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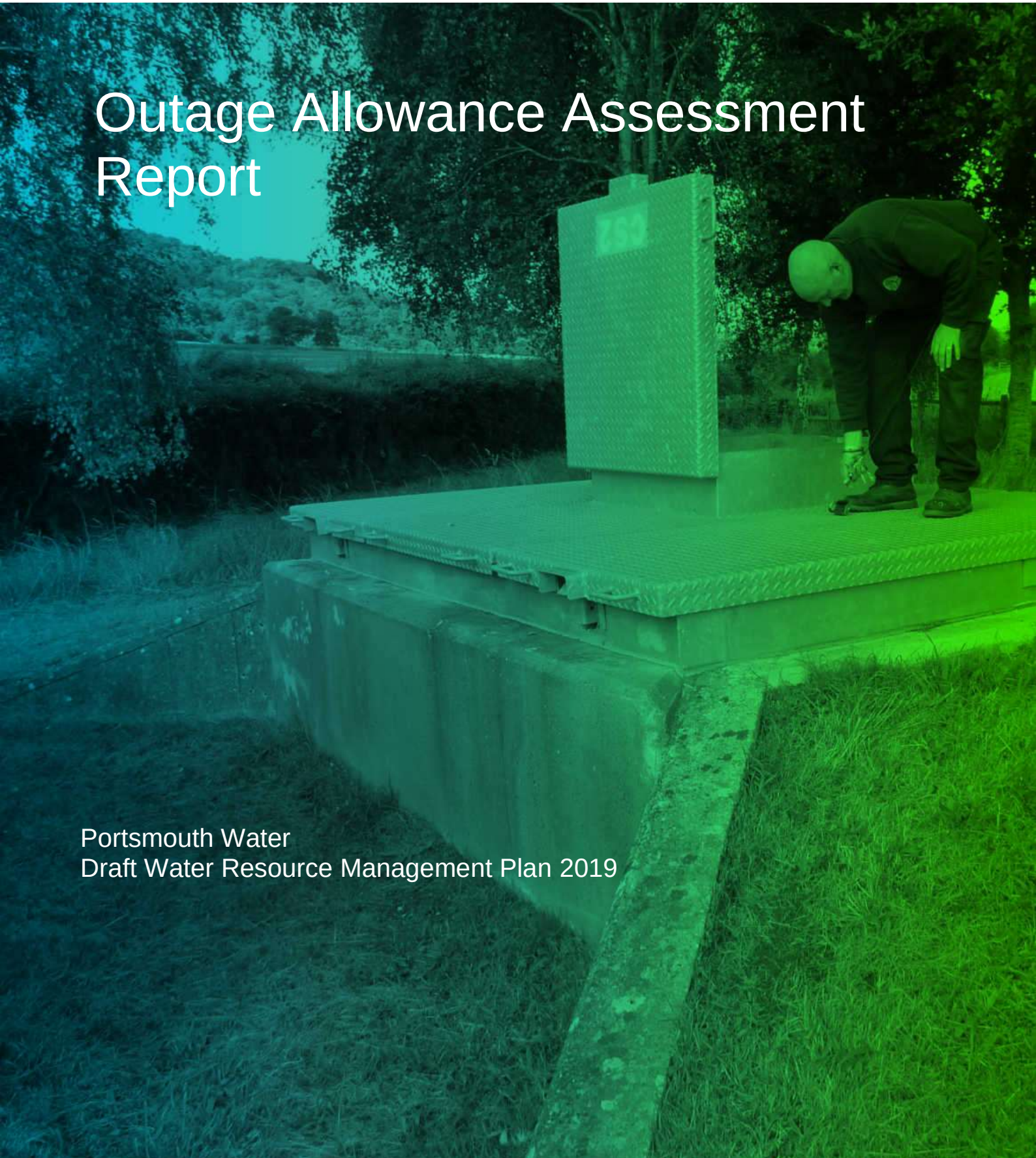
Outage Allowance Assessment Report



Portsmouth Water
Draft Water Resource Management Plan 2019

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Background

As part of the company's 2019 draft Water Resources Management Plan (dWRMP19) submission, Portsmouth Water must calculate the supply-demand balance for its single Water Resource Zone (WRZ) over the 25-year planning period from 2020 to 2045. The supply-demand balance includes an allowance for 'short term losses of supply and source vulnerability', defined as outage by the Environment Agency's *Water Resource Planning Guideline* (WRPG) (April 2017).

Purpose of this report

AECOM has undertaken a reassessment of the outage allowance (OA) for dWRMP19 on behalf of Portsmouth Water, for the dry year annual average (DYAA), dry year critical period (DYCP) and dry year minimum deployable output (DYMDO) planning scenarios. The OA for each of these scenarios is presented in the units of millions of litres per day (megalitres/day or Ml/d) and as a percentage of Deployable Output (% of DO).

This reassessment follows the standard method for the calculation of OA, as developed by UKWIR's *Outage allowances for water resources planning* (1995) and as recommended by the Environment Agency's *WRPG* (April 2017). The method involves the calculation of probability distributions of allowable outage for each outage category, sourceworks and planning scenario, and then the combination of these into overall probability distributions of company allowable outage for each planning scenario. OA values can then be determined from the distribution for each period at an appropriate probability or level of risk.

Results

The results of the OA assessment are summarised in the table below. The selected outage values are for a probability of 95%, or exceedance probability of 5%. The OA is based on the following categories or causes of outage events: planned maintenance or capital works (dry year annual average and dry year minimum deployable output only), chlorination issues, cryptosporidium failure, power failure, pollution incidents, system failures and turbidity problems.

Portsmouth Water's company OA has increased in this assessment compared to the values reported for WRMP14. This is due to a combination of increased numbers of legitimate outage events occurring in the most recent period of data, and improved recording of events in certain categories/at certain sourceworks.

Planning Scenario	Combined Company Outage Allowance	
	Value in Ml/d	As a % of DO
DYAA	14.7	6.5%
DYCP	12.5	4.5%
DYMDO	16.2	6.5%

1 Introduction

1.1 Introduction

Portsmouth Water is required to submit an outage allowance (OA) assessment to the Environment Agency and the Office of Water Services (OFWAT) every five years as part of its Water Resources Management Plan (WRMP) submission.

The Environment Agency's *Water Resources Planning Guideline* (WRPG) (April 2017) defines outage as 'short term losses of supply and source vulnerability'. The purpose of assessing a water company's outage is to calculate an allowance for inclusion within the supply/demand balance, to cover the amount of deployable output (DO) which may be unavailable for use at any given time, due to planned or unplanned outage events. Planned events include temporary shutdown of plant for routine maintenance, and unplanned events include less predictable shutdowns due to such factors as turbidity, power or system failure and source pollution.

1.2 Background

AECOM (incorporating URS) undertook the most recent assessment of the OA in February 2013 for Portsmouth Water's WRMP14, based on an analysis of recorded outage events for the period 2007 – 2013 (AECOM, 2013). For the WRMP09, Portsmouth Water calculated a suitable OA to incorporate within the supply/demand balance, based on an analysis of recorded outage events for the period 1998 – 2006. A summary of the combined company OA results are given in Table 1-1.

