Analysis of the cost of emergency response options during a drought

Final Report

National Infrastructure Commission

13th March 2018

Contract Ref: CCSN17A26 OFFICIAL

S*ensitive* information redacted

Notice

This document and its contents have been prepared and are intended solely for National Infrastructure Commission 's information and use in relation to their drought research programme and NIC reports. The results should not be used in isolation to highlight potential risks to supply, environmental damages or high costs for water customers. The final results of the broader NIC study will be presented in the National Infrastructure Assessment 2018.

This report was commissioned as part of the evidence base for the National Infrastructure Assessment. The views expressed and recommendations set out in this report are the authors' own and do not necessarily reflect the position of the National Infrastructure Commission.

Document history

Job number: 20172248			**Document ref: 20172248.02**			
Revision	Purpose description	Originated	Checked	Reviewed	Authorised	Date
Rev 0	Draft Final report layout and selected background information	SDW, JP, TH, LP, DH	JP	DH	DH	22/1/18
Rev 1	Draft Final Report to support the peer review process	SDW, JP, TH, LP, DH	SDW	DH/SDW	DH	31/1/18
Rev1.1	Draft Final Report to support peer review. Update of MACC curves to WAFU and ship tanker discussions.	SDW, JP, TH, LP, DH, RS (Vivid)	SDW	DH	DH	6/2/18
Rev 2.0	Final Report following peer review	SDW, JP, TH, LP, DH, RS (Vivid)	SDW	DH	DH	23/2/18
Rev 2.1	Final Report following additional comments	SDW, JP, TH, LP, DH, RS (Vivid)	SDW	DH	DH	13/3/18

Client signoff

Client	National Infrastructure Commission
Project	Analysis of the cost of emergency response options during a drought
Document title	Final Report
Job no.	20172248
Copy no.	
Document reference	20172248.02

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1. Introduction

This is the Final Report for the National Infrastructure Commission (NIC) *'Costs of Emergency Response Options during Severe Drought'* project.

The project aims to build a better understanding of the costs of deploying short term emergency measures during severe droughts to avoid 'Level 4' water supply restrictions, such as stand-pipes and rota cuts[1].

In parallel an NIC research collaboration with Oxford University will provide an analysis of longer term 'drought resilience' measures, such as the construction of new reservoirs and water transfers and major demand management programmes. Both projects adopt similar data sources so that the NIC can complete a final assessment on the costs, risks and trade-offs related to (i) infrastructure development, (ii) the level of 'tolerable' or 'acceptable' risk and (iii) improved drought preparedness and the use of emergency measures.

This project focused on public water supplies and does not consider other sectors, such as agriculture, or any indirect impacts of water supply shortfalls on businesses, river navigation or tourism. The results of this study include projected supply short-falls in severe and extreme droughts and the costs of emergency measures without additional investment in long term water resources options. The project results are an input to the larger national study and should not be used in isolation to highlight potential risks to supply, environmental damages or high costs for water customers. The final results will be presented in the National Infrastructure Assessment 2018.

The report is structured as follows:

- Section 2 provides background information on severe droughts in England and defines the size of potential supply shortfalls due to severe and extreme droughts, with and without consideration of future climate change.
- Section 3 provides an overview of the methodology and information on emergency drought option capacity and costs.
- Section 4 describes the individual emergency drought options and assumptions about their feasibility, lead time, performance and utilisation during drought periods.
- Section 5 presents regional portfolios of drought measures for drought prone regions in England selected based on total costs.
- Section 6 presents the main conclusions from the study, including the costs of maintaining supplies in severe droughts.

Five appendices provide more detailed information on the evidence gathered and analysis completed for this study:

- Appendix A provides a more detailed description on the spreadsheet model developed to estimate option capacity and cost, during severe and extreme droughts.
- Appendix B presents some further information based on Water Company Drought Plans.
- Appendix C provides a review of national level drought and infrastructure costs data in the draft Water Resources Management Plans (dWRMPs), which were submitted to Defra in December 2017.
- Appendix D provides evidence from a review of international examples in Australia and California.
- Appendix E summarises some of the evidence from consultation with industry experts.

[1] It is just one research component of larger assessment, which is being completed by the National Infrastructure Commission to inform the National Infrastructure Assessment 2018. It estimates the water available from emergency drought measures and their costs. It does not complete full supply-demand balances or consider drivers such as population growth, economic growth and water efficiency. These are considered in the overall NIC assessment.

2. Background

2.1. Maintaining public water supplies in England during droughts

2.1.1. The links between water resources planning and drought planning

Water resource management plans (WRMPs) are prepared by all water service providers in England and Wales and take a long-term view (at least 25 years) on how to maintain the balance between water supply and demand[2]. Water company drought plans set out the short-term operational steps that are taken as a drought progresses to enhance available supplies, manage customer demand and minimise environmental impacts.

The WRMPs consider historical droughts and levels of service to customers, which describe the frequency of demand restrictions, such as Temporary Use Bans (TUBs) (formerly hosepipe bans), Non-Essential Use Bans (NEUBs) and potential sources of supply through Drought Orders and Permits. More severe demand restrictions such as stand-pipes and rota cuts are considered unacceptable by most water companies, their customers and by Government due to the serious consequences on the UK economy. Building resilience in the water supply can be achieved through a combination of:

- Long term planning (WRMPs) that considers a range of plausible but more extreme droughts and puts demand management and new supply infrastructure in place to maintain supplies during these droughts. Most dWRMPs provide resilience to drought with an annual probability of 0.5%, therefore protecting customers from the most extreme demand restrictions.

- Improved drought preparedness, management and recovery as set out in Drought Plans, that considers the same drought scenarios but relies more heavily on short term measures to maintain supplies.

- Improved system resilience, which includes improvements to water supply networks, water treatment works, potable and raw water transfer capacities, which may introduce greater flexibility and make it easier to implement drought emergency options as and when needed[3].

Resilience duties as laid out in the Water Act (2010) mean that water companies must put plans in place to deal with more extreme events and maintain supplies. However, the development of major infrastructure projects to deal with infrequent events is very expensive, with subsequent impacts on customer bills. In addition, such expenditure cannot always be justified through the standard water resources planning process and could be a special case (and subject to customer and Ofwat approval) in any water company Business Plan.

The right balance between the above approaches depends on a range of factors, including the relative costs, the internal business case, reliability and lead time for implementation of drought emergency measures, environmental risks and consequences of disruptions in supply.

2.1.2. The risk of water resources drought in England

According to a recent Water UK study, the current situation (pre- 2019 plans and *without* further investment) is that around one third of companies can maintain supplies during severe droughts by implementing their Drought Plans, others would find it difficult to maintain supplies and a small number of zones, including London, could have significant deficits and supply problems without investment in supply and demand-side

[2] The duty to prepare and maintain a WRMP is set out in Section 37A-37D of the Water Industry Act 1991.
[3] These measures rely on water availability. The concept of completing some system components in advance and then fast-tracking measures if needed, has not been considered due to high costs and a poor fit with current planning approaches.

measures[4]. (While the dWRMPs propose investment in drought resilience, the premise of this study is to understand the consequences and emergency costs without this investment).

The 'size of the problem' for specific drought scenarios (with no climate change) are short term water supply shortfalls of the order of 320 and 1100 Ml/d for 'severe' and 'extreme' drought scenarios across all companies in England[5].

Potential regional supply shortfalls are summarised for a range of scenarios in Table 2-1. These assume that water companies invest to deal with the "worst historic drought" (with an annual probability of ca. 1%) and have planned for a central Medium Emissions climate change scenario. Therefore, the climate change impact shown in Table 2.1 is an incremental impact based on a more extreme "dry" climate change scenario (for further details of the original analysis see Water UK, 2017).

In terms of the short term 'drought response' at a national scale, there are up to 1500 Ml/d of drought plan options available to water companies, of which 400 Ml/d are straightforward to implement. These "likely" drought plan measures have been included in the Water UK baseline (Section 2.1.3). The additional 1100 Ml/d of drought permit options have been classified as "possible" and "unlikely" and considered alongside other special emergency measures for dealing with severe and extreme droughts. However, these are difficult to implement in a timely manner and the actual "Water Available for Use" (WAFU) from permits and emergency orders during droughts can be substantially less than this (Section 2.1.4).

2.1.3. The study baseline from the Water UK LTWRPF study

The baseline supply-demand deficits used in this study are based on the Water UK study, including Water Resources Management Plan 2014 (WRMP14) options and adjusted to represent a base year of 2016:

- The baseline **includes** a range of drought measures, such as media campaigns, temporary use bans (formerly hosepipe bans), non-essential use bans and the most straightforward drought permits, classified as "likely" in Atkins 2017.
- The baseline **excludes** any planned water resources schemes that maintain supplies for more extreme droughts with an annual probability of less than 1% (return period 1 in 100 years).

Water companies engage with the regulators and their customers through the WRMP and Business Planning processes to set a level of drought risk and resilience. The current round of draft plans in preparation for 2019 indicates that most companies in England are planning to maintain supplies for severe drought events with an annual probability of around 0.5%[6], which is consistent with recent industry research (UKWIR, 2016, Atkins, 2017), planning guidelines (Environment Agency, 2017) and business planning guidance from Ofwat, the economic regulator (Ofwat, 2017). The appropriate level of risk and infrastructure investment is the subject of the main NIC assessment and our assumptions were designed to provide inputs to this study.

The potential supply shortfalls and illustrative example of types of drought options is shown in Figure 2-1, against the potential shortfalls for the Thames region. This region has the highest potential shortfalls but also a wide range of drought permit options (Thames Water, 2018, dWRMP Section 7). The final WRMP19 will propose new supplies and demand reductions which can maintain supplies up to certain level of risk (point A). The relevant water company drought plans include emergency drought permits and orders, which could provide an additional 100 to 200 Ml/d in severe/extreme droughts (point B)[7]. However, the yields of these drought permits are highly uncertain so emergency measures may still be needed to deal with the most extreme droughts, particularly under future "dry" climate change scenarios.

[4] Based on Water UK scenarios of severe drought and base year of 2016 (Atkins, 2017).
[5] Rounded figures based on the Water UK scenarios and assuming that companies invest to deal with the "worst historic drought"; including demand restrictions and the "most likely" drought permits and orders. but excluding any new water transfers between regional water supply areas and any further investment.
[6] This is the same as a drought with a return period of 1 in 200 years on average. Note that the chance of such a severe drought occurring within the future planning period is the "encounter probability." For example there is 12% chance that a region will experience a 1 in 200 year drought (0.5% annual probability) within a 25 year period and 22% chance it will occur on the next 50 years.
[7] The Thames Water dWRMP reports a yield benefit of drought permits across all zones of 203 Ml/d for a severe drought (0.5% annual probability). Our analysis includes some of this in the baseline supply shortfall and adopts a different modelling approach and drought scenario, which is precautionary and indicates lower yield benefits of around 100 Ml/d.

Figure 2-1 Summary of potential regional supply shortfalls and illustration of potential response measures (A – long term investment in new supplies and demand reduction; B use of Drought Permits and C *in extremis* emergency measures)

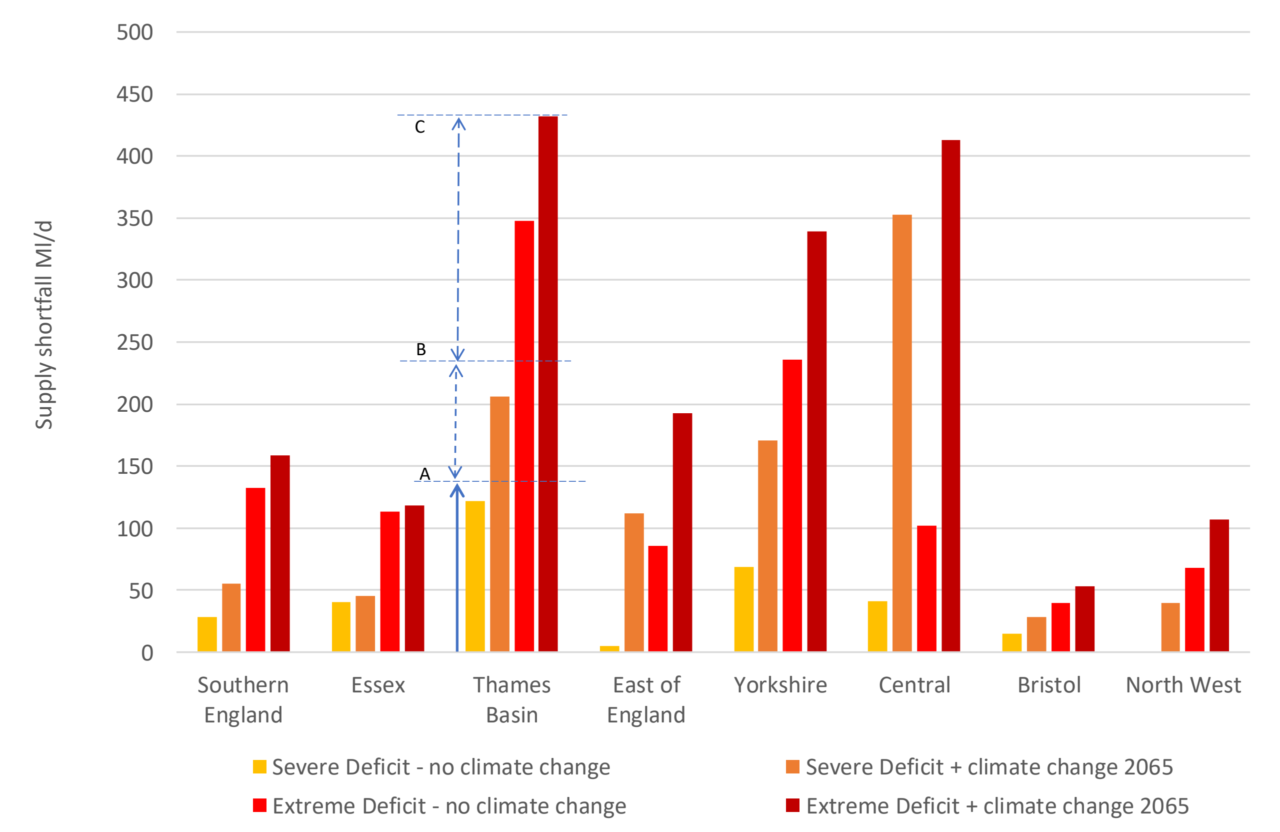


Table 2-1 Summary of potential regional supply shortfalls based on the Water UK LTWRPF study (Atkins, 2017)

	Severe drought (Annual probability 0.5%)		Extreme drought (Annual probability 0.2%)	
Region	**No climate change**	**Including climate change (2065)**	**No climate change**	**Including climate change (2065)**
Southern England	29	55	132	159
Essex	40	45	113	118
Thames Basin	122	206	348	432
East of England	5	112	86	193
Yorkshire	69	171	236	339
Central	41	353	102	413
Bristol	15	28	40	53
North West	0	40	68	107
Sum	*320*	*1010*	*1125*	*1814*

Notes: Assuming investment to maintain supplies in moderate droughts and a central Medium Emissions climate change scenario. Figures based on Water UK (2017) with adjustments for the NIC study.

2.1.4. Emergency drought options

The emergency drought options that can be used to maintain supplies in severe to extreme droughts, when drought severity is beyond the capacity planned for through long-term water resources planning, include:

a. "Medium" and "high" risk drought permits, which can provide supplies but with some risks related to their successful implementation or environmental impacts; these options are described in water company drought plans, were collated in Atkins (2017) and have been updated for this study (Appendix B). The reliable yield of drought permits declines in longer drought situations.
b. Rehabilitation of old groundwater sources, which have been mothballed or are out of use due to water quality issues or environmental impacts;
c. Some small additional river transfers, where infrastructure already exists or schemes that can be implemented very quickly;
d. Emergency desalinisation, where there are possibilities of "plugging in" additional capacity into the water supply network;
e. Enhanced leakage detection and repair, moving beyond what is planned and mobilising teams for greater levels of activity;
f. Radical network management measures to reduce water pressure and consequently demand and leakage.
g. Road tankers to transport water from an area with supplies to zones threatened by shortages.
h. Ship tankers to transport water from elsewhere in Europe to England in the event of extreme drought.
i. Non-potable water reuse or effluent recycling to make greater use of wastewater, including the use of indirect potable re-use where treated waste-water is pumped upstream or into raw water storage reservoirs.
j. Further abstraction from the environment following the introduction of Government emergency powers, which would allow additional water abstraction but would have very high environmental costs.

Options (a) to (c) would have short term environmental impacts and option (b) may have serious drinking water quality issues of concern to the Drinking Water Inspectorate (DWI). Option (j) could have longer term environmental impacts and would be unacceptable in all but the most extreme cases.

Options (f) – (h) would be considered unacceptable by water companies (and their customers) and are clearly a last resort. Further details are provided in Section 4.

Typically, most of these options are screened out of Water Resources Management Plans due to feasibility, cost, environmental and social impacts and promotability but some may remain 'on the table' as last resort emergency measures for extreme drought situations.

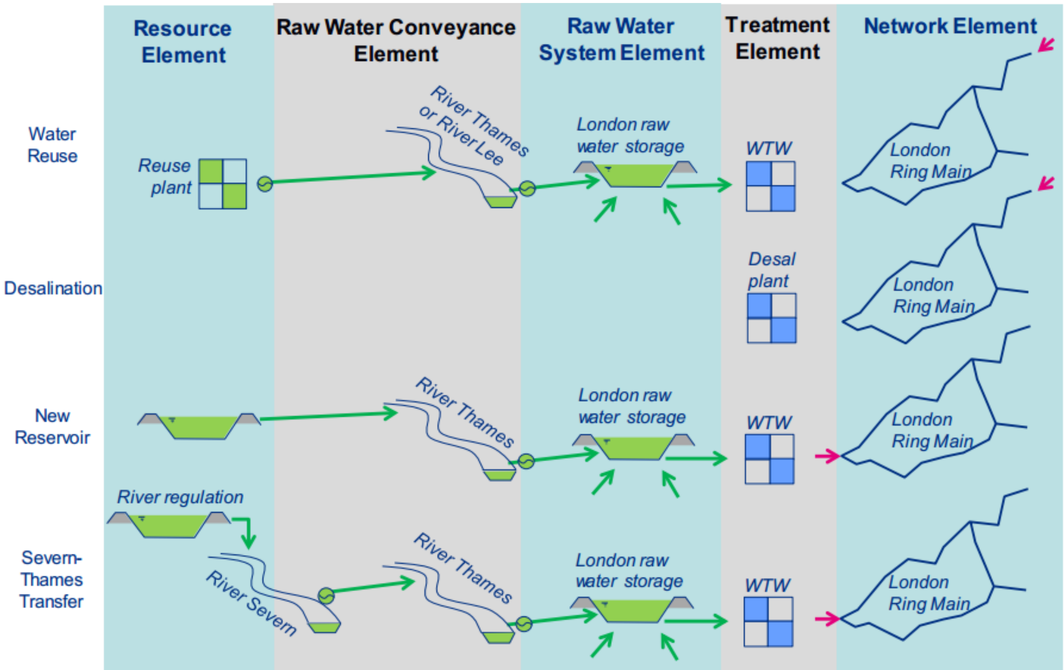
2.1.5. Systems or components of water resources and drought emergency response options

A water resources system is made up many different components to abstract water, transport and treat water for public supply as outlined in Figure 2.2. In the context of the NIC study it is essential to consider components that can be built in advance as part of drought preparedness and those elements that could be brought in during a drought. In practice, most capital costs are likely to be in advance due to short time periods available for drought response. For example:

- For emergency desalinisation there would need to be *'enabling works'* to ensure that they could be implemented within the short timescales of a drought. The company would need to maintain the space for a 'treatment element' as well making sure there was sufficient capacity in the 'network element' to take this water (Figure 2.2).
- For sea tankers there would need to be docking facilities, offloading facilities, storage, connections to the supply network and sufficient capacity.

➢ For water re-use, multiple components would need to be in place to make this feasible. As well as space for package treatment works, there need to be ways of conveying raw water and sufficient capacity in the network to deliver this water.
➢ Transfers are possible as an emergency measure if the donor source of water is reliable and there are no water quality or ecology constraints to making transfers. The rivers or pipes for raw water transfers and network connections need to be in place, as well as contractual agreements to supply, before the drought event. It may be possible to build small pipelines during a drought but not at the scale needed to transfer large amounts of water.
➢ Large infrastructure, such as reservoirs, take many years to plan build and are clearly not an emergency drought option, even for multi-year droughts. However, existing reservoir elements are very useful during droughts and can provide storage for new temporary sources of water, including blending new water sources with the remaining local water supplies[8].

Figure 2-2 Components of water resources options



Source:Thames Water's dWRMP Thames Water, 2017, Section 7.

3. Methodology

3.1. Key concepts in the development of cost curves for drought

3.1.1. Drought scenarios

The following drought scenarios have been considered based on the Water UK project:

- A severe drought, which affects large areas of England with an annual probability of 0.5% (return period of 1 in 200 years)

[8] Blending water is important for maintaining drinking water quality and preventing any damage to the water distribution network by introducing new water with very different chemical characteristics.

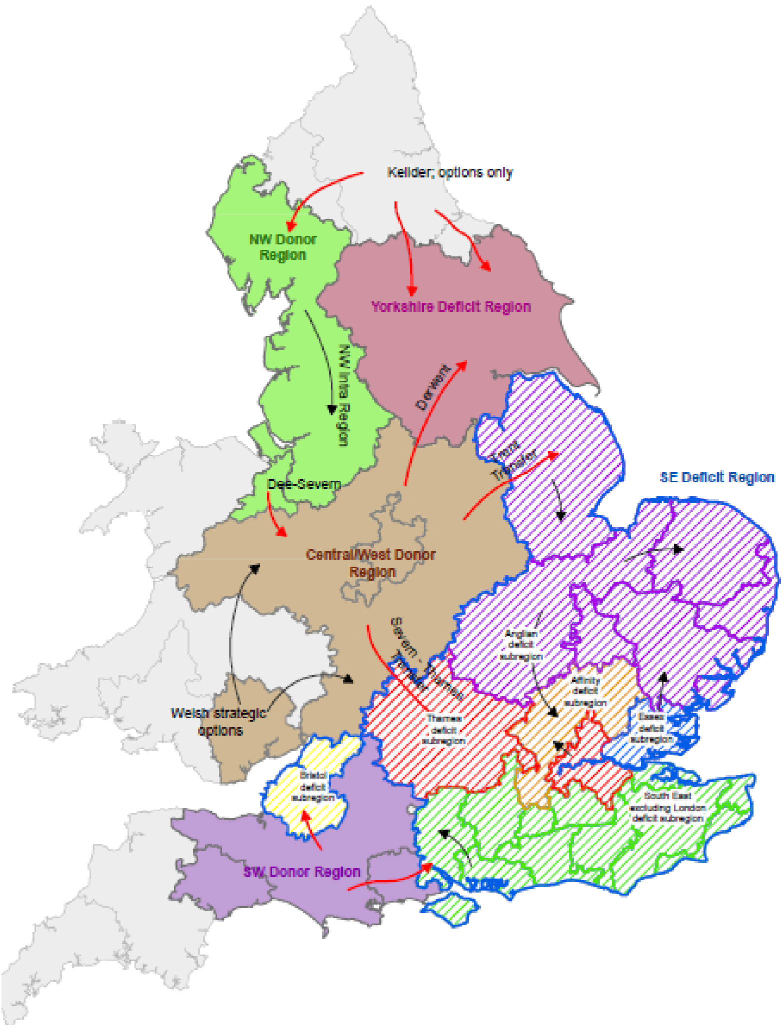
- An extreme drought, which is concentrated on the central, south and east of England with an annual probability of 0.2% (return period of 1 in 500 years), but affects the whole of England at varying levels of severity.

Based on the LTWRPF methodology the impacts of drought (natural variability) and climate change (long term changes in average climate conditions) are additive, so future drought supply shortfalls can be estimated by adding the drought impact to the climate change impact for any specific year.

3.1.2. Spatial scale

This study is concerned with the costs of emergency measures in England but the drought situation varies across the country in terms of the options available for maintaining supplies and potentially for the costs of emergency measures. Therefore, this study has considered nine regions made up of one or more water companies. While all regions experience droughts, some are primarily “deficit” regions that need further resources and others a primarily “donor” regions that have a stronger supply-demand balance (Figure 3.1).

Figure 3-1 Overview of drought sub-regions (deficit, donor and transfer regions) and potential strategic transfers (Source: Water UK, 2017)



This approach means that the assessment of the capacity of options considers company Drought Plans and what is feasible in each region, for example some regions have no access to coastal ports for sea tankering. As the study was only interested in a sub-set of emergency drought options, there were limited costs data available from water companies and insufficient data to vary costs regionally. Therefore, the unit costs of most measures are national estimates. To get to more detailed cost estimates, individual schemes would need to be selected and developed in detail, which is beyond the scope of this study.

3.1.3. System Storage and Implications to the Benefits of Emergency Options

One of the key uncertainties when emergency measures are being compared against ‘conventional’ water resource schemes relates to the fact that the relative benefit of the emergency measure only starts to work as the critical point of the drought is reached. For systems that involve storage (reservoirs or conjunctive reservoir/groundwater/direct river abstraction systems) that means that much of the storage in the system will already have been lost by the time the emergency measure is introduced.

The timing and availability of new resources in comparison to available storage in water resource management planning is normally evaluated using detailed ‘behavioural models’. These models act as simulators of the system, and evaluate how much demand can be met by the system during a design drought. This is referred to as the ‘Deployable Output’ (DO) of the system. When a new resource is added to the system the benefit that this provides is stated according to the amount of additional demand that could be met during the drought scenario with the new scheme in place.

The DO value can range from being quite close to the stated capacity/capability of the option, through to a very small proportion of the stated *capacity* of the option. Examples of the types of schemes are provided below:

1. If a low cost new borehole was developed, then this would tend to be adopted as a ‘baseload’ supply and would therefore be used throughout the whole of the drought period. The ‘DO’ would therefore be equal to the capacity or licence of the borehole.

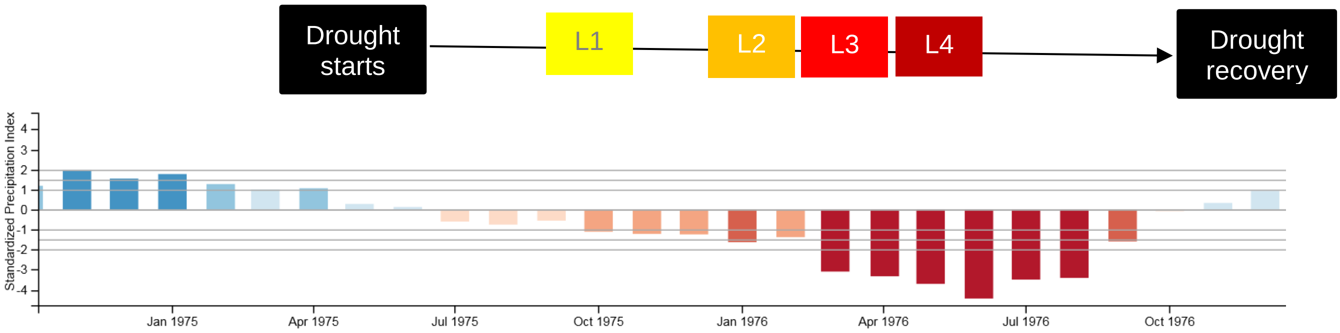
2. If a desalination plant is constructed then typically this would be used once a particular ‘drought warning’ line had been crossed on reservoir storage or regional groundwater levels (due to high operational costs). Therefore, the company would only benefit from desalinisation during some of the drought period. The If the drought trigger is precautionary the DO benefit from desalination would be quite close to the plant’s full capacity.

3. If a winter transfer scheme is used then the benefit depends entirely on the amount of water that would be available for transfer during the winter of the drought event, and that volume of water would effectively be divided over the whole duration of the recession when the benefit is being calculated. Often this means the DO is significantly lower than the capacity (e.g. DO<0.5 times capacity).

Emergency measures represent an extreme version of the desalinisation example, as they are typically very high cost schemes that are deliberately left until they are needed during drought. This reduces the relative cost of the option on an NPV basis, as it might be possible to defer some or even all the cost for several decades. The Australian case studies described in 7.Appendix D presents an example of this in South Australia, where effluent re-use schemes have a much better NPV/benefit ratio if the initial construction is confined to enabling infrastructure, and the more expensive, lower asset life M&E equipment is not procured or installed until it is required during the drought.

