity has confirmed that they have identified that they will need access to the full existing entitlement, 27Ml/d, of treated water bulk supply during peak conditions at various points throughout the planning period.

4.66 The assumptions relating to the Affinity bulk supply transfer at Fortis Green are based upon information provided by Affinity in correspondence on the draft WRMP19. The information relates to calculated usage over the planning period for both the DYAA and DYCP scenarios. The DYAA usage, however, has not been adjusted by Affinity to take account of the DYCP usage. DYAA is the critical condition for us in London, and thus Affinity's demand under dry year conditions needs to be reflected in our DYAA forecasts, rather than peak. Affinity's DYCP use is variable throughout the planning period as it is naturally dependent on weather conditions but is also determined by the development of water supply options identified in their WRMP. To provide a consistent view on usage we have used the DYAA data provided by Affinity and added the annualised DYCP usage to increase the DYAA value. The DYAA usage then reflects the effect on the DYAA utilisation from DYCP. The amendment to the

DYAA profile is based on a 56 day critical period that Affinity supplied for the period 1 April to 30 September. A summary of the subsequently adjusted DYAA profile is given in Table 4-5.

4.67 Additionally, there is a raw water supply from two of our West London reservoirs to an Affinity Water Central treatment works, known as Wraysbury-Sunnymeads, of 2 Ml/d. This forms part of an agreement that permits Affinity Water Central to use our reservoir storage in the event of a serious pollution incident impacting their run-of-river source on the River Thames. The overall agreement is only for the duration of the pollution event but there is a provision for up to 10 Ml/d as a sweetening flow in the connecting pipeline, which can be accounted for as a raw water bulk supply.

4.68 As previously reported in WRMP14, it has been agreed with Affinity that the bulk supply be reduced from 10 Ml/d to 2 Ml/d. The updated agreement now reflects the reduced requirement.

Inset appointments

4.69 Our supply area has a number of Inset Appointments[11] that supply customers in various WRZs. The exports to inset appointments have been uplifted from actual to dry year using the AA and CP uplift factors specific to each WRZ, and these are shown in Table 4-6 and Table 4-7 respectively. These figures are consistent for both AR17 and AR17+ with a marginal increase in the figures for AR18. The Inset Appointment exports are accounted for in the baseline supply demand balance and growth is accounted for within the demand forecasts.

Table 4-6: DYAA exports to Inset Appointments in 2016/17

WRZs for annual average exports to inset appointees	Ml/d
London	2.30
SWOX	0.98
Kennet Valley	0.17
Henley	0.00
SWA	0.26
Guildford	0.00
Total	3.71

[11] An inset appointment (or NAV) is when one company replaces another as the statutory water and / or sewerage company for a specific geographic area.

Table 4-7: DYCP exports to Inset Appointments in 2016/17

WRZs for critical period exports to inset appointees	Ml/d
London	--
SWOX	1.18
Kennet Valley	0.20
Henley	0.00
SWA	0.32
Guildford	0.00
Total	4.00

4.70 AR18 inset appointments in SWA, Henley and Guildford are consistent with AR17 and AR17+ figures. However, AR18 figures in London since AR17 and AR17+ have increased by +0.53 Ml/d DYAA, SWOX by +0.29 Ml/d DYAA and +0.35 Ml/d DYCP and Kennet Valley by +0.04 Ml/d DYAA and +0.05 Ml/d DYCP.

Summary

4.71 The average and peak WAFU for the last reporting year 2016/17 in each WRZ using AR17+ figures are shown in Table 4-8 and Table 4-9 respectively.

Table 4-8: DYAA WAFU 2016/17

WRZ (Units Ml/d)	DO	−	Climate change impact*	−	Constraints	−	Outage	+/−	Bulk supplies and insets	=	WAFU
London	2302.00	−	19.70	−	0.00	−	99.76	−	16.30	=	2166.22
SWOX	329.17	−	1.12	−	0.28	−	17.23	+	1.10	=	311.63
Kennet Valley	143.87	−	1.26	−	0.00	−	2.49	−	0.17	=	139.95
Henley	25.65	−	0.00	−	0.00	−	0.36	N/A	0.00	=	25.29
SWA	185.05	−	0.36	−	2.0	−	9.46	−	2.34	=	170.89
Guildford	65.82	−	0.04	−	0.00	−	1.40	−	2.27	=	62.11
Total	3051.56		22.48		2.28		130.70		19.98		2876.09

** The method for assessing the impact of climate change on supply over the planning period is explained in Para 4.112 to* ***Error! Reference source not found.*** *and in more detail in Appendix U: Climate change.*

Table 4-9: DYCP WAFU 2016/17

WRZ (Units Ml/d)	DO	−	Climate change impact*	−	Constraints	−	Outage	+/−	Bulk supplies and insets	=	WAFU
London**	N/A		N/A		N/A		N/A		N/A		N/A
SWOX	385.38	−	1.28	−	1.19	−	17.23	+	3.82	=	369.50
Kennet Valley	155.40	−	0.94	−	0.00	−	2.45	−	0.20	=	151.77
Henley	25.90	−	0.00	−	0.00	−	0.36	N/A	0.00	=	25.54
SWA	214.40	−	0.24	−	2.0	−	9.46	−	5.32	=	197.38
Guildford	71.70	−	0.04	−	0.00	−	1.40	−	2.27	=	67.99
Total	852.78		2.50		3.19		30.9		3.97		812.18

** The method for assessing the impact of climate change on supply over the planning period is explained in Para 4.112 to* ***Error! Reference source not found.*** *and in more detail in Appendix U: Climate change.*

***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.*

4.72 The modelling of the Target Headroom, and resultant supply demand balance for 2016/17, have been re-run with A17+ figures and therefore differs from those values in the published AR17 and AR18 tables due to the nature of the risk analysis models which uses Monte Carlo sampling techniques. Specifically when inclusion of the AR17+ DO, inset appointments, Outage Allowance and demand forecasts is made and the models re-run, the climate change component changes marginally and thus so does the WAFU.

C. Baseline supply forecast

General

4.73 The baseline supply forecast is built from the base year values discussed above. Activity to the end of 2019/20 is as discussed in Section 2: Water resources programme 2015-2020. Beyond 2020, the following assumptions are made in the baseline plan:

- DO reduces with the cessation of the trading agreements with RWE Npower (from 2020/21) and Essex and Suffolk Water (from 2035/36);
- No increase in DO through new resource developments (these are accounted for within the final plan supply forecast rather than within the baseline supply forecast);
- No change in constraints;
- Process losses, as a percentage of DO, change in proportion to the movement in DO;
- Outage Allowance is flat over the planning period;
- Treated imports and exports are largely unchanged

4.74 The only changes to WAFU are from updates to DO due to:

- The impact of climate change on supplies;
- The inclusion of impacts that reflect changes in upstream licensing that increase river flows and water available for abstraction;
- The impact on DO that will reflect trading agreements that are assumed to expire in line with the current arrangements;
- The impact of sustainability reductions following guidance from the Environment agency in March 2018 (WINEP 3).

Sustainability reductions

Background

4.75 Water companies are required to include an allowance for sustainability reductions in their draft plans. Sustainability reductions are reductions in abstraction that are required to provide environmental improvements, typically through increased flows in rivers which are identified as suffering from low flows due to the effects of abstraction.

4.76 Water companies work closely with the Environment Agency to identify where abstraction may be having an adverse environmental impact and then putting plans in place to address this impact, if necessary. The mechanism by which this is achieved is through the WINEP, which is how the Environment Agency identifies and prioritises its requirements for water companies to undertake measures to improve the environment. The process by which the requirement for sustainability reductions is identified is described in Section 2: Water resources programme 2015-2020. It also explains the sustainability reductions to be delivered before 2020.

4.77 The WINEP classifies sustainability reductions in three ways:

- **Certain**: those for which a full investigation and an options appraisal is complete, the Environment Agency is certain of the need for the sustainability reductions and the water company is in agreement in principle that they should be delivered. These cases will also have been demonstrated to be cost beneficial and affordable (where applicable).
- **Indicative**: those where the investigations have reached a stage where there is sufficient information to include the need for sustainability reductions but the requirement for their delivery has not been agreed between the water company and the Environment Agency. This can include cases where an options appraisal has been completed and the scheme is cost beneficial but is not yet confirmed as affordable, it also includes cases where a change is required to meet a statutory driver either a) before completion of an investigation or b) following completion of an investigation but before completion of an options appraisal. In these cases the cost benefit assessment will be a factor in determining the need for their final delivery but the Environment Agency requires water companies to make allowance for them in their WRMPs. Indicative sustainability reductions are included in the baseline supply demand balance.

- **Unconfirmed**: These are sites where there is a possible but non-quantified change to a licence but the investigations have not reached a stage where there is evidence to justify a sustainability reduction being considered as confirmed or likely.