Table 1-1 Portsmouth Water Outage Allowance – WRMP14 and WRMP09

Planning Scenario	Combined Company Outage Allowance (WRMP14)		Combined Company Outage Allowance (WRMP09)	
	Value in Ml/d	As a % of DO	Value in Ml/d	As a % of DO
DYAA	9.3	3.8%	14.2	5.5
DYCP	4.6	1.4%	16.5	5.3
DYMDO	10.8	3.9%	-	-

A recommendation of the outage assessment carried out for the WRMP09 was that Portsmouth Water should formalise their outage data collection process, and record all available information regarding outages for future analysis. Portsmouth Water has therefore maintained an outage database at an improved level of detail since 2007, and this data is now available for review and analysis.

1.3 The current report

AECOM has been commissioned to undertake the reassessment of the OA for Portsmouth Water's dWRMP19 submission. This reassessment has been completed taking into account of the Environment Agency's WRPG (April 2017) and the following UKWIR guidance:

- *Outage allowances for water resources planning (1995); and*
- *WRMP19 methods – risk based planning (2016).*

The aim of the outage assessment is to calculate probability distributions of allowable outage for each outage category, sourceworks and planning scenario, and then to combine these into overall probability distributions of company allowable outage for each planning scenario. OA values can then be determined from the distribution for each period at an appropriate probability or level of risk.

The key objectives of this analysis can be summarised as follows:

- Review Portsmouth Water's database of recorded outage events, and extract from it a subset of legitimate outage events for further analysis.
- Develop suitable probability distributions to represent allowable outage for each sourceworks and category, based on event magnitudes, durations and frequencies observed in the recorded data set.

- Combine the individual probability distributions into single company distributions representing Portsmouth Water's allowable outage, for each planning scenario.
- Determine OA values, by selecting values from the combined company allowable outage distributions at appropriate levels of risk for each planning scenario.

Section 2 provides the methodology used to undertake the OA assessment, with Section 3 providing analysis of the recorded outage data. Section 4 outlines the outage assumptions made in the assessment; Section 5 summarises the results of the assessment; and Section 6 provides the report conclusions.

2 Methodology

2.1 The Portsmouth Water resource zone

Portsmouth Water operates nineteen Chalk groundwater sources, the Source B springs source and the Source A (River Itchen) surface water source. These sources of water supply a single company-wide Water Resource Zone (WRZ). Therefore this reassessment of OA, as per the previous two OA assessments, has been carried out at the company-wide or single WRZ level.

2.2 Approach

This reassessment of OA follows the standard method for the calculation of OA, as developed by UKWIR in 1995 and recommended by the Environment Agency in their updated WRPG (April 2017).

In this approach, a probability distribution is assigned to each outage category, based on known data and other relevant information relating to event magnitude (deployable output (DO) loss in megalitres/day), event durations (number of days) and event frequencies (average number of occurrences per year). The probability distributions are then combined using the statistical technique of Monte Carlo simulation, which iteratively takes random samples from each distribution and sums them according to specified rules. The summed result of each iteration then forms a point on the curve of the combined distribution; by sampling the distributions over a large number of iterations it is then possible to build up a probability distribution to represent the combined company allowable outage for all sourceworks and categories.

The Monte Carlo simulation software @RISK was used for the analysis, which operates in conjunction with the Microsoft Excel spreadsheet package.

Due to the random nature of the Monte Carlo simulation technique, it is not possible to guarantee that identical results will be generated each time the same simulation is run. However, by selecting a suitably large number of iterations for the simulation, to give an acceptable mean standard error for the simulation results, it should be possible to obtain repeatable results to an acceptable level of accuracy. All Monte Carlo simulations undertaken for this outage assessment have been run for 10,000 iterations, which in practice gives fairly consistent results.

2.3 Planning scenarios

Three planning scenarios have been considered in this outage assessment, as follows:

- Dry Year Annual Average – based on Dry Year Annual Average Demand (DYAA) and Average Deployable Output (ADO);
- Dry Year Critical Period – based on dry year Average Demand in Peak Week (ADPW) and Peak Deployable Output (PDO); and
- Dry Year Minimum Deployable Output – based on dry year demand in the period of minimum resource levels and Minimum Deployable Output (MDO).

2.4 Outage categories

Key outage categories (causes of temporary losses in deployable output) were identified both from the recommended categories outlined in the UKWIR report (1995), and from a review of the key outage causes listed in Portsmouth Water's database of recorded outage events. The outage categories adopted for this analysis are listed in Table 2-1. Further details of the recorded data under each of these categories, and the assumptions adopted for Portsmouth Water's outage assessment in each case, are provided in Sections 3 and 4 respectively.

Table 2-1 Outage Categories

Name	Description
Planned	Outage due to short-term routine maintenance of sourceworks
Chlorine	Outage due to problems with sourceworks chlorination systems
Cryptosporidium	Outage due to cryptosporidium failure at sourceworks
Pollution	Outage due to short-term source pollution (including precautionary shutdown due to pollution risk)
Power	Outage due to short-term power failure, e.g. electrical power cuts
System	Outage due to short-term system failure, e.g. mechanical breakdown
Turbidity	Outage due to turbidity failure at sourceworks

3 Analysis of recorded data

3.1 Data Sources

Data on Portsmouth Water's DO values, for the DYAA, DYCP and DYMDO scenarios, was taken from a reassessment of source DO values undertaken by AECOM in October 2017 (AECOM, 2017). The DO values for a 1 in 20 year event with unrestricted demand were used for all three scenarios.

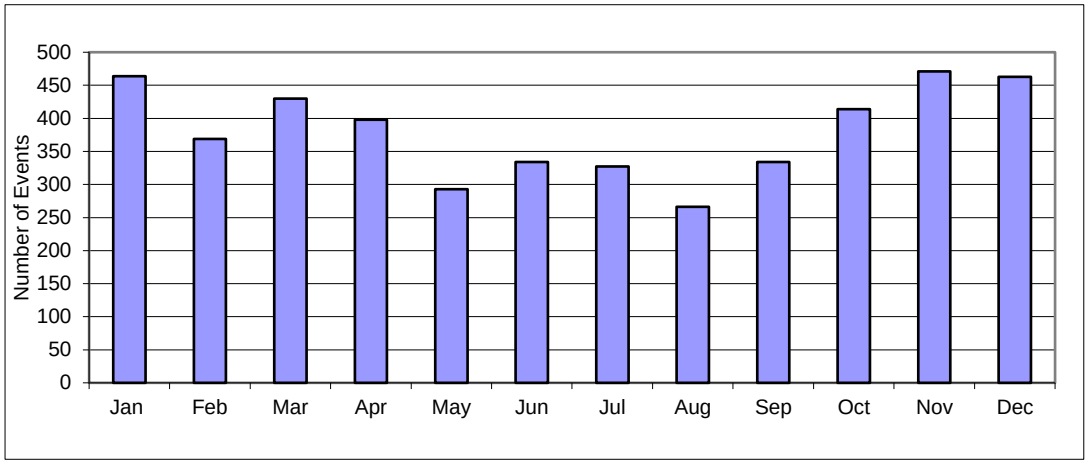
Since 2007 Portsmouth Water's operational staff have maintained a detailed record of actual outage events, on an outage register in spreadsheet format. For each outage event the following information is recorded:

- Start and end date and time, and event duration;
- Site reference, name and affected sourceworks;
- Percentage of deployable output lost, deployable loss rate and total output lost during event;
- Whether the outage event was planned or unplanned;
- Whether the shutdown was short term or long term; and
- The classification and fault code identifying the reason for the shutdown, with further comments as appropriate.

