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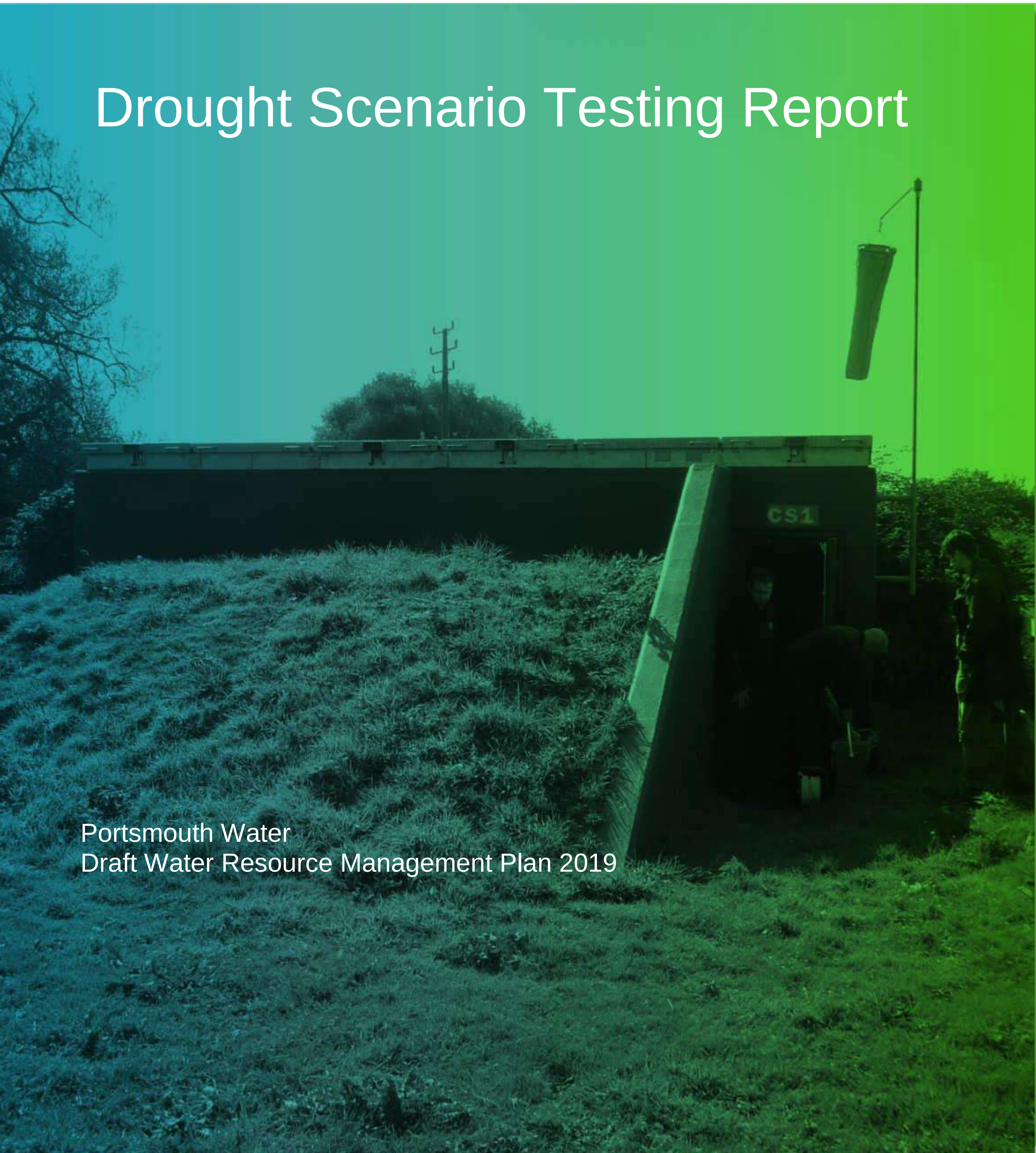
Drought Scenario Testing Report



Portsmouth Water
Draft Water Resource Management Plan 2019

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The methodology adopted and the sources of information used by AECOM in providing its services are outlined in this Report. The work described in this Report was undertaken between February and October 2017 and is based on the conditions encountered and the information available during the said period of time. The scope of this Report and the services are accordingly factually limited by these circumstances.

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Executive summary

AECOM has been commissioned to demonstrate the resilience or vulnerability of Portsmouth Water's single WRZ to drought, based on the approach outlined in the Environment Agency's *Understanding the performance of water supply systems during mild to extreme droughts* (December 2015).

A total of 320 different series of synthetic drought profiles of groundwater level have been created within an existing lumped parameter model for the Idsworth Well (the key observation borehole within the Portsmouth Water area) using stochastically generated climate data for the Portsmouth area. The synthetic groundwater levels and model statistics have been run through the drought scenario testing WRZ model, along with Deployable Output (DO) profiles, demand profiles, allowances for headroom, outage and climate change impacts, and predicted impacts of drought permits and demand restrictions. The output of the analysis is the unfulfilled demand (%) for each drought profile.

The drought scenario testing has been undertaken using a set of conservative and best case DO values i.e. with or without a simultaneous groundwater and surface water drought. The modelling has demonstrated that the Portsmouth Water WRZ (with the drought plan in place) is largely resilient to historic droughts as well as plausible droughts worse than those in the historic record (including beyond a 1 in 200 year condition). The exception is for a conservative DO scenario (combined groundwater and surface water drought) where there is potential for vulnerability to a 6 month drought event with 70-80% rainfall deficit (return period greater than around a 1 in 50 year event).

1 Introduction

1.1 Background

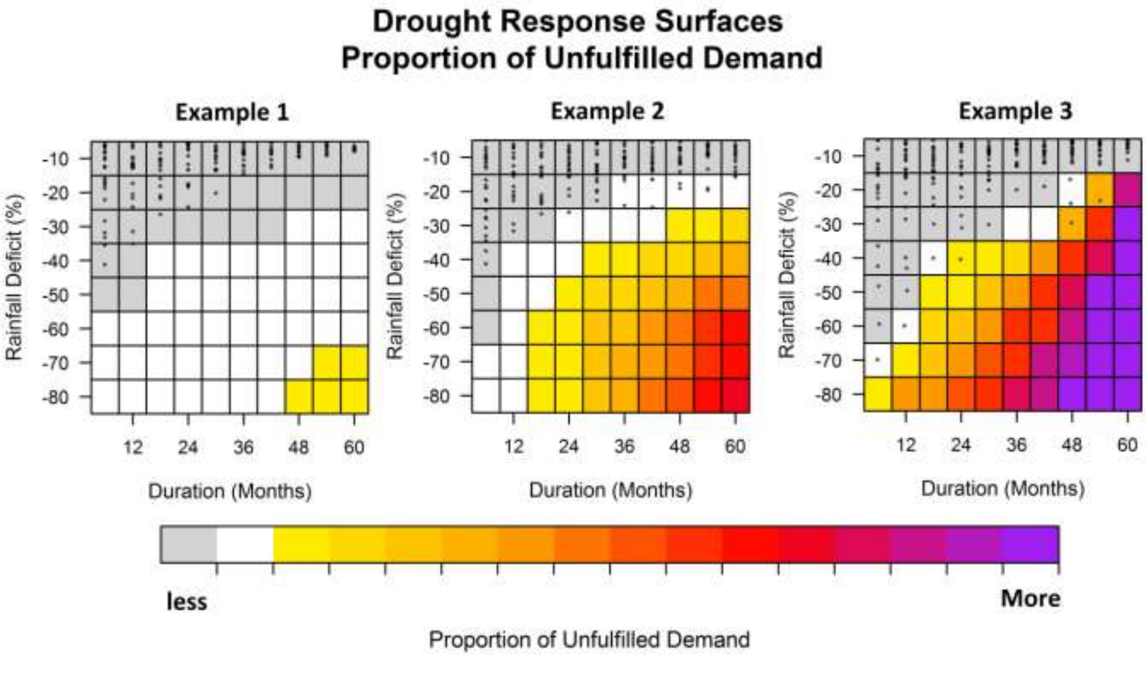
AECOM is working with Portsmouth Water on the reassessment of deployable output (DO) for inclusion in the draft Water Resources Management Plan (dWRMP) 2019 submission. For this reassessment, AECOM has identified the impact of plausible droughts on Water Resource Zone (WRZ) DO using stochastically generated weather outputs within a resource zone model. Additionally, Portsmouth Water has previously tested its Drought Plan against drought scenarios that could occur within its supply area based on historic events; these include single season, multiple season and severe droughts.