The downside to this in the U.K. is that the amount of available storage is relatively low (in comparison to places such as Australia), the duration where emergency options are required is typically relatively short and the warning periods are similarly relatively short. For example, if an emergency option only provides a benefit for the critical 3 months of the drought, but significant storage recession occurs for 9 months before that, then the relative *DO* benefit would be (3/(9+3)) = 27% of the option *capacity*. The timing of drought development in England is illustrated in Figure 3.2 where rainfall deficits are used as surrogate for reservoir or groundwater storage. The drought response escalates from Level 1 with a media campaign, through to rapid succession of usage restrictions (Level 2) to Drought Orders and permits (Level 3) and then emergency measures (Level 4).

Figure 3-2 Drought development (6 month precipitation deficits) and levels of response



Source: Standardised Precipitation Index for 6 months from Centre for Ecology and Hydrology https://eip.ceh.ac.uk/apps/droughts/

This is one of the critical factors that needs to be considered when cost/benefit comparisons are being made between emergency type options and conventional water resource management schemes. Details of how this was considered for this study are provided in Section 3.2.

3.1.4. Issues related to comparing emergency costs with planned drought resilience costs

There are several aspects of the evaluation of effective costs for emergency options that need to be considered before they can be meaningfully compared against 'conventional' water resource options. These are:

1) How much of the proposed expenditure is required before the critical point of the drought (i.e. before 'Level 4' type restrictions are imposed), to ensure that the emergency measure is available during the critical drought period.

2) The frequency at which the different levels costs are expected to be incurred. In the case of emergency options, it is possible that a large proportion of the costs are incurred preparing for droughts, which turn out to be less severe than anticipated. [9] When an NPV analysis is being carried out, then the expected frequency of expenditure is critical to the final cost/benefit of the option.

3) Some options require up front 'enabling works' (e.g. pipeline infrastructure that connects a sea tanker unloading dock to the nearest suitable water company treatment works or reservoir) or annual recurring costs in order to allow the option to be prepared and deployed during the drought (Section 2.15).

Items 1 and 2 above are obviously strongly linked to the way in which water companies manage droughts through the use of 'triggers' and the timing and timescales that are available for actions to be taken between the different trigger levels. As with the option benefits described in Section 3.1.3, the management of the timing and frequency of cost associated with emergency options formed a key part of the cost/benefit analysis framework for this study, as described in Section 3.2 below.

3.2. Drought measures model

A model was developed using available data from draft WRMPs, existing literature and consultation with water company experts.

There are two main components of costs are capital expenditure (capex) and operating expenditure (fixed and variable opex). Capex may include enabling works installed prior to drought as well as costs triggered

[9] Therefore costs will be incurred a number of less severe droughts (in the 1 in 10 to 1 in 100 year return period range) even when the option is not deployed, because the drought event is "broken" by heavy rainfall, e.g. at the end of the 2013 drought.

when there is a threat to public water supply. Opex includes a fixed annual component, such as ground rent and annual maintenance and variable opex when a scheme is used during drought conditions.

Environmental costs were also considered, although we found that there was limited data on environment costs in the draft WRMPs. Some additional information was available as part of the Water Framework Directive (WFD) National Water Environmental Benefits Survey (NWEBS)[10] but the environmental costs data in this study was not designed to be used to assess the impacts of abstraction during droughts.

As discussed previously, there are three important considerations in the development of NPV based cost/benefit analyses for emergency options:

(a) The relative *deployable output (DO)* benefit that can be provided by the option, which is a function of the capacity it provides during the critical emergency period of the drought, the degree to which the water resource system relies on storage and the amount of that storage that is already used up by the time the emergency option is fully deployed;

(b) The amount of time that is available to a water company once relevant drought triggers have been crossed. In some cases, the time taken required to fully deploy an emergency option may be greater than the *lead time* that is available between the relevant warning trigger being crossed and the start of the critical 'failure' point of the drought. Thismeans that the relative benefit will be reduced, or even mean that the option simply isn't viable for that system.

(c) In relation to point b), the amount of expenditure that is required prior to the point at which the emergency option is actually deployed, and the frequency at which that expenditure can be expected over a given planning period.

If drought option costs are to be compared with long term water resources investment costs, this must be on a consistent basis using the same underlying cost assumptions and utilisation assumptions. For these reasons a model of drought costs is provided rather than just a database of costs. The model is presented as three worksheets: (i) Scenario definition, which defines the regional water resources characteristics, lead time assumptions and drought frequencies; (ii) Option inputs, which includes information on capex, opex and environmental costs from available data and (iii) Marginal Abatement Cost Curve (MACC) outputs.

A summary explanation of the content of each of the worksheets, and the calculations and assumptions that have been used to address the three considerations listed above, is provided in Figure 3-3 overleaf.

3.2.1. Marginal Abatement Cost Curves

The outputs can be presented as cost curves with cumulative benefit on the x-axis and costs per Ml/d on the y-axis. The model presents both the Water Available for Use (WAFU) and 'effective capacity' data. The costs are substantially greater and benefits lower for the WAFU data.

The results of the study are presented in Section 5 based on effective capacity but WAFU data may be more appropriate, depending on the overall approach of the NIC study.

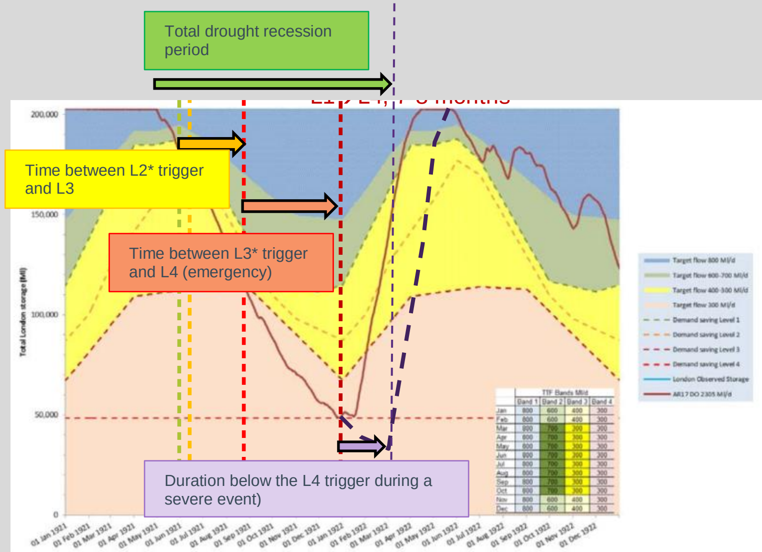
[10] https://www.gov.uk/government/publications/updating-the-national-water-environment-benefit-survey-values-summary-of-the-peer-review

Figure 3-3 Summary of the Option Cost and Benefit Model Components

Scenario Definition Worksheet

Contains estimates of the timings and frequencies involved in a 'typical' expected drought (as a probability weighted average across the range of droughts that might test the system), including:

- Duration of 'significant' recession (the time during which conditions notably deviate from a normal year)
- 'Band 2' frequency and duration – the time between 'level 2' interventions (Temporary Use Bans (TUBs)) being triggered and Level 3 interventions (non-essential use bans, Drought Permits) being triggered.
- 'Band 3' frequency and duration – the time between Level 3 interventions and the Level 4 'emergency' conditions being triggered.
- The expected duration that conditions would continue below Level 4 for a severe or extreme drought, assuming that a company had only planned to a worst historic event.



Options Inputs Worksheet

Contains capex, variable opex, fixed opex, environmental and 'other' costs for each option in terms of £000s per Ml/d *capacity* delivered (*DO* for Drought Permits and Orders).

The worksheet proportions capex, environmental and 'other costs into:

- 'Enabling works' (required once the emergency option is identified as potentially being needed according to the supply/demand balance)
- 'Band 2' costs – i.e. costs that are incurred every time a drought enters band 2
- 'Band 3' costs – i.e. costs that are incurred every time a drought enters band 3.

Environmental costs are incurred at the Band 3 frequency, variable opex is incurred at a frequency of 1 in 66 years*.

Contains the maximum output that can be realistically achieved for each option, based on the information taken from interviews, Drought Plans and the WRMPs.

Contains the minimum time required to start delivering the benefits of the option, *given* the enabling works and costs incurred in bands 2 and 3.

Contains an expected probability of success for the option (i.e. that it can actually deliver the estimated capacity in light of technical and institutional uncertainties).

MACC Summary Worksheet

Contains NPV calculations of band 2, 3 and variable opex (band 4) costs, based on the planning horizon and the expected frequency of each trigger.

Takes the average expected duration of the overall recession and duration of each band and calculates the expected DO (expressed as water available for use, or WAFU) benefit based on the capacity.

For Drought Permit and Order options, the *capacity* is back calculated from the DO (WAFU), as the benefits are expressed by Drought Plans as DO.

Calculates the final, probability weighted cost/benefit for each option.

3.2.2. Definition of costs

The costs were based on draft Water Resources Management Plans (December 2017) (options a – e, I,j) or through interviews (options f – h) or based on NWEBS (j). Draft WRMP costs are for long term investment planning and not for short term options. Therefore, we considered the feasible options lists for all water companies in England and reviewed the ranges of capital, operational and environmental costs presented and, in general, selected 75th percentile costs from this database (high costs). Further discussion of costs by option type is included in Section 4.

3.2.3. Draft Water Resources Management Plans

Each WRMP is supported by a comprehensive set of tables of WRZ level supply-demand balance for the next 25 years and supporting data. The data are generally at an annual time step, starting in the financial year 2019/20, and consider the supply-demand balance based on specific design conditions, such as Average Demand in a Dry Year.

Information regarding the cost and expected savings of company's feasible long-term options were extracted from Table 5 of the dWRMP19's. The various options were categorised into option types as detailed in Table 1. As shown the number of options ranged from 53 effluent reuse schemes to 100s of leakage options.

For all options capex and opex information is available however, most companies did not provide environmental and social costs. In particular, environmental costs for some scheme types were ignored as the data were unreliable (* in Table 3.1).

Table 3-1 Summary of feasible options extracted from first round of dWRMP19 tables (Dec 15th data) to explore specific emergency drought measures

	Number of options	Median Capex (£ '000 per Ml/d)	Median Opex (£ '000 per Ml/d)	Median Environmental and Social Costs £ '000s
Drought Permit	54	27119	1386	1 *
Transfer options	191	3178	162	45
Leakage (all sub-types)	474	4488	461	0.8*
Groundwater Options	128	2803	104	36
Surface Water Options	201	4222	13	13
Effluent Reuse	53	5480	354	68
Desalination	76	6138	1268	229

(*) Surface water environmental costs were used instead of those presented against DPs, Leakage management environmental costs were assumed to be zero.

There was a very large range of option sizes, costs and scheme yields (or demand savings) proposed within the dWRMP19's. The analysis identified that transfer options have the largest range of capex costs per Ml/day saving. Although some obvious errors have been removed from the data, the high figures reported for transfers and drought permit costs are still being checked by the Environment Agency. Opex costs were calculated as the median annual cost over the planning period.

Further details are provided in Appendix C.

3.2.4. Other cost assumptions

The costs for the use of tankers, severe pressure management and leakage are currently based on interview evidence and expert opinion.

It is worth noting that:

1) For Sea Tankering there are two possible scenarios – one where the tankers effectively must be bought and stand idle, and one where there is a good market for tankers to be hired only 3 months in advance. There is an order of magnitude difference in the costs between the two. We have assumed that a market can be created for our assessment but also included the alternative costs in the data provided to the NIC

2) For extreme pressure management you could take either willingness to pay (WTP) for boil water notices and low pressure, or willingness to accept (WTA). Again, there is just under an order of magnitude difference and we adopted the WTP figures. It would be very unusual to use WTA estimates because these are unconstrained by household budgets.

4. Emergency drought measures

4.1. Existing drought permits

What are these?
These are mostly changes in surface water and groundwater abstraction licenses to allow greater abstraction at existing sites or additional sites. Our updated analysis of drought plans suggests that are up to 917 Ml/d of "possible" and "unlikely" permits that could yield 917 Ml/d. It includes just one company that has indicated the possibility of an emergency desalinisation plant to provide 10 Ml/d (Table 4-1).

However, our review indicates that these are often in the 'wrong region', have significant environmental impacts and can be very difficult to implement in time. In the latest dWRMPs companies report very small or no benefits of drought permits, indicating that they do not provide a reliable yield. Only one company in the South East presents a plan that relies on the use of Drought Permits. Finally we have not assessed their viability over much longer duration droughts, such as over three years, and the benefits are likely to be negligible

Table 4-1 Updated analysis of water company drought permits (summary of "medium" and "high" risk permits with "low" risk permits excluded)

Sum of Daily yield (Ml/d)	**Lead time (months)**				
Drought Measure Type (Level 1 class)	**3**	**6**	**9**	**12**	**Grand Total**
Desalinisation				10	10
Groundwater	31	120	43	12	205
Surface water	*401*	210	66	25	701
Grand Total	**431**	**330**	**109**	**47**	**917**

Capacity
The capacities of all drought options are based water company drought plans. For some schemes proper estimation requires detailed behavioural modelling and assumptions were made based on expert opinion. Further details are included in Appendix B. In our model the impact of a long lead time (9 or 12 months) may mean that the drought permit offers little or no benefit.

Costs
The capex of the schemes based at existing abstraction sites is low, so these schemes will always be selected first. The environment costs have been estimated based on the available data for surface water schemes as most permits abstract from or impact surface waters.

Key Uncertainties

The Drought Orders and Permits considered in this study are the less proven, higher risk options that were *not* included in the 'baseline' Water UK study. Whether or not these would be granted in time to achieve the theoretical benefits that could be achieved according to the Drought Plans is generally unproven. As these are generally the lowest economic cost options, the reliability or otherwise of the interventions can have a major impact on the apparent cost of relying on emergency interventions. When evaluating the marginal abetment costs (see Section 5), two approaches to costing this option were therefore considered:

- An 'Optimistic' baseline, where the Permits and Orders were considered to be generally reliable but with potential delays and issues that could reduce the effectiveness

- A 'Pessimistic' approach, where the Permits and Orders are not considered to be reliable, and attract the environmental costs associated with the emergency 'Further Abstraction' described in Section 4.8.

4.2. Borehole rehabilitation

What are these?
These are existing boreholes that have already been drilled within a company area, but have been abandoned or are no longer used. In many cases the licence is still held by the water company. For the purposes of this study it was concluded that attempting to investigate, drill and licence new boreholes would be impossible within the lead times that are available for the drought events, so it is only existing boreholes that have been considered. Most do not have operational pumps or treatment and many are no longer connected to the distribution mains network.

Feasibility
The feasibility of implementing these schemes varies significantly from borehole to borehole. Where the borehole has been abandoned for environmental reasons and there are no particular water quality problems, then it is likely that these could be re-introduced at low cost and within a shorter timescale. Where boreholes have been abandoned due to water quality issues (e.g. hydrocarbon pollution) then timescales can be much longer and likelihood of success much lower.

In all regions the available options have therefore been separated into:

1. 'Low cost' options where simple refurbishment and limited treatment needs such as disinfection only are involved.

2. 'High cost' options where there are complications, normally involving more advanced treatment needs.

Capacity
Specific to each company. The potential and capacity for these schemes has been evaluated from an analysis of each water company's Drought Plan and discussion with companies.

Costs
Taken from the dWRMP19 Table 5 analysis, using the 25^{th} and 75^{th} percentile borehole development costs respectively. Capex is split on a proportional basis according to available lead time into Band 2 and Band 3.

4.3. Emergency Leakage control

What is this?
As the drought approaches Band 2, companies significantly ramp up their Active Leakage Control (ALC) activities to reduce leakage.

Feasibility
Reasonably well tried and tested during previous droughts, but only on a piecemeal basis. There are concerns that contractors/hires may not be available or would become significantly more expensive, if a widespread regional drought occurred.

Capacity
Past evidence and discussion with water companies indicate that this is likely to be practically limited to around 10% of leakage. The capacity was therefore limited at 10% of expected baseline leakage levels in 2040 (based on WRLTPF, minus the 15% leakage reduction currently being advocated by Ofwat).

Leakage detection hires would take approximately 6 months month to be brought up to speed as effective resources, so this has been taken into account when the effective benefits have been calculated.

Costs
Taken as the 75th percentile capex and opex from the WRMP19 Table 5 costs, as it is expected that the majority of proposed reductions will already have been implemented, so achieving the emergency leakage reductions will be towards the upper end of the ALC cost curves. Both capex and opex are incurred during Band 3.

4.4. Severe pressure management

What is this?
Reducing the mains pressure across a distribution zone to lower than the reference 15m during the critical part of the drought. As well as the network activity this would require advanced planning, increased monitoring and mains flushing activities.

Feasibility
Only ever tried by one water company for one day, but some do have plans (of various degrees of development) in place.

Issues surrounding critical users (hospitals, schools, prisons etc), tower blocks and zones with large variations in elevation mean that it is assumed this could only be deployed in 25% of zones without incurring excessive water quality and interruptions problems. Even within those zones it is assumed that half of the options would have to be abandoned due to unforeseen difficulties. Potential to impact on performance commitments and even incur penalties or fines.

Capacity
Based on reducing ADPW pressure to 3m at the high point of the affected zones, savings are estimated at 20% (based on company interviews). It is noted that this is likely to result in daily interruptions at peak times for those customers near the high point of the zone, resulting in boil water notices.

Costs
Monetary costs are based on costs of boil water notices, mains flushing activities, additional monitoring communications etc. However, the bulk of the costs incurred are societal and reputational – for every 2000 customers affected by a boil water notice there is anecdotal evidence (based on interviews) that one customer would fall ill and require hospital admission. Based on PR14 published data the ‘willingness to pay’ (lower bound cost) and ‘willingness to accept’ (upper bound cost) were used to estimate societal impacts of lower pressure and boil water notices. This resulted in an estimated effective opex of between £85 and £454 per m^3 of water saved. A ‘stretch’ option was also considered whereby additional zones where further water quality problems might occur were brought into severe pressure management. Using willingness to accept costs (which is all that are available as water quality compliance is currently so high) from PR14 for reduced water quality, this resulted in an estimated cost of over £2,000 per m^3 saved for the ‘stretch’ distribution zones.

Key Uncertainties

As discussed above, one of the major concerns that water companies have is that the application of this type of pressure management could lead to contamination of the mains and hence ‘boil water’ notices. The problem with this is that such a situation attracts the risk of customers, and in particular vulnerable customers, becoming ill. Water companies would do everything possible to avoid any incidents of that type, and have well practiced procedures for managing such events, but there is no experience of managing the multiple events over extended periods that could occur if this type of emergency drought intervention is used. To reflect this concern, a second ‘pessimistic’ scenario was introduced around the costs whereby 1 customer in 5,000 could experience serious illness per week of boil water notice imposition, and of those up to 25% could result in death. Using a typical ‘value of life’ of £3m, this was found to have a large impact on the economic cost of the option, effectively taking it from £86 per m^3 saved during the event, to £286 per m^3 saved during the event. It should be noted that this scenario is entirely assumption based and does not have any empirical evidence to support the assumptions, but it does reflect the potentially high economic cost of the health risk that has been raised by water companies,

4.5. Emergency desalinisation

What is this?
Conventional desalination schemes where only the enabling infrastructure is constructed and the remaining (largely M&E) costs are deferred until a ‘band 3’ drought event occurs. Consultation for this study with planners working specifically in the water industry concluded that an ESIA is likely to be required for such enabling works, so they would *have* to be delivered in advance.

Feasibility
This can probably be done and delivered, but the main concern is over timescales for procuring, installing and commissioning the M&E equipment, which is estimated by water companies to take at least 6 months, even with enabling works in place. As the costs are so large they would need to wait until the Band 3 trigger thresholds were firmly breached, so in most cases the output would not be available in time for the critical part of the drought. Note that only one company has included this as a drought emergency measure.

Capacity
Generally limited by existing distribution infrastructure (where schemes are possible). The plant would need to connect to a suitably large treatment works or service reservoir(s) to allow some pre-treatment and blending with existing mains water. Plants have slow ramp up times and generally need to operate a baseload to maintain their reliability. Expert judgement based on the WRMPs was therefore used to estimate the potential capability in each drought region.

Costs
Capex taken as 125% of the 75th percentile costs in the dWRMP19 tables, and opex as the 75th percentile. 25% of this was assumed to consist of enabling works.

4.6. Road tankers

What is this?
As per the 1996 Yorkshire Water response; involves tankering either raw or potable water using road tankers.

Feasibility
Tried and tested, but only in a very limited way. Studies have been carried out by several water companies, and some enabling/management works are required, but the practical limitation is on how quickly tankers can be filled and emptied at either end.

Capacity
Although 24/7 working can be used, there is a practical limit, with one tanker refill every 5 minutes being the absolute maximum, even if the site is prepared with multiple filling points. This limits each region to effectively 7Ml/d per feasible tanker route.

Costs
Cost model developed based on average speeds (ONS), tanker refill and waiting time and the cost of ‘all in’ tanker hire from projects in 2012, indexed up to 2017/18.

Key Uncertainties

Although there is a relatively good body of evidence about the cost of tankering from the Yorkshire Water 1995/96 event, and the preparations by other water companies in response to more recent droughts, the ability to maintain very large numbers of road tankers working 24/7 during longer drought events is uncertain, and attract logistical and health and safety concerns. A ‘pessimistic’ scenario whereby the costs per m^3 delivered remain the same, but the availability of capacity reduces by half, was therefore tested as part of the analysis.

4.7. Ship tankers

What are these?
Adapted bulk liquid tankers that take water from either Norway or the Netherlands and deliver to a suitable port location.

Enabling works are required to transfer the water from the port to the nearest suitable water company asset (treatment works or reservoir), as it is not feasible to do this using road tankers given the volumes involved.

Feasibility
The feasibility of this type of option has been explored in some detail by Albion Water, and is certainly a viable approach. Water sources are available on the near continent, and ship transfer time would range from 5 to 7 days for a round trip. That means a fleet of 5 to 7, 200 kilo-tonne tankers could effectively deliver 200Ml/d during a drought critical period. Smaller options (e.g. using 20 kilo-tonne tankers) are also possible.

As discussed below, the cost of this option depends largely on how much tankers need to be hired/owned outside of the drought period, as these are very expensive assets. Three options were therefore investigated:

- A model where the tankers are ordered and used purely during the drought event. This is obviously a low-cost approach, but the timescales involved are impractical and would only be useful during very unusual long duration severe droughts where there was at least 12 months between triggering Level 3 responses (non-essential use bans) and the critical 'Level 4' drought period.

- A model where tankers are purchased and maintained as owned assets, son they are available for use as required. This obviously represents the upper bound (pessimistic) cost approach.

- A model where there is a 'market' for ship based tankering, primarily focused on areas of Europe such as the Mediterranean. In this model it would be necessary to incur some cost before the Level 4 conditions are reached, but significant costs would only be incurred one the Level 3 triggers are breached. Although such a market does not exist now, there are moves within Europe to consider it, and this would become more likely if ship based tankering was supported by the water companies on the eastern and southern side of the UK as a general response to severe drought. This represents the 'optimistic' baseline used for sea tankering.

As tankers would represent a new source of water The Water Supply (Water Quality) Regulations 2016 apply and there would need to be comprehensive water quality testing by the water company.

Capacity
Capacity is effectively constrained by need and infrastructure capacity near to relevant ports. Options of up to 200Ml/d have been considered for London, and up to 50Ml/d considered for the other regions on the eastern and southern sides of the country. For these options it was only considered to be necessary to develop enabling works that connect the relevant ports to existing infrastructure over a relatively short distance. A second set of options was considered where existing infrastructure needed to be upgraded as part of enabling works, to accommodate the increased capacity of the option.

Costs
Three cost models were developed to support each of the options, although Option 1 was not considered to be viable and was not used in the assessment. The cost models were derived largely based on discussion with Albion Water and incorporated:

- The cost of purchasing the water, which included aspects such as the construction and maintenance of loading facilities

- The cost of tanker hire (or ownership – both are expressed as an effective daily rate).

- Fuel and crew costs

- Port and pilotage costs

- Administration and agency costs

- Costs of enabling works

These assumptions were tested as part of the peer review process and found to be reasonable. It was highlighted that capacities might be improved by faster refill rates and the results are highly sensitive to the assumed delivery distance.

4.8. Other supply side measures

Other options were included for specific regions, where these were mentioned within the relevant Drought Permits. These were:

- Some canal and river transfer options in the Thames region. Costs for these were based on the dWRMP19 Table 5 analysis of transfer options.
- Some non-potable and indirect potable effluent re-use options. These are only described by Thames, but they could be used in other regions and were included where additional options were required to meet the potential supply/demand deficit.
- Costs for non-potable use are highly uncertain, as the intention is that the water is used for non-potable industrial requirements and irrigation of non-food vegetation (e.g. parks), so the availability of suitable beneficiaries will be highly variable. The 75th percentile of effluent re-use costs was therefore adopted, but without a premium for the split between enabling works and the emergency procurement/installation.
- Further abstraction from the environment in situations where Government emergency powers was introduced with high environment costs based on NWEBS, so that this option was a last resort before resorting to stand-pipes in England's major cities. The capacities and costs are both highly uncertain.

More details on the assumptions are provided in Appendix A.

4.9. Additional demand measures during drought

Demand reductions related to Temporary and Non-Essential Use Bans are already included in the study baseline. During the peer review process the potential for further reductions was raised. There is limited evidence for further reductions so this was not included as measure in our regional portfolios but may be considered in the broader NIC assessment.

Household demands in England are around 8000 Ml/d and in a drought situation this could to be reduced to under 6800 Ml/d with the imposition of Temporary Use Bans and Non-Essential Use Bans[11]. Therefore, further savings of 5% or 10% have the potential to reduce deficits by around 340 and 680 Ml/d respectively. The actual benefit of any further demand reductions will depend on when they are triggered within a drought. For example, if they become effective at "level 4" the benefits would be around one third of the benefits from implementation before the drought.

5. Regional portfolios of drought emergency measures

This section presents the results for regions in England, focusing on regions for which drought will translate in a reduction of supply (see Table 2-1). The higher-end of the Water Available for Use that could be provided by these emergency measures has been assessed taking into account the scale of these potential shortfalls to provide a cost curve that is wide enough to potentially cover more extreme drought scenarios. The vertical lines in the graphs indicate the potential shortfalls listed in Table 2-1. As such, they do not represent the actual deficits during a drought event but only the change in Water Available for Use (i.e. they are not a supply-demand balance).

[11] Based on population estimates from 2016 and assuming 15% reduction nationally due to TUBS and NEUBS. The demand savings quoted are for households only and exclude non-household use and other components of the Distribution Input, such as leakage and supply pipe losses.

5.1. Deficit regions

5.1.1. Southern England

Without significant investment in the WRMP process, the South East is threatened by water shortages in 'severe droughts'. Our analysis indicates that Drought Permits may not be sufficient on their own. With 'dry' climate change a number of additional emergency measures would be required (Figure 5-1). In the 'extreme' drought situation the full range of emergency options plus additional abstraction from the environment would be required (Figure 5-2).