4.78 A further category was also specified by the Environment Agency in the guidance on sustainability change categories prior to the draft WRMP19. This further category is 'Direction of Travel' and covers situations where the Environment Agency has not identified sustainability changes but has identified the need for investigation though no implementation action is required in AMP7.

4.79 Certain and indicative sustainability reductions are included within the baseline supply demand balance as an adjustment to DO. Unconfirmed sustainability reductions can only be assessed in the WRMP through the running of scenarios, to determine what impact on the WRMP they would have were they to become certain. However, even if the impact is potentially significant, the Water Resources Planning Guidelines (WRPG)[12] do not permit any allowance for them to be included in the preferred plan and thus they do not trigger future investment.

4.80 It is assumed that the WINEP is a key initiative by which our WAFU will be reduced or Headroom increased. However, it should be noted that from our experience to date, the Catchment Abstraction Management Strategies (CAMS) process and the requirements of the Water Framework Directive (WFD) have the potential to result in not only sustainability reductions, but also a very serious limiting of future resource options due to the Environment Agency's view on the catchment's potential to support further abstraction without adverse impact on the environment or groundwater bodies.

Overall policy

4.81 Our policy on sustainability reductions can be summarised as follows:

- The proposed reduction should be justifiable in terms of the three elements of sustainability (economic, environmental and social) and, where relevant, the cost-benefit case should be proven;
- Viable twin-track demand and supply options to replace the loss of supply capability should be in place and operational before the licence reduction takes place;
- The investment needed to replace the loss to supply capability caused by the sustainability reduction should be funded within price limits;
- Under no circumstances would we proceed with the implementation of a sustainability reduction programme without an alternate supply option available, this is to ensure that the security of public water supplies can be maintained.

4.82 It is limiting that the WRPG do not allow a company to take adequate account of the potential impact of future sustainability reductions, where these have not been confirmed by the Environment Agency through the WINEP. We consider the potential loss of supply to be a significant risk to the supply demand balance in view of the likely impact of the WFD and River Basin Management Plans (RBMP) on the future of abstraction licence volumes,

[12] Environment Agency and Natural Resources Wales produced in collaboration with Defra, the Welsh Government, and Ofwat, Water Resources Planning Guideline: July 2018

particularly through the potential reduction required to ensure no deterioration of status. The WRPG approach may not ensure the identification of 'best value' investment schemes and we have therefore included scenarios as part of Section 10: Programme appraisal and scenario testing to ensure that this risk is considered.

4.83 The WFD deadline of achieving 'good ecological status' in all water bodies by 2027 is fast approaching. Some of the measures that may have to be taken to comply with the WFD will take a long-time to fulfil and we do not wish to be in a situation where we are forced into short-term, unsustainable options when there was the opportunity to take a longer term view. Whilst it is likely that the end date of 2027 will be extended, this has not yet been confirmed and we cannot be confident that this will be the case.

4.84 We explore this further through our programme appraisal analysis (Section 10: Programme appraisal and scenario testing) and show how our plan would change against different futures associated with varying levels of sustainability reductions after 2025.

4.85 The Environment Agency released the first summary of requirements (WINEP1) on 31 March 2017 followed by a further release (WINEP2) in 29 September 2017. This provided an indication of the potential sustainability reductions and investigations within our supply area. A further release of the WINEP was provided on 29 March 2018 (WINEP3) which confirmed the requirement as to what should be included within our WRMP – see Table 4-10 for WINEP3 sustainability reductions and Table 4-11 for the impact of these reductions on DO. The Environment Agency WINEP3 contained significant changes when compared with WINEP1 and WINEP2. It changed the status of a number of the schemes such that only Bexley and Hawridge are now 'indicative' schemes meaning they should be included in the baseline WRMP. There are no sustainability reductions specified in WINEP3 as 'unconfirmed'. In addition to the WINEP3 scenario we have developed scenarios to assess the potential impact of sustainability reductions that may be required to achieve WFD deterioration objectives and reductions in chalk stream abstractions which adversely impact on vulnerable chalk streams. These scenarios are included in the WRMP (Section 10: Programme appraisal and scenario testing).

4.86 As detailed in Section 10: Programme appraisal and scenario testing, four additional sustainability reduction scenarios have been run as EBSD 'what if' analysis:

1) **WFD No Deterioration lower scenario**, which is our estimate of a more likely sustainability reductions associated with No Deterioration investigations
2) **WFD No Deterioration higher loss scenario** which is our estimate of the full loss of unused licence at all sources being investigated under No Deterioration
3) **Chalk streams scenario 1** which is our estimate of a medium potential loss scenario from the licences that have adverse impacts on vulnerable chalk streams in the medium to long term
4) **Chalk streams scenario 2** which is our estimate of high potential loss of licences that have adverse impacts on vulnerable chalk streams in the medium to long term.

Table 4-10: Sustainability reductions in the Water Industry National Environment 3 (WINEP3) Programme 2 – 29 March 2018 (Ml/d)

WRZ	Certain			Indicative			Unconfirmed		
	Source	Reduction		Source	Reduction		Source	Reduction	
		DYAA	DYCP		DYAA	DYCP		DYAA	DYCP
London	None			Bexley	8.97	4.18	None		
SWOX	None			None			None		
SWA	None			Hawridge	9.09	9.09	None		
Kennet Valley	None			None			None		
Guildford	None			None			None		
Henley									
Total					18.06	13.27			

Table 4-11: Sustainability reductions impact on DO, including WINEP 3 and AMP6 reductions

Loss of DO (Ml/d)				
WRZ	**Source**	**DYAA**	**DYCP**	**Year**
London**	Bexley***	9.0	--	2024/25
SWOX	Axford*	5.0	6.0	2017/18
	Ogbourne*	4.0	4.7	2017/18
	Childrey Warren	3.7	3.7	2019/20
SWA	Hawridge***	6.8	6.9	2024/25
	Pann Mill	0.0	7.3	2019/20

Note:

** The impact on SWOX shown in the table of the Axford and Ogbourne source DO reductions are from the results modelled in WARMS2.*

***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.*

**** WINEP3 (all other reductions in the table are AMP6 reductions).*

4.87 Sustainability reductions as included in WINEP3 and in the WRMP19 are as described in the following sections.

Certain reductions

4.88 There are no certain reductions included in WINEP3. The known reductions to be implemented in AMP6 are Axford, Ogbourne, Pann Mill and Childrey Warren which are included in baseline DO.

Indicative reductions

4.89 There are indicative reductions included in WINEP3 for Bexley and Hawridge which are included in baseline DO.

Unconfirmed reductions (for scenario planning)

4.90 There are no unconfirmed reductions received in WINEP3. However we are examining a number of scenarios related to WFD No Deterioration and vulnerable chalk streams reductions. The timings of investigations and subsequent options appraisals relating to WINEP3 reductions in abstractions have been agreed with the Environment Agency as part of the ongoing WINEP programme.

4.91 Sustainability reductions are further detailed by WRZ below.

London WRZ

4.92 An investigation has been undertaken into the impact of the abstraction from the Lower River Lee intakes on the Lower Lee. The investigation was completed at the end of April 2018 and concluded that the abstraction has a limited adverse impact on the River Lee and that an options appraisal is required. This is underway and it has confirmed at an early stage that it will not be cost beneficial to make a reduction in baseline DO by way of an abstraction licence reduction. The options appraisal is due to be completed at the end of 2018.

London WRZ: Bexley

4.93 Bexley sustainability reduction has been included in the baseline DO with a potential implementation year of 2024/25 (8.97 Ml/d average).

4.94 An investigation is currently being undertaken into the impact of the water abstraction source at Bexley on the River Cray. The investigation is due to conclude at the end of December 2018. The investigation is currently showing that the abstraction has an adverse impact on the River Cray and that an options appraisal will be required. The options appraisal is also due for completion at the end of December 2018.

4.95 The Bexley licence has a time limited variation to the annual volume. The current annual volume is equivalent to a daily average of 31.7 Ml/d. This condition is time limited and will revert to an annual total equivalent to 22.73 Ml/d from 31 March 2020. It will be necessary to renew this licence variation but it is anticipated that it will again be time limited and that if the investigation demonstrates that the Bexley abstraction has an adverse impact on the River Cray it may not be renewed further in the future. It is assumed that the licence variation will not be renewed beyond 1 April 2025 with the result that a sustainability reduction of 8.97 Ml/d will be required from 1 April 2025.

London WRZ: Sundridge and Westerham

4.96 An investigation has been undertaken into the impact of our abstractions in the Upper Darent from Westerham and Sundridge. It concluded at the end of March 2018 and found that the abstraction does not have a significant adverse impact on the River Darent. However, it is also recommended that an options appraisal should be required by the end of 2018 to determine if any river restoration measures could have a beneficial impact on the drought resilience of the upper Darent.