The Environment Agency's *Water Resources Planning Guideline* (WRPG) (April 2017) has suggested that further resilience testing might be undertaken based on its study '*Understanding the performance of water supply systems during mild to extreme droughts'* (Environment Agency, December 2015). Further background on this study is provided below.

1.2 Environment Agency drought resilience study

An approach to analysing and understanding overall vulnerability and resilience within supply systems is outlined in the Environment Agency's *Understanding the performance of water supply systems during mild to extreme droughts* (December 2015). This study looked at drought duration, rainfall deficit and system performance to display the overall resilience of a supply system. Historic rainfall from a known period or from simulated plausible droughts is overlain on the graphs below to illustrate the response of the supply system to these events in terms of unfulfilled demand.

Figure 1-1 Example graphic from the Environment Agency's *Understanding the performance of water supply systems during mild to extreme droughts*



Where historic rainfall or simulated plausible droughts occur with acceptable levels of unfulfilled demand, as in Example 1 above, this can be used to demonstrate existing high resilience at and beyond the events demonstrated in the WRMP supply-demand balance tables. This reduces the need for further in-depth analyses. Where historic rainfall or simulated plausible droughts occur with unacceptable levels of unfulfilled demand, as in Example 3 above, this can indicate the need for further resilience options to be considered.

The Environment Agency's approach involves 'stress testing' of the water supply system against drought scenarios of different character (e.g. droughts of different duration and/ or rainfall deficit) to improve the understanding of the systems sensitivity to drought. The resulting drought sensitivity framework could be used as an options appraisal tool to look at the benefits of the drought management options, or to assess the impact of infrastructure changes or licence sustainability reductions on drought resilience.

1.3 The current report

AECOM has been commissioned to demonstrate the resilience or vulnerability of Portsmouth Water's single WRZ to drought, based on the Environment Agency approach.

This report presents the methodology used to assess the vulnerability or resilience of the single company-wide WRZ operated by Portsmouth Water to different drought scenarios and its response to various drought management actions that would be implemented by Portsmouth Water. Further background to Portsmouth Water's WRZ is provided in the next section.

2 The Portsmouth Water Resource Zone

The Portsmouth Water WRZ includes parts of South East Hampshire and West Sussex. The company operates nineteen Chalk groundwater sources, the Havant and Bedhampton springs source and the Gater's Mill (River Itchen) surface water source. The Portsmouth Water WRZ is illustrated in Figure 2-1 and further details of the sources are provided in Table 2-1.

Figure 2-1 Location map

Table 2-1 Portsmouth Water sources

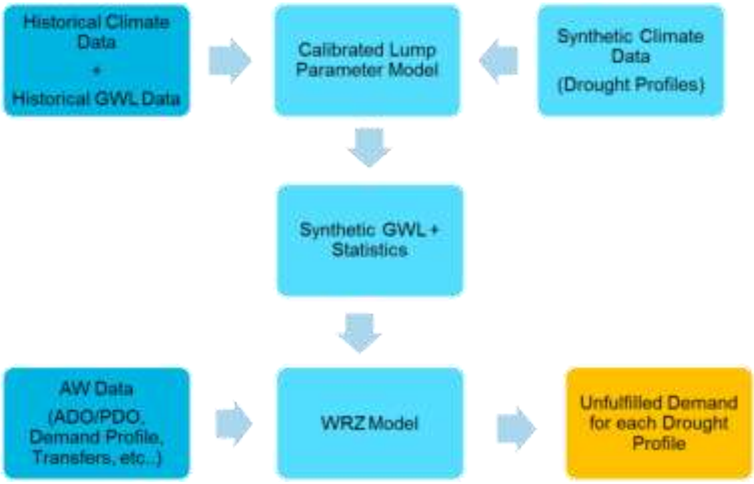
Source Name	Licence		Aquifer/ River
Source T	10/41/542108	Group Licence	Chalk aquifer
Source Q			
Source S			
Source R			
Source M	10/41/522002	Group Licence	
Source L			
Source P	10/41/521502		
Source O	10/41/521301		
Source N	SO/041/0027/004		
Source U	10/41/520101		
Source D	11/42/25.2/50	Group Licence	
Source C			
Source G	11/42/28.3/15	Group Licence	
Source F			
Source K	11/42/33.1/001		
Source I	11/42/33.9/020		
Source E	11/42/28.3/14		
Source H	11/42/28.3/44		
Source J	11/42/33.6/010		
Source B	11/42/36.2/001		
Source A	11/42/22.1/134		River

3 Methodology

3.1 Introduction

The methodology for the drought scenario testing is summarised in Figure 3-1 below. A lumped parameter model is developed for the key observation borehole within the Portsmouth Water area (Idsworth Well) and calibrated using historical climate data and observed groundwater level data. The lumped parameter model is then used to create a total of 320 different series of synthetic drought profiles of groundwater level using stochastically generated climate data for the Portsmouth area. The synthetic groundwater levels and model statistics are ran through the resource zone model, along with Average demand Deployable Output (ADO) and Peak demand Deployable Output (PDO) drought profiles for groundwater and surface water sources, demand profiles and details of drought permits and demand restrictions. The output of the analysis is the unfulfilled demand (% and Ml) and deficit days (no. of days and %) for each drought profile.

Figure 3-1 Drought scenario testing methodology



The development of the lumped parameter groundwater models is described in Section 3.2. Further information on the climate data is provided in Section 3.3.

3.2 Development of lumped parameter model

A lumped parameter model is a spreadsheet-based model that predicts regional groundwater level from rainfall and Potential Evapotranspiration (PET) data, taking into account soil moisture deficit, percolation and potential recharge delays. A lumped parameter model was developed for the Idsworth Well as part of the DO reassessment work (AECOM, October 2017). The input data were daily rainfall and PET data for the Wallington Catchment. The data for the period 1880 to 2005 was derived from the Environment Agency's *Reliability of Public Water Supplies Project* undertaken by URS (July 2011). The climate dataset was subsequently extended from 2005 to 2011 by HR Wallingford, using GEAR daily rainfall and the temperature based Oudin method for PET.

The model was calibrated by visual inspection of the simulated groundwater levels against observed groundwater levels (Appendix A).