Separate spreadsheets have been established for each year, running from 1 April to 31 March. In August 2012, Portsmouth Water provided copies of their outage register spreadsheets covering the period 1 April 2007 to 31 March 2012, with the period from 1 April 2012 to 31 March 2016 provided in August 2016. This data has been combined into a master events log to analyse for this updated assessment of the company's OA.

The total number of outage events recorded by Portsmouth Water during the period 1 April 2007 to 31 March 2016 was 4,563, of which 855 were planned and 3,708 unplanned. Figure 3-1 shows the distribution of these events across the months of the year, and indicates that a greater proportion of outage events have occurred during the winter months than in the summer. This may, to some extent, reflect a policy of scheduling routine maintenance during the winter when demand is generally lower.

Figure 3-1 Seasonal Distribution of Recorded Outage Events, 2007 – 2016



3.2 Determination of Legitimate Outage Events

Many of Portsmouth Water's recorded outage events are not legitimate outage events for the purposes of assessing a suitable OA for the company's supply/demand balance. This reason for this is that either they did not result in a loss of DO or because the DO lost was not required to meet demand at the time of the shutdown.

Sections 3.2.1 to 3.2.5 outline the key exclusions and amendments made to the master events log for the purposes of the OA calculation.

3.2.1 Sources Not Required for Water Supply Purposes

During various times over the recording period a number of the existing sources have not been required for water supply purposes and have been recorded within the outage databases as “Source Not Required”. These events will not be considered as outage events within the proposed assessment, as while they are planned events they do not result from a requirement to maintain sourceworks asset serviceability, and do not represent an unavoidable loss of DO.

3.2.2 Events in Excess of 90 day duration

All planned events in excess of 90 days were excluded from the outage assessment, and where appropriate these have been considered within the company DO and headroom assessments. This is in line with the UKWIR guidance *Outage allowances for water resources planning (1995)*.

In addition, the Woodmancote source has an ongoing turbidity issue that is unlikely to be resolved in the current WRMP cycle. Any outage events reported at Woodmancote are due to a longer term loss in DO rather than true outage events and as such are removed from the outage events log.

Unplanned events in excess of 90 days have been included within the assessment but capped at 90 days, with event durations in excess of 30 days reviewed by Portsmouth Water to reflect realistic lead times for correcting the outage event. These events include:

- A 112-day outage event caused by turbidity at Source O, which occurred during 2011, this has been capped at 90 days.
- A 365-day outage event caused by a system failure at Source F, which occurred during 2015, this has been capped at 30 days.
- A 345-day outage event caused by a system failure at Source G, which occurred during 2015, this has been capped at 30 days.
- A 128-day outage event caused by a system failure at Source K, which occurred during 2015, this has been capped at 30 days.
- A 149-day outage event caused by a system failure for the River Itchen, which occurred during 2015, this has been capped at 30 days. This involved the failure of a booster pump, which was not replaced rapidly due to the source having plenty of spare capacity.

Oil pollution events within the catchment longer than 90 days have been considered within the headroom allowance for dWRMP19. As such, three outage events have been excluded from the outage assessment:

- A 136-day outage event at Source J due to a heating fuel spillage which occurred during 2011.
- A 365-day outage event at Source K due to potential oil pollution from a local site during 2013.
- A 134-day outage event at Source R due to a heating fuel spillage which occurred during 2014.

From a review of the previous outage assessment, it was noted that a number of the recorded outage events that occurred between 2007-2009, but removed from the 2009 outage analysis, are no longer recorded within Portsmouth Water’s outage register and have therefore been excluded from this assessment.

3.2.3 Planned Events

There are a number of atypical planned events recorded at various sites that have been excluded from the outage assessment as they were a result of major capital investment works and are not likely to reoccur.

It has also been assumed that, due to the inherent flexibility within the WRZ, all planned events in excess of 5 days can be readily facilitated by supply from an alternative source and these events are therefore excluded from the assessment. For the assessment of the average demand OA we have capped maintenance periods at each sourceworks to 5 days per year, including a minimum of two days per year for sites with membrane filters (Source F, River Itchen, Works A, Source K and Source P). The average duration of the recorded planned outage events is around 11.8 days however this value is influenced by a number of atypical events as mentioned above; average and maximum durations of no more than 5 days are believed to be more representative of the normal maintenance regime.

3.2.4 Event Magnitudes

With respect to event magnitudes, all events have been assumed to have an outage magnitude of 100% of the DO. From the data reviewed, 65 recorded short term outage events (53 system, 3 power, 5 turbidity, and 4 chlorine events) resulted in partial outages. It is likely that this is due to the relatively small size of the sources and the flexibility within the WRZ to supply from other sources if a particular source is closed.

The events recorded with magnitudes less than 100% related to turbidity are:

- A 1-day outage event at Source L, which occurred during November 2011 and resulted in a 50% reduction in flow.

- A 112-day outage event at Source O, which occurred during 2011, where a partial (80%) outage is recorded. However the comments indicate that only a 15% reduction in flow occurred (flow reduced from 70 l/s to 60 l/s).
- A 0.1-day outage event at Source O, which occurred during 2011 and resulted in an 80% reduction in flow (restarted at 62 l/s).
- A 0.04-day outage event at River Itchen, which occurred during 2015 and resulted in an 80% outage.
- A 0.04-day outage event at River Itchen, which occurred during 2015 and resulted in an 85% outage.

A number of outage events at service reservoir and pump sites have associated event duration but zero magnitude. These are assumed to be for events where the outage has no impact on the DO loss of the associated sourceworks and have been excluded from the assessment.

3.2.5 Event Double Counting

Source B springs are treated at the Works A WTW, and outage data is recorded for all three sites. Some outage events are double counted by being attributed to both the Works A WTW and one of the sources, and also to multiple reasons at the same site. To ensure that outage is not overestimated the data has been sorted to remove double counted events, this consisted of:

- A system event on 10 September 2013 at Works A WTW double counted as a turbidity event for the same time period;
- A system event on 11 December 2013 reported at Source B2 that was double counted as occurring at the Works A WTW;
- A turbidity event on 3 January 2014 at Works A WTW reported twice for the same time period;
- A turbidity event on 11 January 2014 at Works A WTW also reported as a system event for the same time period;
- A system event on 18 January 2014 at Works A WTW also reported as a turbidity event for the same time period;
- A chlorine event on 9 February 2014 that was reported twice at the Works A WTW for the same time period;
- A chlorine event on 3 March 2014 that was double counted as occurring at Source B2 due to a fault at Source B1;
- A system event on 16 May 2014 at the Works A WTW that was double counted as occurring at Source B1;
- A system event on 18 May 2014 reported as occurring at both Source B2 and Works A WTW;
- A system event on 4 December 2014 reported as occurring at both Source B1 and Works A WTW;
- A power event on 24 August 2015 reported as occurring at both Source B;
- A system event on 7 November 2015 at Works A WTW reported with overlapping time periods.

