Thames Water

Final Water Resources Management Plan 2019

Technical Appendices

Appendix J: Outage

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Outage

A. Introduction

J.1 This section of our WRMP19 describes how the temporary loss of resources is allowed for in the supply demand balance. Known as the "Outage Allowance" or more commonly as "outage", the methodology of how this is calculated is explained and the baseline figure is presented

J.2 Outage Allowance is defined and the methodology explained

J.3 This appendix is structured as follows:

- The definition of outage is presented
- The background to the methodology and when to assess outage uncertainty is explained
- The Outage Allowance methodology is explained together with the principles of the approach
- We describe how we approach Outage Allowance assessments
- With the aid of examples the potential variance in outages is explained
- The interpretation of risk is discussed
- The base year outage figures are presented

B. Outage definition and methodology

Definition of outage

J.4 Outage is a temporary short-term loss in supply known as Deployable Output (DO - see Appendix I: Deployable Output). For the purposes of producing our WRMP19, we've examined the updated guidance, including Section 4.10 of the Final Water Resources Planning Guideline (WRPG)[1] and further Environment Agency WRPG supporting documents on outage from July 2016[2]. We have also used the UKWIR reports Outage Allowances for Water Resources Planning[3] and WRMP 2019 Methods – Risk Based Planning[4], the latter stating that the 1995 methodology remains acceptable.

[1] Environment Agency and Natural Resources Wales and also produced in collaboration with Defra, the Welsh Government, and Ofwat, Final Water Resources Planning Guideline, July 2018
[2] Environment Agency, WRMP19 methods: Outage Allowance, July 2016
[3] UKWIR, Outage Allowances for Water Resources Planning, 1995
[4] UKWIR, WRMP 2019 Methods – Risk Based Planning, May 2016

J.5 Note the Environment Agency's 2018 WRPG states that an outage is temporary in the sense that it is retrievable, and therefore the DO lost can be recovered. The period of time for recovery is subject to audit and agreement. If an outage lasts longer than three months, analysis of the cause of the problem would be required in order to determine the legitimacy of the outage. The 2018 WRPG indicates that a water company must determine if it will incorporate an "Outage Allowance" within its WRMP. It also states that the Outage Allowance that a company can use within its WRMP can be developed by following the principles within the Outage Allowances for Water Resources Planning Report.

Definition of Outage Allowance

J.6 We need to incorporate an Outage Allowance in our water supply demand planning in order to account for the planned and unplanned loss of water resources over the plan period. The allowable outage collectively describes the combined risks of the legitimate unplanned and legitimate planned outages. The Outage Allowance being the value of allowable outage expressed in mega litres per day (Ml/d). In responding to Environment Agency comments raised in the consultation on our draft WRMP19 regarding the nature of outages, our outage reporting has not focussed on distinguishing between planned and unplanned outages. As a result it is not possible to use this data to determine with confidence the proportions of unplanned and planned outage. It was, however, possible to retrospectively make a distinction between actual planned and unplanned outage for 2017/18. This shows that the Actual Outages are predominantly unplanned, with just over 15% of the outage impact on DO being planned. It is important to note that this approximately 85:15 split between unplanned and planned outages is dominated by the London water resource zone (WRZ); and in 2017/18, the Actual Outage volume was influenced significantly by the outages of the Gateway water treatment works (WTW) resulting from poor water quality and failures related to asset malfunctions. Accordingly, this split between unplanned and planned outages is unlikely to be representative of the long term record.

Background to outage methodology

J.7 Prior to AMP4 we commissioned consultants to assess industry best practice and develop an outage assessment methodology based upon the UKWIR approach. Their review identified several shortcomings in the earlier methodology and how these could be overcome. The resulting methodology to overcome these shortcomings follows the philosophy behind the UKWIR report referenced by the Environment Agency. It is built around commercially available risk analysis software (@Risk) and it is compatible with the updated methodologies developed by UKWIR for other elements of the supply demand balance. In particular, it is compatible with the headroom methodology outlined in Appendix V: Risk and uncertainty except that it is run on a monthly rather than annual time period.

J.8 The methodology is a pragmatic but conceptually robust method of quantifying the uncertainties in the supply demand balance. The methodology:

- Carries out a full analysis of outage uncertainty in the supply demand balance, giving a range of outputs across the planning period with probabilities and confidence limits

- Is sufficiently robust, in conjunction with a wider economic framework, to justify significant investment decisions in new resources or demand management programmes
- Provides a reliable measure of outage uncertainty that is not constrained within particular limits by the methodology itself
- Enables the uncertainty associated with rare but high consequence events to be evaluated, such as the complete loss of a source due to an infrequent flooding incident

J.9 In common with the headroom methodology, it does not provide a fixed Outage Allowance. Instead, it provides a range of numbers with probabilities and these must be interpreted in conjunction with the other components of the supply demand balance and assessed against a level of risk that is acceptable to the water company and its regulators.

When to assess outage uncertainty

J.10 In general the outage uncertainty is not expected to vary over the planning period, unless issues such as maintenance are identified as either commencing or being resolved at different stages in the planning period, or if a current outage issue is resolved, such as a pump replacement which enables the full DO of the site to be abstracted.

J.11 If the outage is likely to vary, and it is predicted that some action will be taken to remove the risk of a particular outage occurring, then further assessments can be carried out to determine the impact of removing an outage issue on outage uncertainty.

