WRMP24 Outage Allowance

South Staffs & Cambridge WRZ

Project:	SSW Outage Allowance WRMP24		
Our reference:	100101534		
Prepared by:	R MacDonald	**Date:**	19th July 2021
Approved by:	P Chadwick	**Checked by:**	J Bonci
Subject:	Technical Note		

1. Objectives and scope of work

South Staffordshire Water (SSW) requires an update to its outage allowance for both South Staffs and Cambridge Water Resource Zones (WRZs), for inclusion in the WRMP24 supply demand balance forecast.

The objectives of the project are:

- to analyse historical data recorded by South Staffordshire Water (SSW), to identify legitimate outages and produce appropriate probability distributions for the events where there is sufficient data; and
- to determine an outage allowance for SSW under average and peak conditions.

2. Methodology

The outage allowance was determined in line with the Water Resources Planning Guideline for WRMP24, as well as the requirements of Water Resources East (WRE), for Cambridge WRZ, and Water Resources West (WRW), for South Staffs WRZ.

The determination of outage allowance involves the following key steps.

<u>Data compilation, review and analysis</u>

Receive data from SSW. Compile into one dataset and review for any identifiable errors or anomalies

Process data into format required for modelling

<u>Model population and initial analysis</u>

An outage modelling tool was recently developed for WRSE, to facilitate best practice outage analysis. It enables simpler processing of events and PDFs, provides a better audit trail and enables faster and simpler Monte-Carlo model runs without the need for any Microsoft Excel "add-ins". This modelling tool was applied here, as follows:

Set up an outage modelling tool for South Staffs and Cambridge WRZs.

Specify deployable output (DO) data for each WRZ in the Source DO sheet, and evaluate any sources at which DYAA recovery may be possible.

Upload all potentially relevant outage data into each OMT and ensure every event has an appropriate outage category assigned

Run the OMT model to identify a baseline outage value for comparison with WRMP19

Check the allowance at P95 for materiality to WRW/WRE/WRMP. If the outage allowance is potentially material, review the validity of historical data, and test the materiality of clipping the record at different points if required.

Review partial outage materiality and consider whether a shorter more recent data record should be used to specify outage magnitudes, compared to duration/frequency

Screen Events for legitimacy

Screen events for legitimacy according to the following tests:

- Should DO be written down (for long-duration events) and therefore no allowance for outage made?
- Is there sufficient storage in the supply system to buffer the outage impact in full?
- Has subsequent capital investment reduced the risk of the event occurring to zero?
- For DYAA scenario, could the event outage be recovered in full during a dry year through conjunctive use within licences?
- Is the event captured already within target headroom (e.g. long-term nitrate pollution failure)
- Is the event impact so large relative to WRZ DO that it should be assessed as a resilience scenario and excluded from outage?
- Should the event be excluded from DYCP or DYMDO scenarios because it would never happen at those times in a dry year (e.g. planned event, winter power outage only etc).

Adjust event magnitude/duration

Review key event durations/magnitudes and update these where appropriate for planning scenario (DYAA and DYCP) conditions. In particular, consider whether variation between daily and average annual licences, or between individual and group licences, could enable recovery of outage under the DYAA scenario. Determine updated event magnitudes where necessary

Review and adjust site/hazard PDFs

Consider whether historical capital investment has impacted the likelihood of any material hazard/site combinations (taking account of any events that may have been screened out for the same reason). If so, update the likelihood distribution accordingly, based on expert judgement.

Review the magnitude and duration distributions of all material hazard/sites and make any amendments in distribution type (triangular v log normal) considered appropriate.

For material hazard/sites, consider whether any changes to duration, magnitude or likelihood are expected during the planning period, for example due to scheduled capital investment, climate change impacts on DO, or sustainability reductions. Update the M/D/F distributions as required, e.g. reduce magnitude to account for climate losses, adjust likelihood for capital investment.

Baseline Modelling

Run the model to generate the baseline outage allowance. For any areas of uncertainty that might be material, try running scenarios for sensitivity testing and use this to decide on the most appropriate outage scenario and outage allowance for each WRZ.

3. Outage Analysis

The outage allowance was determined in line with the Water Resources Planning Guideline for WRMP24, as well as the requirements of Water Resources East (WRE), for Cambridge WRZ, and Water Resources West (WRW), for South Staffs WRZ.