SWA WRZ: Hawridge

4.97 Hawridge sustainability reduction has been included in the baseline DO with an implementation year of 2024/25 (9.09 Ml/d average and 9.09 Ml/d peak).

4.98 An investigation is currently being undertaken into the impact of the water abstraction source at Hawridge on the River Chess. The investigation is due to conclude at the end of September 2018. The investigation findings to date have suggested that the abstraction has an adverse impact on the River Chess and so an options appraisal would be required. If the investigation concludes with this finding confirmed, the options appraisal would be completed by the end of December 2018.

Summary

4.99 We have included a total of 15.8 Ml/d sustainability reductions in our WRMP19 baseline DO, comprising 9 Ml/d for Bexley and 6.8 Ml/d for Hawridge. These sources are both the subject of ongoing options appraisal and this will include cost benefit analysis. This may result in the implementation of alternative solutions to mitigate the impact of abstraction such as river restoration.

4.100 For the WRMP19 we sought guidance from the Environment Agency on the potential location and magnitude of any sustainability reductions that might arise as a result of the WFD or as a result of investigations undertaken in AMP6; these, if any, are expected to be identified in future WINEP updates. The WINEP includes the requirement for investigations at a number of sources into the potential for increased abstraction to cause deterioration in the water body status. These investigations will be undertaken in AMP7 and are due to be completed at the end of 2022.

4.101 We have estimated reductions in DO to be used as the basis for scenarios to demonstrate the impact of potential sustainability reductions that could be required for WFD No Deterioration and for reductions in abstractions that adversely affect vulnerable chalk streams. These scenarios are only indicative, and future investigations and options appraisals will inform the requirement for actual reductions in the future.

4.102 In summary, we have developed four scenarios to explore the implications of potential sustainability reductions, but reliable estimates of future sustainability reductions are required to enable robust long-term planning. Given the potential magnitude of these reductions, as indicated by the Environment Agency, a major resource development is likely to be required if the potential identified sustainability reductions are to be made. The timing of that water resource being available will dictate the time at which any sustainability reduction can be accommodated where they are found to be cost beneficial.

4.103 We remain reliant upon the Environment Agency to clarify the position on future sustainability reductions. The decisions on long-term sustainability reductions are pivotal to efficient long-term planning and without these decisions being made customer Levels of Service could be put at risk or bills could end up being higher than they need to be.

4.104 The results of this scenario testing are discussed in the programme appraisal analysis in Section 10: Programme appraisal and scenario testing.

No Deterioration

4.105 In addition to the WINEP3 scenario we have developed scenarios to assess the potential impact of sustainability reductions that may be required to achieve WFD deterioration objectives.

4.106 The Environment Agency has an obligation to ensure no deterioration of any water bodies under the WFD, for any category (e.g. water quality and ecology) including the status for river flow and groundwater. Therefore the WINEP also includes a requirement to investigate the impact of existing water abstraction sources that have not been used up to full licensed quantities. Such investigations, which could reduce DO significantly, have the potential to result in some licences requiring sustainability reductions to prevent water body deterioration. The WINEP has not specified any volumes for assessment in our WRMP and so this remains a source of considerable uncertainty for our plan. As the WINEP did not include any additional information on scope or methodology for this assessment, we have included two scenarios to assess the risk arising from no deterioration obligations. The first is a lower loss scenario and the second is a full unused licence loss scenario estimated with the current best knowledge of abstraction impacts. These scenarios are summarised in Table 4-12.

Table 4-12: No deterioration, potential uncertain sustainability reductions*

	No deterioration low loss sustainability reduction (Ml/d)	No deterioration higher loss sustainability reduction (Ml/d)
London	20.00	75.86
Guildford	0	2.87
Henley	0	0
Kennet	6.70	9.89
SWOX	5.00	17.08
SWA	0	0
Total	31.70	105.71

**Accounted for as EBSD 'what-if' scenarios within Section 10: Programme appraisal and scenario testing.*

Vulnerable chalk streams

4.107 In addition to the WINEP3 scenario and scenarios to assess the potential impact of sustainability reductions that may be required to achieve WFD deterioration objectives, we have developed other scenarios to assess the potential impact of reductions in chalk stream abstractions which adversely impact on vulnerable chalk streams and water courses.

4.108 We have made a commitment to cease abstraction from vulnerable chalk streams and water courses. As part of this commitment two different abstraction reduction scenarios have been assessed in the WRMP19.

4.109 The first scenario includes abstraction reductions at a number of sources that have previously been investigated in the Environment Agency's Restoring Sustainable Abstraction Programme and found to have an adverse impact on the environment, but it was not cost beneficial to make a full licence reduction. The sources included in this scenario are Pann Mill, Waddon and North Orpington which equate to a reduction in DO of 26 Ml/d. There are also two licence changes that could be implemented without impacting available water resources, but would have significant capital costs. The first of these is Farmoor where abstraction could be transferred to an intake downstream of the Oxford Watercourses, during periods of low river flows. This option would be associated with implementation of the South East Strategic Reservoir Option and would require a new pipeline to transfer the water from the South East Strategic Reservoir to Farmoor reservoir. The second option is a partial transfer from the abstraction source at New Gauge to existing intakes in the lower Lee system. This option would be associated with upgrading and reconfiguring the raw water network in the Lee Valley area. In line with our commitment to cease abstraction from vulnerable chalk streams this scenario has been included in the preferred plan.

4.110 The second chalk streams scenario includes additional licence reductions, which have a total DO impact of 58 Ml/d. This scenario includes the licence reductions from the first scenario as well as additional reductions at Eynsford, Horton Kirby, Lullingstone, Epsom, Marlborough and Clatford. All of these sources are either currently being reviewed or will be investigated in AMP7 and therefore we need to complete further work to confirm if further abstraction reductions are required to protect vulnerable chalk streams and also to assess the responses to abstraction reductions, such as increased risk of groundwater flooding. We will continue to investigate if further changes to abstractions are required at these sources during the rest of AMP6 and during AMP7.

4.111 The two scenarios are shown in Table 4-13.

Table 4-13: Vulnerable chalk stream reductions

WRZ	Chalk Stream medium loss sustainability reduction (Ml/d)	No deterioration higher loss sustainability reduction (Ml/d)
London	15.97	44.43
Guildford	0	0
Henley	0	0
Kennet	0	0
SWOX	0	3.72
SWA	9.80	9.80
Total	25.77	57.95

Impact of climate change on supply

4.112 Climate change is an important factor in long-term water resource planning. The WRPG requires that the WRMP includes the impact of climate change on DO calculated for the mid-2080s using the Medium emissions scenario as a minimum, and we have specified how this impact is scaled over the planning period.

4.113 Updated climate change scenarios were launched by the UK Climate Impacts Programme (UKCIP) in June 2009, known as the UK Climate Projections 2009 (UKCP09). They provide a large amount of information on how the UK climate may change over the next 100 years in response to different levels of greenhouse gas emissions.

4.114 The projections are 'probabilistic' in the sense that they encapsulate a wide range of possible changes in climate based on observations, climate models and expert opinion.

4.115 The methodology of the climate change impact assessment and how the UKCP09 data has been used is explained in Appendix U: Climate change.

4.116 The central (or 'best estimate') impact of climate change on DO for the 2080s under the Medium Emissions scenario has been determined together with the uncertainty around the data[13]. We have investigated the climate change impacts of a High Emissions UKCP09 scenario for the 2080s within the London WRZ. On average, there is little change in the impact of a High Emissions 2080s scenario compared with a Medium Emissions 2080s scenario. Within the sample of 20 climate change scenarios from the High Emissions 10,000 member ensemble, the weighted average climate change impact is about 12 Ml/d lower (i.e. less severe) with the impact of the very dry end of the sample quite significantly more severe and the impact of the very wet end of the sample significantly less severe.

4.117 The 'best estimate' value for the 2080s (2085/86) under the Medium Emissions scenario for AR17 and AR17+, the figures used for the WRMP19, are shown in Table 4-14, this is applied directly as a change in DO. A negative value indicates a reduction.

4.118 The climate change analysis has not been updated between producing the draft WRMP19 AR17 figures and the WRMP19 AR17+ figures. However, the baseline DOs have been updated to align them with AR17+ figures which has resulted in a marginal change in the climate change impact when determining the 'best estimate' or mean impact value using Monte Carlo techniques within the Target Headroom model. For AR18 the change to the baseline DO in London and SWOX and re-running Monte Carlo within the Target Headroom model has marginally changed 'best estimate' or mean climate change impact value again.

[13] HR Wallingford report (November 2017) 'Trajectory of climate change impacts and scaling' states that 'The range of uncertainty related to system performance [on the London WRZ] within a UKCP09 climate ensemble is significantly larger than that between climate ensembles for different time horizons or emissions scenarios' and the full range of uncertainty within the medium emissions scenario has been captured within headroom (Appendix V: Risk and Uncertainty). Furthermore, HR Wallingford report (March 2019) 'UKCP18 Climate Projections: Thames Water Rapid Assessment' shows that 'the range of uncertainty related to system performance within a UKCP09 or UKCP18 climate ensemble is significantly larger than that between UKCP09 and UKCP18 and the different climate ensembles for different time-horizons or emission scenarios.'