3.3 Summary of Legitimate Outage Events

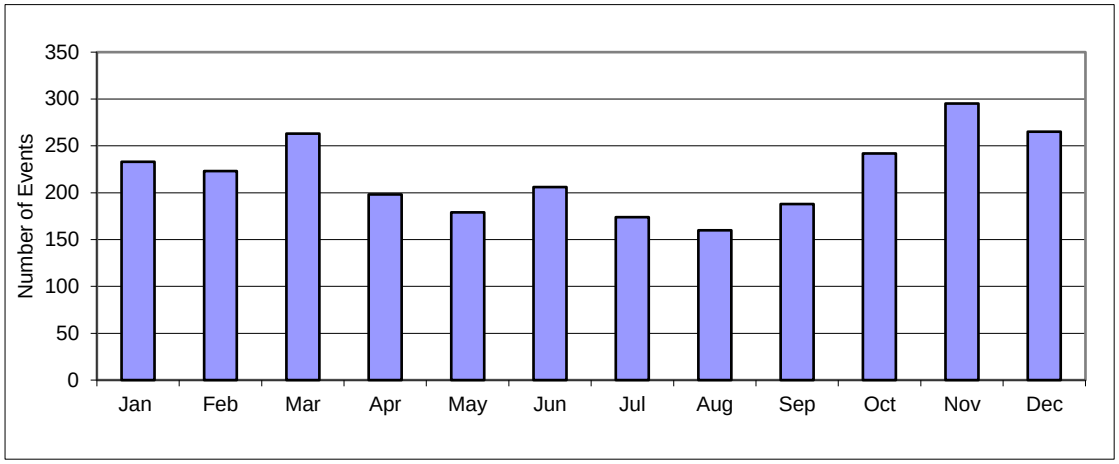
A step-by-step audit process was adopted to exclude all events from the assessment which did not meet the Environment Agency's definition of a legitimate outage event, and amend or re-categorise certain events as outlined in Sections 3.2.1 to 3.2.4 above. The process can be summarised as follows:

- Audit 1: Removal of all planned events from master database where "station not required" or similar narrative is listed within the remarks column, along with all outage events from Woodmancote
- Audit 2: Amendment of master database to cap all unplanned events with durations greater than 90 days to a 90 day maximum, with review of system events above 30 day durations; removal of all planned events greater than 90 days from the outage assessment.
- Audit 3: Correction of all negative duration events.
- Audit 4: Removal of outage events with zero DO impact.
- Audit 5: Removal of events with blank Partial Outputs and zero DO loss.
- Audit 6: All planned events were classified as 'Other' and 3 planned 'Power' events re-categorised as unplanned rather than planned (electrical failures); all unplanned events originally classified as 'Other' reallocated to alternative classifications based on fault code & description (mainly system but also 1 pollution and 3 power).
- Audit 7: Removal of double counted events within the Works A, Source B outage data.

Following the above process resulted in a total of 2,626 legitimate outage events from the period April 2007 – end of March 2016 being selected for further analysis. Of these, 69 were planned and 2,557 unplanned. The seasonal distribution of these 2,626 outage events is shown in Figure 3-2; there are still a greater proportion of events occurring in the winter months, with only 1,105 or 42% of the legitimate events occurring during the months of April to September inclusive.

The full analysis to determine the data set of legitimate recorded outage events is held on the spreadsheet Outage Assessment Data Audit (Rev 9)_V2.xls.

Figure 3-2 Seasonal Distribution of Legitimate Outage Events, 2007 – 2016



Tables 3-1 and 3-2 below provide a summary of the legitimate outage events by category and sourceworks respectively.

Table 3-1 Portsmouth Water Outage Events by Category, 2007 - 2016

Category	Number of Events
Planned	69
Chlorine	948
Cryptosporidium	3
Pollution	4
Power	252
System	1,042
Turbidity	308
Total	**2,626**

Table 3-2 Portsmouth Water Outage Events by Sourceworks, 2007 - 2016

Sourceworks		Number of Events
Source T		65
Source N		54
Source Q		153
Works A	Works A WTW	375
	Source B2	47
	Source B1	64
Source P		262
Source O		58
Source L		284
Source K		142
Source I		16
Source C (and Source D)		73
River Itchen		490
Source S		74
Source F (and Source G)		201
Source N		85
Source E		10
Source H		45
Source R		70
Source J		58
Total		**2,626**

4 Outage assumptions

4.1 Overview

This section outlines the assumptions adopted in determining the event durations and frequencies used to specify the probability distributions for each category and sourceworks. All event magnitudes are assumed to be equal to the full DO value of the relevant sourceworks as outlined in Section 3.2.4 above.

The minimum, average and maximum durations adopted in each case correspond to the 'least credible', 'most likely' and 'maximum credible' values as discussed in the UKWIR guidance and form the parameters of the triangular distributions. These distributions were then sampled in the Monte Carlo simulation process, normalised by the number of days in the period and multiplied by the relevant event magnitude (DO in Ml/d) and event frequency (occurrences per year), to give the distributions of allowable outage for each category and sourceworks.

Portsmouth Water have a total of 20 sources (excluding Woodmancote) but for the purposes of the outage assessment these have been grouped into 18 sourceworks, with Source C and Source D operated together as one sourceworks, and similarly Source F and Source G operated as one sourceworks. The spring sources, Source B2 and Source B1 (treated at Works A WTW), are also grouped as one sourceworks.

The number of sourceworks affected by each category of outage event during the period 2007 – 2016 is shown in Table 4-1.

Table 4-1 Number of Sourceworks affected by each Outage Category during 2007-2016

Category	No. of Sourceworks (of 19)
Planned	15
Chlorine	18
Cryptosporidium	3
Pollution	4
Power	18
System	18
Turbidity	15

4.2 Dry Year Annual Average outage assumptions

4.2.1 Planned events

For any sourceworks where the recorded planned events had minimum, average or maximum durations exceeding 5 days, these parameters were manually adjusted to 5 days before commencing the Monte Carlo simulation. This was undertaken as it is assumed that in drought conditions planned outage events could be limited to 5 days. If necessary, the minimum duration was adjusted upwards to 2 days for those sourceworks with a membrane filter (Source F, River Itchen, Works A, Source K and Source P) to allow a conservative assessment of the outage involved.

The planned outage frequency is set to 1 per year for each site.

Note that the planned outage category is not applicable to the assessment of critical period outage, as it is assumed that planned/routine maintenance would be scheduled outside the period of peak demand.