J.12 In some instances it may not be necessary to carry out a complete and detailed analysis of outage uncertainty. In the situation where DO exceeds demand by at least 25% (the same percentage as in the headroom methodology) then an alternative, simpler methodology can be implemented. An example could be either a blanket estimation (say <5%) across the whole supply area or no allowance as the excess in available resource can deal with any outage requirement.

J.13 In most cases, outage uncertainty should be assessed each month during the critical years of the planning period in order to identify the critical month when outage uncertainty is greatest. 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 becomes 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, exclusion of any ‘residual outages’ would not underestimate outage.

Actual Outage

J.14 A requirement of the annual regulatory submissions is to report on “Actual Outage”. As there is no formal definition of “Actual Outage” from regulators or the Water Industry, we have derived a means by which Actual Outage is measured.

J.15 Actual Outage is the temporary loss of DO in the reporting year weighted by the duration of the loss (in days).

Example: a source DO loss of 10 Ml/d lasts 45 days thus

*Weighted outage = 10 * (45 / 365) = 1.23 Ml/d*

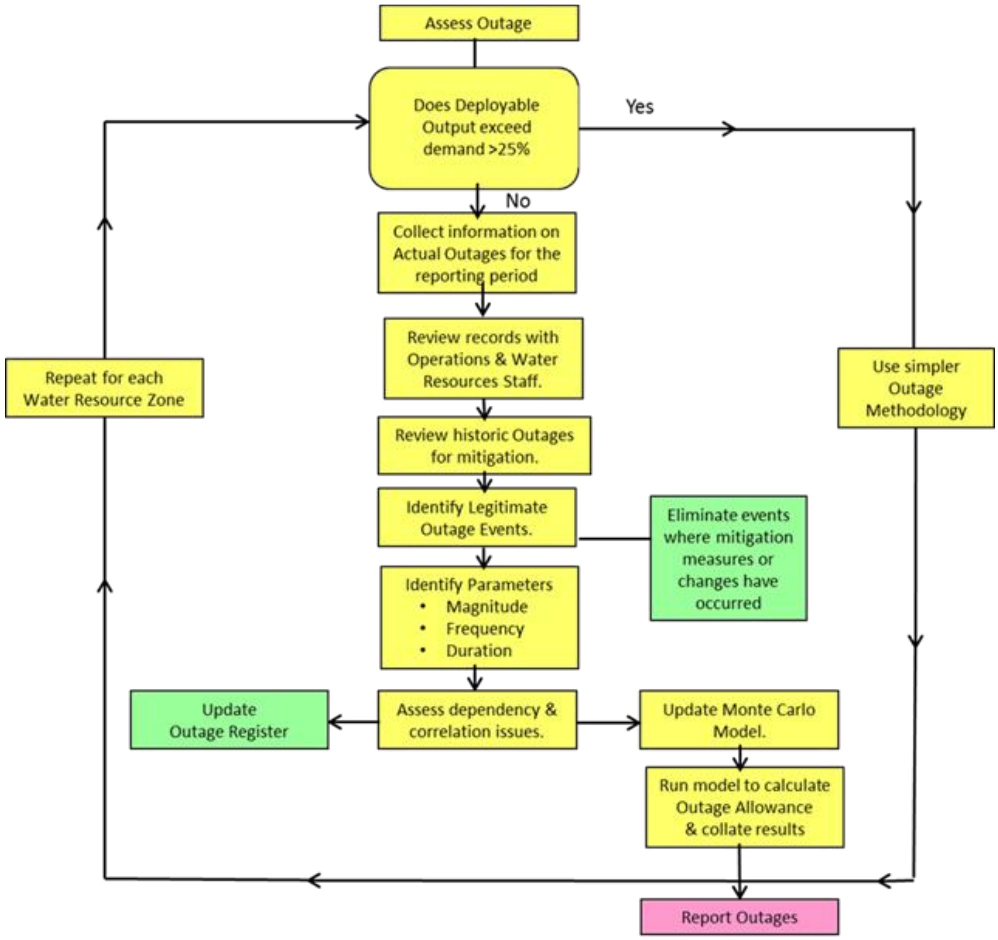
J.16 Each weighted outage is then summed over the reporting year to give a total Actual Outage for the WRZ. This measurement of outage is fundamentally different to the Outage Allowance which is based on risk.

C. Outage Allowance

Outage Allowance methodology

J.17 The methodology starts with an optional screening process to identify whether DO in the resource zone is at least 25% greater than demand. This percentage is the same as that applied to the filter in the headroom methodology. This screening process will determine whether a probabilistic analysis of outage uncertainty is appropriate. A simpler method could be applied if there is evidence that any failures are unlikely to affect supply or the DO. An example of this more simplistic assessment of outage may be a fixed percentage allowance for the resource zone. However, even if there is a significant resource surplus, a full outage assessment may be advisable to provide the level of understanding required within the resource zone.

Figure J-1: Overview of outage methodology



J.18 Having decided to apply the methodology the first stage is to identify, by WRZ, any historical failures of supply. Interviews with relevant staff and interrogation of operational data systems have been used to collect this failure information. Failures generally fall within the following categories:

- power failure (mains or standby)
- algae
- flooding
- turbidity
- pollution of source
- system failure
- raw water transmission
- treatment
- delivery through service reservoirs and treated water pumping
- Supervisory Control and Data Acquisition (SCADA) failures
- statutory Inspections
- engineering upgrades

J.19 A failure to supply, due to the incidence of one of the categories above, may not always be classified as a legitimate outage, and further assessment is required to identify which of these failures are legitimate outages.