3.3 Development of synthetic time series data and drought scenarios

3.3.1 Synthetic climate data

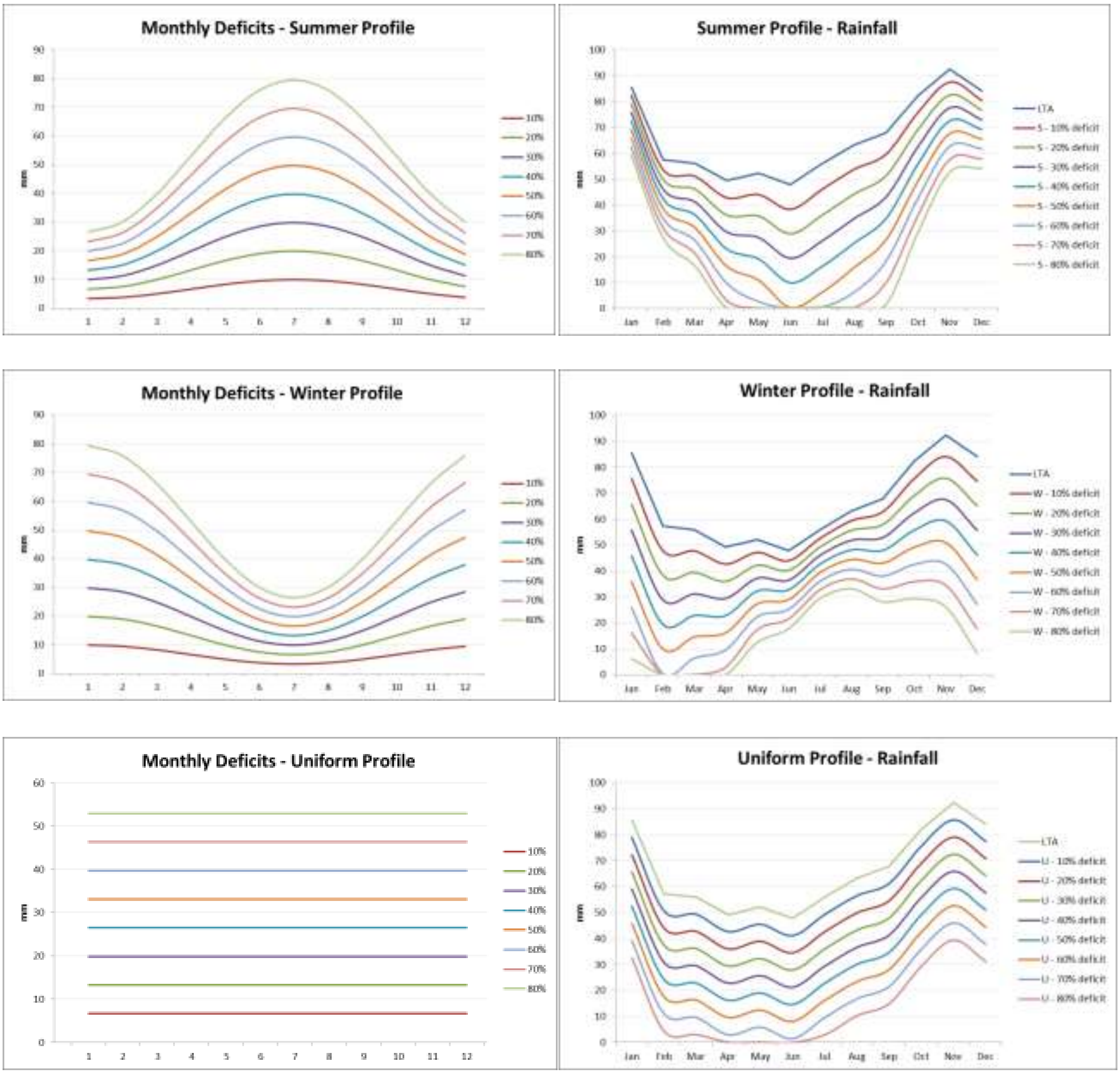
The drought sensitivity framework used a matrix of rainfall deficit duration and intensities as per the guidelines (Environment Agency, December 2015), where durations are on 6 month increments between 6 months and 5 years, and intensities range between -10% and -80% of the Long Term Average (LTA) rainfall. The LTA values are based on stochastic data developed for Portsmouth Water (originally provided by the Water Resources in the South East group).

The rainfall and PET series were developed by resampling months in the stochastic data where rainfall intensity was closest to the planned intensity profile. In addition, seasonality was tested by imposing drought starts either in April or in October and two drought profiles where the deficits are uniform or seasonal i.e. with deficit concentrated in winter or summer. Therefore a total of four different drought profiles exist, each containing 80 different rainfall and PET scenarios with daily values. The following conditions are applied to the four different drought profiles:

- October Profile: October start with uniform rainfall deficits and with PET always equal to 100% LTA;
- April Profile: April start with uniform rainfall deficits and PET always equal to 100% LTA;
- Winter Profile: October start with rainfall deficits concentrated in winter and PET always equal to 100% LTA; and
- Summer Profile: April start with rainfall deficits concentrated in summer and PET always equals to 120% LTA.

The synthetic rainfall and PET values used in the above profiles are presented in Appendix B. The seasonal deficits are calculated using a cosine function as described in the Agency's *Understanding the performance of water supply systems during mild to extreme droughts* (Environment Agency, December 2015). Figure 3-2 below presents the Portsmouth Water synthetic seasonal monthly rainfall, opposed to the monthly rainfall for the uniform profile.

Figure 3-2 Rainfall Profiles



Each drought scenario is inserted within a longer time series of synthetic climate data, resulting in 30 years of data in total; a 10 year run-in that provides similar initial conditions before each drought scenario, followed by the drought scenario varying from 6 months to 5 years length, and then a recovery period of at least 15 years. Each period is characterised by specific rainfall and PET intensities (daily values). The run-in and recovery periods assume rainfall and PET are equal to their respective 100% LTA.

3.3.2 Regional groundwater level time series data

The 30 year periods of synthetic climate data described above were imported into the Idsworth Well calibrated lumped parameter model to create the associated simulated groundwater levels for use in the drought scenario testing WRZ model. Each of the four drought profiles has 80 different rainfall and PET scenarios, and there is a corresponding groundwater level time series for each of these scenarios. The daily groundwater levels were then converted to minimal monthly values to be inserted in the WRZ model.

The first 10 years of the groundwater level series were not imported in the WRZ model as they are only a warm up period necessary to obtain similar initial conditions prior to the drought period.

3.4 Water available for use and headroom

3.4.1 Deployable output values

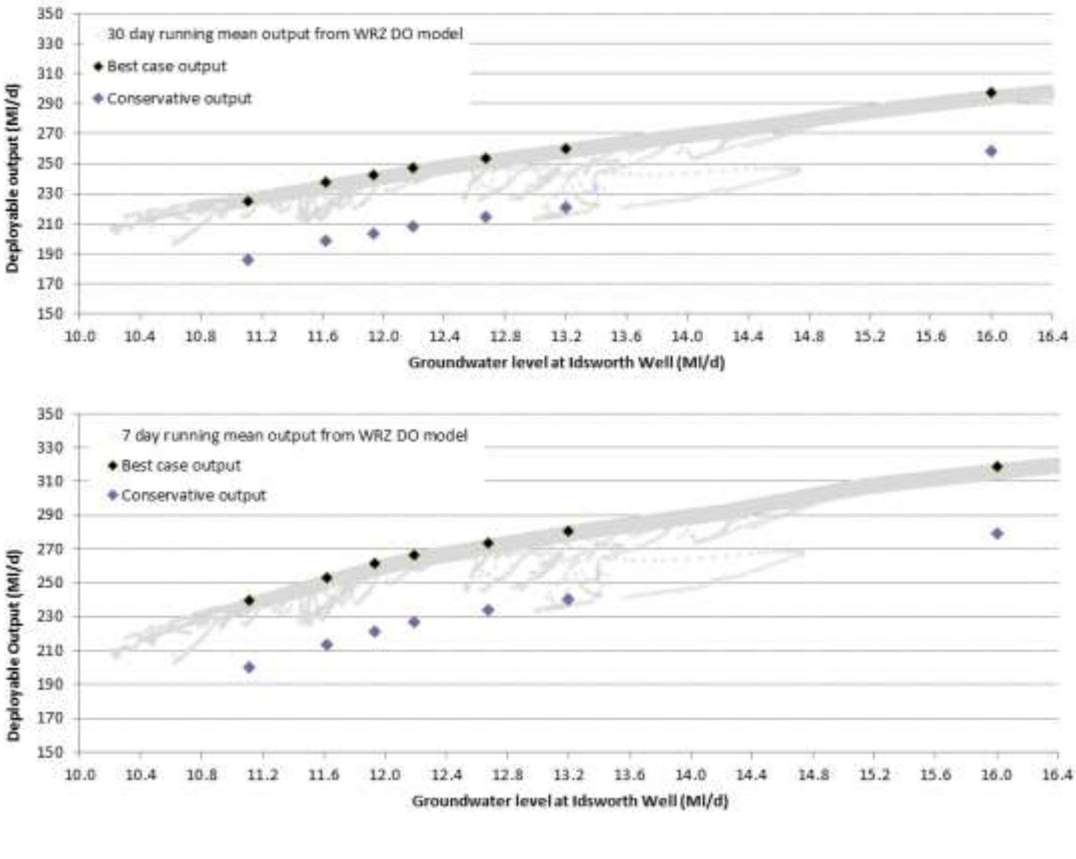
The WRZ DO model from the dWRMP19 DO assessment (not the drought scenario testing WRZ model used for the current assessment) was used to establish a relationship between groundwater levels and DO values; this model is described in AECOM (October 2017). The outputs in Figure 3-3 (grey dots) are representative of a WRZ DO model run where the simulated demand was similar to the average demand used within the drought resilience WRZ model (around 171 Ml/d).