3.1. South Staffs WRZ

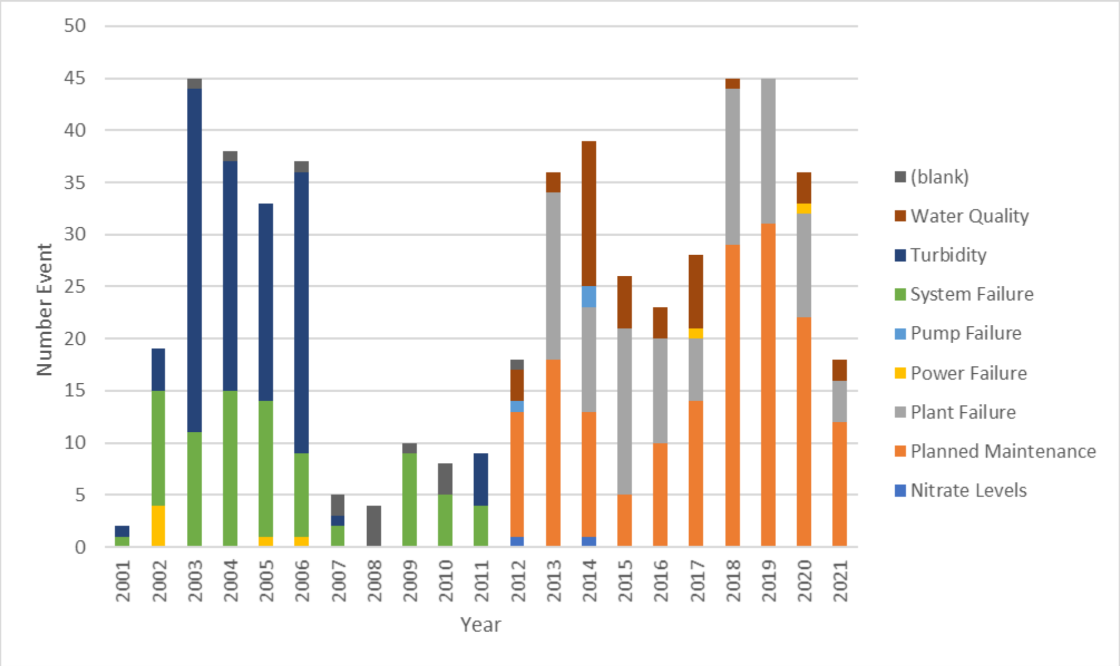
Data compilation, review and analysis

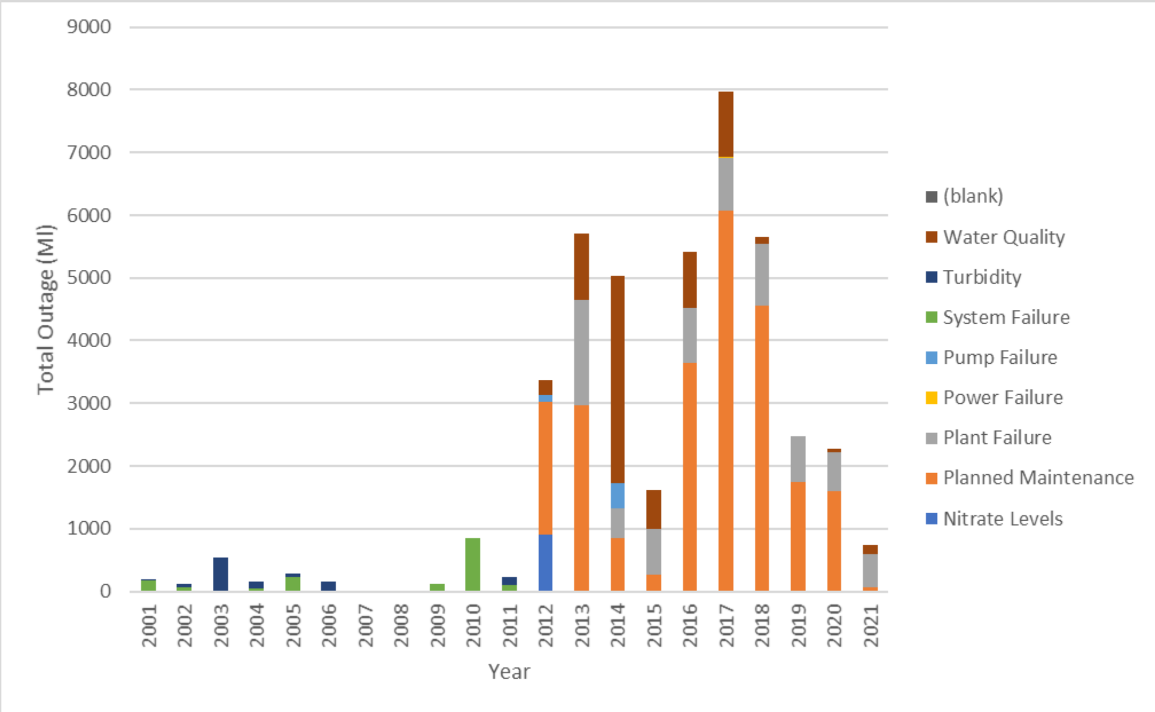
248 events were compiled for the period March 2012 to March 2020.

Table 3.1: SSW source files for outage event data

Source File	Year(s)
SSW Combined Outage Data updated.xlsx	2001-2012
JR13 Outage events with stats.xlsx	2012-13
Outage Review 13_14 corrected 13Aug14.xlsx	2013-14
Outage Calculation JR15.xlsx	2014-15
Outage Calculation JR16.xlsx	2015-16
Outage Calculation JR17 Final v1.xlsx	2016-17
SST outage calc final 201819 "EA Outage Calcs"	2017-18 2018-19
SST 201920 Outage Assessment DJH 05May20 "Outage Log SST"	2019-20
SST 202021 Outage Assessment DJH 25May21 "Outage Log SST"	2020-21

Figure 3.1: SSW historical outage events 2001-2021 by calendar year and event type: number (top) and total loss of output (bottom)





There is a clear shift in data before and after 2012. To reflect the dramatic improvement in data quantity and quality, we clip the record to 2012 onwards.

Loss of output due to planned maintenance appears to show a possible cyclical trend between 2012 and 2020, which may reflect the cyclical changes in investment due to asset management period funding cycles.

Water quality events appear to show a downward trend in output lost…

Model population and initial analysis

- DO table
- Outage category changes?
- To reflect the planning guideline, all events were capped at 90 days duration.

Screen Events for legitimacy

We exclude planned events from the DYCP scenario. We also exclude any events labelled as “Deselect”, “Deselection” or “Covered by events above” with no duration or magnitude specified.