4.2.2 Cryptosporidium events

The WRMP09 outage assessment excluded cryptosporidium events from the analysis as all the treatment works identified as being at risk (Source P, Source K and Source F) had been upgraded with membrane filtration systems.

However there are three cryptosporidium events recorded within the recent outage data provided by Portsmouth Water occurring at Source Q, Source R and Source P, as events lasting less than eleven days. UV treatment is now in place at the Source Q and Source R sources, and as such the cryptosporidium risk is

not included for these sourceworks. The cryptosporidium risk is included at Source P as well as Source I, which Portsmouth Water consider to also be at significant risk.

The minimum, average and maximum duration for the 2 sourceworks included in the cryptosporidium OA are based on the recorded data for Source P. The frequency of occurrence was assumed to be equal to 1 per year but spread evenly between the 2 potentially affected sourceworks, i.e. a frequency of 0.5 per sourceworks.

4.2.3 Pollution events

A number of pollution events of duration greater than 90 days have been excluded from this outage assessment and incorporated within the company's headroom allowance. These events are related to the risk of source pollution due to oil spillages, and represent semi-permanent losses of deployable output which in some cases require capital investment in order to bring the relevant source back into use.

However, the final data set of legitimate outage events does still include four short-term pollution events: 1 each at Source F (a 42-day closure relating to a precautionary shutdown due to a diesel spill in the area), Source J (a 0.1-day event closure related to painters at the site), Source P (a 9.8-day closure relating to concerns of contamination in artesian conditions), and Source K (a 80.5-day closure related to potential contamination from an adjacent site).

It is proposed to incorporate these individual events within the outage calculation as being representative of the generic risk of occasional short-term pollution events. However, the risk has not been specifically applied to other sources to avoid over-estimating the allowance that is required within the supply/demand balance for this type of randomly-occurring risk.

4.2.4 Chlorine failure events

There were 18 sourceworks affected by chlorine failure outages during 2007 – 2016, with event durations ranging from 0.02 to 4 days, with an exceptional 61.1 days recorded at Source R. The frequency of occurrence was variable between sourceworks, for example Source P and Source L had higher numbers of occurrences than other sourceworks. In order to reflect this variation, the minimum, average and maximum event durations and event frequencies were based on the actual data for the 18 relevant sources.

4.2.5 Power failure events

All the sourceworks were affected by power failure outages during 2007 – 2016, with event durations ranging from 0.02 to 2.9 days. The frequency of occurrence was variable between sourceworks, for example the Works A source had 31 occurrences compared to only 1 at Source E. In order to reflect this variation, the minimum, average and maximum event durations and event frequencies were based on the actual data for the relevant sources.

4.2.6 System failure events

All the sourceworks were affected by system failure outages during 2007 – 2016, with event durations ranging from 0.02 to 60 days. Events greater than 20 days are rare, with one occurring at 6 different sourceworks; excluding these longer duration events the maximum duration is 15 days. Events greater than 1 day occur at 11 different sourceworks; these events are treated separately as long term system events. For the system failure events the minimum, average and maximum event durations and event frequencies were based on the actual data for the relevant sources.

4.2.7 Turbidity failure events

There were 15 sourceworks affected by turbidity-related outages during 2007 – 2016, with event durations ranging from 0.02 to 90 days. Events greater than 10 days are rare, with one occurring at 4 different sourceworks, excluding these longer duration events the maximum duration is 9 days. Events greater than 1 day occur at 8 different sourceworks, these events are treated separately as long term system events.

Again the frequency of occurrence was variable between sourceworks, with significant numbers of occurrences at Works A and the River Itchen in particular (this is partly due to better recording practices at these sites having been undertaken after 2013). The minimum, average and maximum event durations and event frequencies were therefore based on the actual data for the 16 relevant sources. It is considered that 15 out of 18 sourceworks is a reasonably representative sample on which to base the outage assessment.

4.3 Dry Year Critical Period outage assumptions

For the DYCP planning scenario, the calculation of outage applies to the critical period of 61 days in June and July representing the period when company demand is generally at its peak. The following key differences to the outage assumptions are applicable to the DYCP scenario:

- Planned events are excluded.

- Event magnitudes are based on Peak Deployable Output (PDO) values.
- Event durations are capped at 14 days; this is in line with the previous (WRMP 2009 and 2014) assessments and is based on the assumption of a faster response time in addressing outage events and returning the affected works to service during the critical period, particularly if demand is high.
- Adjustments to event durations were only required for a small number of sourceworks/outage categories, as follows:
    - Source T (1 turbidity event);
    - Source R (1 chlorine event);
    - Source K (1 pollution event and 1 system event);
    - Source F (1 pollution event and 1 system event);
    - River Itchen (1 system event);
    - Source G (1 system event);
    - Source J (1 system event);
    - Source P (3 system events);
    - Source O (1 turbidity event); and
    - Source S (1 turbidity event).

    All other recorded event durations were of 14 days or less.
- Event frequencies are based on the assumption that outage events occur randomly throughout the year, so that the (normalised) likelihood of occurrence of any particular event is the same during the critical period as for the Dry Year Annual Average scenario. This is in line with the previous assessments. There is insufficient evidence to justify increasing or decreasing the event frequencies for any particular outage category (other than the exclusion of the planned event category as referred to above).

4.4 Minimum Deployable Output assumptions

The minimum deployable output generally occurs during the period August to January depending on hydrological conditions. The same outage assumptions have been used for the DYMDO as for the DYAA scenario, as outlined in Sections 4.2 to 4.8, except that the event magnitudes are based on MDO values. Event frequencies and durations are unchanged from the DYAA scenario, as it is assumed that outage events occur randomly throughout the year and response times recorded on the outage database will be representative of those during the MDO period, as demand is generally lower at this time. Planned maintenance events are still included for the MDO scenario.

4.5 Interdependencies

As each outage event is recorded separately in Portsmouth Water's outage register, with the primary reason for the shutdown noted, it is not necessary to consider interdependencies between the different categories. For example, if a power cut were to cause concurrent system or chlorination failure, this would still be recorded as a single outage event with the primary cause being stated as power failure.

It is possible that there may be interdependencies between sourceworks, for example the occurrence of a severe pollution event at one source may increase the likelihood of an additional pollution event at a neighbouring source. However, there is insufficient data available to be able to quantify any such relationships with any degree of certainty, therefore for the purposes of this outage assessment it has been assumed that there are no interdependencies between probability distributions for individual sourceworks.

The possibility of interdependencies between sourceworks due to nitrate blending schemes has been considered. An outage occurring at a source which is used for blending to reduce nitrates in another source, could in theory lead to an outage at the second source. However, the nitrate blending schemes currently in operation in Portsmouth Water's supply network are based around large storage reservoirs and in some cases use output from more than one lower nitrate source. So there is a very low risk of short term outages at individual sources causing indirect outages at other sources due to nitrate blending requirements. This is borne out by the event records on the company's outage database, which do not indicate any interdependencies of this nature.