Figure 5-1 Severe Drought WAFU, Low Cost Tanker scenario (supply shortfalls 29 Ml/d to 55 Ml/d with "dry climate change" ***and no WRMP investment*****)**

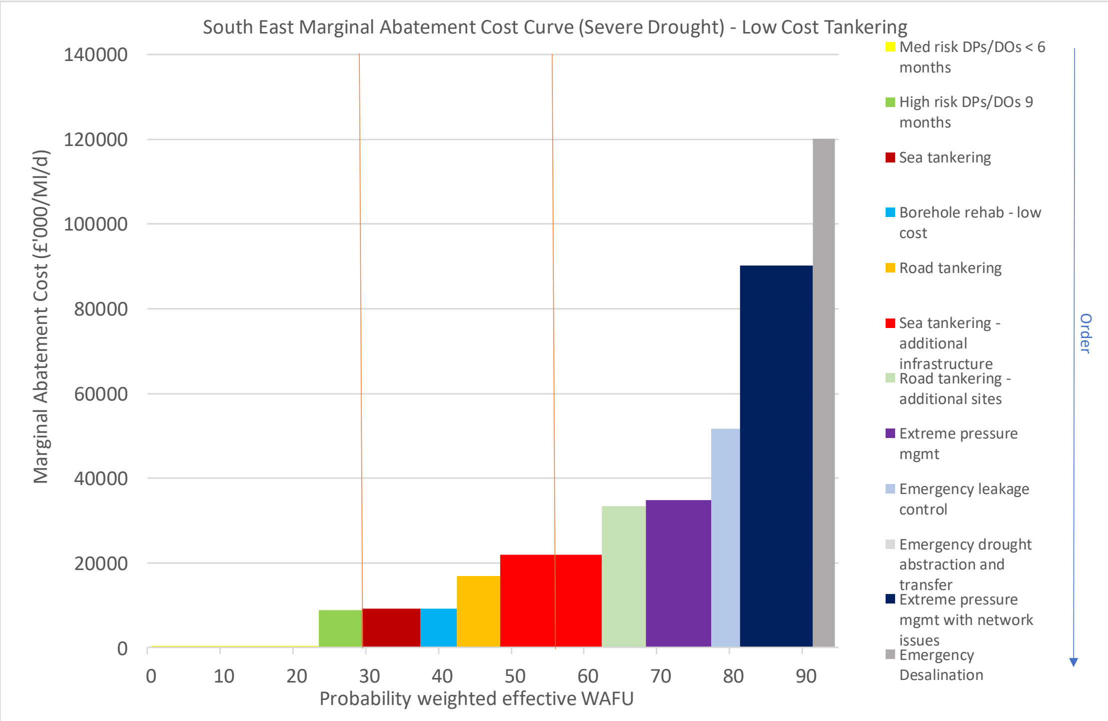
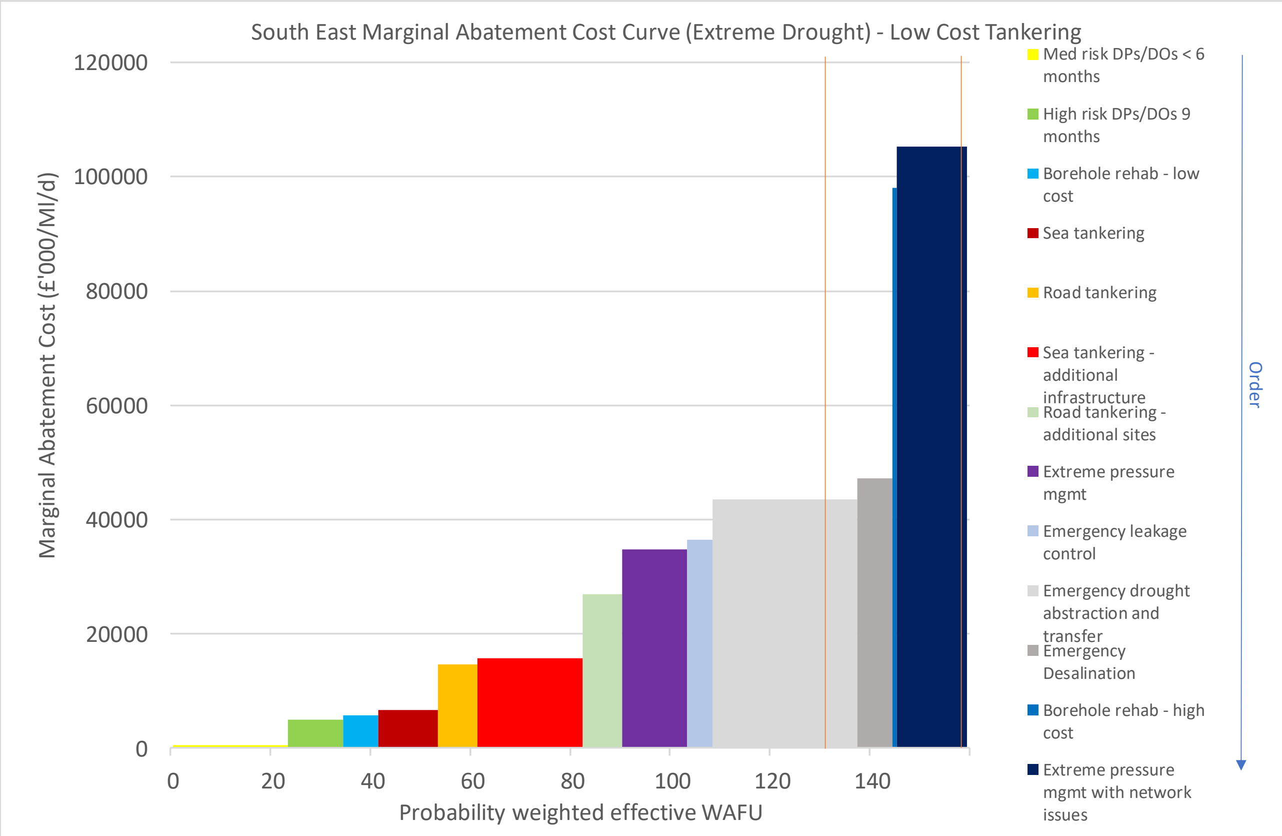


Figure 5-2 Extreme Drought (supply shortfalls 132 Ml/d to159 Ml/d with "dry climate change" ***and no WRMP investment*****)**



5.1.2. Affinity

Based on the Water UK study the Affinity appears to have sufficient drought permits available to cope with extreme droughts. However, its underlying supply-demand balance is marginal so is likely to require investment in supplies and demand reductions to maintain supplies under Dry Year and Peak Demand conditions.

5.1.3. Essex

Without significant investment in the WRMP process, Essex is threatened by water shortages in 'severe' and 'extreme' droughts where supply shortfalls are up to 118 Ml/d with "dry" climate change. This region would require additional abstraction from the environment in severe and extreme drought situations with consequent environmental impacts.

Figure 5-3 Severe Drought in Essex (supply shortfalls 40 Ml/d to 45 Ml/d with "dry climate change" ***and no WRMP investment*****)**

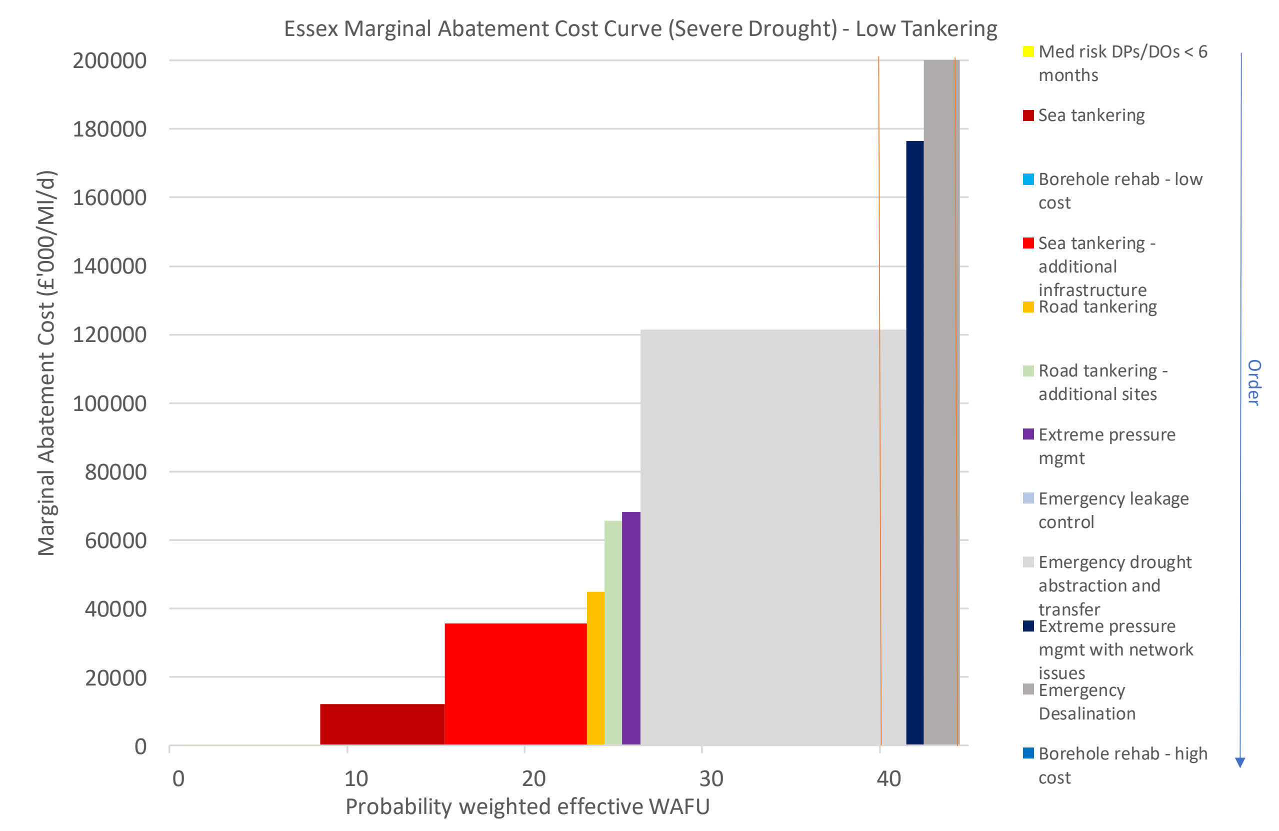
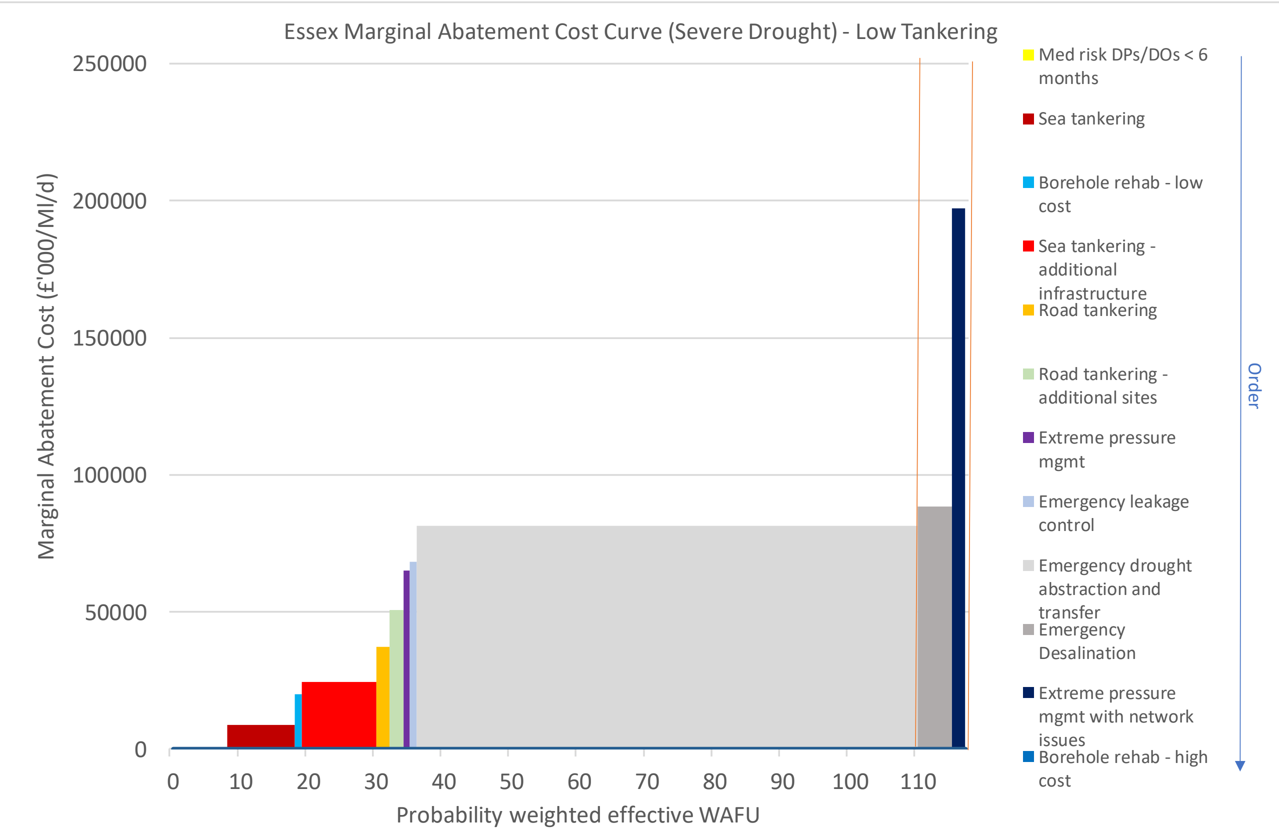


Figure 5-4 Extreme Drought in Essex (supply shortfalls 113 Ml/d to 118 Ml/d with "dry climate change" ***and no WRMP investment*****)**



5.1.4. Thames Basin

Without significant investment in the WRMP process, the Thames including London is threatened by water shortages in 'severe' and 'extreme' droughts where supply shortfalls are up to 432 Ml/d. This region would require large amounts additional abstraction in extreme drought situations with consequent environmental impacts.

Figure 5-5 Severe Drought (WAFU results) in Thames (supply shortfalls 122 Ml/d to 206 Ml/d with "dry climate change" ***and no WRMP investment*****)**

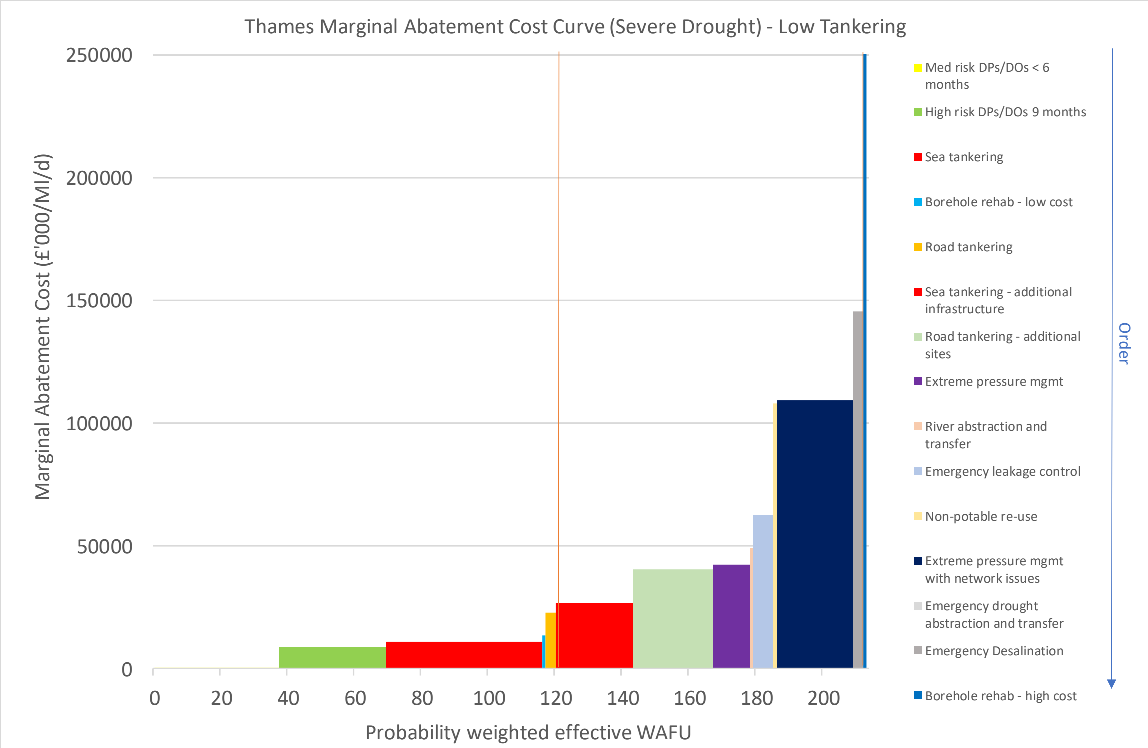
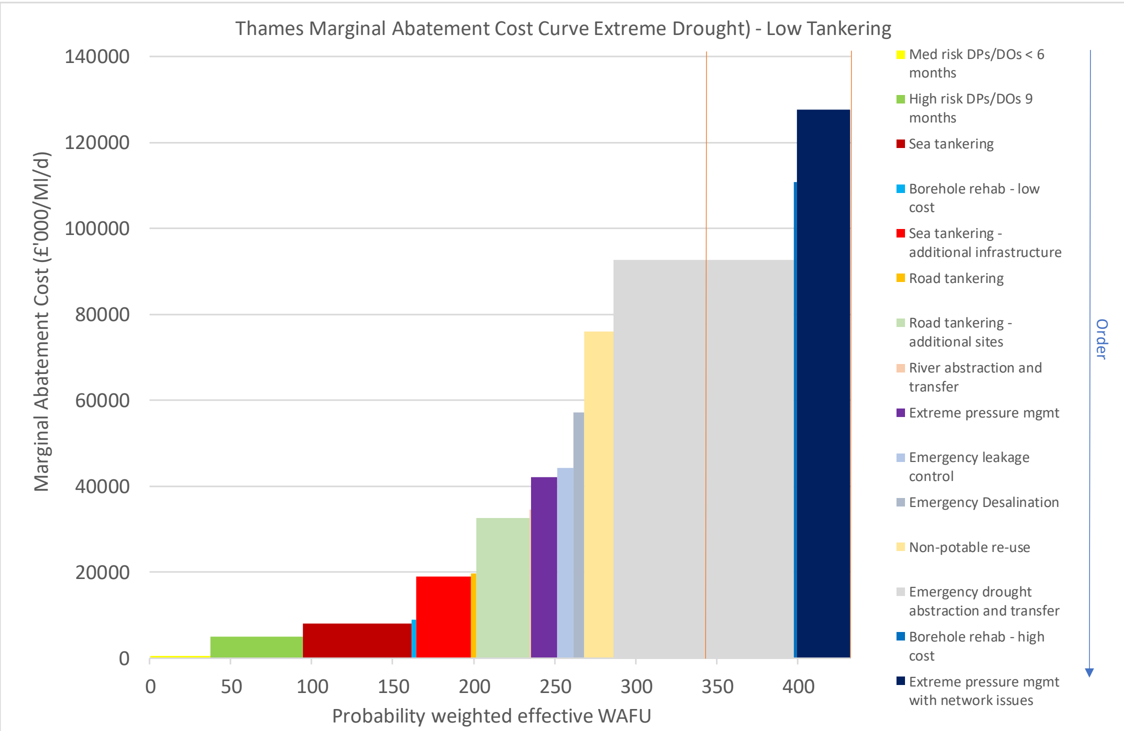


Figure 5-6 Extreme Drought in Thames (WAFU results) (supply shortfalls 348 Ml/d to 432 Ml/d with "dry climate change" ***and no WRMP investment*****)**



5.1.5. East of England

Without significant investment in the WRMP process, the East is threatened by water shortages in 'extreme' droughts where supply shortfalls are 88 Ml/d to 226 Ml/d compared to emergency drought options of 96 Ml/d.

Figure 5-7 Severe Drought in the East of England (supply shortfalls 5 Ml/d to 112 Ml/d with "dry climate change" *and no WRMP investment*)

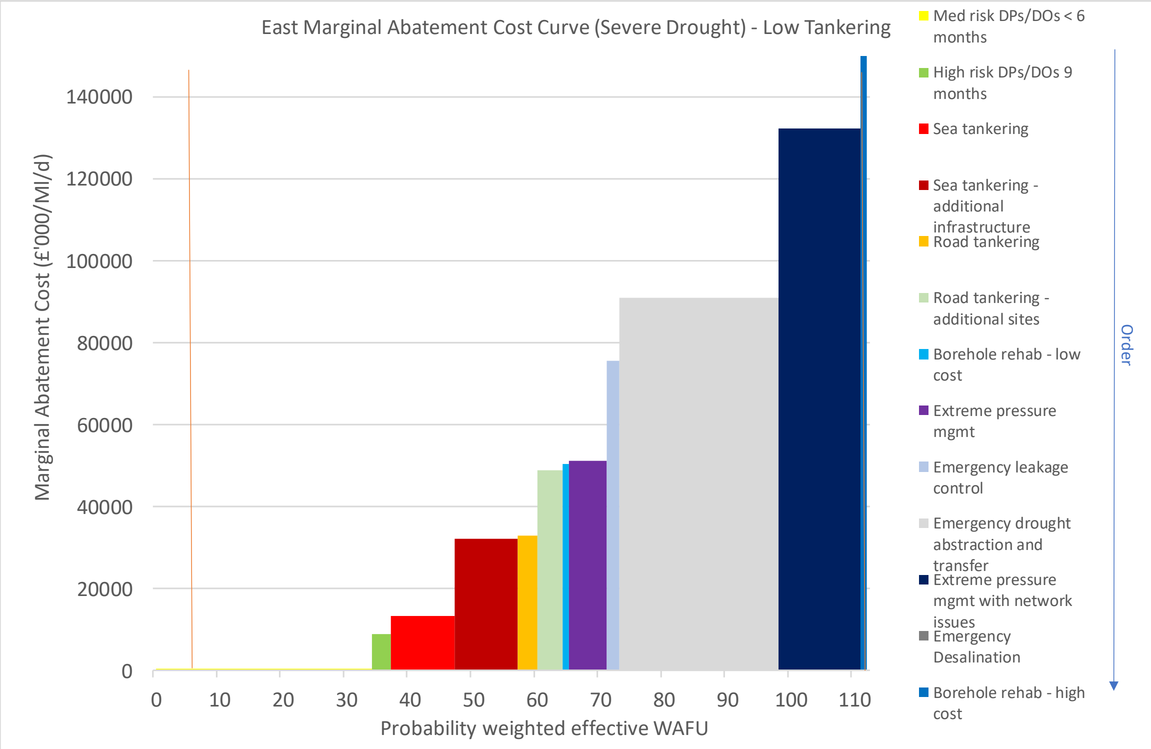
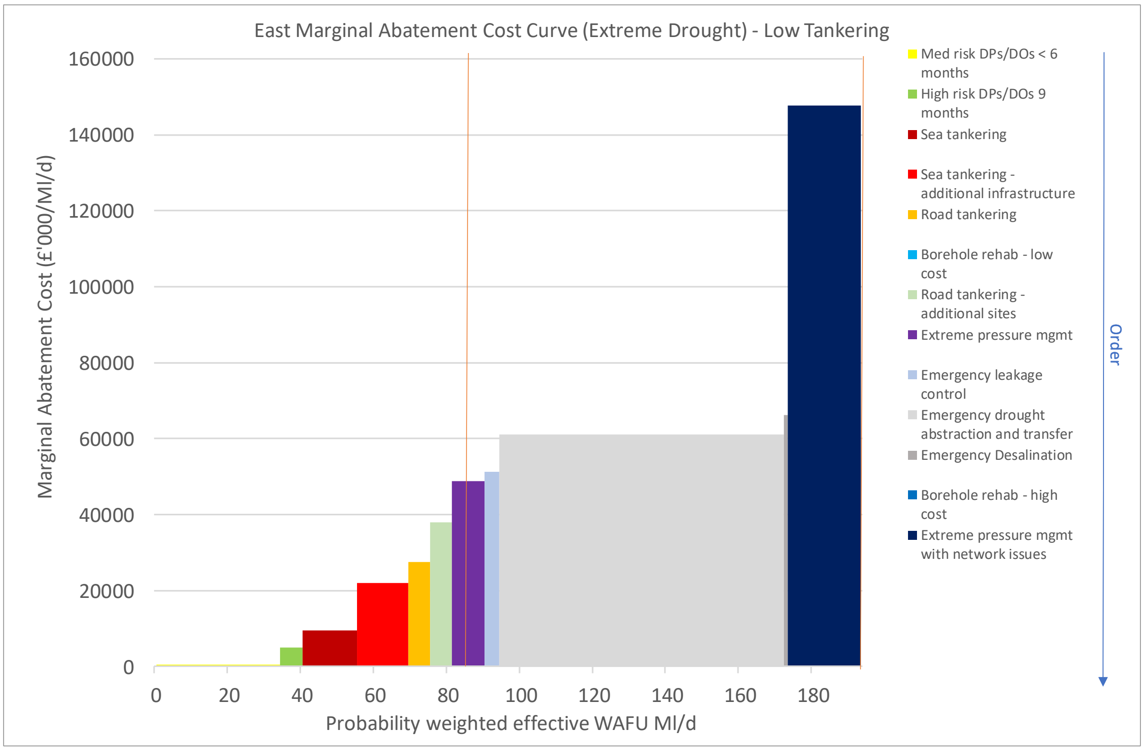


Figure 5-8 Extreme Drought in the East of England (supply shortfalls 86 Ml/d to 198 Ml/d with "dry climate change" *and no WRMP investment*)



5.1.6. Yorkshire

Without significant investment in the WRMP process, the Yorkshire is threatened by water shortages in 'extreme' droughts where supply shortfalls are 236 Ml/d to 339 Ml/d. The region would require additional abstraction for the environment in extreme droughts.

Figure 5-9 Severe Drought in Yorkshire (supply shortfalls 69 Ml/d to 171 Ml/d with "dry climate change" ***and no WRMP investment*****)**

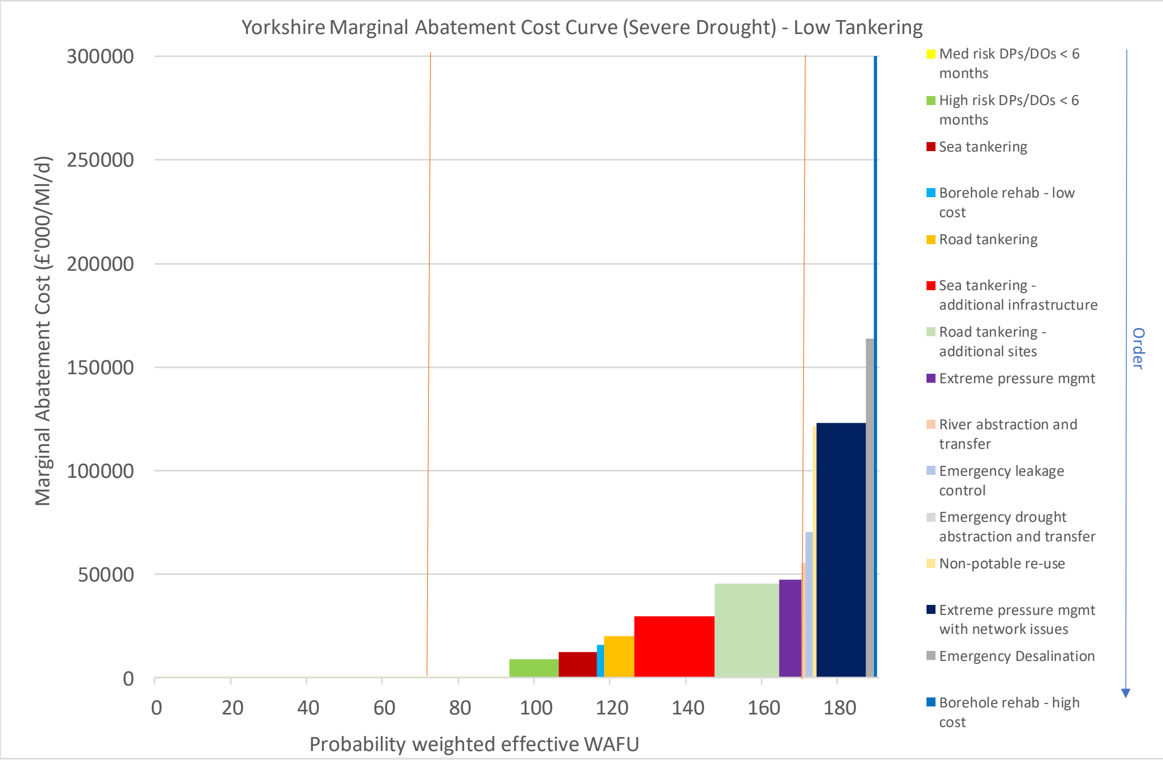
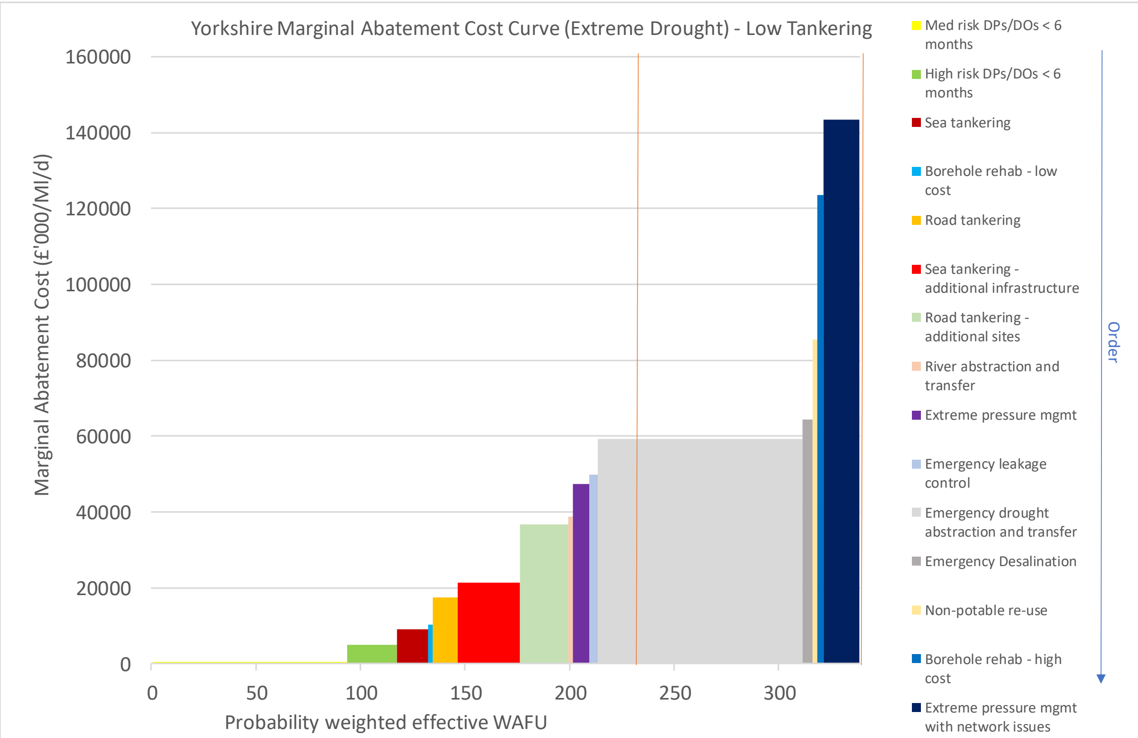


Figure 5-10 Extreme Drought in Yorkshire (supply shortfalls 236 Ml/d to 399 Ml/d with "dry climate change" ***and no WRMP investment*****)**



5.1.7. Central

Without significant investment in the WRMP process, the Yorkshire is threatened by water shortages in ‘extreme’ droughts where supply shortfalls are 102 Ml/d to 413 Ml/d. This region would require additional abstraction from the environment in extreme drought situations with consequent environmental impacts.