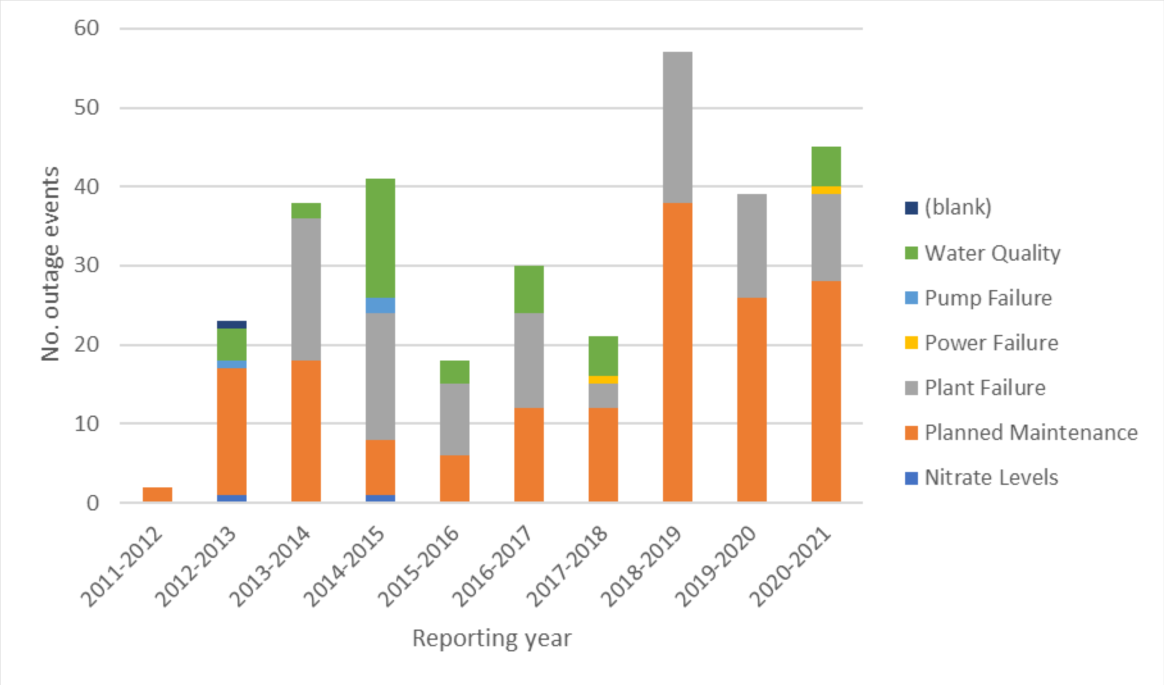
Adjust event magnitude/duration

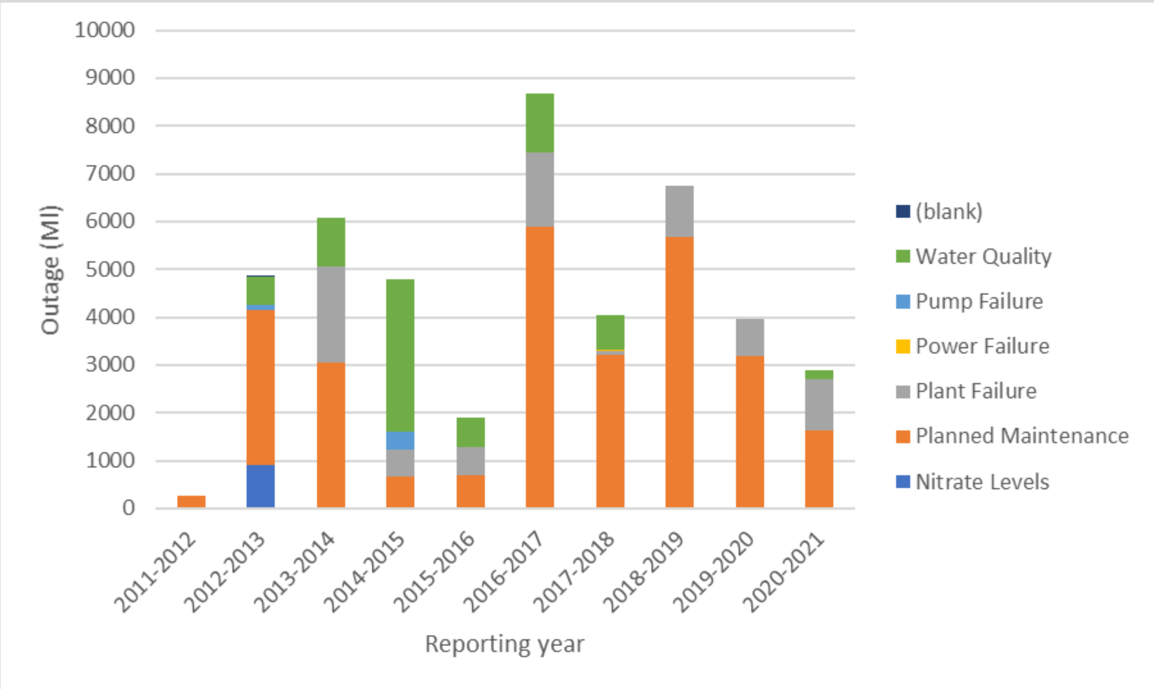
Outage event magnitude is adjusted to take account of any differences in DO compared to the recorded event failure. We assume that event losses of output in Ml/d are expressed relative to peak dry year DO. Event magnitude for DYAA conditions is adjusted downwards by the difference between peak DO and DYAA DO.

Review and adjust site/hazard PDFs

Specify triangular duration distributions for: Ashford, Maple Brook & Kinver planned maint; Pipe Hill WQ; Churchill WQ (ADO only)

Figure 3.2: SSW clipped historical outage events by licence reporting year and event type: number (top) and total loss of output (bottom)





It can be seen that there is notable variation in outage associated with planned maintenance between years, and that as a result of this maintenance, water quality and pump failure outage has decreased significantly over time. Discussions with operational management in South Staffs suggest that the following adjustments to outage distributions are appropriate to take account of these factors:

- Halve the outage duration distribution parameters, to reflect a likely reduction in outage event duration in dry years.

- Reduce the historically recorded frequency of water quality and pump failure events by 75% for outage modelling, to account for the effects of capital investment on mitigating these types of event.

3.2. Cambridge WRZ

Data compilation, review and analysis

Outage data was compiled from the WRMP19 compilation file, "Cam Combined Outage Data RM – Copy", and from a series of files received by email from Dan Clark on 6th May 2021 and from Dan Haire on 25th May (2020-21 data). A summary of the original source files is as follows.