Table 4-14: UKCP09 climate change impact on DO by the 2080s (2085/86)

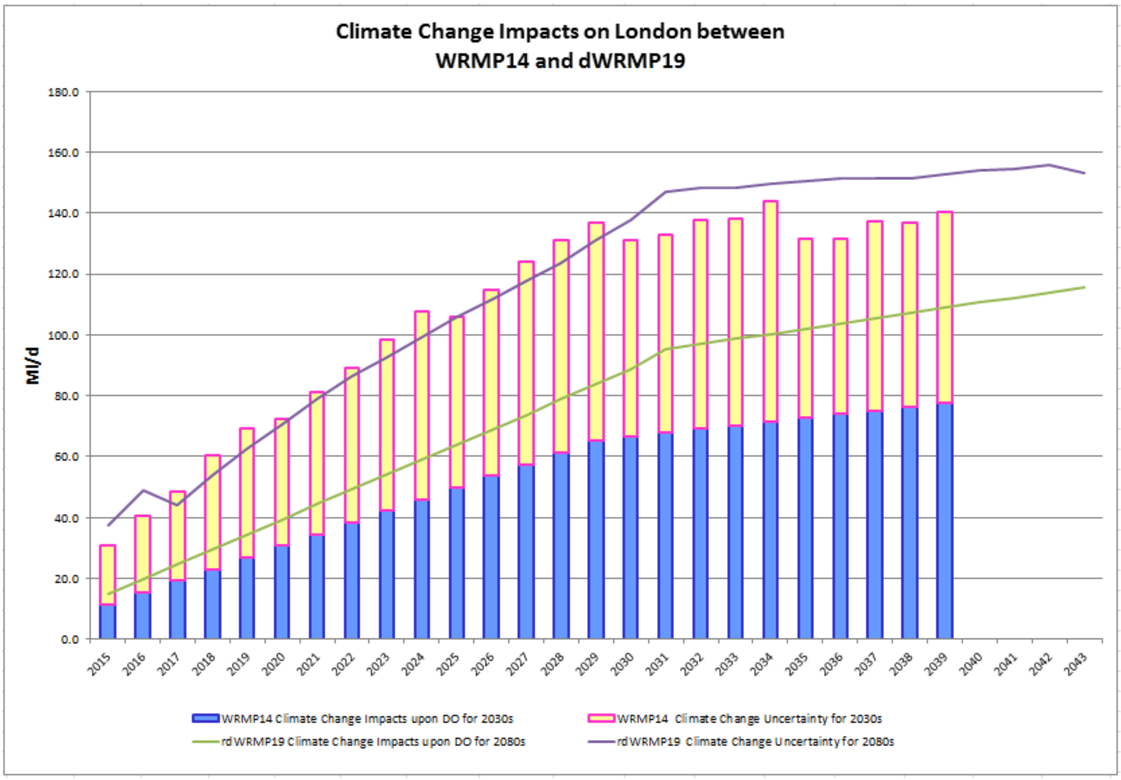
WRZ	UKCP09 climate change impact (Ml/d)			
	DYAA AR17	DYAA AR17+	DYCP AR17	DYCP AR17+
London	-184.9	-187.2	N/A	N/A
SWOX	-10.6	-10.6	-12.1	-12.1
Kennet Valley	-4.0	-12.0	-11.5	-9.0
Henley	0.0	0.0	0.0	0.0
SWA	-1.8	-3.5	-1.2	-2.3
Guildford	0.0	-0.4	0.0	-0.4

**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.*

4.119 The climate change impact has been compared with that from WRMP14, which was based on UKCP09 impacts for the 2030s under the Medium Emissions scenario, and it can be seen from Figure 4-5 that both the central estimate and uncertainty around climate change impacts for London have increased. The uncertainty around the central estimate of climate change impact is accounted for within Headroom the detail of which is dealt with in Section 5: Allowing for risk and uncertainty and Appendix V: Risk and uncertainty.

4.120 A correction was been made to the climate change scaling factors in the Target Headroom model between the draft and final WRMP19 which explains the step in climate change uncertainty for the 2080s in Figure 4-5. For AR17 the Target Headroom model was updated to reflect the updated climate change methodology used to assess climate change impacts for the draft WRMP19. This update was a step change from using climate change UKCP09 medium emissions impacts for the 2030s (in 2035/36) to using the 2080s (in 2085/86). The AR18 review has identified and corrected one omission from the Target Headroom model update namely ensuring that the model is using 2080s as opposed to 2030s scaling factors to scale the climate change impacts through the planning horizon. The impact of this correction is a reduction in the climate change component of Target Headroom uncertainty from 25.2 Ml/d AR17 (29.2 Ml/d AR17+) to 19.07 Ml/d for AR18.

Figure 4-5: Comparison of climate change impacts on London for WRMP14 vs. WRMP19



4.121 The Met Office published the next set of climate projections for the UK, UKCP18 in November 2018. Since publication of UKCP18, Thames Water commissioned HR Wallingford to consider the potential implications on the London WRZ. The resultant March 2019 report 'UKCP18 Climate Projections: Thames Water Rapid Assessment' introduces the UKCP18 climate projections, summarises the key differences with UKCP09, and assesses the potential impacts for the London WRZ in terms of system Deployable Outputs (DO).

4.122 The UKCP18 climate projections include the Medium (SRES A1B) emission scenario for direct comparison with UKCP09 but not the High emission scenario. A new feature of the UKCP18 data, relative to UKCP09, is the inclusion of the latest emissions scenarios used in the Fifth Assessment Report from the IPCC (ie. the Representative Concentration Pathways, RCPs).

4.123 Headline results suggest that when considering a 2080s time-horizon, the assessment of climate change impacts undertaken for the London WRZ for the WRMP 2019 (using UKCP09 Medium Emissions) remains appropriate under the set of probabilistic projections available for different RCPs available within UKCP18.

Summary

4.124 Table 4-15 shows AR17+ WAFU changes over the planning period for the baseline scenario under DYAA conditions for London and DYCP conditions for the zones in the Thames Valley.

The results show a steady decline in WAFU due to the impacts of climate change and include some step changes due to licence changes and changes in the bulk supply assumptions.

Table 4-15: WAFU over the planning period – baseline

WRZ	WAFU (Ml/d)						
	2016/17	**2019/20**	**2024/25**	**2029/30**	**2034/35**	**2039/40**	**2044/45**
London	2166.22	2154.68	2096.03	2071.41	2054.75	2021.83	2013.32
SWOX	369.50	354.82	353.30	351.70	350.62	350.07	349.52
Kennet Valley	151.77	151.06	149.88	148.69	147.89	147.49	147.08
Henley	25.54	25.54	25.54	25.54	25.54	25.54	25.54
SWA	197.38	189.89	182.69	182.39	182.18	182.08	181.97
Guildford	67.99	67.96	67.90	67.85	65.12	65.10	64.97
Total	**2978.39**	**2943.95**	**2875.34**	**2847.58**	**2826.10**	**2792.09**	**2782.40**

WRZ	WAFU (Ml/d)					
	2049/50	**2059/60**	**2069/70**	**2079/80**	**2089/90**	**2099/00**
London	2004.81	1987.80	1970.78	1953.77	1936.76	1919.74
SWOX	348.96	347.86	346.76	345.65	344.55	343.45
Kennet Valley	146.67	145.85	145.04	144.22	143.41	142.59
Henley	25.54	25.54	25.54	25.54	25.54	25.54
SWA	181.87	181.66	181.45	181.24	181.03	180.82
Guildford	64.96	64.92	64.88	64.95	64.92	64.88
Total	**2772.81**	**2753.63**	**2734.45**	**2715.38**	**2696.20**	**2677.02**

D. Drought and risk

Background to stochastic modelling

4.125 In our Water Resources Management Plan 2014 (WRMP14), we discussed whether the risk to supplies from climate change is underestimated using traditional approaches (see Section 5: Allowing for risk and uncertainty and Appendix U: Climate change.

4.126 These approaches primarily use analysis of historic, recorded data for rainfall, evaporation, flow and groundwater levels to calculate DO and the climate impacts on them. There are some limitations to this, particularly with respect to understanding the resilience of the current or future system to different types of droughts that might occur under climate change. The historic record does not contain sufficient representation of extended severe droughts which are likely to become a real and more frequent occurrence under climate change.

4.127 Analysis of the Future Flows[14] dataset confirmed that prolonged periods of drought, more severe than those seen in the historical record, are predicted to occur. This confirms that there is a risk to supplies and that this should be accounted for in long-term planning.