Figure 5-11 Severe Drought in Central (supply shortfalls 41 Ml/d to 353 Ml/d with “dry climate change” *and no WRMP investment*)

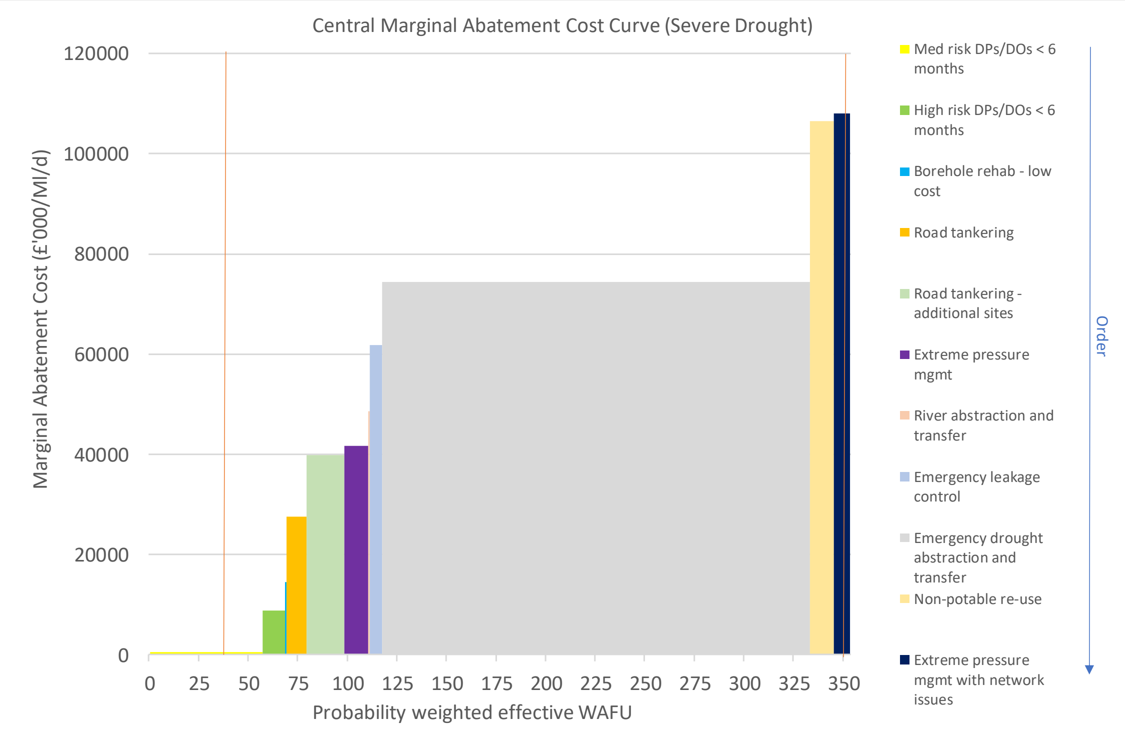
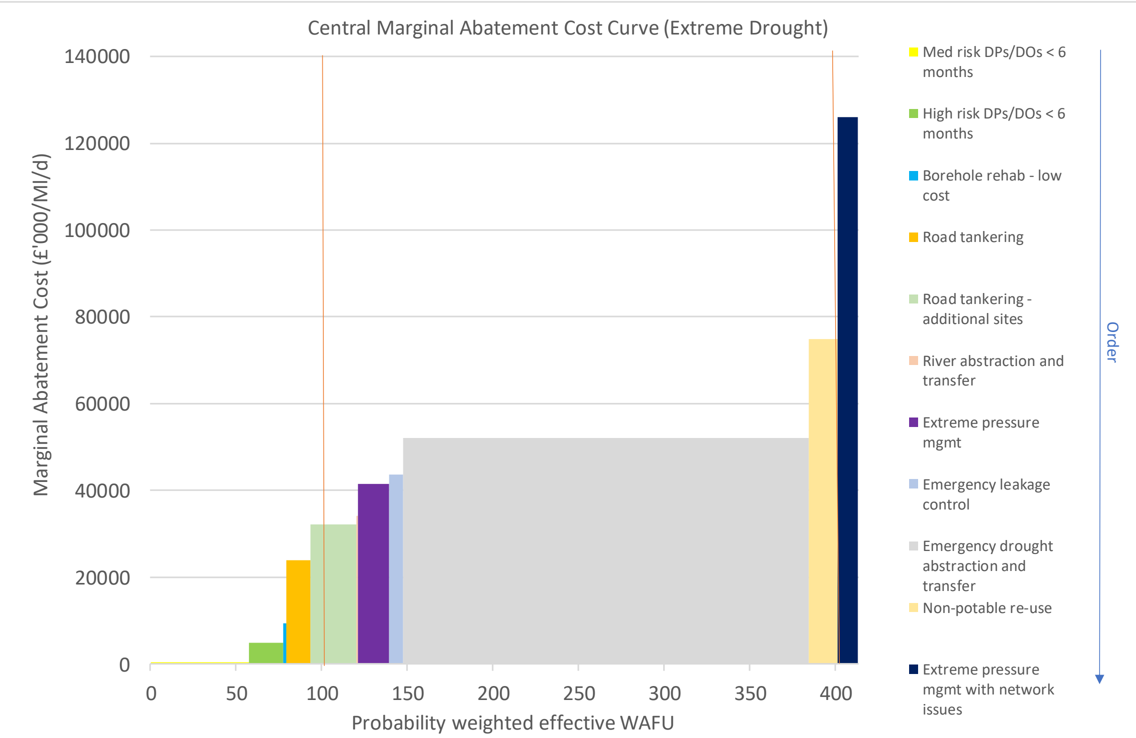


Figure 5-12 Extreme Drought in Central (supply shortfalls 102 Ml/d to 413 Ml/d with “dry climate change” *and no WRMP investment*)



5.1.8. Bristol

Without significant investment in the WRMP process, the Bristol is threatened by water shortages in 'severe' and 'extreme' droughts where supply shortfalls are up to 75 Ml/d compared to emergency drought options of 18 Ml/d.

Figure 5-13 Severe Drought in Bristol (supply shortfalls 15 Ml/d to 28 Ml/d with "dry climate change" *and no WRMP investment*)

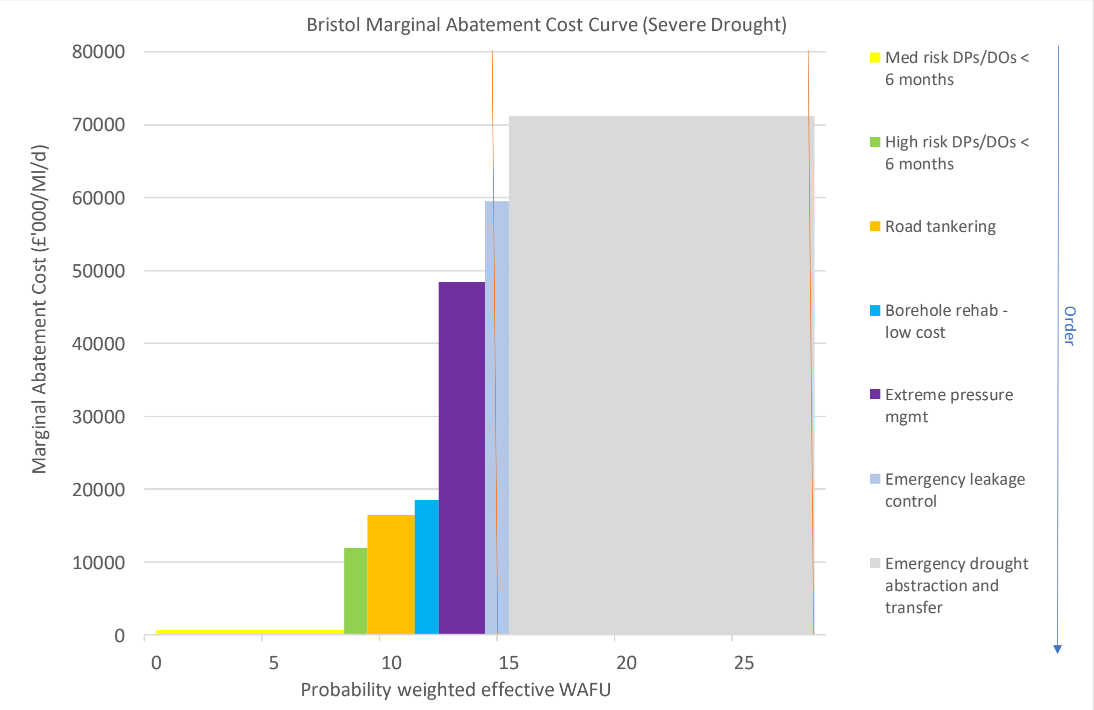
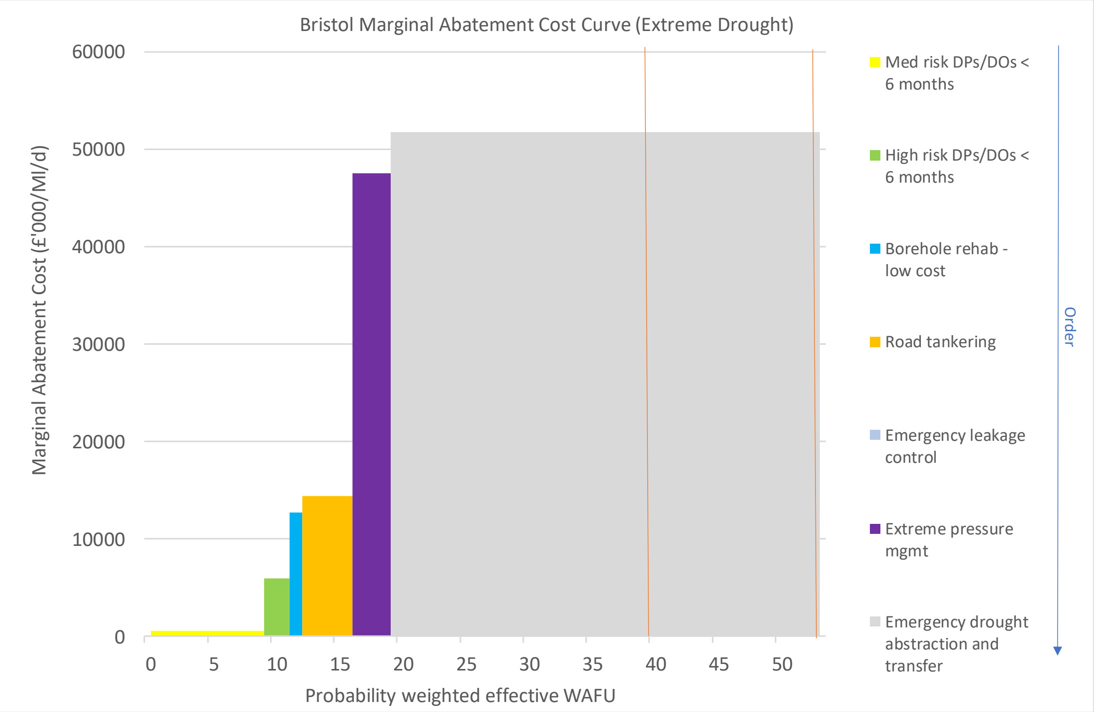


Figure 5-14 Extreme Drought (supply shortfalls 40 Ml/d to 53 Ml/d with "dry climate change" *and no WRMP investment*)



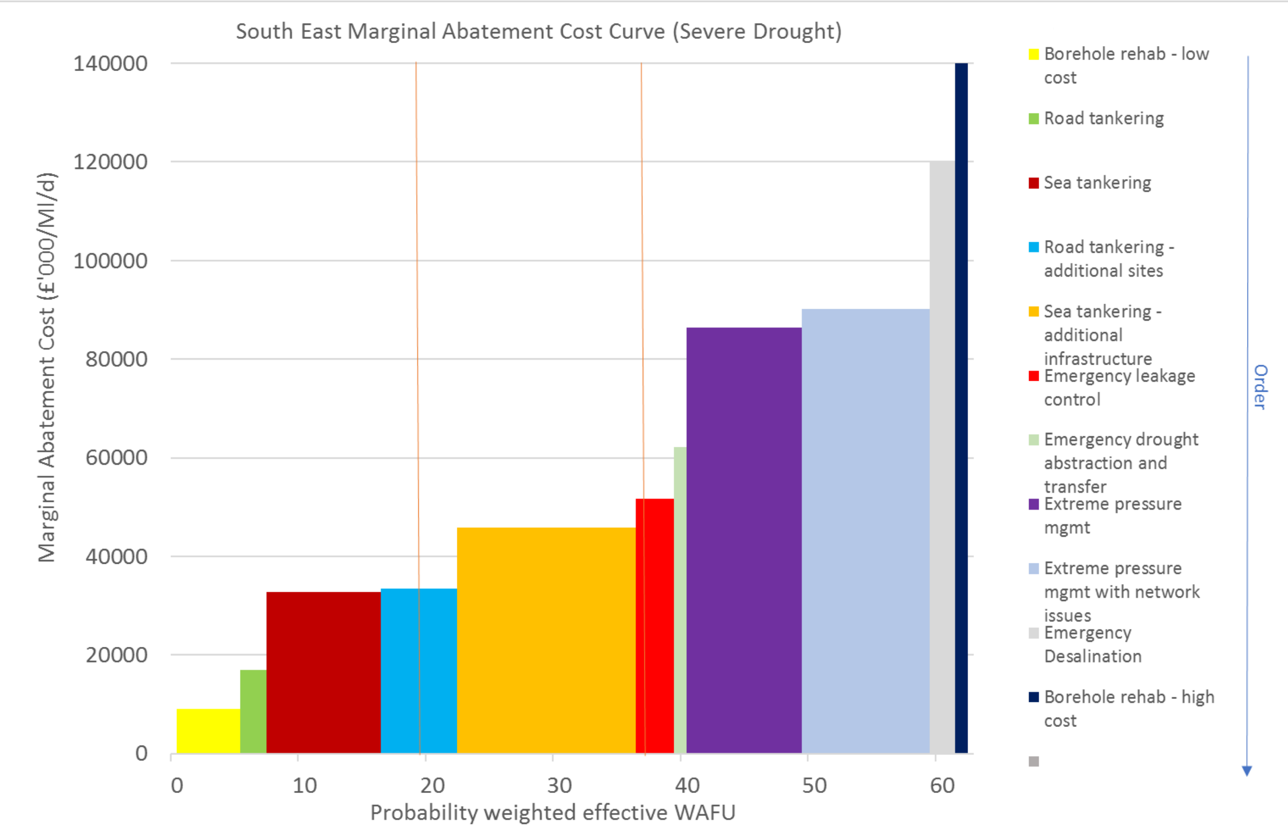
5.1.9. 'Pessimistic' Scenarios for Severe Droughts

As noted in Section 4, some of the less expensive interventions (Drought Orders, road tankering, sea tankering and extreme pressure management) attract very large uncertainties in the true economic costs of the intervention. These have a significant impact on the actual scale and shape of the lower end of the MACC cost curves, and hence strongly affect the apparent cost of emergency interventions, particularly on the 'severe' drought scenarios where the deficits are smaller and hence these lower cost options form a larger part of the response. The 'severe' drought scenarios were therefore run on a more pessimistic basis, whereby the following assumptions were changed around the key uncertainties for some of the more viable options. This analysis comprised:

- The medium and high-risk Drought Orders and Permits being treated as 'emergency' abstractions with associated high environmental costs.
- Ship tankering operating without a functional potable water market, and hence attracting the costs associated with 'option 2' as described in Section 4.7
- Reduced availability of road tankering
- Increased economic costs of extreme pressure management that are reflective of the potential risk to health that the intervention could cause.

An example MACC curves generated for the severe drought scenarios under this more 'pessimistic' approach is provided below and several more are provided in Appendix F. These show that the overall costs increase dramatically, and highlight the uncertainties associated with relying on emergency measures to address potential supply/demand shortfalls under droughts that are worse that the worst historic record.

Figure 5-15 Southern England, Severe Drought WAFU, Pessimistic Option Costs



6. Conclusion

This study has estimated the costs of emergency drought measures for regions in England based on information from water company plans, interviews and expert opinion.

A model was developed to estimate the water available from drought permits and emergency options, considering regional water resources characteristics and issues related to lead times and frequency of option use. Models were provided to the NIC for use in their own study for comparing emergency costs and long term ‘drought resilience’ costs.

The results indicate the many emergency measures are challenging to implement, provide uncertain yields and incur significant costs. For example:

- The regional availability of drought permits is important and has significant impacts on lowering overall emergency costs; however, drought permits may be less reliable for longer durations droughts.
- Some low capacity groundwater options are feasible but do not provide significant yields.
- There is a requirement for enabling works in advance of any severe or extreme drought to allow rapid implementation of other temporary treatment and transfer options.
- There could be supply chain issues emerging during a drought due the availability of equipment and staff resources.
- Water quality constraints are significant for both drinking water quality and at river abstractions.
- Further abstraction from the environment could be required *in extremis*, but this is likely to have significant environmental impacts; the magnitude, extent and duration of damage caused by temporary increased abstraction is not well understood.

The overall NIC National Infrastructure Assessment will complete an assessment of costs, benefits and risks of drought and make recommendations in Summer 2018. This will need to take into account the much higher degree of uncertainty associated with emergency measures in comparison with ‘conventional’ water resources management approaches, some of which are not appropriate to evaluate based on expected probabilities. A ‘pessimistic’ set of outputs has therefore been provided that highlight the range of issues and uncertainties that are potentially associated with emergency drought interventions.

Both the emergency measure capacities and costs are uncertain but, for the first time, this work enables high level comparison between the costs of emergency measures and long-term planning. More detailed analysis at a company or regional scale may help to determine appropriate levels of risk and water levels of service in different regions of England.

In parallel the statutory Water Resources Management Planning process and water company Business Plans should provide measures for maintaining supplies in drought situations. These plans will be completed in late 2018.

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Appendix A. Drought measures cost model

A.1. Introduction

Water companies are not required to provide detailed information on the costs incurred preparing for droughts or implementing drought measures. The project developed a cost model using available data from draft WRMPs, existing literature and consultation with water company experts. This appendix describes the cost model in more detail, including its inputs and major assumptions.

There are two main components of costs are capital expenditure (capex) and operating expenditure (fixed and variable opex). Capex may include enabling works installed prior to drought as well as costs triggered when there is a threat to public water supply. Opex includes a fixed annual component, such as ground rent and annual maintenance and variable opex when a scheme is used during drought conditions. Environmental costs can also be considered, although we found that there was limited data on environment costs in the draft WRMPs.

There are two important considerations in the development of costs: (a) utilisation of the option, which is influenced by the frequency an option is triggered and the period it is used during a drought year; (b) lead time, which is a characteristic of regional water resources affecting the amount of time between successive drought triggers and the period an option would be used. If drought option costs are to be compared with long term water resources investment costs this must be done a consistent basis using the same underlying cost assumptions and utilisation assumptions. For these reasons a model of drought costs is provided rather than just a database of costs. The model is presented as three worksheets: (a) Scenario definition, which defines the regional water resources characteristics, lead time assumptions and drought frequencies; (b) Inputs, which includes information on capex, opex and environmental costs from available data and (c) Marginal Abatement Cost Curve (MACC) outputs. The table below describes key concepts, model inputs and variables. Application to NIC study

Scenario definition

Concept/ variable	Units	Explanation	Source of Evidence
Typical storage recession period (to Level 4 restrictions)	Months	This is the expected time it takes for reservoir (or groundwater) storage to be depleted from a healthy position to a situation requiring emergency measures. The scenario is based on “average expectation” and water resources systems analysis completed for the Water UK study (Atkins, 2017). For a short drought, the time period may be ca. 8 months but for two-year drought there may be a longer slower decline over ca. 20 months. Recession periods vary regionally depending on the balance of groundwater, surface reservoir and “run-of-river” sources. The concept is important because it determines the time available to respond and therefore the feasibility of different drought options.	Water UK, 2017 systems modelling Expert Opinion
Available lead times to Level 4 restrictions	Months	These are time periods to pass from different drought triggers to Level 4 restrictions. As above.	Expert Opinion
Expected drought duration below 'Level 4'	Months	The length of time below the trigger for emergency drought measures. This is important because it affects the length of time that emergency measures are required and therefore the operational costs. Its assumed that a severe drought event lasts for 3 months and an extreme drought event for 5 months.	Expert Opinion and as specified in the Terms of Reference (3 months)

Concept/ variable	Units	Explanation	Source of Evidence
Frequency of event	Probability	This is the annual probability of severe events and extreme events, which is set at 0.005 (1 in 200 years) and 0.002 (1 in 500 years).	Water UK 2017 Ofwat methodology 2017 WRMP guidelines
Utility/trigger multipliers	Factor	This is a factor to account for the requirement to start the drought planning process and implement measures well in advance and therefore to incur costs, when the drought period may subsequently be broken by wetter conditions. It is assumed that emergency measures need to be put in place three times more frequently than they will be required. In addition, its assumed that the level 2 and level 3 restrictions are in place 1 in 10 and 1 in 20 years. The factors are quite conservative for level 2 and level 3 and the multipliers could be greater due to false alarms as well. This can be varied if the reported levels of service in a region are very different from this assumption.	Expert Opinion Consultation with water companies
Total drought storage recession -	Months	Simple addition of recession and duration periods.	Modelled based on above inputs
Percentage of resource base reliant on storage	%	This is proportion of the regional water supply reliant on groundwater and reservoir storage. It is important because storage provide a buffer to drought and greater flexibility and lead time.	Expert Opinion and analysis of dWRMP abstraction licences
NPV calculation horizon	Years	Set to 80 years and used in the economic calculations.	EA WRMP
Economic cost deflator	%	Set to 3% and consistent with HM Treasury Green Book guidance.	HMG Green Book
Climate change		*There are no climate change scenarios defined here. In theory these could affect recessions, lead times and frequencies. However, climate change is introduced later in the analysis with respect to the size of the shortfallsin each region.*	*Expert Opinion*

Inputs

Concept/ variable	Units	Explanation	Source of Evidence
Capacity of option	Ml/d	Capacity estimates from several different sources. Effective capacities were calculated from scenario assumptions related to water resources recession and lead times.	Drought Plans Consultation Expert Opinion
	Ml/d	Drought Permits: A database of all drought permits in England was developed. The "likely" permits were assumed to be in the baseline so the capacities are based on the "possible" and "unlikely" permits that are difficult to implement and may have high environmental costs.	Drought Plans Water UK study

	Ml/d	Borehole Rehabilitation. This is the rehabilitation of additional sites over and above what is included in the Drought Plans.	Drought Plans and consultation with companies.
Option costs	£'000	Sea Tankers, Road Tankers and other emergency measures costs have been developed based on consultation and cross-referencing to costs in dWRMP Table 5. Drought Permits – some costs come from dWRMPs	dWRMP Table 5 Cross-check of capex, opex and environmental costs Expert Opinion
Cost uncertainty	Class	Classification of cost uncertainties, which is generally from "moderate" to "very high"	Expert Opinion
Probability of success	Class	Probability Used in final MACC curves.	Expert Opinion
Environmental risk	Class	Classification based on analysis of drought plans. Note that it is assumed that low risk Drought Permits have already been used to estimate the drought supply-demand deficits.	Drought Plans

Outputs

Outputs	Units	Explanation
Effective Benefit Multiplier	Factor	This is a calculation that checks the lead time to take action and lead time for the option. It will range from 1 to 0, depending on whether there is sufficient time for implementation.
Option benefits	Various	The water delivered by the option using different metrics. The choice of metric for the curve will need to match the water resources study.
Costs build up	£'000s	Capex, fixed Opex, preliminary costs build up by drought band, environmental costs and variable Opex costs.
Probability of success	Probability	This is the chance of success. It is linked to final costs rather than capacities. Its effect is to increase costs.
Net Present Values	£'000s	Total NPV, water available during the drought and capacity values. Bar heights on MACC curve.
Probability weighted effective WAFU and capacity	Ml/d	Bar widths on MACC curve.