J.20 In order to assess which of these failures are legitimate outages under the methodology, the mitigation measures that would be employed, should the failure occur, have been reviewed. This provides a means of addressing whether other resources can cover a failure causing an outage event and whether the resources used can be replaced within a short (seven day) period without impacting on the DO. If this is the case or the failure is for less than 24 hours, then it is not considered as a legitimate outage.

J.21 Once the legitimate outage events have been identified, then the outage issues data can be recorded. The information recorded covers the frequency, magnitude and duration of the events. In general, the outage events will be independent of one another, but sometimes one event will be the result of another, therefore they may be correlated or interdependent ,or they may be mutually exclusive (i.e. one or the other will apply at any one time, but not both). Listing this information effectively in the outage issues log helps define the problem to be assessed.

J.22 This process is repeated for each of the WRZs within the region.

J.23 A Monte Carlo model has been constructed in @Risk to combine the estimates of frequency, duration and magnitude for each of the events to determine the overall distribution of legitimate outage. The outage model sets out a series of spreadsheets in a way that is auditable and easily combined to calculate this distribution. Each outage component in the model is cross-referenced to the outage issues register so that the origin of the data is clear.

J.24 The Monte Carlo model is run to derive the distribution of legitimate outage and the output is presented in tabular and graphical form. The outage model has established formats for the graphical and tabular output.

Principles of the approach

J.25 This methodology requires the uncertainty surrounding the frequency, magnitude and duration of each outage issue to be defined as a probability distribution. All the issues are then combined using Monte Carlo simulation to give an overall outage uncertainty.

J.26 First of all, each outage issue is broken down into three probability distributions. This might take the form of a triangular distribution (or a fixed value) for frequency, a triangular or discrete distribution for magnitude, and a triangular distribution for duration that best fits the available data. An example is given in Figure J-2. The basis for defining these probability distributions is described in subsequent sections.

J.27 Outage events are summed for each month to determine the overall outage uncertainty for the WRZ. This is shown in Figure J-3.

J.28 An inherent assumption in this methodology is that the outage issues are independent. Generally this is the case, but some can be inter-related. Two issues may affect the same source but only result in one outage. In this instance it is necessary to modify the Monte Carlo analysis to allow for these inter-relationships.

J.29 A number of software packages are available for performing Monte Carlo analysis. This methodology has been developed using @RISK, which operates within a spreadsheet environment. When a Monte Carlo simulation is run, it randomly selects numbers from each probability distribution assigned to each outage component. Each set of random numbers effectively simulates a single 'what-if' scenario for the spreadsheet model. As the simulation runs, the model is recalculated for each scenario and the results are presented as a series of forecast charts for outage uncertainty. The simulation stops according to criteria set by the user, which is normally a number of scenarios or trials. The number of trials must be set to give an acceptable mean standard error for the simulation results, whilst controlling the processing time to workable limits. A typical number of trials might be 1,000 to 5,000. If the mean standard error is too high, then it will be impossible to obtain repeatable results for the same set of data. We use 4,000 iterations determined by sensitivity analysis.

Figure J-2: Example of outage probability distributions

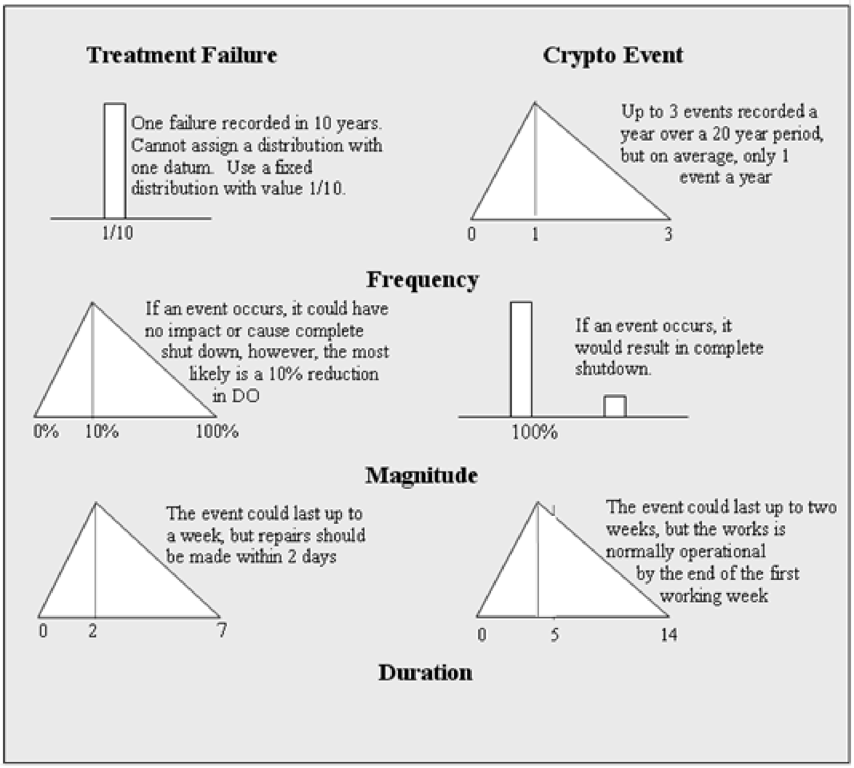
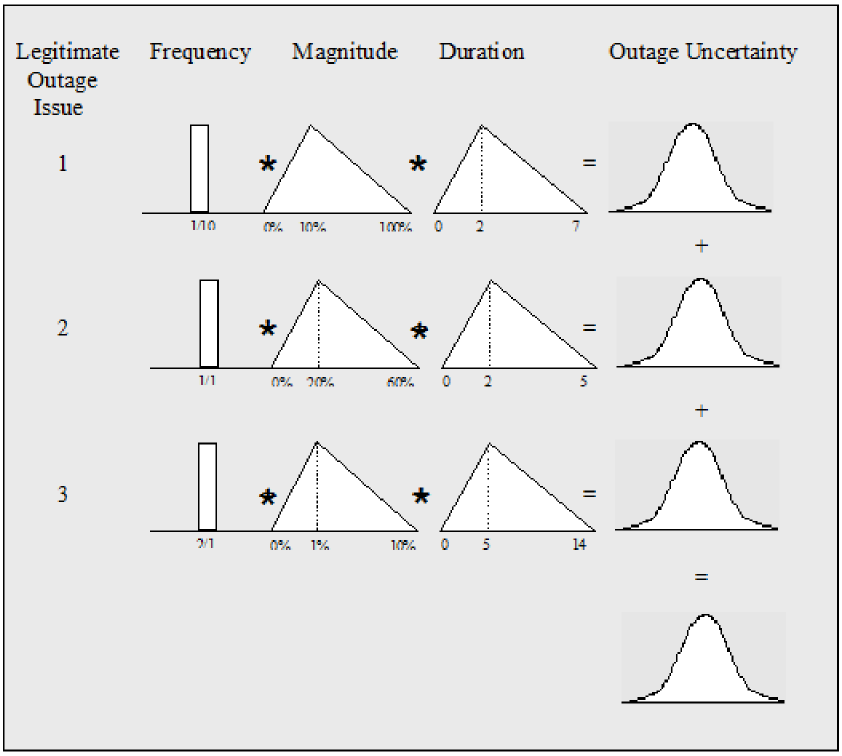