Source File	Year
Outages Longer term, Wquality (SF)	2012
Outages	2013
Site Outage Collection spreadsheet 2013-2014 data collection	2013-14
Site Outage Collection spreadsheet 2014-2015 data collection	2014-15
Site Outage Collection spreadsheet 2015-2016 data collection	2015-16
Outage Summary 2016-17 Mital Summary 2016-2017	2016-17
Site Outage Collection spreadsheet COPY & Calculations for unplanned outage PC	2017-18
CAM outage data 201819 final	2018-19
CAM 201920 Outage Assessment SS 29May20 "Outage Log CAM"	2019-20
CAM 202021 Outage Assessment DJH 25May21 "Outage Log CAM"	2020-21

Data in Site Outage Collection spreadsheet COPY & Calculations for unplanned outage PC was processed to convert daily data into event data with a start and end date.

Events were uploaded into the outage model according to the categories specified in the source files, with interpretation of some categories made from event descriptions.

- If loss output and actual output not specified, we specify duration as "hours out of supply", and magnitude = DO.
- Event site names were updated via a call with SSW to enable events to be matched to source DO.

DO data was input to align with that provided by SSW by email for the headroom analysis, as shown in Table 3.2. DYCP values were as specified at WRMP19, with clarifications for reinstated sources by email 18th June 2021. DYAA values were reassessed for WRMP24.

Table 3.2: Cambridge Deployable Output Values used in Outage Assessment

Source name	Deployable output (Ml/d) DYAA	Deployable output (Ml/d) DYCP
Abington Park	1	4
Babraham	6.42	6.4
Brettenham	8.25	15
Croydon	1.4	1.4
Dullingham	3.24	3.2
Duxford	4.45	5.68

Source name	Deployable output (Ml/d) DYAA	Deployable output (Ml/d) DYCP
Duxford Grange	2.88	2.88
Euston	8	10
Fleam Dyke	14.3	12.7
Fowlmere	3.6	5.4
Fulbourn	1.25	1.49
Great Chishill	1.15	1.06
Great Wilbraham	5.19	9.09
Heydon	1.13	2.13
Hinxton Grange	5.77	6.82
Horseheath	1.4	1.7
Kingston	0.9	0.9
Linton	0	2.73
Lowerfield	3.39	4.27
Melbourn	7.2	9.15
Morden Grange	1.2	1.5
Rivey	1	2.75
Sawston	1.49	2.16
Westley	7.92	10.6
Weston Colville	2.92	2.92
Euston Brettenham	16.25	25
Fleam Dyke 12"	3.27	3.27

Figure 3.3: Number of outage events per year Cambridge WRZ

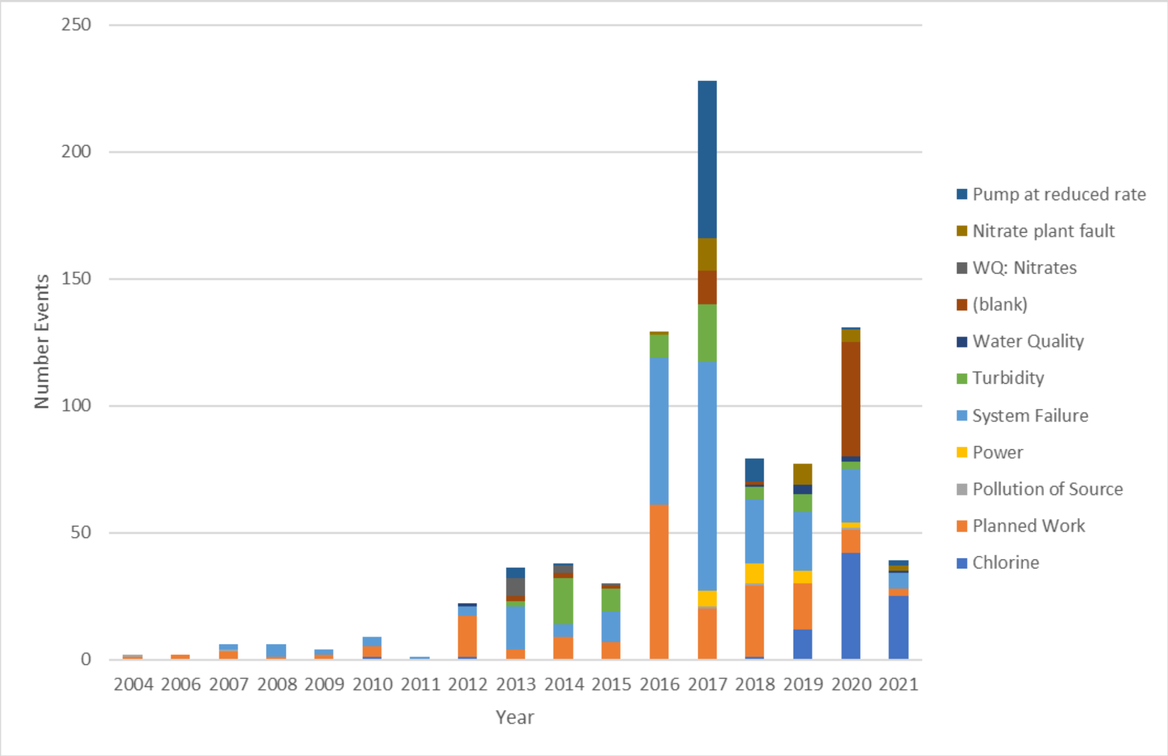
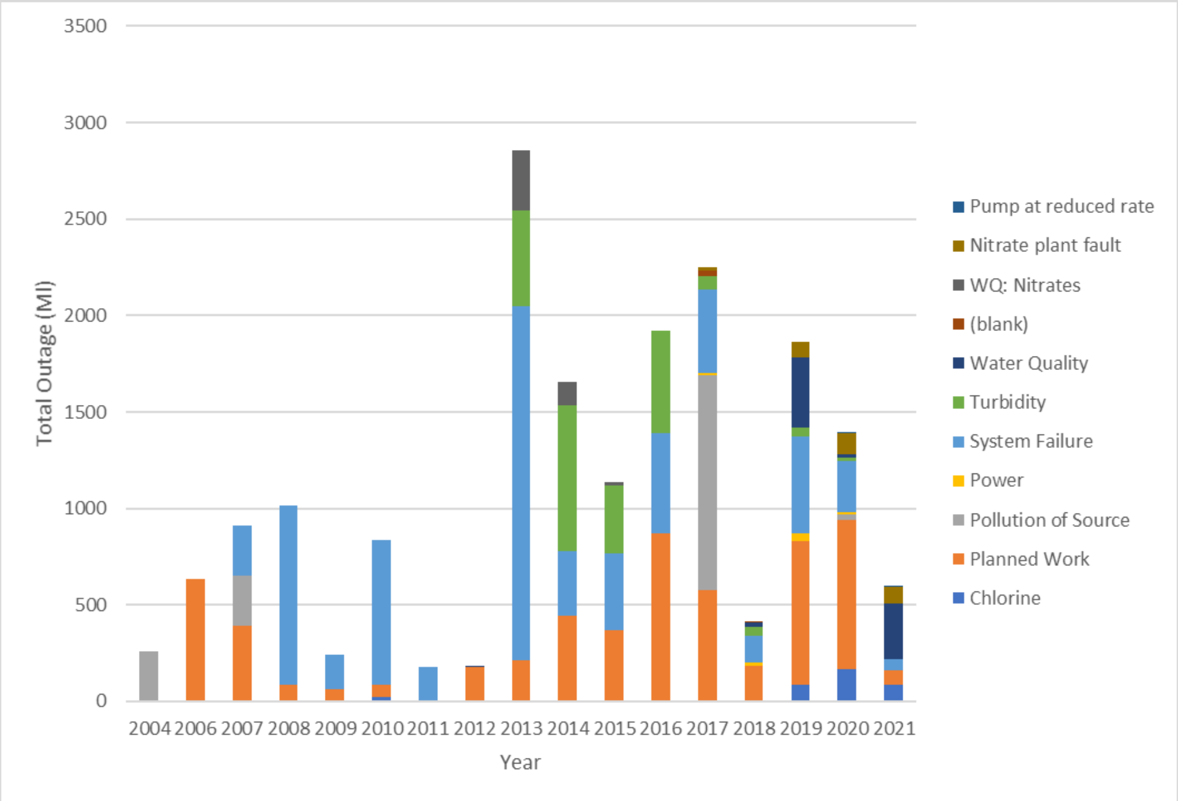