A.1.1. Portfolio Build-up Pro-Forma for South East

Option	Notes on Total Capacity Delivered	Geographical coverage Source of Costs							Probability of success	Lead time
		Full Capex £'000	Enabling works £000	Variable Opex £'000/Ml/ annum	Fixed Opex £'000/annum	Drought costs – prelim. spend (band 2)	Drought costs – prelim. spend (band 3)	Env costs £'000/trigger		
Sea Tankering	30Ml/d total assumed – land 15Ml/d each at Portsmouth and Isle Grain (based on nearby WTW size)	Tankering model	Pipeline to WTW – less than 20km option	Tankering model	Tankering model plus 1% pipeline	None additional	Tankering model	None	1	3 months
Road Tankering	Deliver from Thames Guildford or Portsmouth/Bournemouth – 100 mile round trip option. Max of 10Ml/d from each area – i.e. 20Ml/d	None	Minor	£40.1/m^3 based on 100 mile round trips	Not significant	Not significant	Assume costs start half way through period	None	1	3 months
Severe pressure management	3 million properties in region. Assume 25% viable/required, so maximum of 750,000 properties. Saving @ 8m^3 each over 3 months = 66Ml/d maximum savings for region	None	Minor	£53/m^3 – N.B. as this is pure opex it already accounts for the fact that half of customers will not end up being affected as the scheme will be stopped in that area	Maintain plans @ £20k per annum per company (£100k per AMP)	Assume comms costs etc included in TUBs & NEUB prior to scheme	Include comms costs and monitoring costs at this stage as setup	None (social costs included in main number)	0.5 – risk that option will have to stop due to excessive problems in half the areas	3 months
Intensive leakage control	Max of 10% of leakage remaining; 210Ml/d base @ 2040 from Water UK, * 0.85 * 0.1 = 17Ml/d					50% of band 2 (need to gear up once every 10 years)	Costs at 1/0.82 * max curve step	None (social costs included in main number)	0.75 (been done before, but there are concerns over staff resource availability in a widespread event)	3-6 months
Emergency Borehole refurb	*See Drought Plan Analysis. ✓Around (54 Ml/d) 57% of the available schemes are groundwater related but not all require refurbishment and associated lead time and costs.*	✓WRMP T5 75th percentile for expensive (treatment) options, 25th	None	× WRMP T5 as per capex – *figures for new gw schemes and DPs are very different 10 – 2000 range so assumptions made.*	✓Minor – 1% of capex to maintain site potential	Apportioned from total capex according to timing	Apportioned from total capex according to timing	✓ WRMPT5 75th percentile (rather low no.)	0.75 for low cost – controllable, but not tested, 0.5 for high	3-12 months

	Therefore assumed 4 x 5 Ml/d schemes at low cost and individual 5 Ml/d higher cost schemes. Overall capacity of DPs balanced.	percentile for simple refurb							cost as advanced WTW required	
DPs & DOs	*See Drought Plan Analysis – 64 Ml/d and a mixture of surface water and groundwater schemes. Classified according to risk and lead time.*						High risk @ 75th percentile from T5, med risk @ 50th percentile	Taken 90th percentile from SW abstractions (T5), plus highest cost for high risk schemes	0.5 for med risk and 0.25 for high risk	*See DP/DO analysis*
Emergency desalination	Two potential sites identified in Drought Plans – could possibly consider more. 20Ml/d each	Taken from T5 cost model multiplied by 1.25 = £ 6,408 M per Ml/d	25% of total cost	WRMPT5 model Median £ 2,091 M per Ml/d	Minor – 1% of enabling works	None	25% of total capex	WRMPT5 – median £0.5 M per Ml/d	0.75 – controllable, but not tested	6 – 12 months, assume 6 months with enabling works
Modified options – increased expenditure to allow greater size or deployment in time for the L4 period										
Severe pressure mgmt	Additional option whereby the 50% of areas that otherwise would be stopped due to water quality/network problems continue with the measure	None	Minor	Major additional WTP costs – equivalent to £464/m3	Not significant	None				
High cost borehole refurb – short lead time	As above for high cost borehole refurb – this just incorporates treatment capex up-front to allow rapid deployment of option	Take 75th percentile GW costs	75% of capex taken as enabling works	As above	As above	As above	Remaining 25% capex	As above	Improve to 100% due to enabling works	3-6 months
Sea tankering – additional infra	As per sea tankering, but allows for inland system improvements to allow larger schemes – add 50Ml/d	Take higher end costs – effectively long transfer infra	As above	As above	As above	As above	As above	As above	As above	As above
Road tankering – additional sites	As above, but longer journey and more enabling works.	Take high end 200mile round trip costs	None	£150k per site	£79.4//m3 based on 200mile round trips	Not significant	Not significant	Greater pressure on availability so costs from start of band 3 period	1	3 months

A.1.2. Portfolio Build-up Pro-Forma for Thames Emergency Options

Option	Notes on Total Capacity Delivered	Source of Costs							Probability of success	Lead time
		Full Capex £'000	Enabling works £000	Variable Opex £'000/Ml/ annum	Fixed Opex £'000/annum	Drought costs – prelim. spend (band 2)	Drought costs – prelim. spend (band 3)	Env costs £'000/trigger		
Sea Tankering	200Ml/d Thames estuary option	Tankering model – low costs taken	Pipeline to WTW – less than 20km option	Tankering model – low costs taken	Tankering model plus 1% pipeline	None additional	Tankering model – low costs taken	None	1	3 months (option 3 assumed)
Road Tankering	Deliver from either Anglian or Severn Trent, need to get to Thames reservoirs or Farmoor so 150mile round trip, max 10Ml/d	None	Minor	£51.5/m3 based on 150mile round trips	Not significant	Not significant	Assume costs start half way through period	None	1	3 months
Severe pressure mgmt	6.15 million properties in region @ 2040. Assume 25% viable/required, so maximum of 1.5million. Saving @ 8m3 each over 3 months = 136Ml/d maximum savings for region	None	Minor	£53/m3 – N.B. as this is pure opex it already accounts for the fact that half of customers will not end up being affected as the scheme will be stopped in that area	Maintain plans @ £40k per annum (£200k per AMP)	Assume comms costs etc included in TUBs & NEUB prior to scheme	Include comms costs and monitoring costs at this stage as setup	None (social costs included in main number)	0.5 – risk that option will have to stop due to excessive problems in half the areas	3 months
Intensive leakage control	Max of 10% of leakage remaining; 610Ml/d base @ 2040 from Water UK, * 0.85 (Ofwat 15%) * 0.1 = 52Ml/d					50% of band 2 (need to gear up once every 10 years)	Costs at 1/0.82 * max curve step	None (social costs included in main number)	0.75 (been done before, but there are concerns over staff resource availability in a widespread event)	3-6 months
Emergency Borehole refurb	*See Drought Plan Analysis = 11Ml/d low cost, 20Ml/d high cost*	WRMP T5 75th percentile for expensive (treatment) options, 25th percentile for simple refurb	None	WRMP T5 as per capex	Minor – 1% of capex to maintain site potential	Apportioned from total capex according to timing	Apportioned from total capex according to timing	WRMPT5 75th percentile	0.75 for low cost – controllable , but not tested, 0.5 for high cost as advanced	3-12 months

									WTW required	
DPs & DOs	*See Drought Plan Analysis*						High risk @ 75th percentile from T5, med risk @ 50th percentile	Taken 90th percentile from SW abstractions (T5), plus highest cost for high risk schemes	0.5 for med risk and 0.25 for high risk	*See DP/DO analysis*
Emergency desalination	Beckton area only – likely to be 50Ml/d max given existing infrastructure	Taken from T5 cost model multiplied by 1.25	25% of total cost	WRMPT5 model	Minor – 1% of enabling works	None	25% of total capex	WRMPT5	0.75 – controllable, but not tested	6 – 12 months, assume 6 months with enabling works
River abstraction and transfer	5Ml/d scheme for Oxford only	Take from T5 transfer model (as raw water)	10% of total cost	Minor	Minor	None	Assume 50% of costs	Minor	0.5*0.75 = 0.375 – only applicable for SWOX WRZ and untested	3 months
Effluent re-use	Not stated – minor availability of non-potable use close to STW. Assume 5Ml/d	Multiple small pipelines required but temporary and short distance – use T5 short distance	n/a	WRMPT5 short transfer model	None	Minor	All expenditure to set up operations	Minor	0.5 – entirely unproven	3 months
Modified options – increased expenditure to allow greater size or deployment in time for the L4 period										
Severe pressure mgmt	Additional option whereby the 50% of areas that otherwise would be stopped due to water quality/network problems continue with the measure	None	Minor	Major additional WTP costs – equivalent to £464/m3	Not significant	None				
High cost borehole refurb – short lead time	As above for high cost borehole refurb – this just incorporates treatment capex up-front to allow rapid deployment of optiono	Take 75th percentile GW costs	75% of capex taken as enabling works	As above	As above	As above	Remaining 25% capex	As above	Improve to 100% due to enabling works	3-6 months
Sea tankering – additional infra	As per sea tankering, but allows for inland system improvements to allow	Take higher end costs – effectively	As above	As above	As above	As above	As above	As above	As above	As above

	larger schemes – add 50Ml/d	long transfer infra								
Road tankering – additional sites	As above, but longer journey and more enabling works.	Take high end 200mile round trip costs	None	£150k per site	£79.4//m3 based on 200mile round trips	Not significant	Not significant	Greater pressure on availability so costs from start of band 3 period	1	3 months

A.1.3. Portfolio Build-up Pro-Forma for Central Emergency Options

Option	**Notes on Total Capacity Delivered**	**Source of Costs**							**Probability of success**	**Lead time**
		Full Capex £'000	**Enabling works £000**	**Variable Opex £'000/Ml/ annum**	**Fixed Opex £'000/annum**	**Drought costs – prelim. spend (band 2)**	**Drought costs – prelim. spend (band 3)**	**Env costs £'000/trigger**		
Sea Tankering	Not applicable									
Road Tankering	Deliver from Anglian or Welsh to Birmingham or Notts, so relatively long distance (200 mile round trip). 2 sites @ 20Ml/d max	None	Minor	£63.9/m3 as average for trip	Not significant	Limited	Assume costs start half way through period	None	1	3 months
Severe pressure mgmt	Consider the whole of the Grid so 4.7m properties in region @2040. Assume 25% viable/required, so maximum of 1.2m properties. Saving @ 8m3 each over 3 months = 106Ml/d maximum savings for region	None	Minor	£53/m3 – N.B. as this is pure opex it already accounts for the fact that half of customers will not end up being affected as the scheme will be stopped in that area	Maintain plans @ £40k per annum (£200k per AMP)	Assume comms costs etc included in TUBs & NEUB prior to scheme	Include comms costs and monitoring costs at this stage as setup	None (social costs included in main number)	0.5 – risk that option will have to stop due to excessive problems in half the areas	3 months
Intensive leakage control	Max of 10% of leakage remaining; Ml/d base @ 363Ml/d 2040 from Water UK, 363* 0.85 * 0.1 = 31Ml/d					50% of band 2 (need to gear up once every 10 years)	Costs at 1/0.82 * max curve step	None (social costs included in main number)	0.75 (been done before, but there are concerns over staff resource availability in a widespread event)	3-6 months

Emergency Borehole refurb	*See Drought Plan Analysis – only 1 source @ 9Ml/d*	Take WRMP T5 50th percentile	None	WRMP T5 as per capex	Minor – 1% of capex to maintain site potential	Apportioned from total capex according to timing	Apportioned from total capex according to timing	WRMPT5 75th percentile	0.75 – reasonably likely to work	3-6 months
DPs & DOs	*See Drought Plan Analysis*						High risk @ 75th percentile from T5, med risk @ 50th percentile	Taken 90th percentile from SW abstractions (T5), plus highest cost for high risk schemes	0.5 for med risk and 0.25 for high risk	*See DP/DO analysis*
Modified options – increased expenditure to allow greater size or deployment in time for the L4 period										
Severe pressure mgmt	Additional option whereby the 50% of areas that otherwise would be stopped due to water quality/network problems continue with the measure	None	Minor	Major additional WTP costs – equivalent to £464/m3	Not significant	None				
Road tankering – additional sites	As above, but longer journey and more enabling works.. Extend to all large works at 10ML/d per site (40Ml/d total)	Take high end 200mile round trip costs	None	£150k per site	£79.4//m3 based on 200mile round trips	Not significant	Not significant	Greater pressure on availability so costs from start of band 3 period	1	3 months

A.1.4. Portfolio Buildup Pro-Forma for East Emergency Options

Option	Notes on Total Capacity Delivered	Source of Costs							Probability of success	Lead time
		Full Capex £'000	Enabling works £000	Variable Opex £'000/Ml/ annum	Fixed Opex £'000/annum	Drought costs – prelim. spend (band 2)	Drought costs – prelim. spend (band 3)	Env costs £'000/trigger		
Sea Tankering	50Ml/d total assumed – as per Albion Water proposals	Tankering model	Pipeline to WTW – less than 20km option	Tankering model	Tankering model plus 1% pipeline	None additional	Tankering model	None	1	3 months
Road Tankering	Deliver from Severn Trent, Thames or Yorkshire to larger works so long distance. 200 mile round trip. Assume 2 sites (e.g. Peterborough, Bedford) so 20Ml/d maximum	None	Minor	£62.6/m3 based on 200mile round trips	Not significant	Not significant	Assume costs start half way through period	None	1	3 months

Severe pressure mgmt	3.7 million properties in region. Assume 25% viable/required, so maximum of 925,000 properties. Saving @ 8m3 each over 3 months = 66Ml/d maximum savings for region	None	Minor	£53/m3 – N.B. as this is pure opex it already accounts for the fact that half of customers will not end up being affected as the scheme will be stopped in that area	Maintain plans @ £20k per annum per company (£100k per AMP)	Assume comms costs etc included in TUBs & NEUB prior to scheme	Include comms costs and monitoring costs at this stage as setup	None (social costs included in main number)	0.5 – risk that option will have to stop due to excessive problems in half the areas	3 months
Intensive leakage control	Max of 10% of leakage remaining; 194Ml/d base @ 2040 from Water UK, * 0.85 * 0.1 = 16.5Ml/d					50% of band 2 (need to gear up once every 10 years)	Costs at 1/0.82 * max curve step	None (social costs included in main number)	0.75 (been done before, but there are concerns over staff resource availability in a widespread event)	3-6 months
Emergency Borehole refurb	*See Drought Plan Analysis – 3 expensive and 1 low cost. 6Ml/d expensive total and 1.6Ml/d low cost*	WRMP T5 75th percentile for expensive (treatment) options, 25th percentile for simple refurb	None	WRMP T5 as per capex	Minor – 1% of capex to maintain site potential	Apportioned from total capex according to timing	Apportioned from total capex according to timing	WRMPT5 75th percentile	0.75 for low cost – controllable, but not tested, 0.5 for high cost as advanced WTW required	3-12 months
DPs & DOs	*See Drought Plan Analysis*						High risk @ 75th percentile from T5, med risk @ 50th percentile	Taken 90th percentile from SW abstractions (T5), plus highest cost for high risk schemes	0.5 for med risk and 0.25 for high risk	*See DP/DO analysis*
Emergency desalination	Essex & Suffolk at 5Ml/d total – need WRMP outputs to evaluate Anglian	Taken from T5 cost model multiplied by 1.25	25% of total cost	WRMPT5 model	Minor – 1% of enabling works	None	25% of total capex	WRMPT5	0.75 – controllable, but not tested	6 – 12 months, assume 6 months with enabling works
Modified options – increased expenditure to allow greater size or deployment in time for the L4 period										
Severe pressure mgmt	Additional option whereby the 50% of areas that otherwise would be stopped due to water	None	Minor	Major additional WTP costs – equivalent to £464/m3	Not significant	None				

	quality/network problems continue with the measure									
Sea tankering – additional infra	As per sea tankering, but allows for inland system improvements to allow larger schemes – add 50Ml/d	Take higher end costs – effectively long transfer infra	As above	As above	As above	As above	As above	As above	As above	As above
Road tankering – additional sites	As above, but longer journey and more enabling works. Add a further 2 sites for 20Ml/d.	Take high end 200mile round trip costs	None	£150k per site	£79.4//m3 based on 200mile round trips	Not significant	Not significant	Greater pressure on availability so costs from start of band 3 period	1	3 months

A.1.5. Portfolio Buildup Pro-Forma for Yorkshire Emergency Options

Option	**Notes on Total Capacity Delivered**	**Source of Costs**							**Probability of success**	**Lead time**
		Full Capex £'000	**Enabling works £000**	**Variable Opex £'000/Ml/ annum**	**Fixed Opex £'000/annum**	**Drought costs – prelim. spend (band 2)**	**Drought costs – prelim. spend (band 3)**	**Env costs £'000/trigger**		
Sea Tankering	50Ml/d total assumed – as per Albion Water proposals for eas, but with delivery to Humberside	Tankering model	Pipeline to WTW – less than 20km option (to Hull zone)	Tankering model	Tankering model plus 1% pipeline	None additional	Tankering model	None	1	3 months
Road Tankering	Deliver from Northumbrian or noth Anglian, with disparate WTWs available, so 100mile round trips and up to 40Ml/d	None	Minor	£40.1/m3 based on 100mile round trips	Not significant	Not significant	Assume costs start half way through period	None	1	3 months
Severe pressure mgmt	2.7 million properties in Grid. Assume 25% viable/required, so maximum of 675,000 properties. Saving @ 8m3 each over 3 months = 60Ml/d maximum savings for region	None	Minor	£53/m3 – N.B. as this is pure opex it already accounts for the fact that half of customers will not end up being affected as the scheme will be stopped in that area	Maintain plans @ £40k per annum y (£200k per AMP)	Assume comms costs etc included in TUBs & NEUB prior to scheme	Include comms costs and monitoring costs at this stage as setup	None (social costs included in main number)	0.5 – risk that option will have to stop due to excessive problems in half the areas	3 months
Intensive leakage control	Max of 10% of leakage remaining; 182Ml/d base @ 2040 from Water UK, * 0.85 * 0.1 = 15Ml/d					50% of band 2 (need to gear up once every 10 years)	Costs at 1/0.82 * max curve step	None (social costs included in main number)	0.75 (been done before, but there are	3-6 months

										concerns over staff resource availability in a widespread event)	
Emergency Borehole refurb	*TBC*										
DPs & DOs	*See Drought Plan Analysis*							High risk @ 75th percentile from T5, med risk @ 50th percentile	Taken 90th percentile from SW abstractions (T5), plus highest cost for high risk schemes	0.5 for med risk and 0.25 for high risk	*See DP/DO analysis*
Emergency desalination	Essex & Suffolk at 5Ml/d total – need WRMP outputs to evaluate Anglian	Taken from T5 cost model multiplied by 1.25	25% of total cost	WRMPT5 model	Minor – 1% of enabling works	None	25% of total capex	WRMPT5	0.75 – controllable, but not tested	6 – 12 months, assume 6 months with enabling works
Modified options – increased expenditure to allow greater size or deployment in time for the L4 period											
Severe pressure mgmt	Additional option whereby the 50% of areas that otherwise would be stopped due to water quality/network problems continue with the measure	None	Minor	Major additional WTP costs – equivalent to £464/m3	Not significant	None					
Sea tankering – additional infra	As per sea tankering, but allows for inland system improvements to allow larger schemes – add 50Ml/d	Take higher end costs – effectively long transfer infra	As above	As above	As above	As above	As above	As above	As above	As above
Road tankering – additional sites	As above, but longer journey and more enabling works. Add a further 2 sites for 20Ml/d.	Take high end 200mile round trip costs	None	£150k per site	£79.4//m3 based on 200mile round trips	Not significant	Not significant	Greater pressure on availability so costs from start of band 3 period	1	3 months

A.1.6. Portfolio Buildup Pro-Forma for North West Emergency Options

Option	Notes on Total Capacity Delivered	Source of Costs							Probability of success	Lead time
		Full Capex £'000	Enabling works £000	Variable Opex £'000/Ml/ annum	Fixed Opex £'000/annum	Drought costs – prelim. spend (band 2)	Drought costs – prelim. spend (band 3)	Env costs £'000/trigger		
Sea Tankering	Not considered – distance too great									
Road Tankering	Deliver from Yorkshire over to Manchester/Bolton in the 100mile round trip category.	None	Minor	£40.1/m3 as average for trip	Not significant	Limited	Assume costs start half way through period	None	1	3 months
Severe pressure mgmt	Integrated Zone @ 3.9m. Assume 25% viable/required, so maximum of 1m properties. Saving @ 8m3 each over 3 months = 88Ml/d maximum savings for region	None	Minor	£53/m3 – N.B. as this is pure opex it already accounts for the fact that half of customers will not end up being affected as the scheme will be stopped in that area	Maintain plans @ £40k per annum (£200k per AMP)	Assume comms costs etc included in TUBs & NEUB prior to scheme	Include comms costs and monitoring costs at this stage as setup	None (social costs included in main number)	0.5 – risk that option will have to stop due to excessive problems in half the areas	3 months
Intensive leakage control	Max of 10% of leakage remaining; 381Ml/d base @ 2040 from Water UK, * 0.85 * 0.1 = 32Ml/d					50% of band 2 (need to gear up once every 10 years)	Costs at 1/0.82 * max curve step	None (social costs included in main number)	0.75 (been done before, but there are concerns over staff resource availability in a widespread event)	3-6 months
Emergency Borehole refurb	*See Drought Plan Analysis – large number of low cost options @ 57Ml/d total*	WRMP T5 25th percentile for simple refurb	None	WRMP T5 as per capex	Minor – 1% of capex to maintain site potential	Apportioned from total capex according to timing	Apportioned from total capex according to timing	WRMPT5 25th percentile	0.75 (good chance)	3-6 months
DPs & DOs	*See Drought Plan Analysis*						High risk @ 75th percentile from T5, med risk @ 50th percentile	Taken 90th percentile from SW abstractions (T5), plus highest cost for	0.5 for med risk and 0.25 for high risk	*See DP/DO analysis*

								high risk schemes		

A.1.7. Portfolio Build-up Pro-Forma for South West Emergency Options

Option	Notes on Total Capacity Delivered	Source of Costs							Probability of success	Lead time
		Full Capex £'000	Enabling works £000	Variable Opex £'000/Ml/ annum	Fixed Opex £'000/annum	Drought costs – prelim. spend (band 2)	Drought costs – prelim. spend (band 3)	Env costs £'000/trigger		
Sea Tankering	Not considered – distance too great									
Road Tankering	Deliver from SWW, Bournemouth or Wales; in the 50-100mile round trip category; no need to deliver to Purton so Mendips WTW only option (10Ml/d max)	None	Minor	£34.5/m3 as average for trip	Not significant	Limited	Assume costs start half way through period	None	1	3 months
Severe pressure mgmt	Only Bristol at risk, so 625,000 properties in region. Assume 25% viable/required, so maximum of 156,000 properties. Saving @ 13m3 each over 5 months = 13.5Ml/d maximum savings for region	None	Minor	£53/m3 – N.B. as this is pure opex it already accounts for the fact that half of customers will not end up being affected as the scheme will be stopped in that area	Maintain plans @ £40k per annum (£200k per AMP)	Assume comms costs etc included in TUBs & NEUB prior to scheme	Include comms costs and monitoring costs at this stage as setup	None (social costs included in main number)	0.5 – risk that option will have to stop due to excessive problems in half the areas	3 months
Intensive leakage control	Max of 10% of leakage remaining; 38Ml/d base @ 2040 from Water UK, * 0.85 * 0.1 = 3Ml/d					50% of band 2 (need to gear up once every 10 years)	Costs at 1/0.82 * max curve step	None (social costs included in main number)	0.75 (been done before, but there are concerns over staff resource availability in a widespread event)	3-6 months

Emergency Borehole refurb	*See Drought Plan Analysis – in this case the low cost option would involve Wessex selling water to BRL, so add £500/Ml/d, or £525k over L4 period*	WRMP T5 75th percentile for expensive (treatment) options, 25th percentile for simple refurb	None	WRMP T5 as per capex	Minor – 1% of capex to maintain site potential	Apportioned from total capex according to timing	Apportioned from total capex according to timing	WRMPT5 75th percentile	0.75 for low cost – controllable, but not tested, 0.5 for high cost as advanced WTW required	3-12 months
DPs & DOs	*See Drought Plan Analysis*						High risk @ 75th percentile from T5, med risk @ 50th percentile	Taken 90th percentile from SW abstractions (T5), plus highest cost for high risk schemes	0.5 for med risk and 0.25 for high risk	*See DP/DO analysis*
Emergency desalination	N/A									

Appendix B. Evidence from Drought Plans and environmental costs

B.1. Introduction

This appendix summarises evidence from water company drought plans, which has been collated into a spreadsheet of drought permits. This provides an assessment of the capacity of drought permits, a risk categorisation and estimate of lead time for implementation during drought.

The data were originally collated as part of National Water Resources Long-Term Planning Framework in 2014 but the database has been substantially updated to include more recent drought plans and to enable more quantitative analysis for this study.

B.1.1. The original WRLTPF database

We have used water company Drought Plans to identify the location, estimated frequency of use, nature (e.g. winter/summer) and level of environmental sensitivity of the key drought permits and orders that might be used by water companies during the lead into a severe drought. Each drought permit or order included in company Drought Plans has been categorised as 'likely', 'possible' or 'unlikely' depending on the stated level of environmental risk, priority for implementation and the severity of the drought situation to which is applies. We have also indicated whether a permit/order will be modelled to determine the Deployable Output (DO) benefit under different return periods or whether the DO benefit will be taken as a deterministic value.

Drought permits/orders with a DO benefit of less than 10 Ml/d that are not going to be modelled have been grouped, with the number of such permits/orders shown below where applicable. If an area is not in the table below, there are no drought permits or orders within this area. Drought permits/orders categorised as 'unlikely' will be excluded from the modelling framework.

Company	Area	Drought Permit/Order Group name	Description/number of permits	Model led?	DO benefit (Ml/d)	Likelihood
Affinity Water	Affinity Water - Central	Affinity Water - Central: small permits	3 permits	No	11.64	P
		Affinity Water - Central: unlikely/excluded permits	7 permits	N/A	N/A	U
	Affinity Water - South East	SLYE	Increased abstraction. Priority for implementation: 1	No	2.5	P
		Affinity Water - South East: unlikely/excluded permits	3 permits	N/A	N/A	U
South East Water	South East Water - West	River Ouse (Ardingly Reservoir)	Maintain the MRF of 20 Ml/d but allow abstraction of everything above this up to the licensable limit	Yes	N/A	L
		River Ouse (Ardingly Reservoir)	Reduce augmentation to 2 from 4 Ml/d (winter only)	Yes	N/A	P
		River Ouse (Ardingly Reservoir): unlikely/excluded permits	5 permits	N/A	N/A	U
	South East	South East Water - Mid Kent: small permits	2 permits	No	8.6	L

Company	Area	Drought Permit/Order Group name	Description/number of permits	Model led?	DO benefit (Ml/d)	Likelihood
	Water - Mid Kent	South East Water - Mid Kent: unlikely/excluded permits	6 permits	N/A	N/A	U
Southern Water	Southern Water - West	Permit - Isle of Wight - U433	Concerned with borehole abstraction from Lower Chalk in Lukely Brook Valley	No	7.3	L
		Southern Water - West: unlikely/excluded permits	6 permits	N/A	N/A	U
	Southern Water - Central	Permit - R648 – reduce MRF (winter)	Application to allow a reduction in the MRF at Hardham Weir, which effectively allows greater abstraction from the R648 surface water intake once abstraction in the River Rother becomes constrained by the existing licensed MRF. This option allows both increased supplies and can also be used to maintain storage in E282 and groundwater sources during drought conditions. This remains a viable option for both summer and winter conditions, as it allows more water to be taken from the river when abstraction is constrained by the MRF.	No	5	L
		Permit - R648 – reduce MRF (summer)	As above	No	10	P
		Permit - E282 – reduction in compensation flow	Reduce the compensation flow from E282 reservoir to maintain water levels and E282 WSW to maximise available resources for public water supply. This is a possibility for both summer and winter conditions but typically will only be sought when a specific drought issue is affecting the integrity of the reservoir.	No	3.6	P
		Southern Water - Central: unlikely/excluded permits	4 permits	N/A	N/A	U
	Southern Water - East	Permit - P562 (winter)	P562 is a pumped storage reservoir with abstractions from the River Teise at Smallbridge and the River Medway at Yalding. The Permit may take the form of winter authorisations to allow increased re-filling and conservation of existing storage of P562. The precise conditions applied for will depend upon the severity and timing of each drought.	Yes	N/A	L

Company	Area	Drought Permit/Order Group name	Description/number of permits	Model led?	DO benefit (Ml/d)	Likelihood
		Permit - P562 (summer)	The Permit may take the form of summer authorisations, principally to reduce the requirements of releases to support downstream abstraction at Springfield. The precise conditions applied for will depend upon the severity and timing of each drought.	Yes	N/A	L
		Order - River Medway scheme – further changes to MRF & release factors	Reduce the MRF for abstraction at Springfield, Yalding or Smallbridge and reduce the release factor from P562	Yes	N/A	p
		Southern Water - East: small permits	2 permits	No	2.5	P
		Southern Water - East: unlikely/excluded permits	3 permits	N/A	N/A	U
Portsmouth	Portsmouth	Eastergate Group (Slindon)	The Peak Deployable Output (PDO) of the Eastergate Group of sources at Eastergate, Westergate, Slindon and Aldingbourne is currently limited by the abstraction licence to 41 Ml/d. The Group licence is also constrained by a requirement not to abstract more than 2,100 Ml in any period of 60 days. Under extreme conditions, it may be acceptable to abstract additional quantities, up to 8.5 Ml/d, at Slindon following a Drought Permit to increase the licensed capacity.	No	8.5	P
Sutton & East Surrey	Sutton & East Surrey	River Eden drought permit - 1	A drought permit to enable the winter abstraction from the River Eden to continue for an additional period of time; historically this has been into May, so this permit is often termed the May drought permit	No	+5% DO	L
		River Eden drought permit - 2	A drought permit to enable summer abstraction from the River Eden (after any May drought permit has ceased)	No	+10% DO	P
		Sutton & East Surrey: small permits	2 permits	No	7.08	P
		Sutton & East Surrey: unlikely/excluded permits	1 permit	N/A	N/A	U
Anglian Water	Anglian - Essex, Suffolk, Ely	Anglian - Essex, Suffolk, Ely: small permits	2 permits	No	10.5	L
		Anglian - Essex, Suffolk, Ely: unlikely/excluded permits	1 permit: Alton Water	N/A	N/A	U
	Anglian - Norfolk	River Wensum intake	Increase the annual abstraction quantity for the 24 Norwich boreholes and other boreholes. Subject to ongoing investigations.	No	24	P