4.6 Key changes from 2014 assessment

There has been no significant difference in the approved methodology for outage assessment since WRMP14. However a more recent data set and an improved data collection system at the Works A and River Itchen sites has been used to determine the categories and parameters for the Monte Carlo simulation. Data covering the period 2007 – 2012 was used for the WRMP14 assessment, whereas the current analysis is based on data from 2007 – 2016. This has resulted in the following key differences:

- Increased data collection at the Works A water treatment works, and Source B springs that supply it, has required the outages recorded at the sourceworks and treatment works to be separated in order to ensure the outage assessment does not overestimate the frequency of event occurrences.
- There are a reduced number of sources identified as being at risk of shutdown due to cryptosporidium failures (2 compared to 5 at WRMP 2014). The Woodmancote source was previously included as being at risk, but is excluded from the WRMP 2019 assessment since it is affected by a long term turbidity problem that is not likely to be resolved in the current WRMP cycle.
- The improved data collection system at the River Itchen site has led to a large increase in unplanned outage events being reported. Prior to 2013 no unplanned outage events were reported, this has increased to 494 events from April 2013 onwards.

4.7 Woodmancote deployable output

The Woodmancote source has an ongoing turbidity issue that is unlikely to be resolved in the current WRMP cycle. As such, the DO assessment for the source has set a DO of zero. Therefore no OA for this source included in the outage assessment.

5 Assessment results

5.1 Company outage allowance

Table 5-1 shows the results for the DYAA planning scenario, Table 5-2 shows the results for the DYCP scenario and Table 5-3 shows the results for the DYMDO scenario.

Each table shows the combined outage for the relevant planning scenario, read from the allowable outage probability distribution at probabilities of 50%, 75%, 80%, 85%, 90% and 95% respectively. The OA's are expressed as both values in Ml/d and as percentages of DO.

Table 5-1 Portsmouth Water Outage Allowance – Dry Year Annual Average Scenario

Probability	Company Outage Allowance	
	Value in Ml/d	As a % of DO
50%	11.3	5.0%
75%	12.7	5.6%
80%	13.1	5.8%
85%	13.5	5.9%
90%	14.0	6.2%
95%	14.7	6.5%

Table 5-2 Portsmouth Water Outage Allowance – Dry Year Critical Period Scenario

Probability	Company Outage Allowance	
	Value in Ml/d	As a % of DO
50%	9.1	3.2%
75%	10.5	3.7%
80%	10.8	3.9%
85%	11.2	4.0%
90%	11.7	4.2%
95%	12.5	4.5%

Table 5-3 Portsmouth Water Outage Allowance – Dry Year Minimum Deployable Output Scenario

Probability	Company Outage Allowance	
	Value in Ml/d	As a % of DO
50%	12.5	4.9%
75%	13.9	5.6%
80%	14.3	5.7%
85%	14.7	5.9%
90%	15.3	6.1%
95%	16.2	6.5%

The outage values to be taken forward into Portsmouth Water's supply/demand balance analysis for WRMP19 are based on the 95th percentile, i.e. the values with a 5% risk of exceedance. The OA values adopted are therefore as follows:

- DYAA: 14.7 Ml/d
- DYCP: 12.5 Ml/d
- DYMDO: 16.2 Ml/d

These values will apply across the planning horizon; at present there are no specific future capital projects planned which will significantly alter the outage risk as assessed above. Reductions in the OA have already been implemented, due to recent treatment works improvements carried out by Portsmouth Water.

5.2 Outage by category

The results of the outage assessment for individual categories are shown in Tables 5-4, 5-5 and 5-6 for the DYAA, DYCP and DYMDP scenarios respectively. The 'Unplanned' sub-total has been derived by summing the outputs from all unplanned categories (chlorine, cryptosporidium, pollution, power, system and turbidity) in the Monte Carlo simulation.

Note that the OA values by category in Tables 5-4, 5-5 and 5-6 below do not sum to the company total OA values in Tables 5-1, 5-2 and 5-3 above. This is due to the probabilistic nature of the Monte Carlo simulation, in which outage events in all categories do not occur simultaneously in each step of the iteration. However the results by individual category below give an indication of their relative contributions to the combined company total values.

Note that the Planned and Unplanned categories are not shown for the DYCP, as the Planned category does not apply and the Unplanned sub-total is therefore equal to the company total outage for this scenario.

Table 5-4 Portsmouth Water Outage Allowance by Category – Dry Year Annual Average Scenario

Probability	Company Outage Allowance (Ml/d)							
	Planned	Unplanned	Chlorine	Cryptosporidium	Pollution	Power	System	Turbidity
50%	1.6	9.7	3.2	0.1	0.4	0.2	4.9	0.8
75%	1.6	11.1	4.1	0.1	0.4	0.3	6.3	0.9
80%	1.6	11.5	4.3	0.1	0.4	0.3	6.6	1.0
85%	1.7	11.9	4.6	0.1	0.4	0.3	7.1	1.1
90%	1.7	12.4	4.9	0.1	0.4	0.3	7.6	1.2
95%	1.7	13.2	5.5	0.1	0.4	0.3	8.3	1.3

Table 5-5 Portsmouth Water Outage Allowance by Category – Dry Year Critical Period Scenario

Probability	Company Outage Allowance (Ml/d)					
	Chlorine	Cryptosporidium	Pollution	Power	System	Turbidity
50%	2.7	0.1	0.2	0.3	4.9	0.8
75%	3.5	0.1	0.2	0.3	6.2	0.9
80%	3.7	0.1	0.2	0.3	6.5	1.0
85%	3.9	0.1	0.2	0.3	6.9	1.1
90%	4.2	0.1	0.2	0.4	7.4	1.2
95%	4.6	0.1	0.2	0.4	8.2	1.2

Table 5-6 Portsmouth Water Outage Allowance by Category – Dry Year Minimum Deployable Output Scenario

Probability	Company Outage Allowance (Ml/d)							
	Planned	Unplanned	Chlorine	Cryptosporidium	Pollution	Power	System	Turbidity
50%	1.8	10.7	3.5	0.1	0.5	0.3	5.5	0.8
75%	1.8	12.2	4.5	0.1	0.5	0.3	6.9	0.9
80%	1.8	12.6	4.7	0.1	0.5	0.3	7.3	1.0
85%	1.8	12.9	4.9	0.1	0.5	0.3	7.7	1.1
90%	1.9	13.6	5.5	0.1	0.5	0.3	8.3	1.2
95%	1.9	14.4	5.9	0.1	0.5	0.3	9.1	1.3

As can be seen from Table 5-4, the main contributory factors to the company's OA are those of system failures. The recording of system failure outage events has become more consistent across the sites in recent years contributing to an increase in their frequency in the dataset. Overall, the combined allowance for unplanned outage is significantly higher than for planned outage.

Table 5-5 indicates that the reduced company OA for the DYCP scenario is due to the exclusion of the planned maintenance category, and the reduced contributions from the cryptosporidium, pollution and turbidity categories which are due to capping the event durations at 14 days.

Oil pollution makes a relatively low contribution to the OA; however this is mainly due to the exclusion of a number of long duration events, which have been considered in the headroom analysis.