Figure J-3: Summing outage issues



D. Our approach to Outage Allowance

Outage records

J.30 A schedule of potential outages is provided by Operations for each WRZ for each fiscal year. The details of each outage event are recorded in terms of the nature of the event, when it occurred, for how long and the impact on DO. Table J-1 is an example from the reporting year 2016/17 of outage records available and includes:

- source name
- outage issue
- source DO and impact on DO
- start and end date of the outage issue

J.31 There may be a total loss or a partial loss of DO depending on the nature of the outage; e.g. the loss of a borehole pump may mean just a partial reduction as water can be put into supply from other boreholes on site. The impact on DO is assessed from the nature of the outage event.

J.32 With regard to potential outages at the London major WTWs a record is made in just the same way, however, the impact of these WTWs outages on London's DO is assessed by modelling the reduced output capabilities using the Water Resources Management System (WARMS2) and noting the impact (if any) on the DO.

J.33 Each record of potential outages is assessed to see if this is a legitimate outage that can be included in Outage Allowance. These are then assessed to see that they last longer than 24 hours and if during a drought event mitigation measures could be taken to ensure availability of water going into supply. If, for example, engineering work is planned to be undertaken, could this be postponed until a more suitable time with regard to the maintenance of DO?

J.34 The Actual Outage is calculated from the loss in DO weighted by the duration of the outage. For the Broadmead example in Table J-1 this is 6.8 * 92 / 365 = 1.71 Ml/d.

Table J-1: Recording outages for London

Lee Valley WRZ	Reason for outage	Outage start date	Outage end date	Total no. of days outage	Output capacity reduced to Ml/d	Deployable output (Ml/d)	Actual Outage (Ml/d)
Barrow Hill	Operational issues	01/04/16	31/03/17	365	0	1.72	1.72
Broadmead	Pump failure	01/06/16	31/08/16	92	0	6.80	1.71
ELReD (East Ham)	Treatment issues	13/05/16	15/05/16	3	0	13.20	0.11
Wanstead	Pump failure	02/01/17	08/01/17	7	0	5.38	0.10
Wanstead	Treatment issues	21/11/16	30/11/16	10	0	5.38	0.15
						Total	**3.79**

Modelling Outage Allowance

J.35 Once a probability distribution for each of the risks around magnitude, duration and frequency has been decided, then the outage model requires the probability distribution parameters to be input to the model for each outage issue identified.

J.36 For each outage accepted as legitimate the input to the model includes:

- A unique outage issue reference number
- If event frequency is included in the analysis, the number of events per year and the distribution type
- Minimum, most likely and maximum magnitude of the outage issue, including distribution type
- Minimum, most likely and maximum duration of the outage issue, including distribution type if appropriate
- Any specific comments relating to the outage issue

J.37 The following examples have been compiled to assist the understanding of how an Outage Allowance is calculated using the outage model. To simplify matters single values have been used for magnitude, frequency and duration although often these would be the parameters of the assigned probability distributions e.g. min, max and most likely of a triangular distribution.

J.38 **Example 1:** Assume that a small source has been out of supply due to a treatment problem and it is the first time this has happened in ten years (NYRS).