The WRZ DO is impacted by the combined resource availability at Gaters Mill, Havant and Bedhampton springs and groundwater sources in a given year. In drought years, the combined resource availability will depend on whether the drought condition affects surface or groundwater, or both. This variability is reflected in the range of modelled WRZ DO values for each groundwater level (see the grey dots on Figure 3-3).

In order to account for the possible range of DO values for each groundwater level, a set of conservative values and best case values were estimated. The set of best case values are representative of the maximum DO values output by the resource zone model, whilst the set of conservative values are representative of minimum DO values (see Figure 3-3). The conservative values include the effect of a surface water drought coinciding with a groundwater drought.

Recent communications with Southern Water indicate that the dry weather flow for Chickenhall Sewage Treatment Works may be lower than currently assumed by the DO assessment for Portsmouth Water (Pers. Comms. Paul Sansby, Portsmouth Water, October 2017); it is expected that, overall, this may push the DO versus groundwater level relationship closer to the conservative values on Figure 3-3 under drought conditions.

Figure 3-3 Estimation of DO rates for specific groundwater levels



3.4.2 Outage, climate change impacts and headroom assumptions

The Environment Agency's methodology examines system performance against droughts of varying duration and intensity. System performance is ascertained by looking at the impact of drought on DO. However the use of DO values will overestimate the Water Available For Use (WAFU), as it does not take account of outage and the impact of climate change on DO, or target headroom. Therefore the dWRMP19 values have been included in the model runs, as follows:

- Target headroom: 18.11Ml/d for Dry Year Annual Average scenario (DYAA) based on ADO; and 20.55Ml/d for Dry Year Critical Period (DYCP) based on PDO. These values are for the 95% probability in the year 2020.
- Outage allowance: 14.7Ml/d for DYAA; and 12.5Ml/d for DYCP. These values are for the 95% probability.
- Climate change impact: -1Ml/d for DYAA; and -2.5Ml/d for DYCP. These values are for the central estimate or 'most likely' scenario in the year 2020.

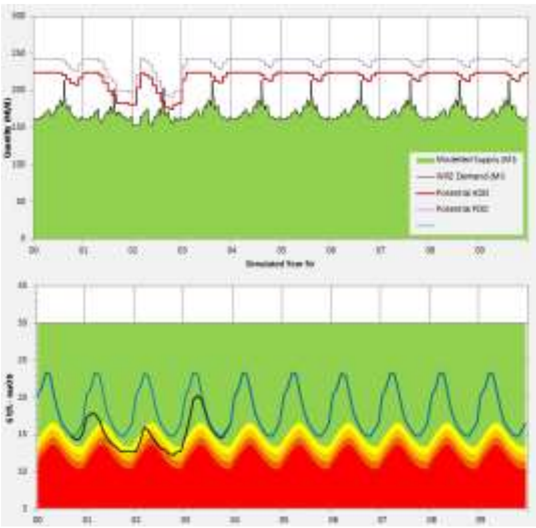
3.5 Development of a water resource zone model to identify drought sensitivity

For the drought scenario testing, a bespoke model for the Portsmouth WRZ has been set up to include the following data inputs:

- 80 sets of synthetic groundwater level time series data (drought profiles);
- 30 day running mean and 7day running mean DO profiles for each groundwater and surface water source in the WRZ, demonstrating drought sensitivity. These values were reviewed and updated by AECOM as part of their DO assessment work for dWRMP19. Where a drought scenario results in a groundwater level that is beyond that for which DOs have been assessed, the DO with groundwater level relationship is extrapolated in the model.
- A typical demand profile. The demand data were provided by Portsmouth Water based on their modelling derived from 2015/2016 data.
- The WRZ model does not take account of Portsmouth Water's bulk transfer arrangement with Southern Water. The bulk supply has been excluded from this testing as it may not be possible to export water during a severe drought.
- Assumed percentage (%) reductions in demand and mega litre per day (Ml/d) increases in supply from the implementation of drought management activities (demand restrictions and supply side permits and orders). These were provided by Portsmouth Water and the trigger levels are set to reflect those in Portsmouth Water's 2013 Drought Plan.

For each monthly time step the model assigns a drought condition to the corresponding simulated groundwater level, based on the previous analysis of the modelled historic groundwater level from the WRZ lumped parameter model. The 30 day running mean and seven day running mean WRZ DO for that drought condition is then used to represent the available supply on a time step basis (following reductions associated with headroom, outage and climate change impacts). The available supply (with or without supply side drought permits and orders) is then compared to the demand profile (with or without the impact of demand restrictions) to calculate the proportion of unfulfilled demand. An example screen shot from the model is provided in Figure 3-4.

Figure 3-4 Example screen shot from the drought scenario testing WRZ model



30 day running mean and 7 day running mean available supply (red and mauve lines) and the modelled demand / supply (black line / green area).

Average groundwater levels (blue line), simulated drought (black line) and drought plan triggers.

Further information on the inclusion of drought management activities is provided below.

3.6 Drought trigger levels and the impact of drought management activities

When drought conditions begin, Portsmouth Water will implement its Drought Plan. This results in a steady escalation of restrictions on the demand for water, from Temporary Use Bans (TUBs) such as bans on the use of hosepipes / sprinklers, to Non-Essential Use Bans (NEUBs, also referred to as ordinary drought orders) that may start to impact businesses in the local area; as a last resort, water companies may also ask for emergency drought orders (e.g. use of standpipes and rota cuts to reduce the demand for water), although these are part of the Emergency Plan and not the Drought Plan. Portsmouth Water has agreed with its customers the frequency at which demand restrictions might need to be implemented (e.g. once every 20 years for TUBs, once every 80 years for ordinary drought orders and once every 300 years for emergency drought orders), known as 'Levels of Service' (LoS).

Additionally the Drought Plan contains supply-side measures to increase the available volume of water. This includes an increase in the licensed abstraction rate at the Slindon groundwater source from 2.5Ml/d to 11.5Ml/d.

Drought trigger groundwater levels have been defined by Portsmouth Water in their 2013 Drought Plan and are presented in Table 3-1 and Figure 3-5. These levels have been calculated by Portsmouth Water using historical information for the last 75 years and the demand and supply side actions have been defined in their 2013 Drought Plan.

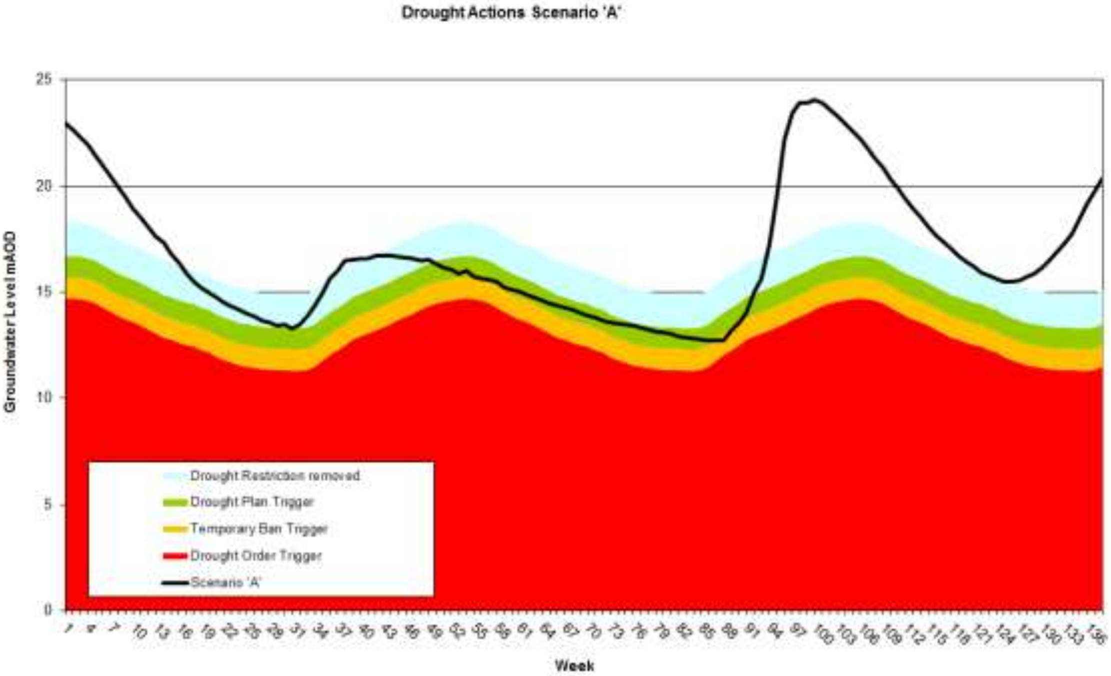
The savings being modelled are for the annual average scenario; whilst the actions are likely to have a greater impact on peak demand, this complexity is not currently modelled; although the savings are conservative, they are reasonable when compared with summarised data for water companies in England (AECOM, April 2015).