4.128 Further climate change evidence for WRMP19 is the MaRIUS project data. We commissioned CEH to complete the Severn Thames Transfer Study (CEH, June 2018) using simulations from the NERC-funded project MaRIUS. The results showed that the number of droughts of moderate severity or greater in the Thames catchment is projected to increase into the future.

Stochastic modelling for the WRMP19

4.129 For the WRMP19, we have noted the Environment Agency's guidance, including Section 3.4 of the 2018 WRPG on drought risk assessment and the UKWIR WRMP19 Methods report on Risk Based Planning[15]. Water companies are encouraged to consider resilience of the supply system to more extreme drought events than might be present in the historical record.

4.130 Sensitivity testing of WRMP14 showed vulnerability of the preferred plan to severe droughts not present in the historic record 1920-2010. We know of a prolonged period of drought in the late 19th century (1890-1910) and Kew Gardens records show intense drought in the mid-18th century.

4.131 We commissioned Atkins, HR Wallingford and the University of Manchester to take this work forward for the WRMP19. The first phase was to conduct a project scoping exercise that defined how the project would be taken forward and objectives of the work including how the outputs were to be used. The outcome was reported in August 2015[16] and followed up with details of the process to be adopted in delivering a stochastically based approach to our water resources planning[17].

4.132 The 'core' of the method is a statistically based weather generator, which is used to generate spatially and temporally coherent artificial drought data that models current climate. The weather and flow generator has been developed based on the rainfall and potential evapotranspiration (PET) in the 20th century and specifically for the known droughts in that period. It uses a multi-site analysis process to evaluate the influences of random variability, regional climatic factors (such as the North Atlantic Oscillation and Mean Sea Surface Temperature) and observable drought anomalies to produce an emulation of the 20th century climate. The model can be run multiple times in order to produce 'what if' analyses of drought conditions that could have occurred within the 20th century.

4.133 The historic PET record that was used for re-sampling and generation was limited to the period 1920–1959 and 1973–1997 inclusive. This was because there is a clear inconsistency within the PET record for the north western half of the catchment, where PET for the period 1950 to 1972 is not consistent with the rest of the record. A further explanation of this difference is provided in Appendix I: Deployable Output.

[14] Centre for Ecology and Hydrology Natural Environment Research Council, Future Flows and Groundwater Levels: British projections for the 21st century, 2012
[15] UKWIR, WRMP19 Methods report on Risk Based Planning, 2016
[16] Atkins, Thames Water Stochastic Drought Generation, Scoping Report, August 2015
[17] Atkins, Thames Water Stochastic Drought Generation, Hydrological Modelling and Weather Generation Review, Technical Note, November 2015

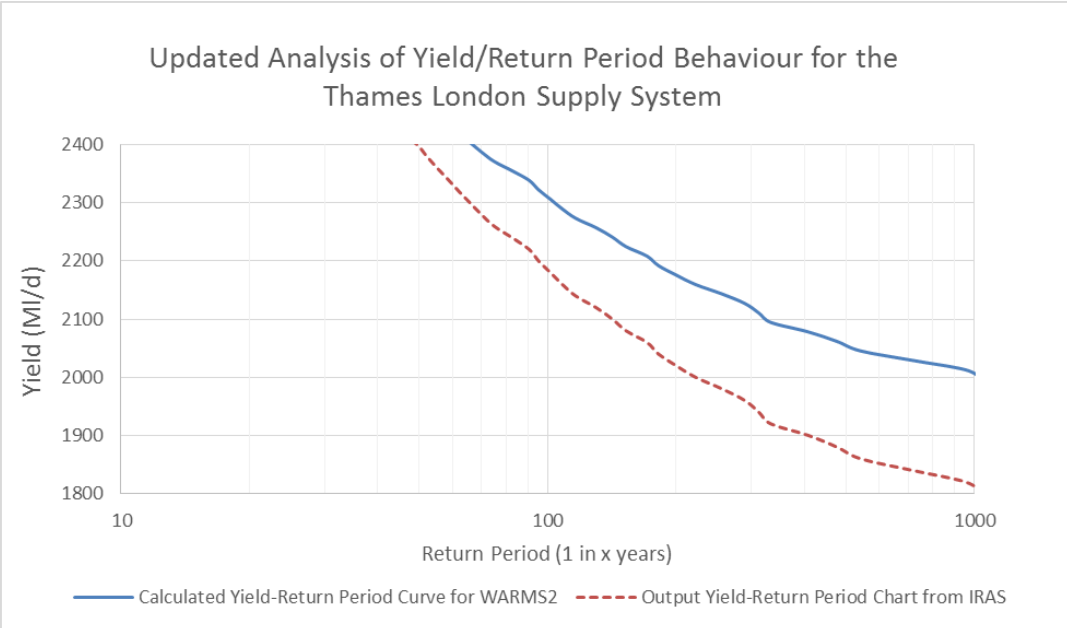
4.134 The rainfall and PET are then run through a Catchmod based rainfall/runoff model to generate multiple 100 year time series of River Thames and River Severn river flows. The River Thames flows are then run through the (IRAS) model, which is a highly simplified, but much faster, version of our WARMS2 water resources model. This carries out a mass-balance analysis of our reservoirs, which can produce yield, resilience and DO metrics in a similar way to WARMS2. The main point of using IRAS is not to replace WARMS2, but to allow the full stochastically generated weather and flow dataset to be analysed within reasonable timescales. The IRAS outputs are then used to rank both individual droughts and each 100 year time series according to water resource severity. This allows specific 100 year sequences, with known relative risk profiles, to be selected for full testing of resilience and key water resource options within the WARMS2 model.

4.135 A full weather data set equivalent to 200 'what if' iterations has been run and the IRAS behavioural analysis tool has been used to analyse the relative return period of all droughts contained within this data set according to system yield. This has allowed a number of 'drought libraries' with known return period events in them to be extracted and run using a more detailed analysis in the WARMS2 behavioural analysis model. Each drought within each 'drought library' is therefore temporally and spatially coherent, and generates time-series that can be run through the existing rainfall-runoff and behavioural models (WARMS2), or used to examine the probability of meteorological conditions associated with events that have been tested in the draft Drought Plan 2017.

4.136 Analysis of the results of this work for London, presented in Figure 4-6, illustrates that a 1:200 year event reduces DO by approximately 130-150 Ml/d (140 Ml/d being the central estimate) and a 1:500 year event reduces it by around 250 Ml/d. Details of this analysis were published by Atkins in July 2018[18]. This report also shows that the current return period of the historic 20th century drought events in the Thames catchment is 1:100 years. Details of the stochastic analysis are presented in Appendix I: Deployable Output.

[18] Atkins, Thames Water Stochastic Resource Modelling Stage 2 and 3 Report, July 2018.

Figure 4-6: London supply system yield/return period



Source: Figure 5.4 Analysis of WARMS2 Yield/Return Period Curve after Catchmod Re-Calibration, Thames Water Stochastic Resource Modelling Stage 2 and 3 report, July 2018 page 37.

4.137 Additional modelling of 1 in 200 droughts in WARMS2 and a comparison of DOs generated to those from IRAS has justified the appropriateness of using IRAS as a screening tool for WARMS2; further details of this analysis is provided in Appendix I.

4.138 We also commissioned Atkins to analyse more severe droughts for the other WRZs; SWOX, Kennet Valley, Henley, SWA and Guildford. These zones were assessed using a simpler EVA methodology. Atkins completed the EVA analysis based on the primary system stress metric for sources that were identified as potentially at risk during a severe drought. For the Kennet and Guildford surface water abstractions, the assessment looked at the annual summer minimum flow. For the Kennet and SWA groundwater sources the assessment used the annual summer minimum water levels in the indicator observation boreholes, which are used for assessing the DO of the sources. For SWOX the assessment calculated the Farmoor reservoir storage minima for the DO demand conditions run in WARMS2. From this assessment an estimated return period for the worst historic drought was calculated from the EVA curve fit, as well as an estimated indicator level for a 1:200 year drought. This was then converted into a DO impact for each source. The full methodology for each WRZ is detailed in Appendix I.

4.139 The following text is taken from the ‘Thames Water Table 10 Extreme Value Analysis’ (November 2017) report[19], although the report itself contains a lot more detail:

> *‘This report contains an evaluation of the potential risks faced by Thames Water in WRZs outside of London during severe (1 in 200) and extreme (1 in*

[19] Atkins, Thames Water Table 10 Extreme Value Analysis, November 2017

500) droughts, and is written to act as a support to Thames Water's Appendix A: Table 10 of the WRMP19 submission. The form of assessment is relatively simple and follows the EVA principles outlined in the UKWIR 'WRMP19 Methods: Risk Based Planning' guidance. In order to provide inputs to Appendix A: Table 10, the impact of the two drought severities has been calculated in relation to the 'baseline' DO, which has been calculated separately by Thames Water and in all cases is equal to the calculated DO for the overall worst historic drought on record for each WRZ.'