Company	Area	Drought Permit/Order Group name	Description/number of permits	Model led?	DO benefit (Ml/d)	Likelihood
	Anglian – Ruthamford & Fenland	Grafham Water	50% MRF reduction at intake on River Great Ouse - winter	Yes	N/A	L
		Pitsford	50% MRF reduction at intake on River Nene - winter	Yes	N/A	L
		Rutland Water	50% MRF reduction at intake on River Nene - winter	Yes	N/A	L
		River Wissey intake	Increased abstraction licence for the supporting groundwater source	No	10	P
		Anglian – Ruthamford & Fenland: unlikely/excluded permits	3 permits	N/A	N/A	U
Severn Trent	Severn Trent	Drought permit: The Derwent Valley Reservoirs	This drought permit will: - reduce the aggregate quantity of compensation water from Ladybower Reservoir to the River Derwent and to Jaggers Clough from 74 Ml/d (or 92 Ml/d when flow at Derby is <340 Ml/d) to 51 Ml/d - reduce compensation water from Ladybower Reservoir from 54 Ml/d to 34 Ml/d	Yes	N/A	P
		Drought permit: The Tittesworth Reservoir and River Churnet Conjunctive Use Area	Variation to the compensation requirements from Tittesworth Reservoir and Deep Haye Valley. Would also ask for a variation to the Leek Groundwater Unit abstraction licences. This will assist the refill of Tittesworth Reservoir. This drought permit will: - Allow the compensation flow at Tittesworth Reservoir (including Solomon's Hollow) to be reduced from a minimum of 14.8 Ml/d to a minimum of 6.8 Ml/d - Authorise abstracting 8 Ml/d from the Abbey Green borehole, operating outside the borehole's abstraction licence limits, to discharge into the River Churnet 1.8 km downstream of Tittesworth reservoir - Remove the requirement for a total minimum discharge of 19.32 Ml/d to be released from a combination of Tittesworth Reservoir (including Solomon's Hollow) and Deep Hayes.	Yes	N/A	P
		Drought permit: The River Leam at Leamington and the River Avon at Stareton	This drought permit will: - Authorise abstraction at Eathorpe on the River Leam to Draycote Reservoir at any time of year when the lower storage condition at Draycote Reservoir would normally prohibit such abstraction	Yes	N/A	P

Company	Area	Drought Permit/Order Group name	Description/number of permits	Model led?	DO benefit (Ml/d)	Likelihood
			- Relax the prescribed flow in the River Leam at Princes Drive Weir in Leamington from 18 Ml/d to 12 Ml/d - Reduce the hands-off flow in the River Avon at Stareton of 45 Ml/d to 35 Ml/d exclusively to allow us to transfer additional water from the River Avon at Brownsover into Draycote reservoir.			
		Severn Trent: unlikely/excluded permits	3 permits	N/A	N/A	U
Wessex	Wessex	Wessex: unlikely/excluded permits	5 permits	N/A	N/A	U
Essex & Suffolk	Essex & Suffolk	Essex & Suffolk: small permits	6 permits	No	6.28	P
		Increase restricting annual quantity on Redgrave Group Licence	The potential drought action is to apply for a drought permit/order to increase the annual quantity of the Redgrave Group licence. A suggested increase would be from 2500 Ml/yr to 3000 Ml/yr. The sources that would be utilised more to facilitate this are Mendlesham, Eye and Wortham.	Yes	N/A	P
		Increase restricting annual quantity on Bedingfield Licence	The potential drought action is to apply for a drought permit/order to increase the annual quantity of the Bedingfield abstraction licence. A suggested increase would be from 200 Ml/annum to 500 Ml/annum. The daily licensed quantities would remain unchanged.	Yes	N/A	P
		Essex & Suffolk: unlikely/excluded permits	1 permit	N/A	N/A	U
South Staffs	South Staffs	South Staffs: unlikely/excluded permits	1 permit	N/A	N/A	U
Dwr Cymru Welsh Water	SEWCUS	SEWCUS: Small permits	2 permits	No	4.4	P
		Reduce compensation water releases from Llwynon Reservoir	Tier 1 - more likely to be implemented	Yes	N/A	P
		Compensation Water Reduction of 50% at Pontsticill Reservoir	Tier 1 - more likely to be implemented	Yes	N/A	P
		SEWCUS: unlikely/excluded permits	8 permits	N/A	N/A	U
Yorkshire	Yorkshire	Re-commission Gorpley Reservoir and Water Treatment Works	This option will use existing infrastructure that is currently mothballed. Gorpley Water Treatment Works will be reinstated to treat supply taken from Gorpley reservoir under the existing licence.	No	4.9	L

Company	Area	Drought Permit/Order Group name	Description/number of permits	Model led?	DO benefit (Ml/d)	Likelihood
		Silsden Reservoir abstraction	Water abstracted from Silsden Reservoir will be transferred through an existing pipeline to the Nidd Aqueduct. The abstraction will only be made when the reservoir stocks are above 55Ml.	No	10	L
		Yorkshire: Small permits	8 permits	No	39.04	P
		Damflask Reservoir	Compensation releases / maintained flows will be reduced by 50% to 67% of the licensed requirement. Reductions will be considered on a selective basis as some releases are more critical than others.	No	10.5	P
		River Wharfe at Lobwood increased abstraction	Increase abstraction	Yes	N/A	P
		River Hull at Hempholme increased abstraction	Increase abstraction	Yes	N/A	P
		Yorkshire: unlikely/excluded permits	37 permits	N/A	N/A	U
United Utilities	United Utilities	United Utilities: small permits	4 permits	No	15.9	L
		Jumbles Reservoir drought permit/order: reduce compensation flow from 19.9 to 12.0 or 6.0 Ml/d	The drought option would reduce the compensation flow requirement from 19.9 Ml/d to between 12 Ml/d and 6 Ml/d. This would result in a temporary reduction in the flow from Jumbles reservoir to Bradshaw Brook. The precise reduction would be discussed fully with the EA and would depend upon the need for additional water, time of year and prevailing environmental circumstances. The benefit to deployable output of the associated supply reservoirs of Wayoh and Entwistle would be between c.8 Ml/d to 14 Ml/d depending on the magnitude of the compensation flow reduction applied for.	No	11	L
		Longdendale Reservoirs drought permit/order: reduce compensation flow from 45.5 to 22.5 or 15 Ml/d	The drought option would reduce the compensation flow requirement from 45.5 Ml/d to 22.5 Ml/d or 15 Ml/d. This would result in a temporary reduction in flow from the Longdendale reservoirs to the River Etherow. The precise reduction would be discussed fully with the EA and would depend upon the need for additional water, time of year and prevailing environmental circumstances. The benefit to deployable output of the source would be between c.23 Ml/d to 30 Ml/d	No	26.5	L

Company	Area	Drought Permit/Order Group name	Description/number of permits	Model led?	DO benefit (Ml/d)	Likelihood
			depending on the magnitude of the compensation flow reduction applied for.			
		River Lune LCUS drought permit/order: reduce prescribed flow from 365.0 to a minimum of 200 Ml/d	The drought option would reduce the prescribed flow requirement at Skerton Weir from 365 Ml/d to a minimum of 200 Ml/d. This would allow UU to abstract from the River Lune (part of the Lancashire Conjunctive Use Scheme, LCUS) at lower river flows than normal. This would result in a temporary reduction in the flow in the River Lune. The precise reduction would be discussed fully with the EA and would depend upon the need for additional water, time of year and prevailing environmental circumstances The potential benefit of drought powers at River Lune (LCUS) is dependent upon the exact scope of the application and the pattern of weather conditions. Drought powers to allow increased abstraction from the River Lune (LCUS) will reduce demand on the Lake District and Pennine reservoirs. Under dry winter conditions, the benefit could be 50 Ml/d for the period January to March inclusive. The benefits of drought powers would be greatest over a dry winter to aid refill of reservoirs	Yes	N/A	L
		Ullswater drought permit/order: reduce hands-off flow conditions; construct temporary outlet weir to raise lake level by up to 0.15m and/or relax 12-month rolling abstraction licence limit	Drought powers could cover any or all of the following aspects to allow UU to continue abstracting: Reduce hands-off flow in the River Eamont at Pooley Bridge to a minimum of 95 Ml/d Construct a temporary outlet weir to raise the lake level by up to 0.15m Relax 12-month rolling abstraction licence limit The scope of required powers would be discussed fully with the EA and NE and will depend upon the need for additional water, time of year and prevailing environmental circumstances. The benefit to deployable output depends on the extent of the drought powers applied for and the pattern of weather conditions. Under dry summer weather conditions, the benefit could be 50-60 Ml/d. The benefit of the temporary weir is only	Yes	N/A	L

Company	Area	Drought Permit/Order Group name	Description/number of permits	Model led?	DO benefit (Ml/d)	Likelihood
			realised if there is sufficient rainfall to provide refill of the storage capacity provided behind the weir structure. Under dry winter conditions, the benefit has been estimated as 70-100 Ml/d, if the hands-off flow is reduced to 95 Ml/d			
		Lake Vyrnwy drought permit/order: reduce compensation flow from 45.0 to 25.0 Ml/d	Reducing the compensation flow from 45 Ml/d to 25 Ml/d would result in a temporary reduction in flow from Lake Vyrnwy to the Afon Vyrnwy. The precise reduction would be discussed fully with the EA and Natural Resources Wales and would depend upon the need for additional water, time of year and prevailing environmental circumstances. The benefit to deployable output of the reservoir would be c.20 Ml/d	Yes	N/A	L
		United Utilities: unlikely/excluded permits	4 permits	N/A	N/A	U
Thames Water	Thames Water - Provinces	River Thames @ Farmoor	Category 1, priority 1	Yes	N/A	L
		Meysey Hampton	Category 1, priority 2	Yes	N/A	P
		Thames Water - Provinces: small possible permits	6 permits	No	23.25	P
		Thames Water - Provinces: small likely permits	2 permits	No	8.5	L
		Thames Water - Provinces: unlikely/excluded permits	10 permits	N/A	N/A	U
	Thames Water - London	Lower Thames	Category 2, priority 1	Yes	N/A	P
		Thames Water - London: unlikely/excluded permits	9 permits	N/A	N/A	U
	Thames Water - Guildford	Shalford	Category 2, priority 1	No	2.5	P
		Thames Water - Guildford: unlikely/excluded permits	1 permit	N/A	N/A	U

B.2. Environmental costs

The costs of abstraction for all drought permits is based on surface water abstraction environmental costs in the dWRMP tables. The 75th percentile cost was £77,000 per Ml/d and the 90th percentile cost was £562,000 per Ml/d. Most permits impact on surface water and there was insufficient data to provide more detailed estimates.

For any further abstraction from the environment we assumed that this would be highly damaging and estimated a cost loosely on the NWEBS WFD data set[12]. We assumed that abstraction would reduce 100km of "good status" river to "poor ecological status" using the highest cost available from the analysis. The kind of application is not what the data were developed for, therefore this is highly uncertain.

Some example costs in £'000s per km of river are summarised below. These indicates costs of £6 to £22 million per 100km of river length per year for these example basins compared to an average for England and Wales of £7 million per 100 km of river length per year. Damages could be greater if rivers were damaged and took many years to recover and far less if only local reaches were impacted. A figure of £10 million was deemed appropriate, which is about 18 times greater than was assumed for Drought Permits.

		Bad to Poor			Poor to Mod			Mod to Good			
Some examples	**Length km**	**Low**	**Central**	**High**	**Low**	**Central**	**High**	**Low**	**Central**	**High**	**Sum High**
London	316	43	52.2	61.5	51.2	62.3	73.4	61	74.2	87.5	222.4
Medway	554	28.3	34.4	40.5	33.4	40.6	47.9	39.5	48.1	56.7	145.1
Mersey Estuary	257	21.4	26.1	30.8	25.1	30.6	36.1	29.5	36	42.5	109.4
Derbyshire Derwent	374	17.8	21.7	25.6	20.7	25.3	29.8	24.2	29.6	34.9	90.3
Test and Itchen	414	16.4	20	23.5	19	23.1	27.3	22.2	27	31.8	82.6
Cam and Ely Ouse (including South Level)	964	13	15.9	18.8	14.9	18.2	21.5	17.3	21	24.8	65.1
Irwell	351	20.9	25.5	30.1	24.5	29.8	35.2	28.8	35.1	41.4	106.7

[12] https://www.gov.uk/government/publications/updating-the-national-water-environment-benefit-survey-values-summary-of-the-peer-review

Appendix C. Review of Draft Water Resources Management Plans

C.1. Comments on individual company plans

The following sections describe some of the main features of the draft WRMPS with respect to water supply, drought risks and option costs. Most companies are included but Yorkshire (arrived late) still needs to be added.

C.2. Affinity Water

Baseline risks		Stated levels of service					Resilience to drought		
Water balance	Drought risk	TUBS	NEUBS	Permits	EDOs	Chosen[13]	Tested	Level	Comments
M	M	1 in 10	1 in 40	1 in 60	Never	1 in 60	Y	1 in 200	Plan driven by sustainability reductions equivalent to 7% of resources. Drought resilience dependant on improving network connectivity Table 5 included feasible Drought Permit schemes with costs based on capacity

C.2.1.1. Main features of the dWRMP

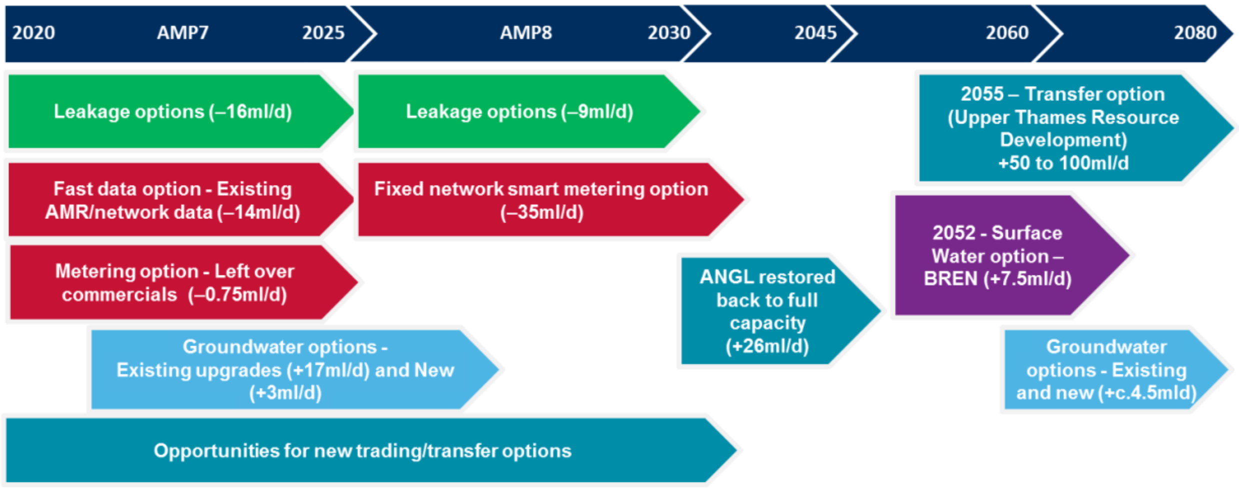
Affinity Water is a water supply only company, which derives most of its supply from groundwater sources (65%) and has some direct abstraction from the River Thames and other surface waters (35%). A key challenge faced by the company is to reduce abstraction to improve flows in chalk streams. In the Central Region there is an agreement to reduce abstraction by 42 Ml/d by 2020 and a further 10.2 Ml/d by 2025.

The plan includes a preferred scenario, alternative plan scenarios and regulatory aspirational scenarios for consultation with customers. This allows the company to demonstrate the costs, benefits and risks associated with whatever plan is supported by customers. The company have re-assessed their supplies including drought resilience by hindcasting the historical record back to 1900, a period that included some severe droughts. This resulted in a 'downturn' of Deployable Output by 42 Ml/d.

The company's preferred solution to maintain supplies, given the reduced abstraction and drought risks, is based primarily on demand management (metering and leakage), selective new groundwater development and making good use of existing transfers. The plan takes a long term view out to 2060 and the key features are summarised in Figure 2-1. The 'preferred plan' investment is around [redacted].

Figure 7-1 Affinity Water's Preferred Plan

13 As indicated on the WRP title page



Preferred demand and supply side options for dWRMP19 delivery programme

C.2.1.2. Drought resilience measures

The plan highlights improvements to network connectivity at a local scale and a more robust approach to DO assessment leading to mark down of DO of around 42 Ml/d (*this figure is quoted but there is a higher mark down of 84 Ml/d for Average Deployable Output in Table 18, presumably as the new dWRMP figures also include reduced abstraction/sustainability losses*). In this context, a significant proportion of dWRMP investment has been driven by the consideration of drought resilience (50% of the mark reduction in DO).

C.2.1.3. Emergency drought measures

Affinity Water expect to implement drought permits and orders to provide additional resources, except in a severe drought with a return period of 1 in 60 to 1 in 80 years accordingly to their dWRMP (Affinity Water, 2017a, s2.4.5). The company is consulting customers on the levels of service expected and may make changes as part of the final plan.

In the dWRMP Table 10.5, the company state that both *"the draft 2017 Drought Management Plan and the dWRMP19 both assume the use of demand restrictions (TUBs and demand side drought orders) and the % reduction in demand for TUBs plus demand side drought orders is similar (although not identical, owing to differences in the nature of the dWRMP19 decision making tool and the draft 2017 Drought Management Plan scenarios testing tool). With respect to supply-side measures, the Drought Management Plan describes all of the potential drought permits, whereas the dWRMP19 decision making tool has only selected those drought permits required to satisfy any supply demand deficits in the 1 in 200-year alternative scenario."*

This indicates that there are drought permit options with a potential yield of 78.96 Ml/d and that only around 60% of this volume would be required in a severe drought (Table 2-1). However, the available permits tend to involve increased abstraction or relaxation of licence constraints and have high environmental risks. In the Water UK study less than 10 Ml/d of these permits were deemed 'probable' and the rest were 'unlikely.' ***In our cost model we have assumed 78 Ml/d of drought options and a further 5 Ml/d of further borehole rehabilitation.***

Table 7-1 Availability of drought permits in the Affinity Water Drought Plan and dWRMP

Zone	Drought Plan	dWRMP 1 in 200 year	Comments
WRZ1	**17.66 Ml/d** Drought permit AMER (8 Ml/d) Drought permit HUGH (1.75 Ml/d) Drought permit HUNT (2.91 Ml/d) Drought permit PICC (5 Ml/d)	**5 Ml/d** Drought permit PICC (5 Ml/d utilisation)	**12.66 Ml/d** additional drought permits available
WRZ2	**15.61 Ml/d** Drought permit BOWB (5.82 Ml/d)	**9.79 Ml/d**	**5.82 Ml/d** additional drought permits available

Zone	Drought Plan	dWRMP 1 in 200 year	Comments
	Drought permit FRIA (9.79 Ml/d)	WRZ2 Drought permit FRIA (9.79 Ml/d utilisation)	
WRZ3	**28.69 Ml/d** Drought permit OFFS/OUGH (1 Ml/d) Drought permit WELL (0.3 Ml/d) Drought permit FULL (9.09 Ml/d) Drought permit WHIH (18 Ml/d)	**0.05 Ml/d** WRZ3 Drought permit WELL (0.05 Ml/d utilisation)	**28.64 Ml/d**
WRZ4	None	None	None
WRZ5	**8.73 Ml/d** Drought permit THUN (2.73 Ml/d) Drought permit UTTL (6 Ml/d)	**6 Ml/d** WRZ5 Drought permit UTTL (6 Ml/d utilisation)	**2.73 Ml/d**
WRZ6	None	None	None
WRZ7	**8.27 Ml/d** Drought permit SBUC (2 Ml/d) Drought permit SDRE (2 Ml/d) Drought permit SHOL (0.77 Ml/d) Drought permit SLYE (3.5 Ml/d)	None	**8.27 Ml/d**
Summary	**78.96 Ml/d** of drought permits available in the drought plan	**20.84 Ml/d** of drought permits used in 1 in 200 year DO assessment	**58.12** Ml/d

Source: Affinity 2017a, dWRMP Table 10

C.3. Southern Water

Baseline risks		Stated levels of service					Resilience to drought		
Water balance	**Drought risk**	**TUBS**	**NEUBS**	**ODOs**	**EDOs**	**Chosen[14]**	**Tested**	**Level**	**Comments**
Deficit	H	1 in10	1 in 20		1 in 500	1 in 10	Y	1 in 200	Driven by large sustainability reductions, which may reduce the levels of service in the short term.

Note: In the short-term the sustainability reductions in the Western Area may experience very different levels of service, for a period of up to 10 years. These sustainability reductions mean there is an increased risk of needing TUBS and DOs. TUBS could be required as often as once every two or three years, and Drought Orders and Permits could be required one or two times every 10 years on average.

Return period (Annual probability)	Description	Marginal Benefit of Drought Orders and Permits (Ml/d)
1 in 100 years (1 %)	Drought permits / orders (total)	
1 in 200 years (0.5%)	Drought permits (total)	101.8
1 in 500 years (0.2%)	Drought permits (total)	233.3

[14] As indicated on the WRP title page

C.3.1.1. Main features of the dWRMP

The greatest challenge that Southern Water is facing is the reduction to their abstraction licences, due to sustainability reductions imposed by the Environment Agency to protect and improve the environment. Current known changes are within the Western area which could result in SW losing half of their currently available water in drought. However, there are also further potential reduction in Hampshire, and in Sussex and Kent. Other challenges that SW is facing are future climate change uncertainty and increasing levels of households and population.

The strategy for the Eastern supply area includes development of a strategic shared resource with South East Water, and a continued drive for water efficiency. This approach includes a minor raising of Bewl Reservoir. The strategy for the Central supply area is dominated by the need to counteract potential future sustainability reductions of which the full extent currently remains unknown. Potential solutions to the sustainability reductions include desalination options, indirect water reuse schemes, aquifer storage and recovery, metering, reducing leakage and catchment management. The Western supply area is the only supply area with known sustainability reductions which could cause a loss of up to half of the currently available water in a drought. SW has proposed the following schemes additional bulk supplies from Portsmouth Water, large scale desalination, various water reuse schemes, catchment management and increased reliance on Drought Orders to secure supply until new resources are available.

SW calculated their supply demand balance during a 1 in 200 year drought for each of their supply areas. The Eastern and Central areas are expected to move into deficit in 2027-28, as a result of sustainability reductions. In the Western area due to immediate sustainability reductions there will be a significant supply demand balance deficit throughout the planning period.

C.3.1.2. Drought resilience measures

Southern Water has identified a number of options within each of the areas' strategies as providing greater system resilience to drought events. In the Western area the Test to Itchen pipeline and Woodside transfer valve have been identified as providing greater resilience by providing greater connectivity between the Western area resource zones.

Within the Central area an option to reverse the SW-SB main has been identified as increasing resilience by allowing Brighton to support Worthing, as well as Worthing supporting Brighton. In the Eastern area Stourmouth WSW will provide greater resilience in the Kent Thanet resource zone by providing more flexibility to have a surface water source in a groundwater dominated resource zone.

C.3.1.3. Emergency drought measures

Southern Water has a number of emergency drought options listed within Table 10 of their WRMP which are consistent across water resource zones. These are listed below:

- Adapt groundwater and surface pumping patterns to maximise storage
- Start discussions with neighbouring water companies regarding bulk transfer arrangements
- Implement TUBs, effectiveness, estimated at 5% of CP demand
- Implement NEUs, effectiveness estimated at 8% of CP demand
- Emergency Tankers

In addition to the above emergency drought measures, there are a number of water resource zone specific options in Isle of Wight, Hampshire Rural, Hampshire Southampton East, Kent Medway East, Kent Medway West, Kent Thanet, Sussex Hastings, Sussex North and Sussex Worthing.

The majority of these additional measures are drought permits to reduce minimum residual flow requirements or increase abstraction constraints. The following measures are those specifically highlighted in Table 10 of the WRMP, that reduce the minimum residual flow, and therefore allow more water to be abstracted:

- Drought Order to remove requirement for Minimum Residual Flow condition at the Sheep Dip Weir on the Lukely Brook
- Drought Order to reduce the Minimum Residual Flow in the Caul Bourne
- Drought Order to reduce Minimum Residual Flow constraints in the River Medina to allow increased transfers to and augmentation of the Eastern Yar

- Drought Permit to reduce Minimum Residual Flow Constraint on the River Test
- Drought Permit to reduce River Medway Minimum Residual Flow condition (Four stage reduction in minimum residual flows)
- Drought Order to Reduce Minimum Residual Flow Licence constraint at Southmouth to allow increased abstraction
- Drought Permit to reduce Minimum Residual Flow condition on the River Brede for Powdermill Reservoir
- Drought Permit to reduce Minimum Residual Flow condition on the River Rother for Darwell Reservoir (Two stage reduction in minimum residual flows)
- Drought Permit to reduce minimum residual flow condition at Pulborough (Three stage reduction in minimum residual flows)

The following emergency drought orders, are specifically highlighted in Table 10 of the WRMP, that increase that alter abstraction licenses or introduce additional sources:

- Drought Order to remove groundwater level dependant abstraction licence constraint at Shalcombe
- Recommission groundwater source in River Test Valley
- Drought order to recommission unlicensed site in the Test Valley
- Drought Order to operate Candover Scheme to augment flows in the River Itchen
- Drought Order to increase September monthly abstraction licence limit and reduce the Hands-Off Flow condition in the River Itchen
- Drought Permit to remove seasonal (Oct-Apr) licence constraint on Faversham groundwater sources
- Re-commission Stourmouth source
- Drought Permit to increase daily peak abstraction licence at Sandwich source (1.3Ml/d)
- Drought Permit to remove licence condition for Darwell Reservoir allowing minimum storage to be reduced (Stage 1)
- Drought Permit to reduce compensation flow from Weir Wood Reservoir to River Medway
- Drought Permit to increase abstraction licence daily limit at North Arundel

C.4. South East Water

Baseline risks		Stated levels of service					Resilience to drought		
Water balance	**Drought risk**	**TUBS**	**NEUBS**	**ODOs**	**EDOs**	**Chosen[15]**	**Tested**	**Level**	**Comments**
M	M	1:10	1:40	Not stated	Not stated		Y	1:500	

C.4.1. Main features of the dWRMP

South East Water provides its water from surface water (73%), groundwater (19%) and transfers from neighbouring water companies (8%), to three main areas (Sussex, West, and Kent) and 8 water resource zones (WRZs).

The region faces a number of unique challenges:

- Area of serious water stress (designated by Defra in 2007)
- High reliance on groundwater
- Unusually rich in biological diversity, cultural heritage and a higher than average number of protected landscapes in the region, including a World Heritage Site (Canterbury Cathedral), and 196 SSSIs
- South East of England – growing population and substantial new housing needs
- Highest number of neighbouring water companies of anywhere else in the UK

[15] As indicated on the WRP title page

Overall, the supply demand balance (SDB) shows the Company to be in a better position than at this time in WRMP14, reaching a deficit (both for DYAA and DYCP) at 2044/45 (and as early as 2030 when taking a zonal approach). The most significant driver of the deficits 2020-2045 being sustainability reductions, and beyond this, impacts of population growth and climate change.

A variety of options have been considered in the Company's preferred plan, summarised in the table below:

Table 7-2 SEW Preferred Plan Options

	2020-25	2025-30	By 2044	By 2079
Leakage	3.8	6.3	7.0	14.0
Water efficiency	2.2	1.9	5.7	20.7
Groundwater	18.2	18.5	22.7	29.6
Surface Water	0.0	0.0	35.7	75.1
Water treatment	0.0	9.0	9.0	9.0
Effluent re-use	0.0	25.0	34.0	48.8
Desalination	0.0	0.0	0.0	70.0
Regional Transfers	0.0	0.0	9.0	27.0
Totals	**24.2**	**60.7**	**123.1**	**294.2**

This leads to an overall increase of water supply by 294.2 Ml/d, at a cost [redacted]

C.4.2. Drought resilience measures

In the company's baseline supply forecast the levels of resilience were based on the worst historical drought on record (1:100) – through scenario modelling, the Company proposes to move to Defra's reference 1:200 reference level of service. It was imperative in the company's decision-making process to consider which of these levels of drought resilience to plan for (1:100 or 1:200). The output of running initial models showed that planning for a 1:200 drought only had marginal increases in capital expenditure over the 60-year planning period, so a 1:200 period was selected.