- The **magnitude** (m) is the loss of DO which is its total DO of 5 Ml/d and a fixed distribution is used as there has been only one incident by which to define magnitude
- The **duration** (d) of the event is 15 days and impacts on one month of the year, which has to be reflected in the frequency. Only one figure is available from the information sourced for event frequency, so it is not plausible to apply any distributions. Therefore a single value is used in event frequency
- The **frequency** (f) should reflect the likely chance of occurrence of a given outage in any one year, and is not simply the number of events divided by the period of record. The likely frequency of occurrence of an outage can be subjective, given the nature of the risks posed and steps taken to mitigate such events. However, for this source the frequency applied is 1 year multiplied by the 1 month divided by the number of years of record:

  *(N*NM) / NYRS = 1*1/10 = 0.1*

J.39 Thus the probability of the event for that month of the year is 0.10

J.40 And hence the outage risk assigned (magnitude*frequency*duration) / no. days in the month is (5 * 0.1 * 15) / 31 = 0.24 Ml/d in the month that it occurred and zero for all other months.

J.41 If however, the event were to last for more than one month the calculation is the same but needs to account for those months where the outage has occurred. If say the event lasts all year then;

- The **duration** (d) of the event is 365 days and thus impacts on each month of the year; so this also has to be reflected in the frequency. Only one figure is available from the information sourced for event frequency, so it is not plausible to apply any distributions. Therefore a single value is used in event frequency
- Again, the **frequency** (f) should reflect the likely chance of occurrence of a given outage in any one year and is not simply the number of events divided by the period of record. The likely frequency of occurrence of an outage can also be subjective, given the nature of the risks posed and steps taken to mitigate such events. In this example, the frequency is now multiplied by the number of months affected (NM), as determined by the length of the outage event. For this source the frequency applied is one year multiplied by the 12 months divided by the number of years of record:

  *(N*NM) / NYRS = 1*12/10 = 1.2*

J.42 Thus the probability in any month of the year is 1.2/12 (number of months affected) = 0.10

J.43 Hence the outage risk in each month is (5 * 0.1 * 31) / 31 = 0.5 Ml/d

J.44 The inputs can be far more complicated however, depending on the nature of the events and frequency is particularly open to interpretation.

J.45 The duration and timing of an event within the year is also important as Outage Allowance is based on outages that occur in the critical month.

J.46 **Example 2:** If there were three sources that experienced outages each of 15 days duration but in different months and had been assigned different frequencies to reflect the ten year record of such events previously then the outage risk would be as in Table J-2. Note if the duration is less than a complete month the m*f*d is divided by the number of days in the month to give a value in Ml/d for the month. The Actual Outage during the period is shown in, with a total of 1.24 Ml/d.

Table J-2: Outage for the critical month – example 2

	Magnitude (Ml/d)	Frequency	Duration days	Outage risk (Ml/d)			Actual outage
				Jan	Feb	Mar	
Outage 1	5	0.3	15	0.73			0.21
Outage 2	10	0.2	15		1.07		0.41
Outage 3	15	0.1	15			0.73	0.62
Total				**0.73**	**1.07**	**0.73**	**1.24**

J.47 Thus February would be the critical month with the largest outage to which a risk of 5% would be applied giving an Outage Allowance of around 1 Ml/d. The other two outages would therefore not feature as part of the Outage Allowance. Thus only 42% (1.07/(1.07+0.73+0.73)) of the outage risk occurs in the critical month.

J.48 **Example 3:** If however, Outage 1 actually occurred in February and not January the story would be different as shown in Table J-3.

Table J-3: Outage for the critical month – example 3

	Magnitude (Ml/d)	Frequency	Duration days	Outage risk (Ml/d)			Actual outage
				Jan	Feb	Mar	
Outage 1	5	0.3	15		0.80		0.21
Outage 2	10	0.2	15		1.07		0.41
Outage 3	15	0.1	15			0.73	0.62
Total				**0.00**	**1.87**	**0.73**	**1.24**

J.49 Here the outage risk is increased to 1.87 Ml/d from which the Outage Allowance is determined with a 5% risk and February remains the critical month. The outage in March would not contribute to the outage risk and thus only 72% (1.87 / (1.87+0.73)) of the outage risk experienced in that year occurs in the critical month.

J.50 **Example 4:** If however, Outage 1 actually occurred in March the story would be different again as shown in Table J-4.

Table J-4: Outage for the critical month – example 4

	Magnitude (Ml/d)	Frequency	Duration days	Outage risk (Ml/d)			Actual outage
				Jan	Feb	Mar	
Outage 1	5	0.3	15			0.73	0.21
Outage 2	10	0.2	15		1.07		0.41
Outage 3	15	0.1	15			0.73	0.62
Total				**0.00**	**1.07**	**1.46**	**1.24**

J.51 Here the outage risk becomes 1.46 Ml/d from which the Outage Allowance is determined with a 5% risk however, March becomes the critical month. Hence only 58% (1.46 / (1.46+1.07)) of the outage risk experienced in that year occurs in the critical month.

J.52 Thus the timing of any outages are critical in determining Outage Allowance and whilst just three months are shown here the same would apply throughout the year. The examples also show that Actual Outage can be larger or smaller than outage risk depending on the timing of the outage events in any year.

Interpretation of risk

Impact of record length on Outage Allowance

J.53 From an assessment of the historic outage record we noted that the Thames Water Outage Allowance was biased by the earlier record from which it had been calculated; an important element in the calculation of the frequency of events. On reviewing the results for the reporting period 2015/16 they indicate that using the more recent record gives a better reflection of recent events and the level of Actual Outage. Thus on comparing the London results (seen in Table J-5) the Outage Allowance is greater using the more recent AR08 to AR16 data compared to that using the AR02 to AR16 data, the full record. It is also noted that the Outage Allowance is now more in line with the Actual Outage.