4.140 For the Guildford, Kennet and SWA WRZs the primary analysis was carried out for the summer Dry Year Critical Period (DYCP) as this generates the greatest stress in the supply/demand balance, however Dry Year Annual Average (DYAA) conditions were also assessed to allow completion of Appendix A: Table 10. For SWOX only the DYAA was analysed as the WRZ incorporates the Farmoor storage reservoir. For the Henley WRZ there are no sources vulnerable to drought DO impacts, so no analysis was required for Appendix A: Table 10.

4.141 Analysis of the results indicates that there is a reduction in DO for a 1:200 year event for SWOX, Kennet Valley and SWA, but that Henley and Guildford are resilient[20]. The impact on DYAA DO of a 1:200 year drought is summarised in Table 4-16 and for DYCP DO in Table 4-17.

4.142 The stochastic analysis has not been updated between the draft and final WRMP19 however the baseline DOs have been updated to align them with AR17+ figures.

Table 4-16: Risk to DYAA DO of increased drought severity

WRZ	AR17+ DYAA DO (Ml/d)	Critical year (Ml/d)	DO of 1:200 drought (Ml/d)	Impact on DO of 1:200 drought (Ml/d)
London	2302.00	1921	2162.00	140.00
SWOX	329.17	1976	323.29	5.88
Kennet Valley	143.87	1976	141.07	2.80
Henley	25.65	1976	25.65	0.00
SWA	185.05	1976	183.19	1.86
Guildford	65.82	1992	65.82	0.00

[20] Atkins, Thames Water Table 10 Extreme Value Analysis, November 2017

Table 4-17: Risk to DYCP DO of increased drought severity

WRZ	AR17+ DYCP DO (Ml/d)	Critical year (Ml/d)	DO of 1:200 drought (Ml/d)	Impact on DO of 1:200 drought (Ml/d)
London*	N/A	N/A	N/A	N/A
SWOX	385.38	1976	378.51	6.87
Kennet Valley	155.40	1976	152.04	3.36
Henley	25.9	1976	25.9	0.00
SWA	214.40	1976	211.14	3.26
Guildford	71.70	1992	71.70	0.00

4.143 We have assessed the impact of more severe droughts in the WRMP19 and Drought Plan. We have assessed the impacts of a 1:200 year drought for our WRMP19 and included the assessment results in Appendix A: Table 10. This demonstrates that we can manage a 1:200 year drought but would require the use of Drought Permits for an extended period. We have assessed the potential impact of 1:300 and 1:500 droughts in our Drought Plan and this also shows that it is possible to maintain supplies through these droughts with the use of Drought Permits over an extended period and with Drought Orders to ban non-essential use. This means that we do not plan for reaching Level 4 and our Levels of Service reflect this. However the environmental and economic impact of this prolonged use of Drought Permits and DOs would be severe, particularly on the environment, and in our view it is not acceptable to plan on this basis. Therefore we plan to develop in increased resource base so that we are resilient to 1:200 year drought without the requirement for prolonged use of drought permits. Section 11: Preferred plan describes how the preferred plan will increase the company's level of drought resilience from 1 in 100 to 1 in 200 by 2030.

4.144 It should be noted that the resilience described in our Drought Plan is only for the duration of the current plan, up to 2024/25, after which we will develop our next edition of the plan. Therefore the plan does not include the impacts of future growth in population or climate change and so without new resource development or improved supply demand balance we are not likely to be resilient to more severe droughts for the period of our next Drought Plan.

4.145 For the London WRZ, 'drought severity' has been calculated using the WARMS2 model that quantifies the combined duration and intensity of a drought, as stated according to the amount of stress it places on the London water resource system. All drought severities (return periods) have been defined according to the relative London system yield as calculated in IRAS, with the return period of each drought calculated based on a simple ranked return period analysis. The 'severity' of each drought therefore takes into account all of the meteorological drought attributes (timing, duration and intensity) and expresses them in terms of the impact that they have on the London system yield. This represents the best practice for drought analysis as described in the UKWIR 2016 'WRMP19 Risk Based Methods'

Guidance[21] and the Environment Agency 2017 'Drought Vulnerability Framework' Guidance (Environment Agency, 2017[22]).

4.146 In 2017 the Environment Agency issued guidance on the production of DVS. The essence of a DVS is a chart with an x-axis of drought length, a y-axis of rainfall, and a z-axis (represented using colours) showing a system drought performance metric. The concept is that a water resource system should be tested against droughts of various durations and intensities, in order to identify tipping points where system performance quickly degrades and to highlight areas of relative vulnerabilities of water resource systems. These DVSs were initially to be produced for inclusion in WRMP19, although the Environment Agency later withdrew this requirement, suggesting that DVSs should be included as part of the Annual Review process.

4.147 We have decided to include DVSs for the London WRZ, our most vulnerable and complex WRZ, within the WRMP19 as these are useful illustrations of the impact that droughts, across a range of varying intensities and durations as well as severities, have on the supply system. We have followed a slightly different methodology than initial EA guidance suggested regarding the production of DVSs, where it was suggested that DVSs should present days of emergency restrictions at a level of demand equal to distribution input (DI) plus Target Headroom. We have instead decided to present yield-based metrics on our DVSs in order to align with Appendix A: Table 10. This has also allowed us to produce a more meaningful system metric for our planning, particularly relating to WRMP responses regarding the consideration of contrasting extreme and severe drought profiles and our drought resilience across a range of 'types' of droughts. In addition, data was also readily available for the production of a DVS using a yield-based metric, where further modelling would have been necessary to produce a DVS using days of emergency restrictions. A final point is that 2017 Environment Agency guidance on the production of DVSs was withdrawn so the production of a yield-based DVS, presented here, is going beyond the requirements within the current Environment Agency guidelines for the WRMP19.

4.148 DVSs for the London WRZ are presented in Figure 4-7 and Figure 4-8 under worst historic (1 in 100 year) company drought resilience using a yield-based metric to align with Appendix A: Table 10. These surfaces present the resilience / sensitivity to droughts of different durations, intensities and severities and the range of drought 'types' of varying duration and intensity which the drought severities presented in Appendix A: Table 10 (1 in 100, 1 in 200 and 1 in 500) account for. The DVSs also include points relating to the historical record to indicate how the worst historical events relate to more extreme events.

[21] UKWIR, WRMP19 Methods report on Risk Based Planning, 2016
[22] Using the Drought Vulnerability Framework in Water Resources Management Plans, 2017, Environment Agency

Figure 4-7: DVS for London WRZ with Supply Demand Balance (SDB) as the metric and historic droughts, characterised by percentage long term average (LTA) rainfall and duration, shown with a 'calendar' year end point under worst historic (1 in 100 year) drought company resilience