The relative contributions of the Planned and Unplanned OA to the overall company total (DYAA scenario only) are shown in Figure 5-1.

Figures 5-2, 5-3 and 5-4 indicate the relative contributions of each of the outage categories to the overall company OA, for each of the three planning scenarios.

Figure 5-1 Portsmouth Water Outage Allowance (Planned, Unplanned and Total), Dry Year Annual Average Scenario

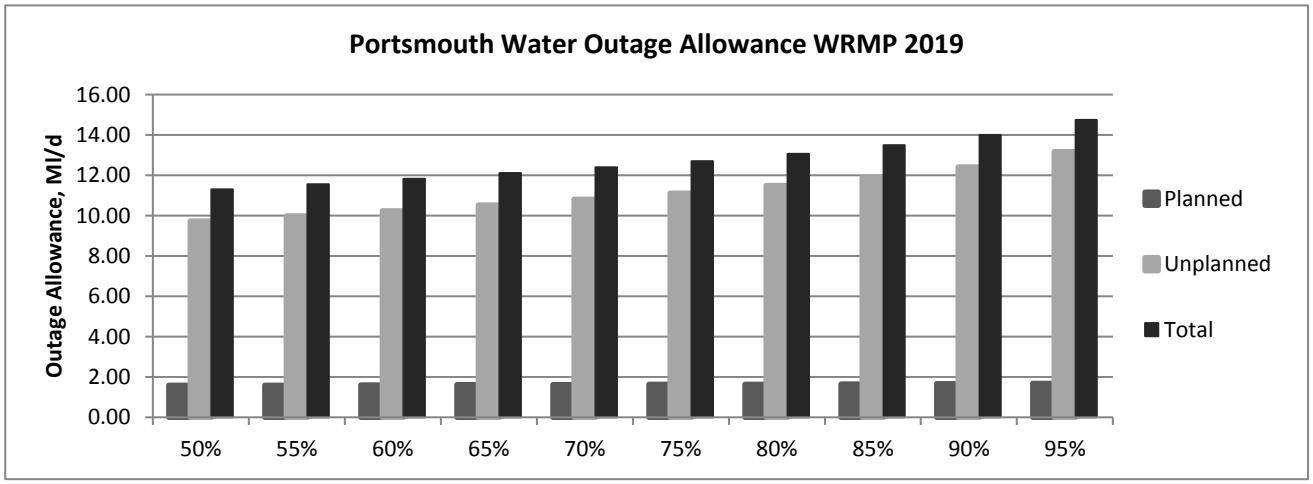


Figure 5-2 Relative Contributions of Outage Categories to Total Outage Allowance, Dry Year Annual Average Scenario, 95% Probability

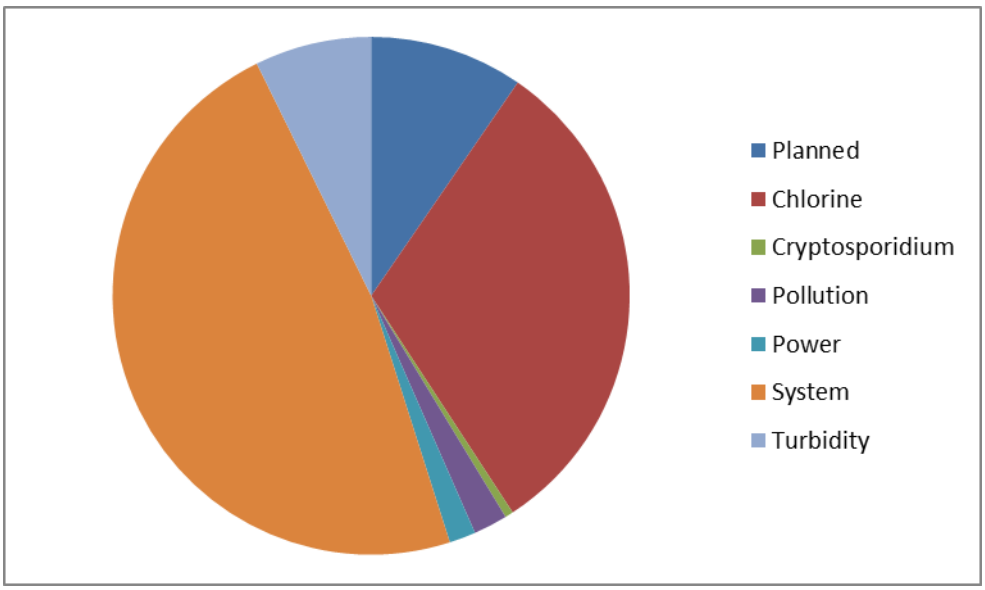


Figure 5-3 Relative Contributions of Outage Categories to Total Outage Allowance, Dry Year Critical Period Scenario, 95% Probability

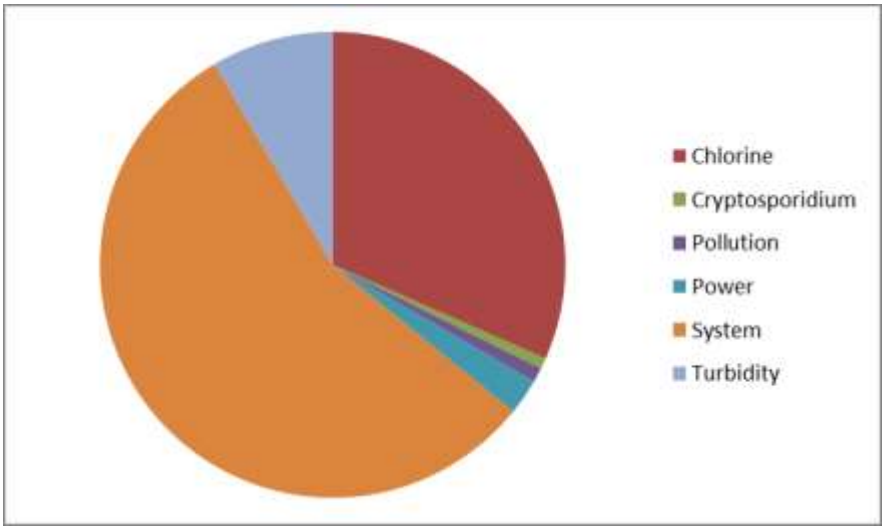
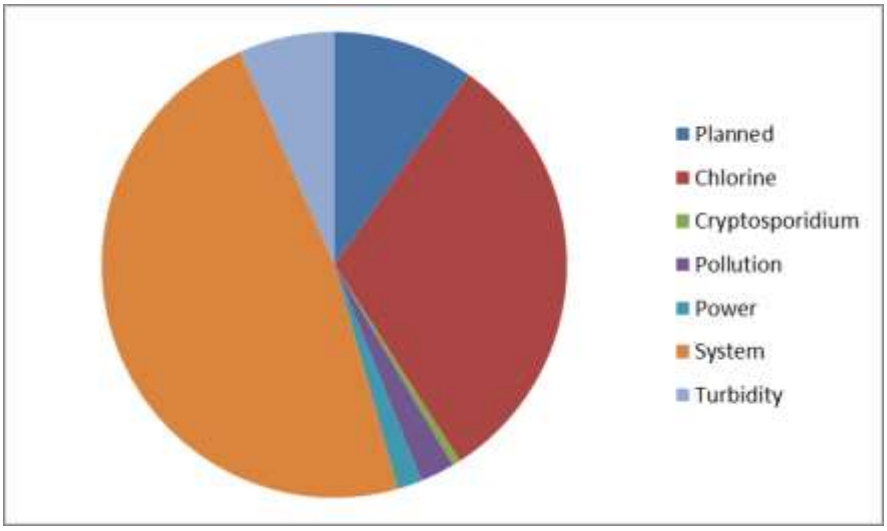