Table 3-1 Portsmouth Water drought trigger levels and assumptions for modelling

Trigger level name	Description of trigger	Demand side actions	Supply side actions
Drought Restrictions Removed	Groundwater levels in non-drought or 'dry' year. Set 1.6m above the Drought Plan Zone.	Drought Restriction Removed.	-
Drought Plan Zone	Groundwater levels set 1m above the Temporary Ban Zone trigger level; expected to be reached in the first year of drought.	Drought Plan Trigger - initiate media campaign and increase water efficiency messaging whilst asking for voluntary reductions in usage and enhanced leakage.	-
Temporary Ban Zone	Groundwater levels assumed to occur in a 1 in 20 year drought event and set 1m above the Drought Order Zone; expected to occur in the second year of a drought.	Temporary Use Ban Trigger – assume a **5%** reduction in demand in the model.	-
Drought Order Zone	Groundwater levels assumed to occur in a 1 in 80 year drought event.	Ordinary Drought Order Trigger – assume a **7%** reduction in demand in the model.	Additional abstraction as a result of implementing a Drought Permit; 9Ml/d licence uplift at Slindon; however source output is constrained to **6.5Ml/d** by operational pump capacity.
Emergency Plan	Groundwater levels assumed to occur in a greater than 1 in 300 year drought event.	Emergency Drought Order Trigger – the demand reduction may be around 27% of demand*. However for the purpose of the current modelling, the maximum demand reduction remains at **7%**.	Additional abstraction as a result of issuing a Drought Order (see above). Further additional abstraction available but quantity not known and not considered in model.

*Demand reductions include the impact of implementing Emergency Drought Orders. These are not considered to be within the remit of the Portsmouth Water Drought Plan and instead would be implemented following the enactment of the Portsmouth Water Emergency Plan, as a drought of this level of severity would be classified as a civil emergency.

Figure 3-5 Portsmouth Water drought triggers



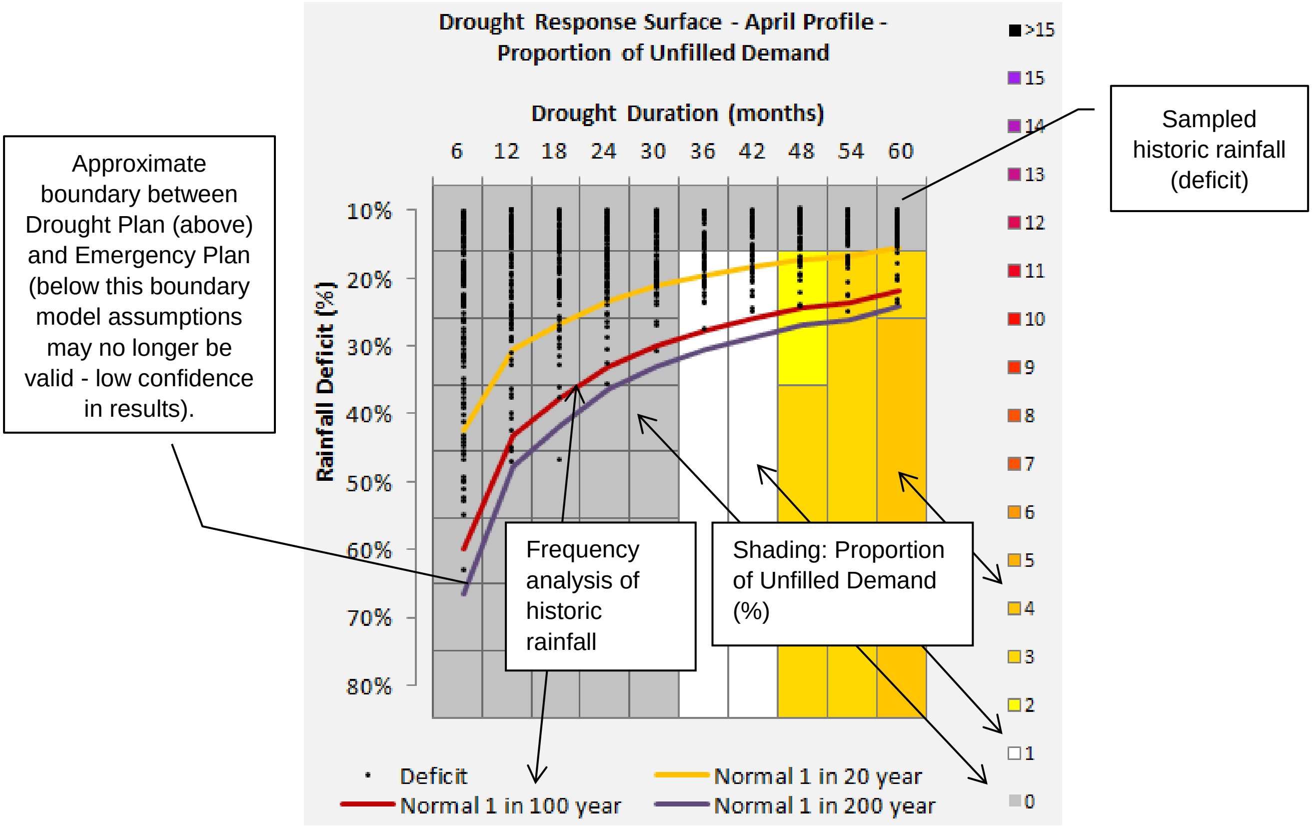
3.7 Presentation of model results

The presentation of results is aimed at achieving a similar presentation to that used within *Understanding the performance of water supply systems during mild to extreme drought*s (Environment Agency, 2015). The results from the drought scenario testing provide three dimensions of information: drought duration, drought intensity and system performance. The results are presented on a drought 'matrix' displaying the drought characteristics of duration on the x-axis and intensity (rainfall deficit with respect to LTA rainfall) on the y-axis, with the proportion of unfulfilled demand represented by coloured squares (expressed as a percentage). A different drought matrix is provided for each modelled drought profile; Summer, Winter, April and October.

In order to provide some context to the drought scenarios, historical rainfall data have been analysed to calculate the same drought characteristics as those described above. The resulting points have been plotted onto the drought matrices and an example presentation is shown in Figure 3-6. Return periods from a frequency analysis of the Wallington rainfall data are also shown on Figure 3-6 to help demonstrate that parts of the presentation matrix represent conditions that are significantly more severe than the climate conditions experienced between 1880 and 2011 (the zone beyond the historic data and the 1 in 200 year return period line); in this zone the assumptions in the model may no longer be valid owing to a lack of experience with this level of drought severity, although these conditions would be dealt with via emergency planning and not the drought plan. Therefore the aim is to demonstrate that the resource zone is at least resilient to the rainfall deficits observed in the historic rainfall record.

The results of the testing are presented in Section 4.

Figure 3-6 Example matrix presentation



4 Results and assumptions

4.1 Introduction

This section presents the drought response surfaces for the Portsmouth Water WRZ according to the four different drought profiles (summer, winter, October and April). Four scenarios have been explored to (i) reflect the variability in available supply within a combined surface water and groundwater system (i.e. the best case and conservative DO scenarios) and (ii) understand the impact of drought management activities:

- Results without drought management activities and a conservative DO versus groundwater level relationship (see Section 4.2). These results demonstrate the drought resilience of the WRZ when drought management activities such as demand restrictions and drought permits are not implemented. It does not reflect how the WRZ is operated, although it helps to demonstrate the impact of management activities.
- Results without drought management activities and a best case DO versus groundwater level relationship.
- Results with drought management activities and a conservative DO versus groundwater level relationship (see Section 4.3). These results demonstrate the drought resilience of the WRZ when taking into account the implementation of demand restrictions and drought permits according to the Portsmouth Water 2013 Drought Plan.
- Results with drought management activities and a best case DO versus groundwater level relationship.