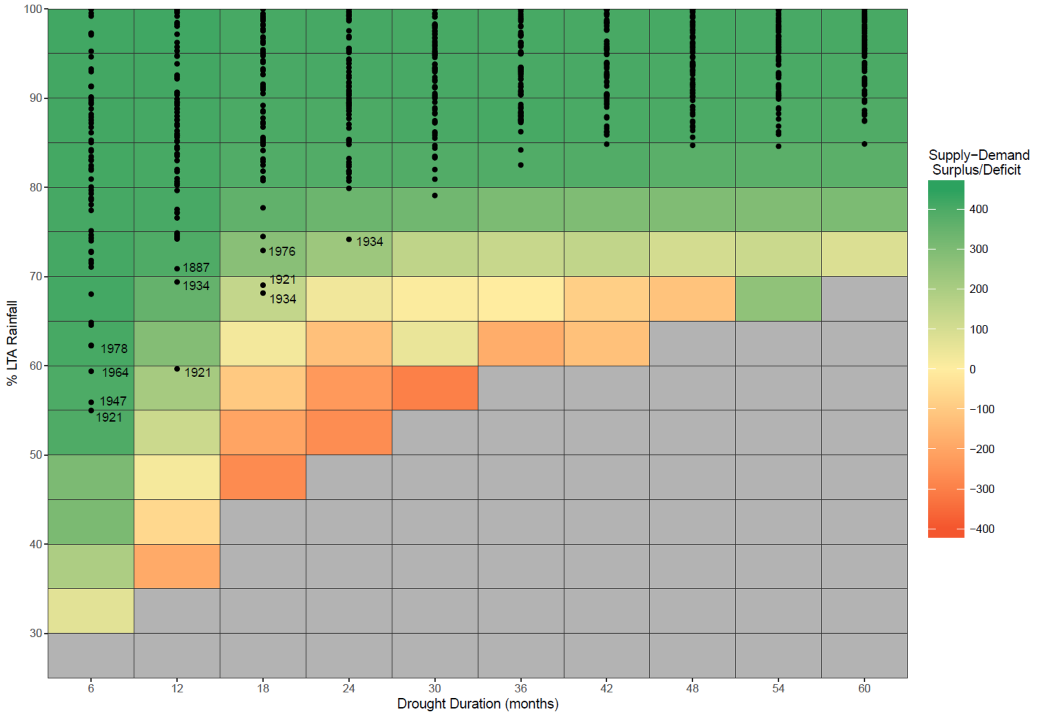
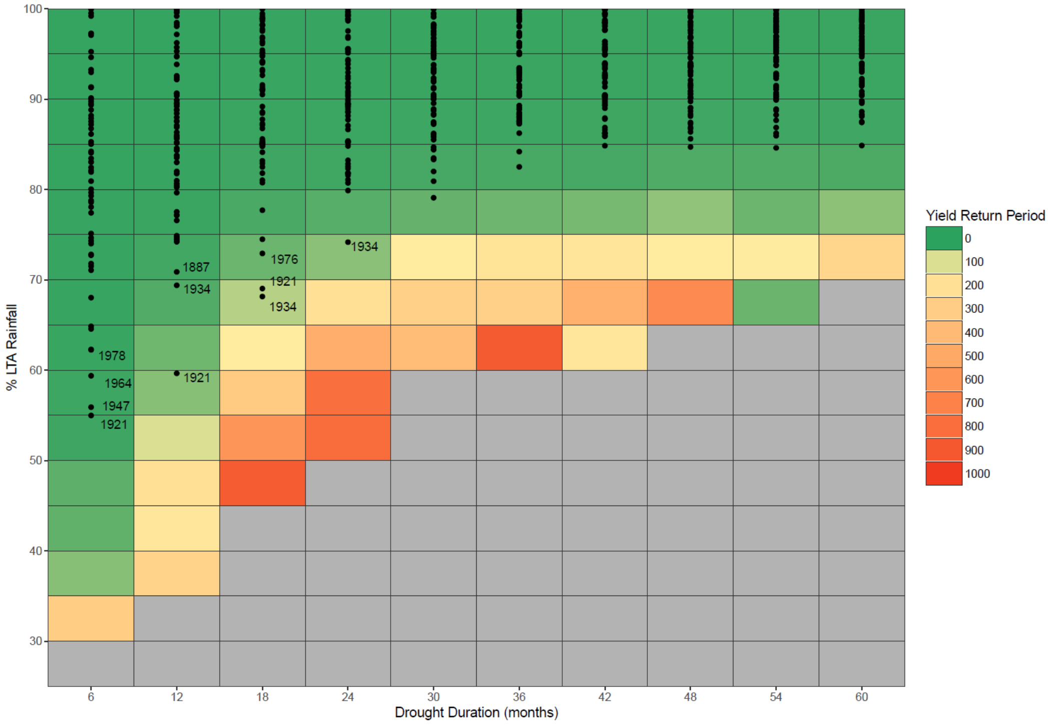


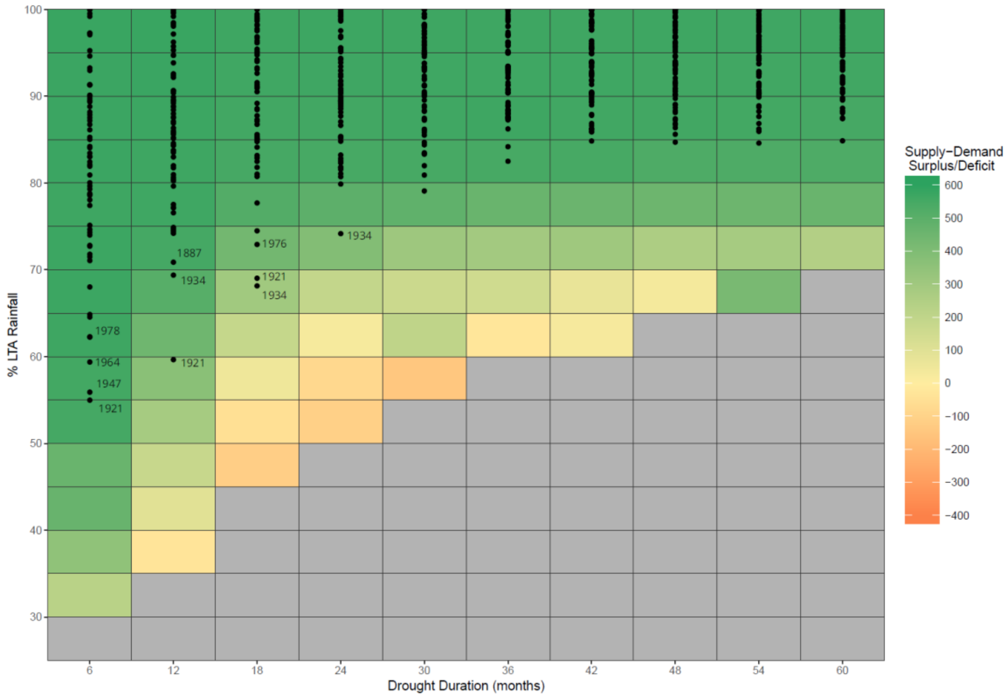
Figure 4-8: DVS for London WRZ with return period of average yield as the metric and historic droughts, characterised by percentage long term average (LTA) rainfall and duration, shown with a 'calendar' year end point



4.149 The DVSs presented here in Figure 4-7 and Figure 4-8 are for the base year of the WRMP19 to align with Appendix A: Table 10 for the London WRZ under worst historic (1 in 100 year) company drought resilience.

4.150 The DVS presented in Figure 4-9 is an illustration of how company resilience will improve in 2030 following the step up in company drought resilience from resilience to a worst historic (1 in 100 year) to a 1 in 200 year drought. This aligns with the 2030 drought resilience scenario presented in Appendix A: Table 10 for the London WRZ. See Section 11: Preferred plan for the suite of demand and supply options selected in 2030 which result in this increased 1 in 200 resilience see Section 11: Preferred plan.

Figure 4-9: DVS for London WRZ with Supply Demand Balance (SDB) as the metric and historic droughts, characterised by percentage long term average (LTA) rainfall and duration, shown with a 'calendar' year end point under 1 in 200 drought company resilience.



4.151 The key point from Figure 4-7, as expected, is that the London WRZ is most vulnerable to droughts of 18-24 months. This is where cells change colour relatively quickly from green (surplus) to orange (deficit) as percentage long term average (percentage LTA) rainfall decreases, and also where historical events plot closest to the green-yellow-orange tipping point. For events longer than 24 months, while severe impacts do occur, they are well beyond events that have historically occurred, and are well outside the scope of consideration within planning (e.g. the 30 month, 55-60% LTA cell shows a very severe impact, but this has a yield return period of over 1000 years).

4.152 When Figure 4-8 with return period of average yield as a metric is viewed in conjunction with the DVS with SDB as the metric Figure 4-7, the worst historic critical drought event experienced in the London WRZ, the 1921 drought, is shown to have a 1 in 100 years yield impact (Figure 4-8) and is not shown to result in a deficit (Figure 4-7). This demonstrates that for the base year of the WRMP19 the London WRZ the baseline DO is resilient to a worst historic 1 in 100 drought event and this level of resilience is maintained for the first 10 years of the plan.

4.153 The 'severity' of each drought under which the preferred programme has been tested takes into account all of the meteorological drought attributes (timing, duration and intensity) and expresses them in terms of the impact that they have on the London system yield. For the critical 1 in 100 drought event Figure 4-8 demonstrates that this covers a range of percentage long term average rainfall deficits and durations.

4.154 When considering the impact of more severe droughts under worst historic (1 in 100 year) company drought resilience, the droughts which do result in a deficit in Figure 4-7 and which have a return period of greater than 1 in 100 in Figure 4-8, for the first 10 years of the WRMP the Drought Plan shows that:

- 1 in 200 year droughts in Figure 4-8 can be managed but would require the use of Drought Permits for extended periods of time, i.e. greater than 12 months
- It is possible to maintain supplies through 1 in 300 and 1 in 500 droughts in Figure 4-8 with the use of Drought Permits over an extended period and with Drought Orders to ban non-essential use.

4.155 This means that we are robust against Level 4 severe drought restrictions and our Levels of Service reflect this. However, as noted above, the environmental and economic impact of this prolonged, extended use of DPs and DOs would be severe, particularly on the environment, and in our view it is not acceptable to plan on this basis.

4.156 Therefore we plan to develop an increased resource base so that we are resilient to the 1 in 200 year droughts identified in Figure 4-8 from 2030 onwards without the requirement for prolonged use of drought permits. Figure 4-9 presents a DVS for 2030 and the step change to 1 in 200 drought resilience in the London WRZ.