Figure 3.4: Cumulative Outage DO losses per year Cambridge WRZ



Data in Site Outage Collection spreadsheet COPY & Calculations for unplanned outage PC was processed to convert daily data into event data with a start and end date.

Events were uploaded into the outage model according to the categories specified in the source files, with interpretation of some categories made from event descriptions.

- If loss output and actual output not specified, we specify duration as "hours out of supply", and magnitude = DO.
- Event site names were updated via a call with SSW to enable events to be matched to source DO.

DO data was input to align with that provided by SSW by email for the headroom analysis, as shown in Table 3.2. DYCP values were as specified at WRMP19, with clarifications for reinstated sources by email 18th June 2021. DYAA values were reassessed for WRMP24.

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Croydon	1.4	1.4
Dullingham	3.24	3.2
Duxford	4.45	5.68
Duxford Grange	2.88	2.88
Euston	8	10
Fleam Dyke	14.3	12.7
Fowlmere	3.6	5.4
Fulbourn	1.25	1.49
Great Chishill	1.15	1.06
Great Wilbraham	5.19	9.09
Heydon	1.13	2.13
Hinxton Grange	5.77	6.82
Horseheath	1.4	1.7
Kingston	0.9	0.9
Linton	0	2.73
Lowerfield	3.39	4.27
Melbourn	7.2	9.15
Morden Grange	1.2	1.5
Rivey	1	2.75
Sawston	1.49	2.16
Westley	7.92	10.6
Weston Colville	2.92	2.92
Euston Brettenham	16.25	25
Fleam Dyke 12"	3.27	3.27

Figure 3.3 and Figure 3.4 show a notable increase in the number and cumulative impact of events from 2013 onwards. This is believed to be a result of notable improvements in outage data collection at that time. We therefore clip the record in 2012 to avoid artificially decreasing the frequency of event types.

Model population and initial analysis

- Removed events pre-2012, though with distributions for pollution at Duxford specified based on 2004/05 events
- Capped event durations at 90 days
- Planned work excluded from peak outage

Screen Events for legitimacy

- All events screened out at WRMP19 ("FALSE" specified against allowable outage) excluded on grounds of Reduced sourceworks output due entirely to lack of demand or to operating philosophy.
- All deselected events excluded on grounds of Reduced sourceworks output due entirely to lack of demand or to operating philosophy.
- All events specified as “Pump at reduced rate” or “Well rest” excluded on grounds of Reduced sourceworks output due entirely to lack of demand or to operating philosophy
- Screened out Horseheath mothballing event
- Babraham "General ability to achieve its maximum PWPC - site was required to run at reduced flow to meet contact time requirements prior to chlorination upgrade" event screened out on grounds of Reduced sourceworks output due entirely to lack of demand or to operating philosophy
- All planned events excluded from peak outage.
- Specified separate hazard type for Babraham ("Pump at reduced rate"). Screen out, as Babraham DYAA DO has been reduced due to licence condition.
- Planned events at Duxford and Fulbourn screened out on grounds of capital investment reduced risk to zero, as “Planned maintenance will not occur again” stated by SSW in email 22nd June 2021
- Westley system failure events show a notable negative correlation between duration and magnitude. Therefore, we separate out long and short duration events into separate distributions to avoid skewing the results.
- Dullingham planned outage includes 3 events in a single year, totalling 203 days. To comply with the EA guidance, we exclude two of these events (on grounds of Reduced sourceworks output due entirely to lack of demand or to operating philosophy) such that total duration in one year is limited to 83 days.