A brief description of the results and is provided in the sections below.

4.2 Results without drought management activities

The results from the runs without drought management activities are illustrated in Figure 4-1.

The results for the conservative DO run demonstrate that for most of the historic drought scenarios (where the black dots occur on the matrix), the WRZ can meet demand, as indicated by the grey areas on the matrix. However there is a small amount of unfulfilled demand, as indicated by the white areas on the matrix, and therefore some vulnerability to drought within the Portsmouth Water WRZ to severe drought events (and greater than a 1 in 20 year return period). The unfulfilled demand within the range of historic droughts is highest for the 6 month drought event with 70-80% rainfall deficit under the Winter and October profiles.

The results from the best case DO run demonstrate that the Portsmouth Water WRZ is mostly resilient to historic droughts as well as plausible droughts worse than those in the historic record. The exception is the 6 month drought event with 70-80% rainfall deficit under the Winter and October profiles where the unfulfilled demand for the scenario is between 0% and 1%.

4.3 Results with drought management activities

The results from the runs with the implementation of drought management actions are illustrated in Figure 4-2.

The results for the conservative DO run with drought management activities demonstrate that the Portsmouth Water WRZ is largely resilient to droughts more severe than a 1 in 200 year condition. The exception is the 6 month drought event with 70-80% rainfall deficit on the Winter and October profiles, where there is potential for vulnerability to droughts with a return period of around 1 in 50 years. Note this scenario assumes that extreme surface water and groundwater droughts occur simultaneously.

The results for the best case DO with drought management activities demonstrate that the Portsmouth Water WRZ is resilient to historic droughts as well as plausible droughts worse than those in the historic record (including beyond a 1 in 200 year condition). This scenario assumes that an extreme surface water and groundwater drought do not occur simultaneously (i.e. the Gater's Mill abstraction on the River Itchen is not adversely impacted by drought).

Note that emergency plan measures have not been included in these scenarios i.e. the impact of standpipes and rota cuts. These would further reduce the magnitude of the deficits in the bottom right corner of the matrices.

Figure 4-1 Unfulfilled demand with no drought management activities

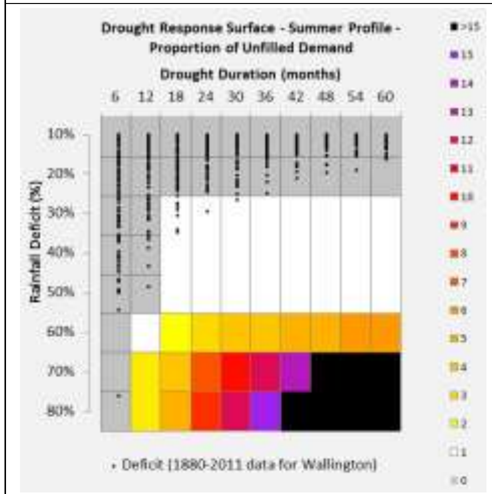
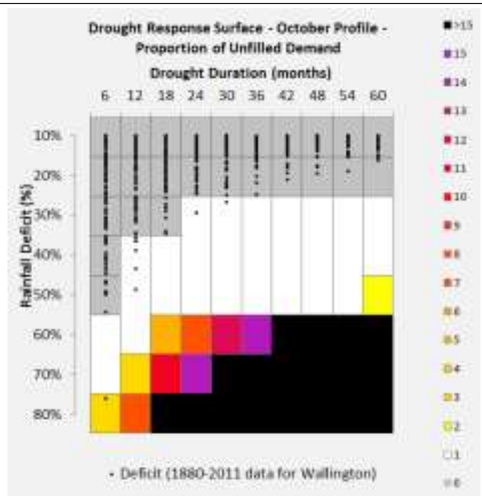
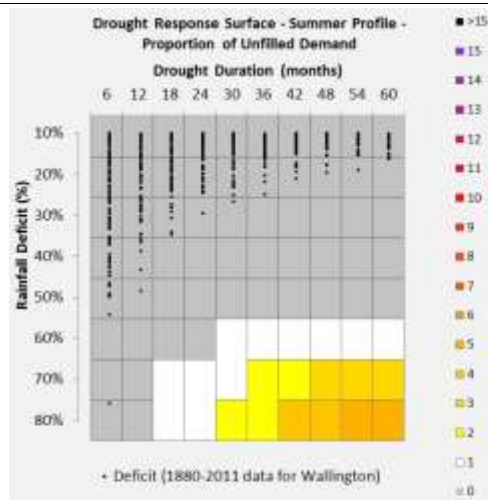
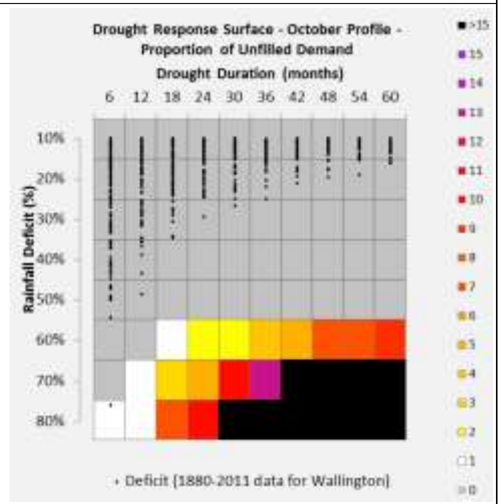
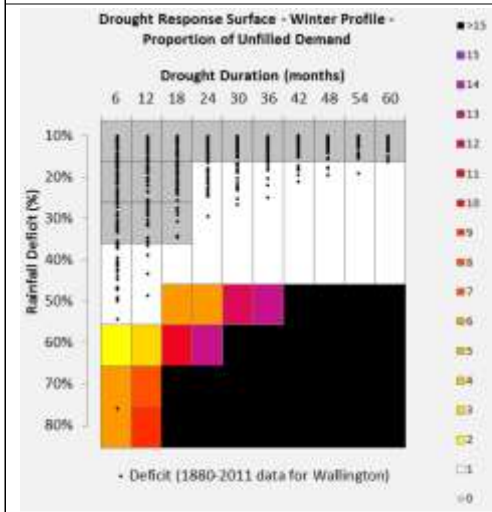
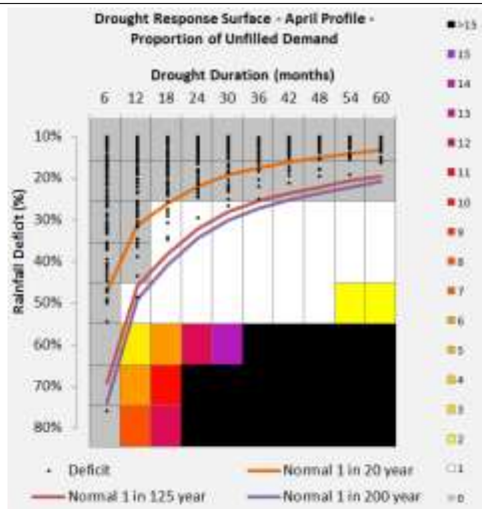
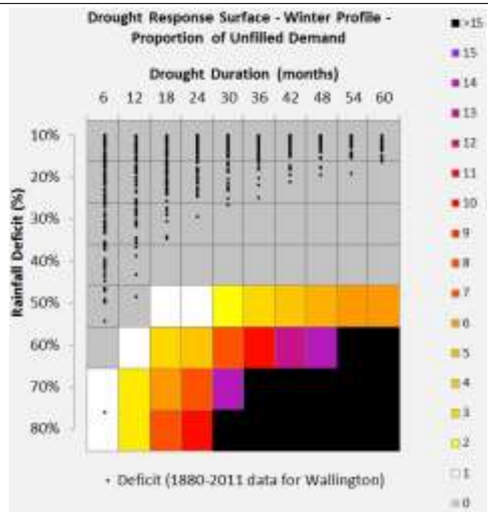
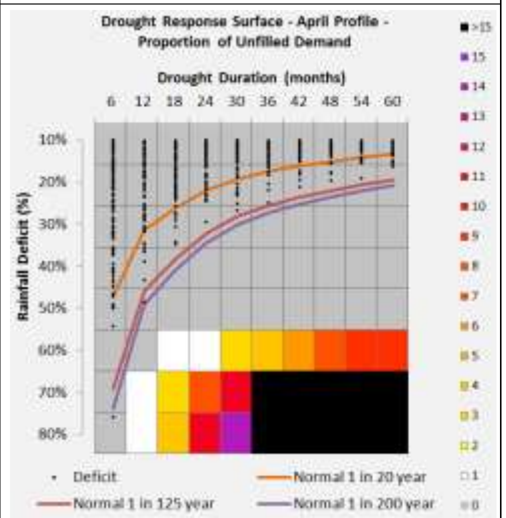
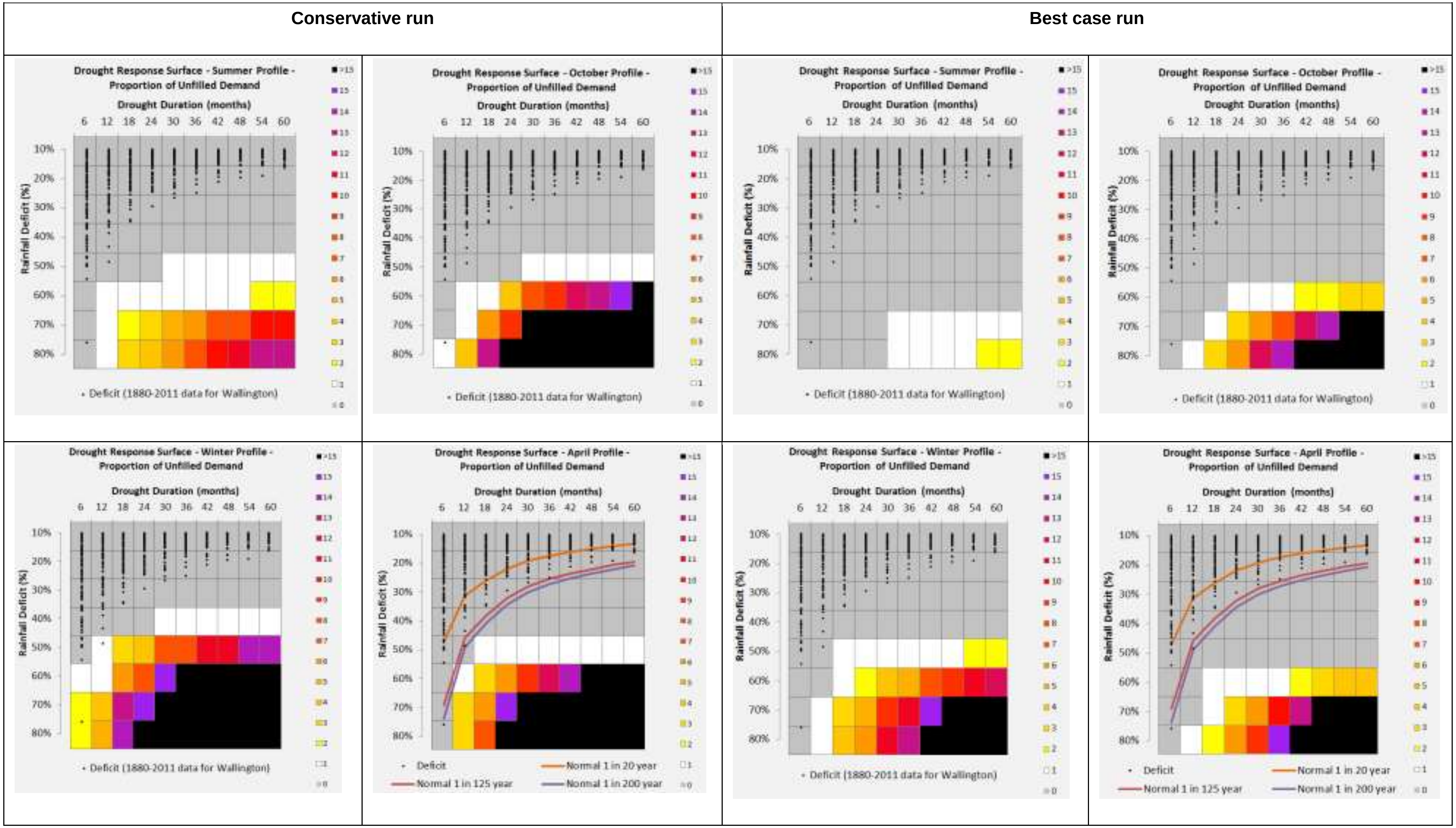
Conservative run		Best case run	
			