Of the options chosen, a variety of these will contribute to an overall increased level of drought resilience:

- Effluent reuse – any such approach will lead to a reduction of input into the system, during times of low yield. Various measures are being introduced from 2030 onwards.
    - Eg: Wetherlees WwTW into the Great Stour indirect use of effluent
- Desalination – the ability to use salt-water sources as viable water sources, means that the system can cope with reduced freshwater input (even if at high cost) – Between 2044 and 2079, SEW will implement 70Ml/d savings through such schemes.
    - Eg: Reculver RO desalination of brackish groundwater
- Increasing groundwater sources means that there is a greater amount of water that can be abstracted from aquifers, as long as license constraints are not breached. There are multiple investments in increasing such sources throughout the time period of the study.
    - Eg: Aylesford Newsprint – using existing groundwater sources
- Surface water – increasing surface water capacity will have an impact, by creating a greater initial volume of water to draw upon in times of need.
    - Eg: Broad Oak reservoir capacity increase to 5,125 Ml/d

The changes to the SDB for these (and a rough implementation timetable) can be seen in Table 7-2.

C.4.3. Emergency drought measures

The following measures were implemented as potential drought options (and passed all three levels of options appraisal carried out by SEW):

- Enhance sources at Balcombe (2 new boreholes) (licence of 0.68Ml/d – currently unused)

- New licence / redistribution of licence at Halling Lake – sustainability concerns, BUT is a drought plan option (concerns from sustained use)
- Groundwater development at Brown Woods – reallocating the licence 3km north of existing licence
- Licence change at Oakhanger-Oaklands-Southlands – no abstraction at critical period given;
- Reinstatement of Hackenden WTW (delivery of 1Ml/d into WRZ2)
- Drought management permits:
  - River Ouse
  - River Cuckmere.

The following were considered, but not included in the final plan:

- Relicense Sedlescome abstraction (currently expired) – 2 new boreholes, with capacity of 1.5Ml/d;
- *Bulk supply from Scandinavia – costs considered too extravagant, and bad public relationships to tanker in water from abroad;*
- New Drought Permits (multiple) refused:
  - Upper Ouse
  - Lower Ouse
  - River Cuckmere
- Potential new service reservoir – considered too costly
- WRZ-wide drought management permits for WRZ 1,5+6

Overall, no indication was given for the overall severity of drought needed for these options to be implemented. It was interesting to note that a variety of drought options were included that had potential sustainability concerns, or needed further testing, however those that may adversely affect public confidence were discarded (i.e. the tankering of water from Scandinavia).

At the time of this assessment (December, 2017), Table 10 and Table 10.5 were both incomplete in the draft plan, which limited potential analysis of the plans.

C.4.4. Costs of emergency drought measures

The following costs are based on long term planning but provide some relevant information for emergency options.

Desalinisation (indirect relevance)

Table 7-3 CAPEX, OPEX [NPV], AIC and AISC of desalination options suggested by South East Water in the dWRMP

Measures	Count	CAPEX[NPV] (£k)	OPEX[NPV] (£k)	Average AIC (p/m3)	Average AISC (p/m3)
Desalination	9	[redacted]	[redacted]	[redacted]	[redacted]

All costs based on capacity

Effluent recycling (indirect relevance)

Table 7-4 CAPEX, OPEX [NPV], AIC and AISC of effluent recycling options suggested by South East Water in the dWRMP

Measures	Count	CAPEX[NPV] (£k)	OPEX[NPV] (£k)	Average AIC (p/m3)	Average AISC (p/m3)
Effluent reuse	3	[redacted]	[redacted]	[redacted]	[redacted]

All costs based on capacity

Other relevant information (indirect relevance)

Table 7-5 CAPEX, OPEX [NPV], AIC and AISC of other options suggested by South East Water in the dWRMP

Measures	Count	CAPEX[NPV] (£k)	OPEX[NPV] (£k)	Average AIC (p/m3)	Average AISC (p/m3)
Conjunctive use	4	[redacted]	[redacted]	[redacted]	[redacted]
Active leakage management	16	[redacted]	[redacted]	[redacted]	[redacted]
Aquifer recharge	2	[redacted]	[redacted]	[redacted]	[redacted]
Commercial water audit	8	[redacted]	[redacted]	[redacted]	[redacted]
Customer education / awareness	24	[redacted]	[redacted]	[redacted]	[redacted]
GW enhancement	1	[redacted]	[redacted]	[redacted]	[redacted]
GW new	4	[redacted]	[redacted]	[redacted]	[redacted]
Metering compulsory	8	[redacted]	[redacted]	[redacted]	[redacted]
Metering optants	8	[redacted]	[redacted]	[redacted]	[redacted]
New reservoir	4	[redacted]	[redacted]	[redacted]	[redacted]
Other Distribution Side	71	[redacted]	[redacted]	[redacted]	[redacted]
Other leakage control	32	[redacted]	[redacted]	[redacted]	[redacted]
Outdoor water efficiency devices	8	[redacted]	[redacted]	[redacted]	[redacted]
Pressure management	32	[redacted]	[redacted]	[redacted]	[redacted]
Retrofitting indoor water efficiency devices	8	[redacted]	[redacted]	[redacted]	[redacted]
SW new	1	[redacted]	[redacted]	[redacted]	[redacted]
Water treatment works capacity increase	6	[redacted]	[redacted]	[redacted]	[redacted]
Grand Total (incl. effluent reuse and desalination)	249	[redacted]	[redacted]	[redacted]	[redacted]

C.5. Bournemouth and West Hampshire

Not assessed as low risk

C.6. Portsmouth Water

C.6.1.1. Summary on levels of service and drought resilience

Baseline risks	Stated levels of service	Resilience to drought	

Water balance	Drought risk	TUBS	NEUBS	ODOs	EDOs	Chosen[16]	Tested	Level	Comments
Deficit	Medium	1 in 20	1 in 125	1 in 80	1 in 200	1 in 20			Plan driven by provision of bulk supplies to Southern Water from new groundwater sourced reservoir at Havant Thicket.

C.6.2. Main features of the dWRMP

Portsmouth water supplies a population of around 722,000 in the Portsmouth area. The company has no significant raw water storage and relies on winter recharge of groundwater, and abstracts approximately 170 Ml/d from boreholes, natural springs and one river.

Portsmouth Water is not a resource stressed company and they have been advised by the Environment Agency that sustainability reductions will not be imposed. The overall supply assessment has resulted in a lower estimate of Deployable Output and water available for use than in WRMP14, reduced by 7%.

The main feature of the plan is to provide bulk supplies to Southern Water with supplies expected to increase by 9 Ml/d in 2022/23 and a further 21 Ml/d in 2028/20 up to 60 Ml/d. These supplies have been agreed in principle but will require further detailed negotiations before they are confirmed. The additional supplies will require resource development on Portsmouth Water's behalf which has been accounted for by Havant Thicket, a groundwater supplied reservoir.

Under the baseline scenario, with the additional bulk supplies to Southern, the supply demand balance is in deficit and schemes will have to be brought forward to correct this. The company has been assessed as having a medium risk to drought.

Portsmouth Water lists six key elements of their plan:

1. The company is forecasting a falling per capita consumption over the planning period due to its new approach to domestic metering
2. The company is planning to reduce leakage significantly over the planning periods as a result of investment in District Meter Areas
3. The company can accommodate requests from Southern Water for bulk supplies to support the environment elsewhere in the region
4. The company will further develop resources at Worlds End and Havant Thicket with the associated recreational and biodiversity benefits at Havant Thicket reservoir
5. The company will meet the longer-term supply challenges of rising population and climate change and can demonstrate that it will continue to have no detrimental impact on the environment;
6. The company can quantify how resilient supplies are to greater and more frequent droughts expected in the future and provide confidence that it can meet such events.

C.6.3. Drought resilience measures

Although Portsmouth Water do not have any significant raw water storage, the South Downs chalk aquifer is very resilient to drought. Through analysis of the most severe single season drought in the historic record Portsmouth Water have concluded that they are resilient to single season droughts. They have tested resilience to multi-season droughts through scenario testing and groundwater simulations.

- Dry Year (1 in 20)
- Scenario 'A' Historic Drought (1 in 40)
- Scenario 'B' Extended Drought (1 in 80)
- Scenario 'C' Serious Drought (1 in 125)
- Scenario 'D' Severe Drought (1 in 200)

[16] As indicated on the WRP title page

They also state that more extreme droughts were tested although they have not been included in the WRMP. At a drought level of 1 in 125 years non-essential use bans and drought permits will be required, and in a scenario of 1 in 200 years stand pipes are only just avoided.

The plan states that there would be an option to reverse the increased bulk supply to Southern Water in an emergency, however as Southern Water would not have a surplus during drought conditions this will only increase resilience for Portsmouth Water under 'Normal Year' conditions. Metering and water efficiency options are selected as well as DO recovery schemes.

C.6.4. Emergency drought measures

Portsmouth Water have one emergency drought permit, Slindon Drought Permit, which they expect to implement during drought events of 1 in 125 or higher severity. The permit is expected to provide additional resource of up to 8.5 Ml/d and is included in both the dWRMP and Draft Drought Plan.

The dWRMP states that their Drought Plan also references the use of a Gater's Mill Drought Order, however, this is a short term measure to satisfy Southern Water's needs rather than Portsmouth's and is not included in the dWRMP.

In the dWRMP Table 10.5, the company stat that *"there is only one Drought Supply Measure in the WRMP and this is the potential Drought Permit at Slindon. This Drought Permit is for 8.5 Ml/d at average and peak, and it has potential impact on the Arundel Park SSSI. Portsmouth Water will work with Southern Water to develop the monitoring plan and mitigation measures for this site. The Drought Permit is only required for serious droughts with a return period of greater than 1 in 80 years. Demand restrictions are brought in in phases and these are set out in the table above. The Historic Drought Scenario 'A', would see calls for restraint followed by hosepipe bans. As the drought developed, and a serious shortage of rainfall existed, then Non Essential Use Restrictions could be imposed. These restrictions would be in place for six months but this period could be extended in the most severe droughts. Each drought is different and the exact timing of restrictions will vary from drought to drought."*

C.6.5. Costs of emergency drought measures

Drought permits

Table 7-6 Drought Options AISC in Portsmouth Water's dWRMP

Option Name	AISC at Average DO (p/m3)	Yield (Ml/d)
Voluntary Restraint	[redacted]	4.3
Temporary Bans	[redacted]	8.3
Non-Essential Use Bans	[redacted]	7.9
Slindon Drought Permit	[redacted]	8.5

Desalinisation (indirect relevance)

No desalination schemes in the plan.

Effluent recycling (indirect relevance)

Table 7-7 Effluent Re-use AISC

Option Name	AISC at Average DO (p/m3)	Yield (Ml/d)
Budds Farm	[redacted]	20.0

Other relevant information (indirect relevance)

Table 7-8 Other relevant feasible options AISC

Option Name	AISC at Average DO (p/m3)	Yield (Ml/d)
Havant Thicket Winter Storage Reservoir	[redacted]	23
Leakage Management: deployment of permanent noise loggers	[redacted]	4.9
Leakage Management: installation of district meters	[redacted]	5.1
Lekage	[redacted]	

Pressure Management and increased find and fix activity considered to be baseline activity with little further benefit to be achieved. Four DO recovery schemes are selected in the plan but no information cost information is available.

C.7. Sutton and East Surrey Water

Baseline risks		Stated levels of service					Resilience to drought		
Water balance	Drought risk	TUBS	NEUBS	ODOs	EDOs	Chosen [17]	Tested	Level	Comments
Deficit		1:10	--	1in20	Extreme / Emergency Only		Y	1in200	

C.7.1. Main features of the dWRMP

Sutton and East Surrey is an area that is classified as being under serious water stress, with multiple key drivers:

- Population growth (to 1million by 2080)
- Climate change impacting the availability of water resources
- Mitigation of impacts of abstraction and treatment

The plan overall shows a surplus of resources until nearly 2050, at which point demand + headroom (200million litres a day) > supply (190million litres a day). Forecast deficit of 22.7million litres a day by end of forecast period.

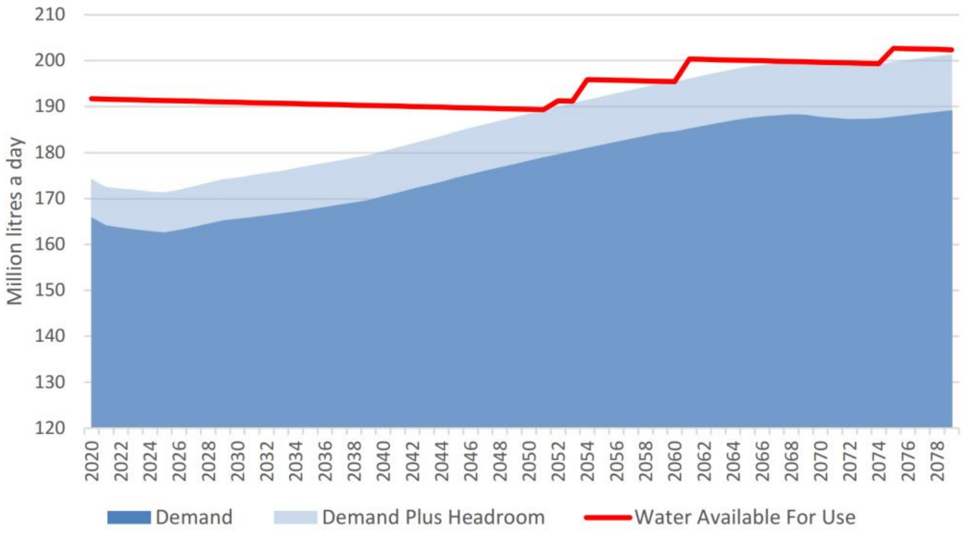
Plan focusses on demand side options:

- Reductions in leakage of 15% greater than 2020 targets;
- Proportion of customers metered: 80% @ 2020, 90& @ 2030;
- Smart devices: 10% @ 2025 (1.5% reduction decrease);
- Align metering programmes with home water efficiency check programme
- Assess best approach to implement water efficiency programme for non-household (NHH) customers, working with retailers, businesses and other NHH properties.

Supply side:

- Increase WAFU:
  - Additional abstraction from new and existing boreholes in the River Mole catchment and in Kenley and Purley.

[17] As indicated on the WRP title page



C.7.2. Drought resilience measures

In the option selection criteria, drought resilience was considered as a scoring criteria (falling under 'social impact') in the second screening of options, with the following classification:

"Would scheme improve drought resilience thus reducing risk of drought permits, [hosepipe] bans etc. Score 3 for ASR scheme, 2 for groundwater, 1 for surface water [sic]"

Options selected:

- Outwood Lane → Increase in daily licence from 3 to 8 Ml/d, providing moderate levels of resilience for groundwater resources
- Fetcham Springs (new borehole) → Increase PDO by 3.148 Ml/d, providing moderate levels of resilience for groundwater resources
- New Middle Mole Abstraction Source → providing moderate levels of resilience for groundwater resources. Using this source for 50% of the water availability reduces the ADO on other sources (so they can be increased to meet the existing licence)
- North Downs Confined Chalk AR extension 2 → Increased artificial recharge that could be drawn during drought periods when other sources have low yield.
- Lowering pumps at Kenley and Purley → Increase Kenley PDO by 6 Ml/d and Purley by 8.5 Ml/d, providing moderate levels of resilience for groundwater resources
- Leatherhead licence increase → Increase licence by 2 Ml/d, providing moderate levels of resilience for groundwater resources
- New Lower Mole Abstraction source → providing moderate levels of resilience for groundwater resources. Using this source for 50% of the water availability reduces the ADO on other sources (so they can be increased to meet the existing licence)
- Raising of Bough Beech Reservoir → increase the volume of stored water. However, surface water likely to deplete before ground water resources.

C.7.3. Emergency drought measures

The Company expects to implement TUBs 1:10 and Drought Orders for 1:20 year droughts.

As the drought progresses in severity, the Company will implement Drought Orders and Permits to both increase Supply and decrease Demand – however, these were not included in the demand reductions or any additional calculations – this will lead to overall increased drought resilience of the system. This means that for the 1:200 drought, in the WRMP no drought permits are implemented, yet in the drought plan, 6.8Ml/d drought permits and 42.1 Ml/d demand reduction due to TUBs etc, have been implemented.

The WRMP does not go into detail regarding the emergency drought measures, and when they would be implemented.

Table 7-9 Availability of drought permits in the Drought Plan and dWRMP

Zone	Drought Plan	dWRMP 1 in 200 year	Comments
SES (not split by WRZ)	Drought permits: 0 Ml/d TUBs & Ordered: 0 Ml/d	Drought Permit: 6.8 Ml/d TUBs & Ordered: 42.1 Ml/d	Additional Drought Permits Available: 6.8 Ml/d Additional TUBs available: 42.1 Ml/d

C.8. Essex and Suffolk Water

Baseline risks		Stated levels of service					Resilience to drought		
Water balance	Drought risk	TUBS	NEUBS	ODOs	EDOs	Chosen[18]	Tested	Level	Comments
Surplus	Low	1 in 20							

C.8.1.1. Main features of the dWRMP

The Essex and Suffolk supply area is located in one of the driest areas of the country, and therefore faces particular challenges of growing demand, uncertainty from climate change and a lack of new intrinsic water resources. Despite these challenges ESW have a sustainable secure supply of water over a 40-year planning horizon. They employ a twin track method of demand management and water supply solutions. In the dWRMP ESW demonstrate a supply surplus, across all 4 WRZ.

C.8.1.2. Drought resilience measures

Essex and Suffolk has tested the resilience of the water supply system against severe drought, at a return period of 1 in 200 years, the analysis confirmed that even under severe drought conditions a supply surplus would be maintained and therefore is resilient to severe drought.

C.8.1.3. Emergency drought measures

Essex and Suffolk do not include any benefits from supply drought measures (orders or permits) in the baseline supply forecast. No additional detail is provided within Table 10 of the WRP tables.

C.9. Thames Water

Baseline risks		**Stated levels of service**					**Resilience to drought**		
Water balance	**Drought risk**	**TUBS**	**NEUBS**	**ODOs**	**EDOs**	**Chosen**[19]	**Tested**	**Level**	**Comments**
London deficit	High (Water UK)	1 in 10 (sprinklers) 1 in 20	1 in 20	1 in 20	1 in 125	1 in 125	Y	1 in 200	London's DYAA balance is currently in deficit. LoS moving from 1 in 125 to 1 in 200 year for Level 4

C.9.1. Main features of the dWRMP

Thames Water supplies around 2,600 million litres of water a day to a population of approximately 10 million located across six water resources zones in London, Guildford and the Upper Thames river basin (Banbury,

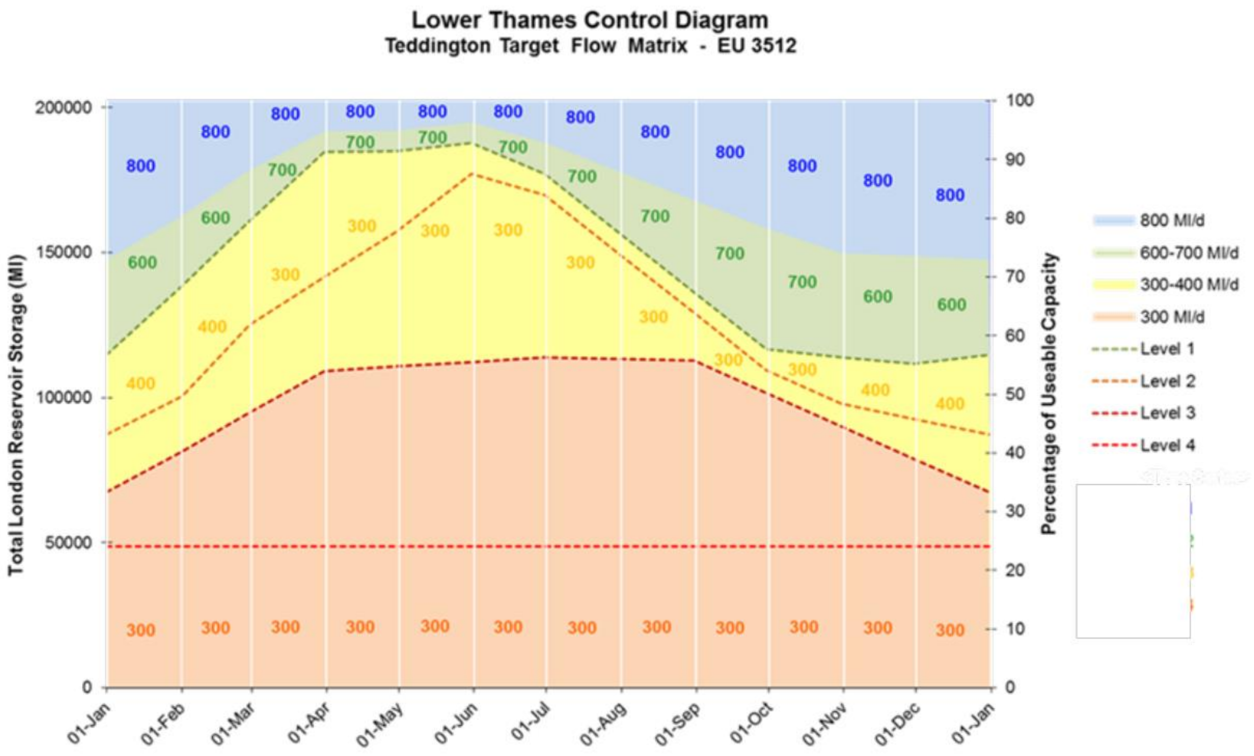
[18] As indicated on the WRP title page
[19] As indicated on the WRP title page

Aylesbury, High Wycombe, Slough, Reading, Newbury, Swindon and Cirencester). Water is abstracted from surface water and groundwater and the largest London zone is heavily reliant on water abstracted from the River Thames and Lee, which is stored in reservoirs surrounding the capital.

Temporary Use Bans (formerly hosepipe bans) and NEUBs are anticipated 1 in 20 years, on average (annual probability of 5%). The use of more extreme measures (standpipes and rota cuts) are stated with a frequency of "never" followed by "[i]n reality this equates to 1 in 125 years on average."

The Water UK work highlighted that London may be a far greater risk of water shortages during severe and extreme droughts than previously thought (Water UK, 2017).

The key factor for drought in London is abstraction from the River Thames, which is controlled by the Lower Thames Control Diagram (LTCD) that links that amounts of water that can be abstracted to the amount of storage in the London reservoirs (see below, Thames Water, 2017, Figure 4-4).

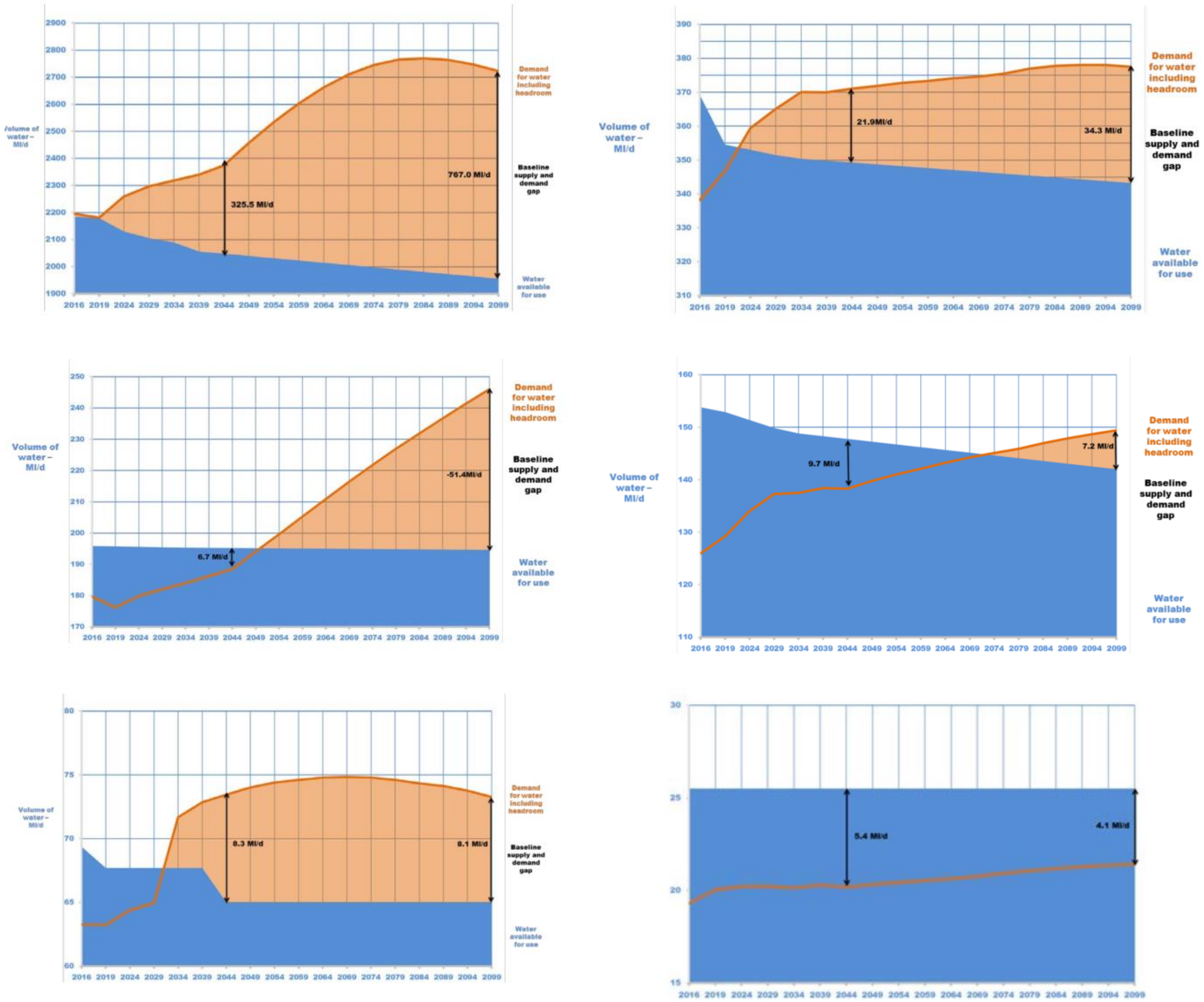


Assessments of the amount of water available in London are highly sensitive to the model used and the choice of climate and drought scenarios. In the dWRMP the impact of using a 1 in 200 year drought was a reduction in London's Deployable Output by 140 Ml/d (6%) and revised climate change methods also reduced future water availability.

The baseline DYAA supply-demand position for London is particularly challenging with the potential for significant deficits by 2025, which would continue to grow due to population growth, climate change and reductions in supply due to environmental legislation (sustainability reductions). The exert below from the dWRMP summarises the forecast (Thames Water, 2017, Table 6.1).

WRZ	Item	Volume (Ml/d)					
		2019/20	2024/25	2029/30	2039/40	2074/75	2099/00
London (DYAA)	Demand	2058	2097	2116	2161	2575	2552
	Headroom	123	162	181	178	170	170
	Supply	2179	2130	2106	2056	1998	1956
	Balance	-2	-130	-191	-283	-747	-767
	(WRMP14)	-133	-213	-292	-416		

For other London zones the challenge is related to peak demand only and is relatively small. The baseline supply demand problem for London, SWOX (Peak), SWA (Peak), Kennet Valley (Peak), Guildford (Peak), Henley (Peak) is summarised below, based on Section 6 of the dWRMP (zones are ordered top to bottom and left to right):



C.9.2. Drought resilience measures

Thames Water have a number of strategic water resources drought schemes that have an important impact on London's Deployable Output. These are use before Drought permits are implemented. For further details refer to Thames Water's draft WRMP Section 7 and Appendix I (Thames Water, 2018).

C.9.3. Emergency drought measures

There are options for further emergency measures in London and other zones. For further details refer to Thames Water's draft WRMP Section 7 (Thames Water, 2018).