Adjust event magnitude/duration

A review of the event duration distributions for hazard type/source combinations contributing most significantly to outage showed that triangular duration distributions are most appropriate for:

- Duxford pollution
- Fleam Dyke pollution and system failure,
- Fulbourn planned work

- Hinxton Grange turbidity
- Westley system failure

Log normal duration distributions are considered most appropriate for all other source/hazard combinations.

Triangular magnitude distributions are considered most appropriate for all source/hazard combinations. Due to the limited number of events, we apply fixed frequency values to all source/hazard combinations.

Review and adjust site/hazard PDFs

Hinxton Grange, Horseheath and Melbourn have suffered notable turbidity events historically, related to low groundwater, and high rainfall/recharge events. Some mitigation has been put in place at Hinxton Grange to redirect inundation of site from upgradient drainage (boundary bund). Therefore, the risk related to these events is most likely mitigated now. Amazon filters have been installed at Horseheath, so the risk will be lessened, although not removed entirely. The DO would only be impacted with a significant recharge event. At Melbourn, the channel of an adjacent ditch is now maintained, which will also reduce the frequency of any event here.

To account for the mitigation, we reduce the fixed frequency value by 90% for turbidity outage at Hinxton Grange, Horseheath and Melbourn.

SSW has undertaken a considerable programme of planned maintenance work in Cambridge WRZ over recent years, such that recent planned outage is recognised as too high to represent required planned outage in a future dry year. Expert judgement estimates that the duration of planned work in a dry year is likely to be half the average recorded in recent years, and we allow for this in the final outage run by reducing the duration distribution parameters by 50% for all planned outage distributions.

4. Outage Results

Outage modelling was undertaken incrementally via a series of model runs, to enable the impact of specific assumptions to be explicitly quantified.

4.1. South Staffs WRZ

The results of the outage allowance Monte Carlo modelling for South Staffs WRZ are presented below.