			

Figure 4-2 Unfulfilled demand with drought management activities



4.4 Key limitations and assumptions

There are a number of important limitations associated with the modelling and results presented within this report. These are described below and should be taken into consideration when interpreting the outputs:

- The WRZ model is based in Microsoft Excel and used for a high level strategic assessment. It is not as sophisticated as models developed in Miser and Aquator water resources software (for example). This limitation may hide localised distribution issues.
- The impact of drought on DO is extrapolated where the drought is extreme i.e. beyond the drought plan and into emergency conditions. There is significant uncertainty around the DO values under these extreme droughts and it is uncertain if the extrapolation overestimates or underestimates the available supplies.

The conclusions and recommendations of this assessment are provided in the next section.

5 Conclusions & recommendations

5.1 Conclusions

Portsmouth Water is currently developing a new Drought Plan for consultation. Drought scenario testing has been undertaken for the company region in line with regulator guidelines. The drought sensitivity framework uses a matrix of rainfall deficit duration and intensities, where durations are on 6 month increments between 6 months and 5 years, and intensities range between -10% and -80% of the Long Term Average (LTA) rainfall. The results of the modelling demonstrate the degree to which the Portsmouth Water supply area is resilient to historic droughts as well as plausible droughts worse than those in the historic record.

The drought scenario testing has provided some useful high level outputs and an understanding of Portsmouth Water's resilience to various drought severities and durations. However it is important that the limitations of the modelling outlined in this report are considered when interpreting the results. In particular, the squares in the results matrices that are below the historic data and 1 in 200 year event line represent conditions worse than those covered by the Drought Plan; these droughts are likely to fall within the remit of the Emergency Plan and the assumptions within the models may no longer be valid.

The drought scenario testing has been undertaken using a set of conservative and best case DO values i.e. with or without a combined groundwater and surface water drought. The modelling demonstrates that for a conservative DO run (simultaneous groundwater and surface water drought) there could be vulnerability to a 6 month drought event with 70-80% rainfall deficit on the Winter and October profiles (return periods greater than around a 1 in 50 year event). Otherwise the resource zone (with the drought plan in place) is resilient to droughts with a return period greater than the 1 in 200 year condition.

For the best case DO run (only a groundwater drought), the modelling demonstrates that the Portsmouth Water WRZ (with the drought plan in place) is resilient to historic droughts as well as plausible droughts worse than those in the historic record (including beyond a 1 in 200 year condition).

The scenarios described above include a headroom allowance, outage allowance and climate change impacts in line with the draft Water Resource Management Plan 2019.

5.2 Recommendations

The recommendations from this study are as follows:

- It would be useful to re-run the models to include DO values from proposed key WRMP options; this will help to understand how options may improve resilience to drought.
- Further sensitivity testing may be appropriate e.g. testing of alternative drought management trigger levels.
- The DO of the Gater's Mill surface water abstraction should be reassessed once further information on the dry weather flow of Chickenhall sewage treatment works is obtained.
- Given the assessed impact of combined surface water and groundwater droughts on DO, it is recommended that the River Itchen flow is considered for inclusion as a trigger in future drought plans.

6 References

AECOM (October 2017), *Deployable Output Assessment*

AECOM (October 2017), *Target Headroom Assessment Report*

AECOM (September 2017), *Outage Allowance Report*

AECOM (April 2015), *Annex A: Water Availability Assessment, Strategic Water Infrastructure and Resilience, Final Report*. Environment Agency

Environment Agency (April 2017), *Water Resources Planning Guideline: Interim update*

Environment Agency (December 2015), *Understanding the performance of water supply systems during mild to extreme droughts*.

Portsmouth Water (2013). *Final Drought Plan*.