4.157 For the Thames Valley WRZs, the drought resilience has been assessed as detailed within the Drought Plan. Where potential vulnerabilities to drought were identified for sources then these were estimated using similar methods to those detailed in the EA draft 'Drought Vulnerability Framework' with the estimates based on groundwater levels, minimum river levels or reservoir storage as appropriate. As for the London WRZ, the drought severity risks therefore inherently account for both duration and intensity of droughts.

4.158 The impact on DO of a 1:500 year drought on all WRZs is presented in Appendix I: Deployable Output and is included as a 'what-if' scenario as part of programme appraisal in Section 10: Programme appraisal and scenario testing. An additional scenario exploring the timing of delivering 1 in 200 drought resilience is also included within Section 10: Programme appraisal and scenario testing.

E. Water Resources in the South East Group

Purpose

4.159 We have been working with five other water companies (Portsmouth Water, South East Water, Southern Water, Affinity Water and Sutton & East Surrey Water), the Environment Agency, Ofwat, Natural England, CCWater and consultant partners to identify potential opportunities for sharing of resources in the South East of England[23].

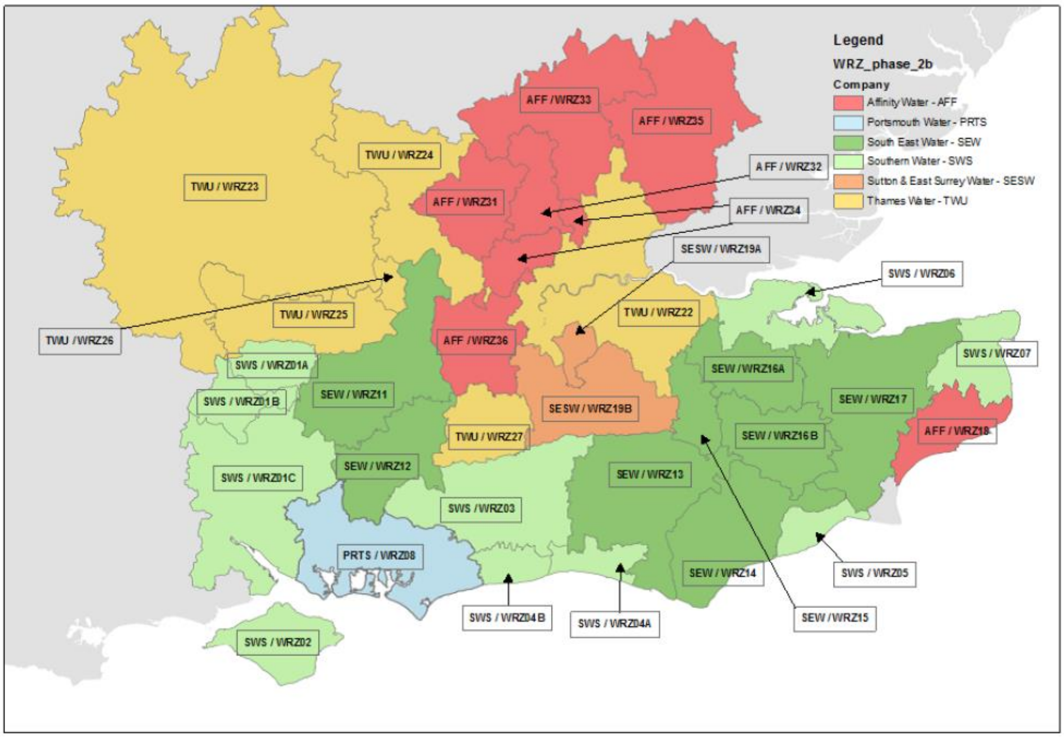
4.160 The overall aims of the WRSE group are:

'to identify and investigate a range of regionally based scenarios which when collated will form a range of potential regional strategies; and

to work together to understand the investments required for those strategies[24].'

4.161 The outcomes of this project have been designed to inform the participating water companies (supply areas shown in Figure 4-10), of potential resource sharing options for consideration in their own water resource management plans and to provide a regional framework for the requirement for strategic resource development for the south east of England. The group addresses all aspects of water resources planning and attempts to identify areas of common ground, which can then be adopted by the water companies for planning should they chose to do so.

Figure 4-10: Water companies participating in WRSE and their respective WRZs



[23] WRSE, Collaborative Agreement, April 2016
[24] Water Resources in the South East of England, Memorandum of Understanding, January 2016

Background

4.162 The WRSE work is focussed around the strategic application of a water resource planning options selection model, with the objective function of balancing supply and demand across the region at least cost. The model has been constructed to satisfy the requirements and principles of the WRPG. It contains water resources planning options for all participating companies, including; various types of new resources, existing supply enhancements, demand management options (leakage reduction, household metering, household and non-household water efficiency) and raw and treated water transfers between resource zones and water companies. An 80 year planning horizon to 2080 was chosen and several scenarios considered exploring the uncertainty inherent in forecasting future water resource development requirements. These included:

- A range of medium and high DI forecasts
- A variety of different drought severities representing historical twentieth century droughts, 1 in 200 year severe drought events and 1 in 500 year extreme drought events
- Reductions in water availability linked to the effects of climate change
- Application of the WINEP sustainability reductions
- Application of drought permit options and drought order water use restriction savings
- Reductions in raw water availability linked to water quality issues and other extreme weather events in addition to drought

4.163 The WRSE work is jointly funded by the water companies and the Environment Agency. CH2M (now Jacobs) was commissioned to apply the modelling consultancy package. Other parallel work packages undertaken by other consultants for the WRSE Group were:

- Independent project management (Atkins)
- Construction and application of a water resources system simulation model of the South East area (Atkins and the University of Manchester)
- Cumulative and in-combination environmental impact assessment of the water resource options selected within the WRSE water companies' draft WRMP19 plans, subsequently updated to reflect WRMP19 plans (Ricardo)

Scenario development

4.164 A 60-year planning horizon to 2080 was chosen. At different phases of the five years of the WRMP development process, the most up-to-date understanding of the supply demand forecasts and options available from all companies has been input, and several scenarios examined to explore the uncertainty inherent in forecasting future water resource development requirements. Scenarios have included combinations of:

- A range of medium and high DI forecasts
- A variety of different drought severities representing historical twentieth century droughts, 1 in 200 year severe drought events and 1 in 500 year extreme drought events

- Reductions in water availability linked to the effects of climate change
- Application of the WINEP sustainability reductions
- Application of supply side drought permit options and drought order water use restriction savings
- Reductions in raw water availability linked to water quality issues and other extreme weather events in addition to drought
- Aspirational leakage and PCC reduction targets[25]
- Application or removal of temporary use ban (TUBs) savings during drought

Options available

4.165 All options available in the constrained lists of all companies in the WRSE are updated for the regional model for each phase. Utilisation of existing transfers within the region is modelled, together with potential new transfers available for selection. The costs are annuitised. Options and transfers available in the WRSE model are detailed in Section 7.

WRSE Modelling Phases

4.166 All companies provided their most up-to-date baseline supply, demand, headroom and option data for modelling purposes for the five different phases:

- **Phase 1:** April 2014 to March 2015 – scoping, preparation, formalisation of modelling work
- **Phase 2:** April 2015 to August 2017 – main period of technical assessment and development using WRMP14 data. Application of Info-Gap stress testing of selected investment portfolios
- **Phase 3:** September 2017 to January 2018 – final strategic modelling runs using data that companies use for their draft WRMP19 plans
- **Phase 4:** February 2018 to December 2018 – forecasts and options data updated with revised draft position and further aspirational leakage and PCC targets
- **Phase 5:** January 2019 to March 2019 – final update of options and investigation of parallels and differences between regional and company EBSD programme appraisal

4.167 The intention of the Phase 5 modelling was to allow water companies to assess consistency of the WRSE results with their own revised draft WRMPs, to understand the causes of any significant differences and to support companies in the submission of their plans.

4.168 For Phase 5, a total of eleven core scenarios were run through the WRSE model using different combinations of:

- Drought severities representing 1 in 200 year severe drought events and 1 in 500 extreme drought events

[25] Beyond reductions from currently available demand options

- Application of the WINEP uncertain sustainability reductions at 50% or 100%
- Application or removal of TUBs savings
- Application or removal of drought permits and orders

4.169 These were assessed against further comparison runs restricting the options available within specific scenarios to those identified in company plans as preferred. This was to facilitate understanding of how individual company plans work together in the regional context and where areas for better synergy may be apparent. The latest results of the Phase 5 modelling are discussed in Section 11 Preferred plan, Part L.

4.170 The final report from the WRSE group is expected to be published in Spring 2019, which will outline potential solutions available to meet the South East regional deficit.

4.171 WRSE will play an important role in improving the resilience of the South East region. Recent discussions between the CEOs of the six companies and regulators have confirmed this role, moving the WRSE into the strategic development of the regional plan for WRMP24. We have committed to our involvement within the group, and included funding within our plan to assist and drive development.