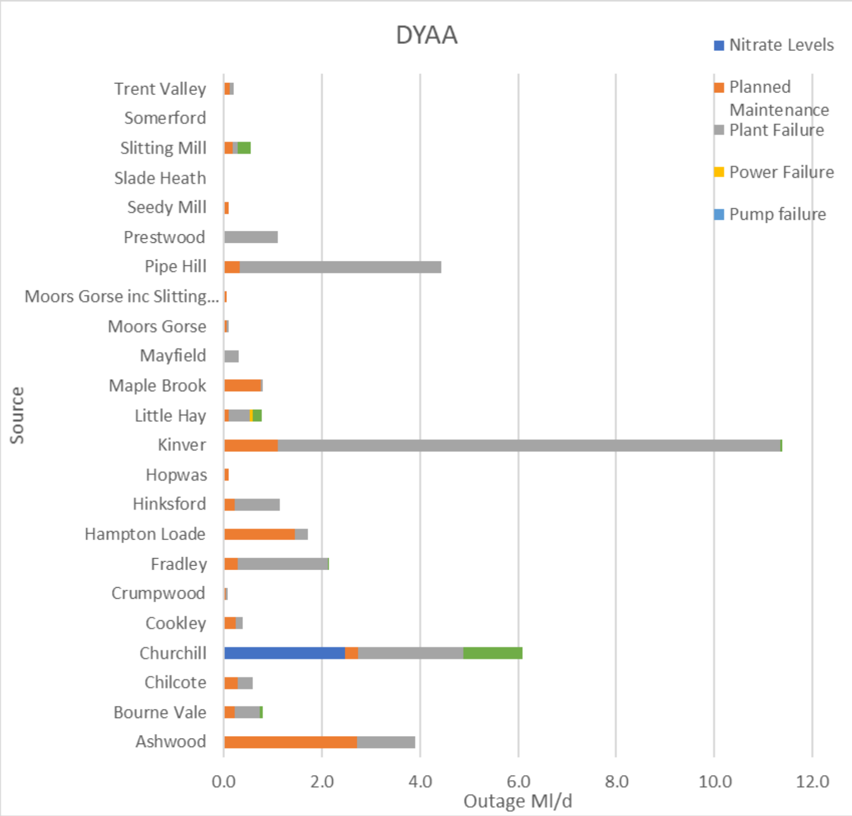
Table 4.1: SSW Outage Allowance Results

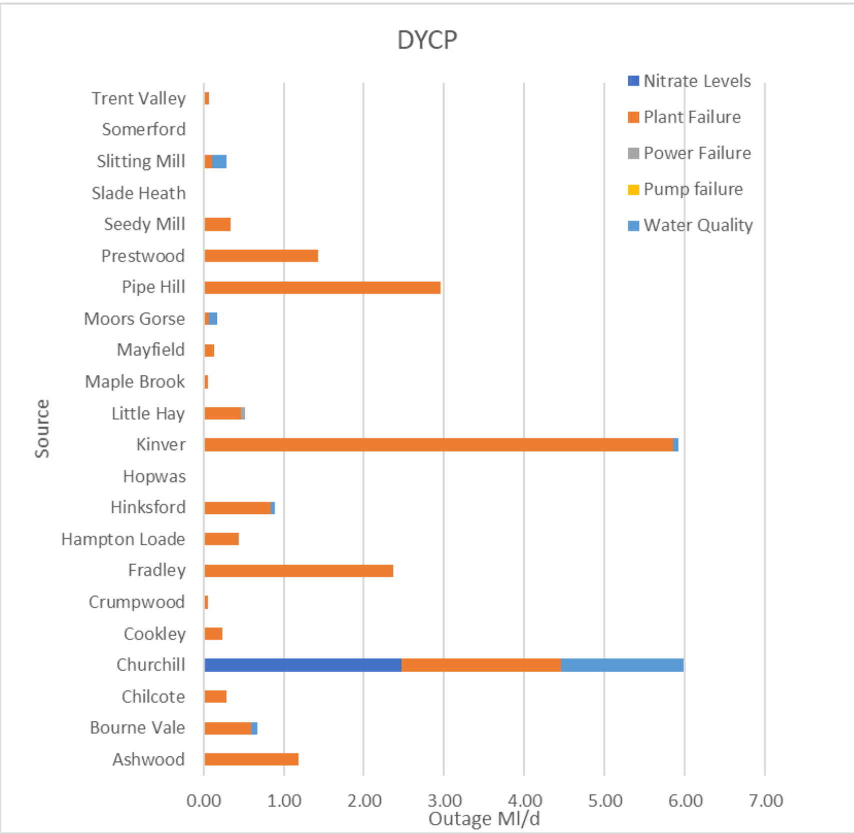
	DYAA				DYCP				
Run	**MC P70 Ml/d**	**MC P80 Ml/d**	**MC P90 Ml/d**	**MC P95 Ml/d**	**MC P70 Ml/d**	**MC P80 Ml/d**	**MC P90 Ml/d**	**MC P95 Ml/d**	**Description**
WRMP19	6.9	8.3	10.3		4.2	5.6	8		**Sep-17**
Run 0	5.0	6.3	9.0	14.0	2.8	3.4	4.2	5.4	**WRMP24 model with data 2001-2017**
Run 1	16.6	18.9	21.8	24.9	7.9	9.2	11.2	13.5	**Data 2012 to 2020**
Run 2	16.6	18.8	22.4	24.7	7.9	9.2	11.2	13.5	As Run 1 but all unplanned maintenance specified as planned
Run 3	14.5	16.3	19.5	22.9	7.6	8.8	10.7	12.8	As Run 1 excluding Ashwood planned maintenance
Run 4	15.5	17.5	22.0	24.8	6.8	7.7	9.8	12.0	As Run 1 excluding Pipe Hill WQ
Run 5	14.7	16.2	19.4	22.1	6.1	7.3	9.0	10.4	As Run 1 excluding Kinver plant maintenance
Run 6	16.2	18.7	22.1	25.1	7.3	8.5	10.9	13.2	**As Run 1 including 2020-21 event data**
Run 7	17.5	20.0	24.3	28.4	7.6	8.7	10.6	12.9	As Run 6 with Hampton Loade and Seedy Mill DO updated to 181 and 54 Ml/d
Run 8	18.1	20.6	24.0	27.6	7.4	8.9	11.2	13.5	As Run 7 with Bourne Vale DO increased from 0 to 4.5/4.8 Ml/d
Run 9	18.1	20.9	25.0	28.4	7.5	8.6	10.8	13.0	**As Run 8 with other minor changes to DO**
Run 10	12.9	15.4	19.0	21.6	7.8	9.0	11.0	13.3	As Run 9 with planned maintenance frequency halved, to reflect dry year conditions
Run 11	10.0	12.0	16.5	19.1	7.5	9.1	11.2	12.8	As Run 9 with planned maintenance duration halved, to reflect dry year conditions
Run 12	**8.2**	**10.1**	**14.2**	**16.9**	**5.5**	**6.5**	**8.8**	**10.5**	**As Run 11 with water quality and pump failure event frequency reduced by 75%**
Run 13	7.9	9.7	13.8	16.6	5.0	6.2	8.1	9.7	As Run 13, with Churchill nitrate outage excluded

The breakdown of outage allowance drivers by source and hazard type is shown in Figure 4.1.

Water Resources West (WRW) advises all companies in the WRW region to use the 80th percentile outage percentile. For SSW, this percentile is 10.1 Ml/d for DYAA and 6.5 Ml/d for DYCP.

Figure 4.1: SSW Outage Allowance Breakdown by Source/Hazard: DYAA (top) and DYCP (bottom)





4.2. Cambridge WRZ

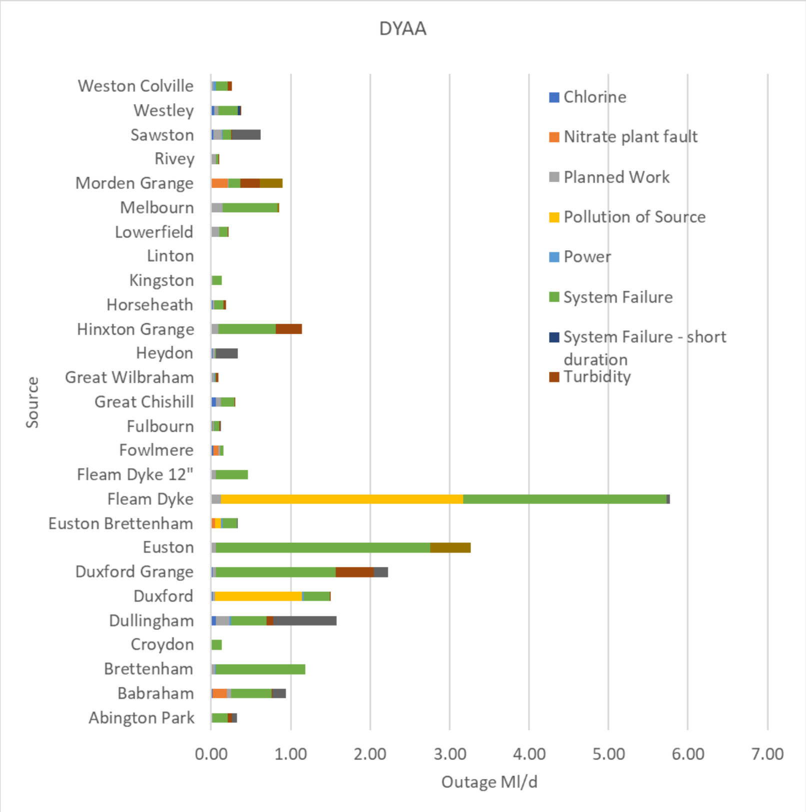
The results of the outage allowance Monte Carlo modelling for Cambridge are presented below.