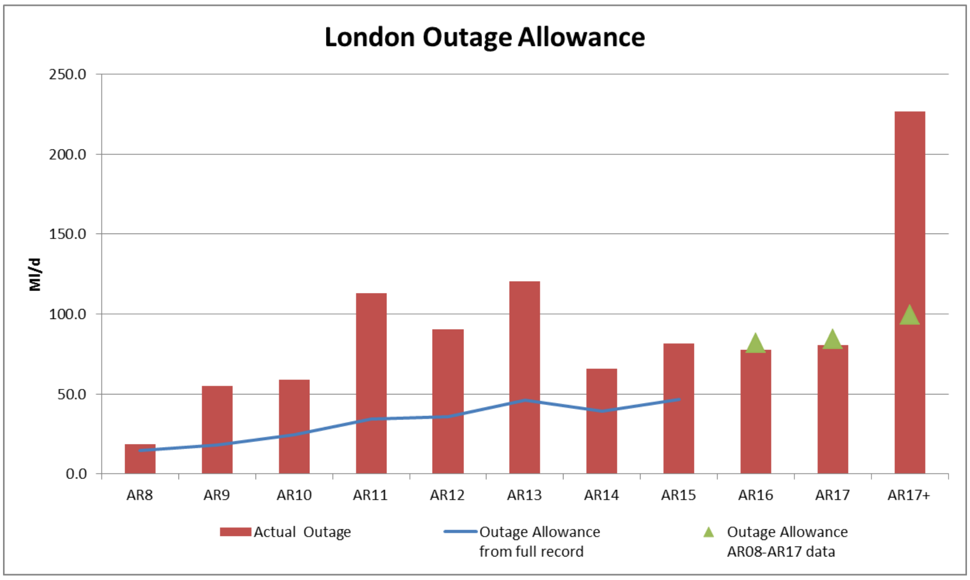
J.54 Figure J-4 shows for London the difference between Actual Outage and Outage Allowance. AR17+ Actual Outage during the reporting year 2017/18 has been much larger than any reporting year to date, principally due to a large outage at our London Gateway WTW. So our Actual Outage for this year is much larger than our Outage Allowance. Investment has been made at Gateway WTW and this works has been returned to supply (see Table J-8).

J.55 Following detailed discussions with the Environment Agency and after reviewing our approach and datasets against that 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 historical data used in the assessment. Therefore, in reporting our Outage Allowance for the Annual Return, from 2016 we started to use the more recent record of outages in our reporting, the data for which started from the period 2007/08. We are now also taking into account outages from 2016/17 as well as 2017/18.

Table J-5: Outage Allowance using different length of records

Outage Allowance – (Ml/d)	**n=15 years AR02 to AR16**	**n=9 years AR08 to AR16**
Outage Allowance - data and frequency for specified period n (Ml/d)	51.2	81.7

Figure J-4: Annual review 2017+ Outage Allowance and Actual Outage



J.56 In addition, where measures have been taken to mitigate the risk of an outage being repeated, this is also taken into consideration. For example, where a site has been re-commissioned following engineering work to resolve water quality constraints on supply through installation of new or modified treatment processes, the outages previously experienced that drove the need for investment will be removed from the historical record. Indeed if the risk is deemed remote then professional judgement may be relied on to assign frequency.

J.57 Although shortening the historical outage record has in increased confidence in the calculated Outage Allowance, in order to avoid the calculated value to be 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 which, if viewed in isolation, would be seen as a frequent occurrence. 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.

J.58 To reflect this historical position and mitigate an overly skewed Outage Allowance the outage record was lengthened from 10 to 30 years, as it was felt appropriate to limit the impact on outage of this type of event. If this decision was reversed and only the ten year record were considered then the outage would increase. The programme of raw water tunnel relining is coming to an end and will be complete in the next few years. Accordingly, we have removed some of the reservoir and raw water tunnel outages from the historical record and will remove all of these outages when the relining programme is finished to reflect the reduction in risk as a result of asset investment.

Base year Outage Allowance

J.59 Each year, as part of our reporting for the Annual Review, we review our Outage Allowance and examine any changes to the information on which the Outage Allowance is assessed. The methodology used for evaluating outage is compatible with the latest UKWIR methodology used for assessing headroom uncertainty (see Appendix V: Risk and uncertainty). The method provides an assessment of the uncertainty surrounding outage within the supply demand balance, with a range of probabilities and confidence limits.

J.60 Table J-6 summarises the Outage Allowances used for strategic planning purposes by WRZ for the years 2015/16 (AR16), 2016/17 (AR17) and the values at WRMP14 based on AR13 data, as well as the baseline for the WRMP19, i.e. AR17+.

Table J-6: Outage Allowance 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 Dry Year Annual Average (DYAA) and Dry Year Critical Peak (DYCP)*

*** 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*

J.61 The Outage Allowance is currently considered to be same for both the DYAA and DYCP conditions. Historically, we have not recorded outages against peak Dos. One of the key reasons is 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.

J.62 Table J-6 shows that since WRMP14 the allowances have increased in some WRZs and reduced in others. Given that we are reporting Actual Outage on an annual basis in the

Annual Review it was felt appropriate to simultaneously update the view of the Outage Allowance in the WRMP14, as events in any year influence the risk perceived. For the WRMP19 we take a snapshot in time as to the baseline Outage Allowance and assume this applies over the planning period, i.e. the Outage Allowance used in the baseline forecast is considered to remain constant across the planning period. As regards future Outage Allowances 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. Accordingly, 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.