Figure 5-4 Relative Contributions of Outage Categories to Total Outage Allowance, Dry Year Minimum Deployable Output Scenario, 95% Probability



5.3 Outage by sourceworks

A summary of the OA for each sourceworks is shown in Table 5-7. These values have been selected from the allowable outage distribution for each individual sourceworks derived by summing the distributions for all the relevant categories applicable to each sourceworks, within the Monte Carlo simulation. Table 5-7 shows only those values read off at the 95th percentile of each sourceworks distribution. Again, it should be noted that the outage values by sourceworks do not sum to the company total OA due to the probabilistic or randomised nature of the Monte Carlo simulation.

It should be noted that the relative contributions of each sourceworks to the overall outage values reflect mainly the occurrences at these sourceworks within the recorded outage data for 2007 – 2012 (with the exception of the cryptosporidium and planned categories where some adjustments have been made to the recorded data for the purposes of the outage assessment, as outlined in Section 4). The apportionment of the OA between Portsmouth Water's sourceworks will not necessarily represent the apportionment of actual recorded outage events in future; however the recent recorded data has been used to produce a representative value for the total company outage which may be expected in future.

Table 5-7 Portsmouth Water Outage Allowance by Sourceworks, 95% Probability

Sourceworks	Dry Year Annual Average (Ml/d)	Dry Year Peak Week (Ml/d)	Dry Year Minimum Deployable Output (Ml/d)
Source T	0.2	0.2	0.2
Source M	0.1	0.08	0.1
Source Q	0.6	0.6	0.6
Works A	4.6	4.8	4.9
Source P	1.0	1.0	1.3
Source O	0.4	0.07	0.3
Source L	2.9	3.2	3.4
Source K	0.6	0.3	0.7
Source I	0.03	0.02	0.04
Source C	0.4	0.2	0.4
River Itchen	4.0	3.9	4.4
Source S	0.07	0.05	0.1
Source F	1.0	0.7	1.3
Source N	0.4	0.4	0.4
Source E	0.01	0.00021	0.01
Source H	0.2	0.06	0.2
Source R	3.1	0.2	3.2
Source J	0.3	1.0	0.4

The probability distribution graphs for total company OA are included in Appendices A, B and C, for each planning scenario. For the DYAA and DYMDO scenarios, both the Planned and Unplanned OA distributions are also shown.

Appendices D, E and F contain tornado graphs showing the regression coefficients of each category/sourceworks, in order of their relative contributions to the combined outage values. Note that a maximum of 16 factors can be shown on the tornado graph.

The graphs in the appendices are all outputs from the @RISK software used to undertake the Monte Carlo simulation.

5.4 Comparison with previous assessments

The results of the previous and current outage assessments are presented in Table 5-8 (the DYMDO scenario was not calculated in the WRMP04 and WRMP09 submissions).

The current assessment has produced OA values which are similar to those produced by the WRMP09 study, and higher than those produced by the WRMP14 study. The differences from the WRMP14 study values are mainly due to improved recording of system and chlorine events, particularly at the River Itchen (where no unplanned events were included in the WRMP14 assessment) and Works A sites. The assessment has factored in the event frequencies (likelihoods) as well as magnitudes to account for the variable frequencies recorded; as such the increased number of outage events recorded is reflected in the increased OA values.

The WRMP09 assessment included source pollution events at Source C, Source R, Source P and Source T. These have not re-occurred in the recent recorded outage data set, in part due to treatment works improvements such as a membrane filter to prevent cryptosporidium at Source P, and activated carbon filters at Source C. Furthermore, the most significant source pollution event in the WRMP09 assessment was a lengthy shutdown at Source C due to the risk of oil pollution, this type of longer-term loss in deployable output is now included in the headroom allowance for the Draft WRMP 2019 submission.

In summary, Portsmouth Water's company OA has increased in this assessment compared to the previous values reported at WRMP14. This is due to a combination of increased numbers of legitimate outage events occurring in the most recent period of data, and improved recording of events in certain categories/at certain sourceworks as discussed above.

Table 5-8 Portsmouth Water Outage Allowance – Comparison with Previous Results

Submission	Combined Company Outage Allowance (Ml/d)		
	DYAA	DYCP	DYMDO
WRMP04	1.9	12	-
WRMP09	14.2	16.5	-
WRMP14	9.3	4.6	10.8
WRMP19	14.7	12.5	16.2

6 Conclusions

Table 6-1 shows a summary of the results of this outage assessment. The OA figures in Ml/d shown in Table 6-1 are the outage values to be incorporated within Portsmouth Water's supply/demand balance analysis and the dWRMP report due for submission in December 2017.

The selected outage values are for a probability of 95%, or exceedance probability of 5%. The OA is based on the following categories or causes of outage events: planned maintenance or capital works (dry year annual average and dry year minimum deployable output only), chlorination issues, cryptosporidium failure, power failure, pollution incidents, system failures and turbidity problems.

Table 6-1 Portsmouth Water Outage Allowance – Summary

Planning Scenario	Combined Company Outage Allowance	
	Value in Ml/d	As a % of DO
DYAA	14.7	6.5%
DYCP	12.5	4.5%
DYMDO	16.2	6.5%

7 References

AECOM (2017), *Portsmouth Water WRMP 2019 Studies – Deployable Output Assessment,* October 2017.

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UK Water Industry Research (UKWIR) (2016), *WRMP19 methods – risk based planning*.

UKWIR (1995), *Outage Allowances for Water Resource Planning: Operating Methodology*, 1995.

Appendix A. @RISK Summary Output – Total Company Outage Allowance – Combined Probability Distributions – Dry Year Annual Average Scenario

Appendix B. @RISK Summary Output – Total Company Outage Allowance – Combined Probability Distributions – Dry Year Critical Period Scenario

Appendix C. @RISK Summary Output – Total Company Outage Allowance – Combined Probability Distributions – Dry Year Minimum Deployable Output Scenario

Appendix D. @RISK Summary Output – Total Company Outage Allowance – Tornado Graphs of Regression Coefficients – Dry Year Annual Average Scenario

Appendix E. @RISK Summary Output – Total Company Outage Allowance – Tornado Graphs of Regression Coefficients – Dry Year Critical Period Scenario

Appendix F. @RISK Summary Output – Total Company Outage Allowance – Tornado Graphs of Regression Coefficients – Dry Year Minimum Deployable Output Scenario

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