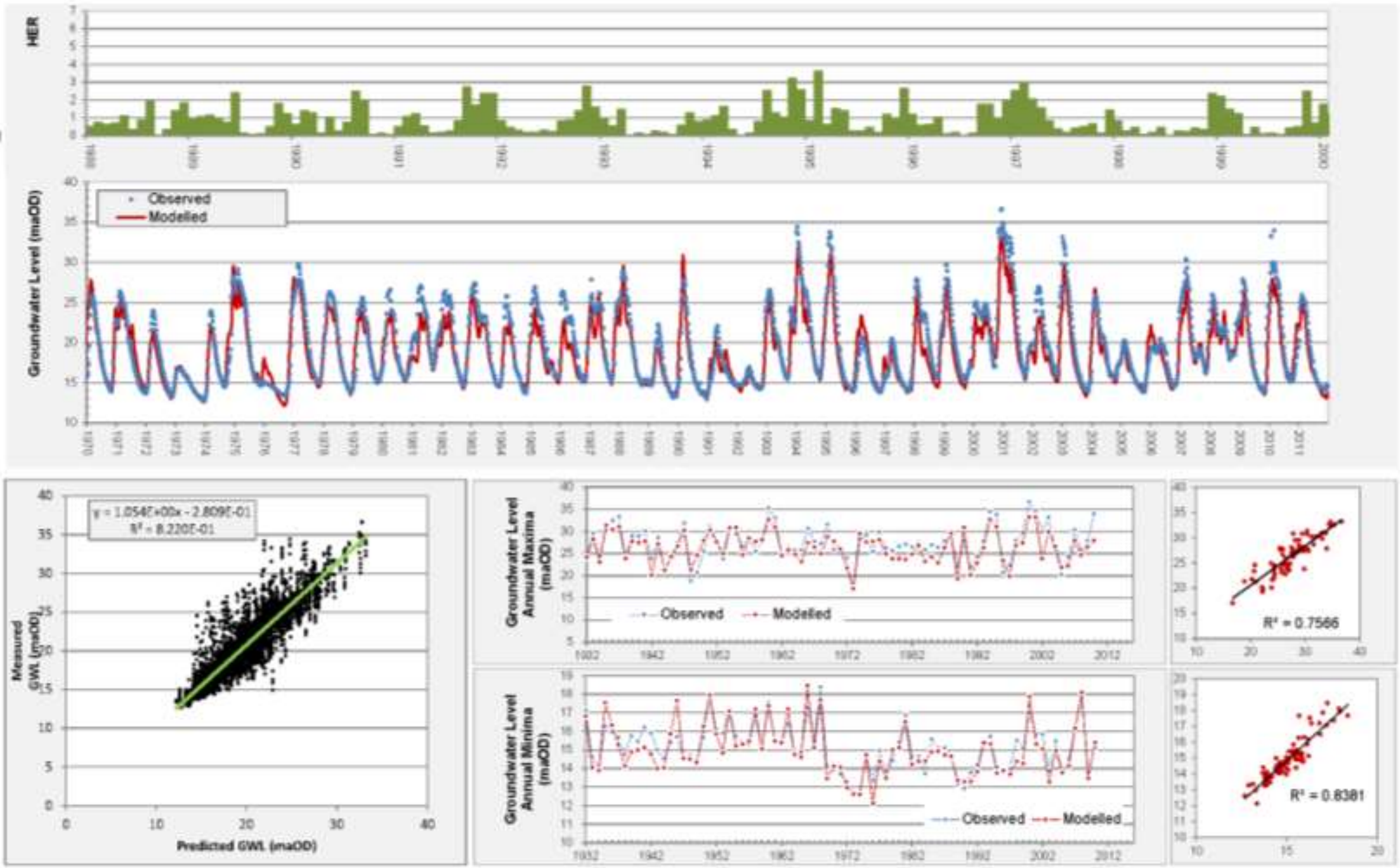
URS (July 2011). *Reliability of Public Water Supplies Project*. Environment Agency.

Appendix A. Lumped parameter model for Idsworth Well

2017 Drought Scenario Testing

Lumped parameter model for Idsworth Well observation borehole

Appendix A



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Appendix B.Wallington synthetic rainfall and PET values used in the drought profiles

B.1.1 Baseline Conditions

Rainfall and PET during Baseline Conditions

Month	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
Rainfall (mm)	85.61	57.39	56.06	49.38	52.22	47.83	55.99	63.25	67.92	82.35	92.45	84.23
PET (mm)	15.23	20.75	37.13	52.49	72.91	74.61	80.82	72.34	50.78	35.85	19.59	14.28

B.1.2 Summer Profile

Rainfall during Drought Conditions in the Summer Profile

Deficit	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
10%	82.30	53.64	51.09	42.75	43.94	38.34	46.06	53.76	59.64	75.73	87.48	80.47
20%	78.99	49.89	46.12	36.13	35.66	28.85	36.12	44.27	51.37	69.11	82.51	76.72
30%	75.68	46.13	41.16	29.51	27.38	19.36	26.19	34.78	43.09	62.49	77.55	72.97
40%	72.37	42.38	36.19	22.89	19.11	9.87	16.26	25.29	34.81	55.86	72.58	69.21
50%	69.06	38.62	31.22	16.26	10.83	0.38	6.32	15.80	26.53	49.24	67.61	65.46
60%	65.74	34.87	26.26	9.64	2.55	0.00	0.00	6.31	18.25	42.62	62.65	61.70
70%	62.43	31.11	21.29	3.02	0.00	0.00	0.00	0.00	9.98	36.00	57.68	57.95
80%	59.12	27.36	16.32	0.00	0.00	0.00	0.00	0.00	1.70	29.38	52.71	54.19

Evapotranspiration during Drought Conditions in the Summer Profile

Month	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
PET (mm)	18.28	24.91	44.56	62.99	87.49	89.53	96.98	86.81	60.93	43.03	23.51	17.14

B.1.3 Winter Profile

Rainfall during Drought Conditions in the Winter Profile

Deficit	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
10%	75.68	47.90	47.78	42.75	47.25	44.08	52.68	59.49	62.95	75.73	84.17	74.74
20%	65.74	38.42	39.50	36.13	42.28	40.32	49.37	55.74	57.99	69.11	75.89	65.25
30%	55.81	28.93	31.22	29.51	37.32	36.57	46.06	51.98	53.02	62.49	67.61	55.76
40%	45.88	19.44	22.95	22.89	32.35	32.81	42.75	48.23	48.05	55.86	59.33	46.27
50%	35.94	9.95	14.67	16.26	27.38	29.06	39.43	44.47	43.09	49.24	51.06	36.78
60%	26.01	0.46	6.39	9.64	22.42	25.30	36.12	40.72	38.12	42.62	42.78	27.29
70%	16.08	0.00	0.00	3.02	17.45	21.55	32.81	36.96	33.15	36.00	34.50	17.80
80%	6.14	0.00	0.00	0.00	12.48	17.79	29.50	33.21	28.19	29.38	26.22	8.31

Evapotranspiration during Drought Conditions in the Winter Profile

Month	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
PET (mm)	15.23	20.75	37.13	52.49	72.91	74.61	80.82	72.34	50.78	35.85	19.59	14.28

B.1.4 April and October Profile

Rainfall during Drought Conditions in the April and October Profiles

Deficit	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
10%	78.99	50.77	49.44	42.75	45.59	41.21	49.37	56.62	61.30	75.73	85.82	77.61
20%	72.37	44.15	42.81	36.13	38.97	34.59	42.75	50.00	54.68	69.11	79.20	70.98
30%	65.74	37.53	36.19	29.51	32.35	27.96	36.12	43.38	48.05	62.49	72.58	64.36
40%	59.12	30.91	29.57	22.89	25.73	21.34	29.50	36.76	41.43	55.86	65.96	57.74
50%	52.50	24.28	22.95	16.26	19.11	14.72	22.88	30.13	34.81	49.24	59.33	51.12
60%	45.88	17.66	16.32	9.64	12.48	8.10	16.26	23.51	28.19	42.62	52.71	44.50
70%	39.26	11.04	9.70	3.02	5.86	1.48	9.63	16.89	21.57	36.00	46.09	37.87
80%	32.63	4.42	3.08	0.00	0.00	0.00	3.01	10.27	14.94	29.38	39.47	31.25

Evapotranspiration during Drought Conditions in the April and October Profiles

Month	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec
PET (mm)	15.23	20.75	37.13	52.49	72.91	74.61	80.82	72.34	50.78	35.85	19.59	14.28

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