J.63 The Outage Allowance for the WRMP19 is as described as AR17+ in Table J-6. The change in Outage Allowance between WRMP14 (77.39 Ml/d) and draft WRMP19 (130.7 Ml/d) is largely driven by changes in the London WRZ and the methodology change 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 final WRMP19 as shown in Table J-6. As part of a continual data improvement process, our reported AR18 Outage Allowance has now decreased from the WRMP19 baseline figure of 99.76 Ml/d to around 93 Ml/d in the London WRZ.

J.64 The Outage Allowance is different to the Actual Outage which will occur in any one particular reporting year. There is no standard industry methodology for calculating Actual Outage and we have derived a means by which it can be measured, as summarised in the equation below.

J.65 Actual Outage is the temporary loss of DO in the reporting year weighted by the duration of the loss (in days).

Example: a source DO loss of 10 Ml/d lasts 45 days thus

*Weighted outage = 10 * (45 / 365) = 1.23 Ml/d*

J.66 Each weighted outage is then summed over the reporting year to give a total Actual Outage for the WRZ, as reported in the Annual Review. This is fundamentally different to the Outage Allowance in the WRMP19, the calculation of which is based on risk and therefore reflects the probability of an outage event happening again in the future.

J.67 Details of the individual sites which comprise the Actual Outages are reported in the Annual Review to the Environment Agency together with the Outage Allowance and, therefore, are not set out here. The information allows Actual Outage to be compared with the Outage Allowance, i.e. the figure used for planning purposes in the WRMP19. Information was collated for the period from April 2016 to the end of March 2017 for the draft WRMP19, and updated in the final WRMP19 to include the most recently available information from 2017/18. This information has been used to update the baseline Outage Allowance for each WRZ, reported in Table J-6 as the AR17+ Outage Allowances.

J.68 The level of risk of an outage occurring depends at least in part on the length of record available over which to assess the risk; currently we have eleven years of records from 2007/08. This is a relatively short period of record and it is inevitable that not all sources of outages will have been experienced in this period. As our documented experience of different causes of outage increases it follows that our Outage Allowances can be expected to increase. This is despite the delivery of investment to address outages experienced earlier in the period of record.

J.69 The risk of outage for each month of the year is calculated by sampling the probability density functions of magnitude, frequency of occurrence and duration for each month of the year and multiplying them together. Thus the annual Outage Allowance is the highest monthly value in the year derived from the sample statistics.

J.70 The difference between the Outage Allowance and the Actual Outage that has occurred over the period 2007/08 to 2017/18 across all WRZs is shown in Table J-7 and Figure J-4. An update of the Outage Allowance assessment is also presented, which shows an increase in Outage Allowance primarily as a result of length of record now being used to calculate Outage Allowance and a number of recent, large outages. The Outage Allowance considered for the WRMP19 for the whole Thames Water area is 130.7. A summary of the changes in outage at WRZ as reported in the Annual Review 2017 is given in Table J-7.

J.71 As we collect more data on outage events our understanding of the risk to water supply improves and simultaneously so does our understanding of the actions that can be taken to reduce the risk. The improved records on outage and the period of time over which these data have been collected means that the total Outage Allowance in the WRMP19 has increased. We anticipate that the Outage Allowance will level out with time although there will inevitably be some variance as this is the nature with such “unplanned events”. We consider that the current level of Outage Allowance is reasonable given the complex nature of London’s water resources.

J.72 In addition, progress has been made on restoring many of the London outages of long duration. An update on progress with ongoing activities and investigations in London is shown in Table J-8, with Table J-9 showing an update on progress for Thames Valley.

Table J-7: Outage assessment Annual review 2017+

Outage Assessments forecast for Inclusion in AR18 (Ml/d) -- Outage Allowance @ 5% Risk

Resource Zone	SWOX	KV	HEN	SWA	GUI	London	Total
Outage Allowance dWRMP08	10.61	1.60	1.07	3.00	0.38	11.53	28.22
Outage Allowance WRMP09/JR08	10.62	1.68	1.05	3.06	0.38	14.76	31.57
Outage Allowance Update 2009	13.33	2.18	1.06	9.53	0.64	17.97	44.70
Outage Allowance JR10	13.14	1.79	1.06	9.71	0.65	24.47	50.82
Outage Allowance JR11	15.28	1.78	1.06	10.84	0.62	34.57	64.15
Outage Allowance AR12	15.04	1.77	1.08	11.97	0.78	36.04	66.67
Outage Allowance AR13 (WRMP14)	14.88	1.85	1.05	12.53	0.81	46.27	77.39
Outage Allowance AR14	15.34	2.14	1.04	12.27	0.77	39.32	70.88
Outage Allowance AR15	16.76	2.01	0.93	13.73	0.85	46.44	80.72
Outage Allowance AR16	16.73	2.80	0.44	10.75	1.25	81.72	113.69
Outage Allowance AR17	17.50	2.59	0.40	9.99	1.33	84.55	116.36
2007-8 Actual Outage	4.27	4.50	0.00	0.00	0.00	18.7	27.4
2008-9 Actual Outage	11.92	4.55	0.61	10.65	1.13	54.8	83.7
2009-10 Actual Outage	4.86	0.02	0.00	5.52	0.00	58.8	69.2
2010-11 Actual Outage	11.59	0.00	0.00	10.97	0.00	113.3	135.9
2011-12 Actual Outage	2.73	0.00	0.01	9.95	1.06	90.4	104.1
2012-13 Actual Outage	3.83	0.02	0.00	18.30	2.08	120.3	144.5
2013-14 Actual Outage	4.18	1.81	0.00	13.84	0.81	65.8	86.4
2014-15 Actual Outage	7.63	1.73	0.00	11.12	2.98	81.5	105.0
2015-16 Actual Outage	3.77	0.00	0.05	1.68	4.14	77.6	87.2
2016-17 Actual Outage	4.72	0.01	0.00	4.84	2.07	80.5	92.2
AR17+ Actual Outage	6.09	0.28	0.04	9.95	1.57	226.5	244.4
Outage Allowance AR17+	17.23	2.49	0.36	9.46	1.40	99.76	130.7