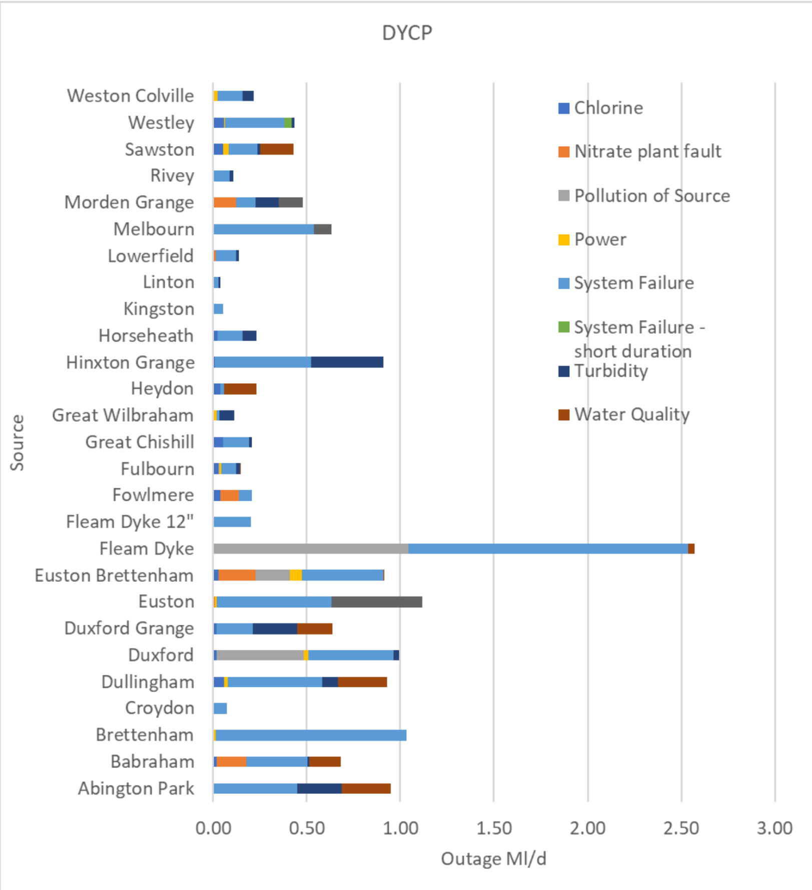
Table 4.2: Cambridge Outage Allowance Results

	DYAA				DYCP				
Run	MC P70 Ml/d	MC P80 Ml/d	MC P90 Ml/d	MC P95 Ml/d	MC P70 Ml/d	MC P80 Ml/d	MC P90 Ml/d	MC P95 Ml/d	Description
WRMP19	**4.8**	**5.97**	**7.66**	**9.19**	**2.1**	**3.22**	**8.68**	**15.27**	Jan-2019
Run 0	**6.2**	**8.0**	**10.3**	**12.4**	**2.5**	**2.9**	**3.5**	**4.1**	As Run1, including pre-2012 events
Run 1	**7.9**	**9.2**	**11.4**	**13.3**	**4.2**	**4.7**	**5.5**	**6.1**	2012 to 2020 Data
Run 2	7.7	9.1	11.1	12.5	4.3	4.7	5.4	6.1	As Run1, Fleam Dyke Pollution excluded
Run 3	7.5	9.0	11.1	13.0	4.2	4.7	5.4	6.0	As Run1, Fleam Dyke System failure excluded
Run 4	6.9	8.5	10.4	12.2	4.2	4.7	5.5	6.2	As Run1, Fleam Dyke System failure & pollution excluded
Run 5	7.3	9.0	10.9	12.6	4.2	4.7	5.5	6.1	As Run1, Hinxton Grange Turbidity excluded
Run 6	7.2	8.8	10.8	12.7	4.2	4.7	5.4	5.9	As Run1, all events capped at 60 days
Run 7	**8.2**	**9.6**	**11.7**	**13.8**	**4.5**	**5.0**	**5.7**	**6.3**	**As Run1, with 2020-21 data included**
Run 8	6.7	8.2	10.3	12.0	3.8	4.3	4.9	5.4	As Run7, Fleam Dyke pollution & system failure excluded
Run 9	7.9	9.2	11.1	12.7	3.9	4.4	5.0	5.6	As Run7, Hinxton Grange turbidity excluded
Run 10	7.3	8.7	10.7	12.5	3.7	4.2	4.9	5.7	As Run 7, excluding Hinxton Grange and Horseheath turbidity
Run 11	7.9	9.5	11.4	13.5	4.2	4.7	5.3	5.9	As Run 7, with Westley system failure frequency halved
Run 12	**6.9**	**8.5**	**10.8**	**12.8**	**3.7**	**4.1**	**4.6**	**5.1**	**As Run 7 with screening/adjustment applied as per report section 3.2**
Run 13	6.0	7.0	9.3	11.1	3.2	3.6	4.0	4.5	As Run 12 with Fleam Dyke system failure excluded
Run 14	6.4	7.7	9.9	11.8	3.4	3.8	4.4	4.9	As Run 12 with Fleam Dyke pollution excluded
Run 15	6.5	7.5	9.7	11.5	3.6	4.0	4.7	5.3	As Run 12 with Melbourn turbidity excluded
Run 16	**6.4**	**7.6**	**9.7**	**11.2**	**3.5**	**4.0**	**4.6**	**5.2**	**As Run 12 with Horseheath & Melbourn turbidity frequency reduced by 90%**
Run 17	**4.9**	**6.0**	**8.0**	**9.6**	**3.2**	**3.5**	**4.1**	**4.6**	**As Run 16 with planned duration distributions halved and all planned events excluded from peak**

The breakdown of outage allowance drivers by source and hazard type is shown in Figure 4.2. For Cambridge, we consider that, as at WRMP19, the 70th percentile outage is most appropriate, given the nature of the sources and network connectivity within the WRZ. That is a value of 4.9 Ml/d for DYAA and 3.2 Ml/d for DYCP.

Figure 4.2: Cambridge Outage Allowance by Source/Hazard: DYAA (top) and DYCP (bottom)





A. Quality Assurance

Detailed quality assurance (QA) was undertaken throughout the outage allowance analysis, in line with industry best practice. A log of the QA can be provided under separate cover.