Table J-8: London sources with outage of lengthy duration

Source	Reason for outage	Comments
Queen Mary and Mother Reservoirs	Pump outages and restrictions	Pumps repaired.
Staines North Reservoir	Maintenance	Essential work completed on the inlet/outlet tower.
New River Head	Sand ingress to borehole	Ground condition investigations being planned. SDO reduced to 0 Ml/d for AR17 therefore no longer included as outage.
Brixton	Treatment process issues	Recommissioning of WTW completed. Source returned to supply in April 2018.
Battersea	Treatment process issues	Recommissioning of WTW continuing. Source expected to be available during summer 2018.
Epsom (Railway Borehole)	Turbidity	Railway Borehole available and pumped to WTW for supply. SDO reduced to reflect water quality restrictions.
Gateway	Water quality & treatment process issues	Ultrafiltration (UF) & Reverse Osmosis (RO) membranes replaced, microbiological contamination investigation completed & chemical dosing lines replaced. Source returned to supply in January 2018.
Hoddesdon Transfer	Water quality & asset operational issues	Water quality investigation in progress, status of pumping station investigated. Capacity of Rye Meads STW to be increased as part of growth investment, with completion in 2018/19.
Hornsey	Water quality	Water quality investigation completed. New ultraviolet (UV) process for Cryptosporidium treatment being constructed. Source planned for return to supply in summer 2018.
Langley Vale	Water quality	Water quality investigation completed. Installation of Cryptosporidium filtration planned. Source planned for return to supply in summer 2018.
Ladywell Fields	Operational issue	Fibre optic communication connection with site resolved. Source returned to supply in April 2018.
Nonsuch	Turbidity & operational issues	Electrical supply issues, which have now been resolved, also restricted output due to turbidity.
Streatham	Planned work	Water treatment disinfection process improvement undertaken & site recommissioned. Source returned to supply in spring 2018.
Waddon	Water quality	Water quality investigation completed. New filtration process for Cryptosporidium treatment being constructed. Source planned for return to supply in summer 2018.

Table J-9: Thames Valley sources with outage of lengthy duration

Source	Reason for outage	Comments
Eton	Plant availability	Increased capability of filtration process for *Cryptosporidium* treatment constructed.
Hawridge	Operational issue	New run to waste pipeline & borehole soakaway in construction. Increase in source output planned for summer 2018.
Witheridge Hill	Turbidity/operational issues	Site run to waste recommissioned, water quality sampled & site recommissioned into supply. Source returned to supply in March 2018.

J.73 We are pro-actively looking to reduce outage events and the length of time sites are out of service. In response to comments from the Environment Agency raised during the consultation on our draft WRMP19, we are also considering the significance of outages longer than 90 days on Outage Allowance and the supply demand balance, as well as the consequences for our preferred programme. This analysis is presented as a 'what-if?' scenario in the WRMP19, Section 10: Programme appraisal and scenario testing. The context is that outage events longer than 90 days exist in our historical record and, in strict adherence to outage guidance, should perhaps have been reported as losses of DO. There have also been occasions where outages have occurred which were initially envisaged as being simple issues, but which turned out to be more complex issues, and so taking longer to return assets to being available. As a result, it was not felt that removing these longer historical outages from our record would present a fair representation of our experience of outage.

J.74 On the management of future outages, we are developing plans and programmes for returning sources to availability, including justifying outages with durations of greater than 90 days. For example, investment in WTWs upgrades may require design, construction and commissioning programmes longer than 90 days, but should not be considered a loss of DO as they will often be complete within a given reporting year. In addition, such upgrades may enable the removal of associated outages from the historical record. However, if on putting a plan together, it becomes apparent that resolution of the outage will require a more complex and longer programme of works than originally envisaged, this could result in it being considered as a loss of DO.

J.75 On our proposed approach to historical outages, we have amended the historical outage record and the associated outage model to cap all historical outages at 90 days, as discussed with the Environment Agency. This approach reduces the Outage Allowance for London by 18.9 Ml/d, i.e. a potential improvement to the supply-demand position. It is this alternative analysis that forms the basis for the supply demand planning scenario presented in Section 10: Programme appraisal and scenario testing to explore the implications that this change in methodology would have for our preferred programme.

J.76 To ensure future outage risk is managed, we are developing plans and programmes for returning sources to availability and maintaining that availability into the future. This includes identifying the issues causing the outages, the outage impact on DO, the actions being undertaken to address the outage as well as the outcomes. This may eventually lead to a reduction in the number of events being recorded in the database with a knock-on benefit to the reported Outage Allowance.