C.10. Anglian Water

Baseline risks		Stated levels of service					Resilience to drought		
Water balance	**Drought risk**	**TUBS**	**NEUBS**	**ODOs**	**EDOs**	**Chosen[20]**	**Tested**	**Level**	**Comments**
Deficit	Medium	1 in 10	1 in 40		1 in 100	?	Y	1 in 200	

Return Period	Description	Marginal Benefit of drought permits and orders (Ml/d)
1 in 50 – 100 years	Drought permits / orders (total)	24
1 in 150 years	Drought permits / orders (total)	10
1 in 200 years	Drought permits / orders (total)	4.5

C.10.1. Main features of the dWRMP

Anglian Water is the largest water and wastewater company in England and Wales by geographic area, and supplies from a combination of groundwater and surface water sources.

Anglian Water state that their greatest challenges come from population growth, climate change, sustainability reductions and the need to increase resilience to severe drought. Sustainability reductions also provide a great deal of uncertainty, which will not be resolved until 2023. Two scenarios have been developed to cover the uncertainty of the sustainability reductions. In the 'Principal Planning Scenario' the combined impact is 307Ml/d with an additional impact in the 'Adaptive Planning Scenario' of 165Ml/d. This is distributed unevenly across the WRZ with 12 of 28 WRZ in deficit by the end of the period.

AWS propose demand management as a priority, with a detailed 25-year demand management strategy. This is in combination with specific supply side solutions including trading with Affinity and Severn Trent, increasing connectivity and several new resources.

C.10.2. Drought resilience measures

To help address the challenges faced by drought and to build drought resilience AWS has set up Water Resources East, this has highlighted a number of options that can help to build resilience, including increased reservoir storage, and a strategic network of transfers that will help to build resilience. Following the 1988-92 and 2011-12 drought some £37 million and £47 million respectively were invested in new assets to improve resilience.

C.10.3. Emergency drought measures

Anglian Water undertook an assessment of the drought permits and orders included under Drought Plan 2014 and concluded that they could not be considered reliable enough to offset of WRMP severe drought investments, and they therefore have not included in the options appraisal process, but the benefit has been included in the Table 10 Drought Plan section. No additional detail on the additional emergency drought measures have been provided in Table 10.

[20] As indicated on the WRP title page

C.11. Bristol Water

Baseline risks		Stated levels of service					Resilience to drought		
Water balance	Drought risk	TUBS	NEUBs	ODOs	EDOs	Chosen [21]	Tested	Level	Comments
Deficit	L	1 in 15	1 in 33	N/A	1 in 100	1 in 15	Y	1 in 200	

C.11.1. Main features of the dWRMP

Bristol Water covers a rapidly developing area with a projected population increase between 2020 and 2045 of approximately 0.3 million people up to 1.5 million. They plan to implement ongoing improvements in domestic water efficiency and metering and so despite the population growth are not forecasting a significant increase in overall demand during the planning period. They plan to meet changes in demand in the medium-term by further reducing leakage.

Bristol Water comment on the integrated nature of their supply network and range of water sources available to them as factors mitigating against the impact of climate change in their region.

In the longer term, Bristol Water aim to address any deficit through reduction in losses on raw water systems and changes in bulk transfer of water to or from other water companies.

Table 7-10 shows the key changes to Bristol Water's plan since WRMP14.

Table 7-10 Changes to Bristol Water's WRMP since WRMP14

Item	Change from WRMP14 to WRMP19	Approximate impact of change on future deficit
Deployable output	We are now planning for the most severe drought on record (1933/1934) – this reduces the amount of water we assume to be available and is now compliant with EA guidance	Increases potential future deficit by 11Ml/day
Headroom	WRMP19 will use a variable (increasing) risk profile across the planning period. This is compliant with EA guidance and is their preferred approach	Reduces potential future deficit by 18Ml/day
Climate Change	Planning approach updated in line with new EA Guidance. This indicates a lower impact of climate change on our resource profile than in WRMP14	Reduces potential future deficit by 12 Ml/d
Leakage and losses	We have re-assessed our leakage reduction targets in light of the changes to the supply-demand forecasts. We have also carried out additional assessment of our raw water losses which has identified scope for increasing Water Available for Use	Proposed leakage reduction to 37 Ml/d by 2024/25 to reduce potential future deficit by 6 Ml/d Proposed reductions to raw water losses by 2034-35 to reduce potential deficit by 4.7 Ml/d
Demand assumptions	The proposers of a potential new power station considered as part of the 2014 WRMP. No large industrial demand is included in the baseline calculation and SSE plc (formerly Scottish and Southern Energy plc.) has been advised that this	Reduces potential future deficit by 41 Ml/d

[21] As indicated on the WRP title page

Item	Change from WRMP14 to WRMP19	Approximate impact of change on future deficit
	demand is not being included in our planning. A full assessment of future demand has been carried out using microcomponent analysis (Section 7)	

C.11.2. Drought resilience measures

Bristol Water's option appraisal process included a multi-stage, multi-screening process that incorporated an assessment of the resilience benefits of each option alongside their other criteria. Leakage reduction is one of the select options which the company notes will increase their resilience to drought as well as meeting the increased demand forecast over the planning period.

In general Bristol Water's resilience assessment shows that:

- Customer demand management and leakage reduction measures provide a lower level of resilience benefit due to the relatively low level of water savings achieved relative to the total customer demand for water. The key benefit is a reduction in demand during period of peak demand and/or water scarcity and therefore providing an increase to the resilience of the supply network
- Resource management options provide a low to moderate level of resilience benefit depending on the specific nature of the scheme and the volume of additional water supply capacity provided by the option
- Production management options provide the highest level of resilience benefit, reflecting the nature of the investment which will increase the reliability and robustness of the treatment processes and assets

C.11.3. Emergency drought measures

Bristol Water list 3 drought permit measures in dWRMP Table 10.5 that are included in their Drought Plan but not their dWRMP. These are:

- Temporary variations to bulk supply agreements with Wessex Water
- Honeyhurst & Rodney Stoke (Well head)
- Reduction of Blagdon Reservoir compensation release (drought permit)
- Reduction of Chew Reservoir compensation release (drought permit)
- Reduction of Cheddar Ponds compensation release to Cheddar Yeo River augmentation measure (drought permit)

In addition to these supply measures, Bristol Water detail many demand side measures that are included in their dWRMP and Drought Plan:

- TUBS (1 in 15-year LoS)
- NEU bans (1 in 33-year LoS)
- Emergency Drought Order (1 in 100-year LoS)

Table 7-11 summarises the benefits included in dWRMP Table 10 associated with their 1 in 200 drought scenario.

Table 7-11 Availability of drought permits in the Drought Plan and dWRMP

Zone	Drought Plan	dWRMP 1 in 200 year	Comments
Bristol Water (1 WRZ)	**5.52 Ml/d** Up to 4.33 Ml/d from 3 supply drought permits Up to 1.19 Ml/d from NEU bans	**19 Ml/d** Up to 11.2 Ml/d from use of emergency storage Up to 7.8 Ml/d from TUBS	Bristol Water's DP was not included in the Water UK DP database. Therefore we assume 6 Ml/d of low risk, 11 of medium and 8 of high risk in our assessment.

Bristol Water have a level of service of 1 in 100 for the implementation of an emergency drought order in the form of rota cuts and stand pipes. This level of service is justified in their dWRMP as follows, "*Due to the fact PR19 stated preference valuations were low, the outcome of qualitative research and the fact Bristol Water already operate to a 1-100 year drought it is proposed that there is no change to this level of service in this WRMP.*" (p.42)

C.11.4. Costs of emergency drought measures

Drought permits: No drought permits are considered in the dWRMP.

Desalinisation (indirect relevance): No desalination options considered.

Effluent recycling (indirect relevance): No effluent re-use schemes proposed.

Other relevant information (indirect relevance): Bristol Water include a number of potential feasible schemes in their dWRMP Table 5. Table 7-12, Table 7-13Table 7-14 show the stated costs based on capacity of each scheme for Bristol Water's leakage, transfer and refurbishment related schemes.

Table 7-12 Leakage control costs (preferred options in bold). Costs are based on capacity.

Option Name	Yield (Ml/d)	CAPEX NPV £000	OPEX NPV £000	AIC (p/m3)	AISC (p/m3)
ALC 0.5	0.5	[redacted]	[redacted]	[redacted]	[redacted]
ALC 1.0	1	[redacted]	[redacted]	[redacted]	[redacted]
ALC 1.5	1.5	[redacted]	[redacted]	[redacted]	[redacted]
ALC 2.0	2	[redacted]	[redacted]	[redacted]	[redacted]
ALC 2.5	2.5	[redacted]	[redacted]	[redacted]	[redacted]
ALC 3.0	3	[redacted]	[redacted]	[redacted]	[redacted]
ALC 3.5	3.5	[redacted]	[redacted]	[redacted]	[redacted]
ALC 4.0	4	[redacted]	[redacted]	[redacted]	[redacted]
ALC 4.5	4.5	[redacted]	[redacted]	[redacted]	[redacted]
Pressure Management 0.5	0.5	[redacted]	[redacted]	[redacted]	[redacted]
Pressure Management 1.0	1	[redacted]	[redacted]	[redacted]	[redacted]
Pressure Management 1.5	1.5	[redacted]	[redacted]	[redacted]	[redacted]
Pressure Management 2.0	2	[redacted]	[redacted]	[redacted]	[redacted]
Reduced leakage from raw water mains	4.7	[redacted]	[redacted]	[redacted]	[redacted]

Table 7-13 Transfer scheme costs (preferred options in bold). Costs are based on capacity.

Option Name	Yield (Ml/d)	CAPEX NPV £000	OPEX NPV £000	AIC (p/m3)	AISC (p/m3)
Purchase water from 3rd parties from water companies	10	[redacted]	[redacted]	[redacted]	[redacted]
Reduction of bulk transfer agreement with Wessex Water	11.37	[redacted]	[redacted]	[redacted]	[redacted]

Option Name	Yield (Ml/d)	CAPEX NPV £000	OPEX NPV £000	AIC (p/m3)	AISC (p/m3)
Reduction of bulk transfer agreement with Wessex Water	**6.37**	[redacted]	[redacted]	[redacted]	[redacted]

Table 7-14 Refurb and increased capacity scheme costs (preferred options in bold). Costs are based on capacity.

Option Name	Yield (Ml/d)	CAPEX NPV £000	OPEX NPV £000	AIC (p/m3)	AISC (p/m3)
Alderley WTW – increased production	2	[redacted]	[redacted]	[redacted]	[redacted]
Honeyhurst GW – back into supply	2.4	[redacted]	[redacted]	[redacted]	[redacted]
Catchment Management of Mendip Lakes – loss recovery to manage algal blooms	0.394	[redacted]	[redacted]	[redacted]	[redacted]
Cheddar WTW – increased production	4	[redacted]	[redacted]	[redacted]	[redacted]
Charterhouse – increase performance	1.7	[redacted]	[redacted]	[redacted]	[redacted]
Forum – increase performance	2.64	[redacted]	[redacted]	[redacted]	[redacted]

C.12. Yorkshire

C.13. United Utilities

C.14. Severn Trent Water

Baseline risks		Stated levels of service					Resilience to drought		
Water balance	Drought risk	TUBS	NEUBS	ODOs	EDOs	Chosen[22]	Tested	Level	Comments
M	L	1 in 33			Never		Y	1 in 200+	Already resilient to 200 year drought without significant new investment

[22] As indicated on the WRP title page

C.14.1. Main features of the dWRMP

Severn Trent Water is one of the largest water supply and sewerage companies serving more than 4.3 million customers in England and Wales. It recently purchased Dee Valley Water and plans to split the companies into an English only and Welsh only company in 2018.

The water company faces significant challenges to decrease abstraction at environmentally sensitive sites and to manage the potential impacts of climate change on supplies. Its plan is focussed on demand management (reducing leakage and promoting water efficiency), increasing the regional supply network so that water can moved around more easily and on optimising the balance of imports and exports across the region.

Significant progress has already been made on leakage, which will have reduced by 72Ml/d (15%) between 2010 and 2020, alongside reductions in water consumption by around 45Ml/d through water efficiency programmes.

C.14.2. Drought resilience measures

The company have tested their plan against severe drought (1 in 200 year, 0.5 % annual probability) and demonstrated that it can currently maintain supplies without major new investment. Therefore, it does not need immediate investment to maintain supplies during drought but will seek to maintain this level of resilience future.

The company's approach to resilience ensuring the customers can be supplied by more than one source of water. For example, Birmingham receives its water supply from the Elan Valley Aqueduct (EVA). As part of the last WRMP and Business Plan a major scheme was developed to promote resilience of the EVA so that supply can be maintained even when sections of the aqueduct are closed for maintenance. The company is exploring similar schemes for other parts of its supply area and these may feature more strongly in the Business Plan 2018. These schemes have multiple benefits in that they can help to move water around a larger strategic grid during a drought or unplanned works or pipe failure.

C.14.3. South Staffs

The company's proposed and reference levels of services are as follows:

Table 18: Levels of service assessed against deployable output

Restriction	Company proposed levels of service	Reference levels of service
Temporary use bans (formerly hosepipe bans)	1 in 40 years	1 in 10 years
Non-essential use bans (Ordinary Drought Order)	1 in 80 years	1 in 40 years
Rota cuts or standpipes	1 in 200 years	Not applicable

C.14.3.1. Main features of the dWRMP

South Staffs Water is responsible for supplying public water to 1.25 million customers across parts of the West Midlands, Staffordshire and Worcestershire. The region is divided into 20 water supply zones which are supplied by both surface and groundwater sources (50% by two surface water sources – the River Severn and Blithfield Reservoir and 50% by 26 groundwater sources situated mainly in the central and southern areas of the region).

A key challenge faced by the company is to invest in their two major water treatment works to make sure we have enough high-quality water to meet demand and ensure long-term resilience of their network. South Staffs plan includes a 17% reduction in leakage by 20245/25, increased customer water metering and decreasing customer demand by 1 litre per person per day, by 2024/25.

Figure 7-2 South Staff's Preferred Plan

Key element of plan	What will be done
Leakage	By 2024/25, we will reduce total leakage on our network by 12Ml a day from the 2019/20 Performance Commitment level of 70.5Ml a day. This is a transformational 17% reduction, which we will achieve through a combination of pressure management and active leakage control. We will consider the benefits of developing a live network where data can help identify leaks more quickly and improve performance.
Metering	We will continue to build on our engagement with customers to educate them around the benefits of having a water meter. We will aim to encourage an additional 2,600 households a year to switch to a water meter above the number included in our baseline forecasts over the lifetime of this WRMP. This will give us a target level of 73% of customers with a water meter by 2039/40 (which is in line with the target we set in our 2014 WRMP), and 78% by 2044/45 (compared with our baseline target of 68% by 2044/45). We are looking at options for 'smart meter' devices that would help customers monitor and control how much water they use – something our customers said would be useful to them.
Water efficiency	We will reduce baseline PCC by 1l/h/d by the end of the five-year period from 2020 to 2025. We will work with developers to explore incentives for them to include rainwater harvesting and greywater recycling within new sites. We will continue to work with customers and target water efficiency advice at those who may be concerned about whether they can afford to pay their water bills. We will report the findings from the 'WaterSmart' trial that we are currently carrying out in our Cambridge region in our final WRMP.
Water supply	Our work to develop this WRMP has shown that continuing with our existing base of sources is the most efficient way to operate over the next 25 years. We will invest in our two major treatment works to ensure high-quality, secure and reliable water supplies and to maintain existing capacity now and in the future. We will reduce the volume of groundwater we are entitled to take from the environment by about 6Ml a day (4%) where necessary to manage the risk of causing deterioration to that environment. We will invest in new treatment processes at two of our groundwater sources, which will enable them to be brought back into supply.
Resilience	We will liaise with our neighbour, Severn Trent Water, to further explore a bulk supply trade to provide additional resilience to our water supply system – especially during the period of investment in our two major treatment works.
Environment and sustainability	We will pilot an innovative service package in 2018 for customers who are particularly interested in any potential impact of our activities on the environment, and will monitor the success of this. We will continue working with the Environment Agency to achieve objectives around the Water Framework Directive and river basin management plans.

C.14.3.2. Drought resilience measures

Drought measures included within the South Staffs dWRMP and drought plan

Trigg er level	Drought measure	Supply-/ demand side	Comments	WRMP	DP
1	Appeals for restraint	Demand	Extra promotion of water efficiency and increased publicity campaign	Yes	Yes
1	Increased leakage detection and repair	Demand	Yield dependent on conditions and leakage levels	No	Yes
1	Operation of River Blithe pumpback	Supply	Yield based on model parameters	Yes	Yes
1	Ensure existing ground and surface water sources fully operational	Supply	Yield dependent upon conditions and operational readiness	No	Yes
1	Conserve Blithfield Reservoir	Supply	Yield based on model parameters	Yes	Yes
1	Maximise use of enhanced groundwater treatment sites	Supply	Yield dependent upon conditions and operational readiness	No	Yes
1	Transfer of potable water to Blithfield Reservoir	Supply	Yield based on model parameters	Yes	Yes
2	Review potential for bulk supplies to/from Severn Trent	Supply	Yield dependent upon conditions and operational readiness	No	Yes
3	Temporary use (hosepipe) ban	Demand	Yield estimated from UKWIR studies	Yes	Yes
3	Enhanced pressure management	Demand	Yield dependent on conditions and leakage levels	No	Yes
3	Non-essential use ban	Demand	Yield estimated from UKWIR studies	Yes	Yes
3	Implement drought permit on the River Blithe/Trent	Supply	Included in table 10 not DO estimate	(Yes)	Yes
3	Implement drought order at River Severn Works	Supply	Included in table 10 not DO estimate	(Yes)	Yes
3	Operation of Blithfield Reservoir at low levels	Supply	Yield not currently well understood	No	Yes
n/a	Rota cuts	Demand	Civil emergency measure only	No	No

Additional measures

“The additional measures that can be drawn on in the case of a drought that are not included within the WRMP are:

• the River Blithe/Trent Drought Permit – this allows us to operate the River Blithe pumpback when flows in the River Trent at North Muskham fall below the ‘Hands off flow limit’; and

•the River Severn Drought Permit – this allows us to abstract from the river at low flow conditions when the Environment Agency is seeking reductions in abstraction under their River Severn Drought Order.

The benefits of these measures can be estimated and have been included within WRMP table 10 of the WRMP.

In addition, our drought plan identifies the possibility of operating Blithfield Reservoir at low levels – that is, below historic minimum operational levels. Following works in the 1990s there are no remaining hydraulic constraints to this procedure, but there are uncertainties over water quality in the reservoir at these levels which may limit the volumes of water that can be safely treated. Accordingly, there is little certainty over yield and this measure has not been included in WRMP table 10".

Contingencies for extreme droughts

"Our analysis shows our supplies are resilient for a range of droughts across the 25-year planning period. Accordingly, we are not putting forward any new drought management options in addition to those currently in our existing drought plan. In our consideration of sustainability changes in section 7.9 we outline the possibility that the Environment Agency may require further reductions in abstraction to prevent deterioration of the environment. Currently we consider these are at worst an additional 11Ml/d, which would be still leave us able to manage an extreme drought scenario. However, it is likely, in this eventuality, we would seek to agree local mitigation measures to allow continued abstraction of some of these sites in a sustainable way to allow us to maintain our current levels of drought resilience".

Appendix D. Evidence from the drought management in Australia and California

This section presents learnings from Australia and California water industry on supply side options for drought management and suggests experts for interview in both countries.

It is structured as follows:

— Section D.1 summarises the key lessons;
— Section D.2 identifies some useful reports and papers; and
— Section D.3 suggests experts for interviews and provides their contact details.

D.1. Key lessons

A**ustralia's Millennium Drought, that lasted from 1997 to 2010, has several lessons for the UK.**

While drought is not unusual in Australia, the Millennium Drought was of unprecedented severity, duration and geographical extent, affecting most of the continent for over a decade. The observed reductions in streamflow were outside historical record as well as more severe than projected changes to mean climate for 2030. Australian water industry was unprepared for the drought, resulting in a crisis. Customers were subjected to severe restrictions and some planning decisions were made without independent scrutiny, resulting in inefficient investments. The gradual realisation of the severity of event sparked a series of responses including some world-leading innovations, as well as some good and poor examples of water planning and management.

Initially public water suppliers responded by focussing on demand management programmes, including water efficiency campaigns and mandatory restrictions, but these were not sufficient. Restrictions were not applicable to water use in homes, but were aimed at reducing or disallowing outdoor water use. The Australian public was supportive of the restrictions and water efficiency campaigns, and between 2002 and 2008, average per capita consumption in Australia's cities declined by 37%. However, prolonged restrictions on outdoor use led to loss of green spaces and amenity areas and has been blamed for negative social impact.

As the drought deepened, reserves across south-eastern Australia dwindled, and governments assumed control of water resources planning and decided to invest in major supply augmentation. A range of measures including some innovative supply side measures were developed.

— **Readiness to build**: for the first time, governments contemplated real options planning, based on the principle of readiness. For example, by being ready to construct Sydney's desalination plant as insurance should dam levels drop below a specified trigger level (30%). This allowed for greater flexibility for investment by making the expenditure staged and modular, and allowed for the option to curtail the completion of a plant if conditions changed.
— **Access to dead storage**: construction of pumps and infrastructure to access water below gravity offtakes within existing dams. In Sydney, this increased in the system yield by nearly 10% in 2006.
— **New inter-catchment transfers:** construction of new pipelines and channels to transfer water from other catchments. This proved useful for increasing yield in South East Queensland. In Victoria, a significant investment, USD 1.4 bn, was made in transfers from irrigated agriculture by improving irrigation efficiency. This was shared between irrigators, the environment and the city of Melbourne.

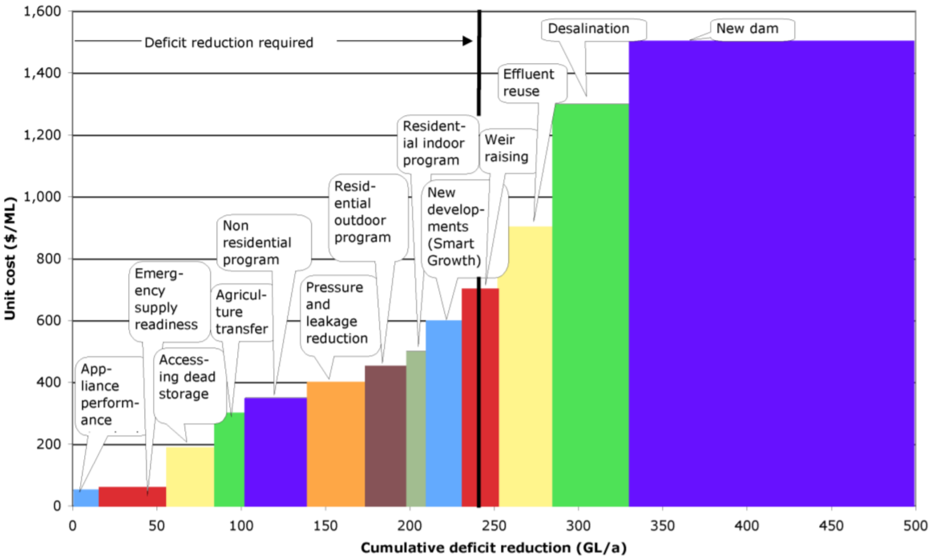
- **Groundwater extraction infrastructure:** for long-term and/or emergency replenishment of water supplies.
- **Desalination**: construction of seawater desalination plants for supply of water to coastal cities. Two desalination plants supplied 40% of Perth's water.
- **Major re-use**: large-scale high quality recycled water treated for various sectors from residential estates to large industrial customers for non-potable purposes to offset potable water demand. In Melbourne, recycled water production from wastewater treatment plans was increased and supplied for a range of uses including agriculture, local sports grounds and public open spaces.
- **Indirect potable reuse**: blending of advanced treated, recycled or reclaimed water into a natural water source (groundwater basin or reservoir) that could be used for drinking (potable) water after further treatment.
- **Decentralised (building or precinct) wastewater reuse**: decentralised systems have significant potential for achieving avoided costs in new developments for sewage infrastructure.

The UK can learn from Australia's readiness based approach and use of diverse supply sources. Figure 1 shows a MACC for selected supply and demand side measures undertaken in Australia. It reveals that emergency supply readiness, access to dead storage and agriculture transfers are cheaper than desalination and construction of new storage.

Regional integration helped coordinate water supply strategy. During the drought there were more than 20 councils in the south-east Queensland region providing separate water services. In response, the Queensland Government established the Queensland Water Commission, which was given overarching policy, planning, and regulatory functions that allowed for the coordination of water use information, strategy development, and project implementation across formerly fragmented water supply services managed by individual councils.

The Millennium Drought also provides a cautionary lesson. Careful planning by government agencies and utilities in several instances was set aside by political decisions. These included construction of desalination plants and inter-catchment transfers regardless of dam levels. This resulted in over-investment in expensive and energy-intensive large-scale infrastructure: costly stranded assets in many cases. The lesson highlights the risk of crisis-driven decision making.

Figure 1. **MACC for selected supply and demand side measures**



Source: *(Alliance for Water Efficiency; Institute for Sustainable Futures; University of Technology Sydney; and Pacific Institute 2016)*

Like Australia, California took steps to develop alternative water supplies when droughts occurred.

— **Recycled water and brackish groundwater** were used widely in the 1987-1992 drought.

— **Desalination plants** have been developed as a response to the more recent 2012-16 drought. However, in many cities the desalination plants and recycled water plants have been shut down.

Figure 2X shows operational characteristics and cost ranges for some options in California.

Figure 2. **Operational characteristics and cost ranges for some portfolio options in California**

Method	Operational pros and cons	Illustrative cost range ($/af)
Demand and reallocation		
Water transfers	**Pros:** Flexible tool for lowering costs of dry-year shortages and enabling long-term reallocation of supplies as economy shifts **Cons:** Potential economic harm to selling regions	50–550
Agricultural water use efficiency	**Pros:** Reduces total stream diversions and pumping; enables farmers to raise yields and limit polluted runoff. **Cons:** May not generate net savings that make water available for other users; net use reductions often require fallowing (Box 2.1)	145–675 (per acre-foot of net use reduction)
Urban water use efficiency	**Pros:** Savings can often occur without loss of quality of life; high net savings possible in coastal areas and with landscape changes; some actions also save energy **Cons:** Requires implementation by large numbers of consumers; can be especially difficult for outdoor water uses, which depend on behavior as well as technology	225–520 (per acre-foot of gross use reduction)
Supply management		
Conjunctive use and groundwater storage	**Pros:** Flexible source of storage, especially for dry years **Cons:** Slower to recharge and harder to monitor than surface storage	10–600
Recycled municipal water	**Pros:** Relatively reliable source in urban areas **Cons:** Public resistance can preclude potable reuse	300–1,300
Surface storage	**Pros:** Flexible tool for rapid storage and release **Cons:** Potential negative environmental impacts; small value of additional storage with a drier climate	340–820+ (state projects)
Desalination, brackish	**Pros:** Can reclaim contaminated groundwater for urban uses **Cons:** Brine disposal can be costly	500–900
Desalination, seawater	**Pros:** "Drought-proof" coastal urban supply tool, especially useful in areas with few alternatives **Cons:** Potential environmental costs at intakes and for brine disposal; sensitive to energy costs	1,000–2,500

Source: (Hanak et al. 2011)

D.2. Useful reports

Australia

- (Piure 2014): Markets, water shares and drought: Lessons from Australia What can the water industry in England and Wales learn from Australia's water reform story?
- (Alliance for Water Efficiency; Institute for Sustainable Futures; University of Technology Sydney; and Pacific Institute 2016): Managing drought: learning from Australia
- (S.Kiem 2013):Drought and water policy in Australia
- (Horne 2016): Water policy responses to drought in the MDB, Australia
- (Kendal 2013): Drought and its Role in Shaping Water Policy in Australia
- (Institute for Sustainable Futures and University of Technology Sydney 2017): Urban Water Futures: Trends and Potential Disruptions
- (Public Policy Institute of California 2016): Managing Water for the Environment During Drought: Lessons from Victoria, Australia
- (Jaeckel 2015): Water Resource Management and Drought: What can Southern California Learn from Australia's Millennium Drought?

California

- (Alliance for Water Efficiency; Institute for Sustainable Futures; University of Technology Sydney; and Pacific Institute 2016): Managing drought: learning from Australia
- (Public Policy Institute of California 2015): Policy Priorities for Managing Drought
- (Hanak et al. 2011): Managing California's Water: from conflict to resolution

D.3. Interviewees

Australia

- **Professor Stuart White, Director, Institute for Sustainable Futures**. With over twenty years' experience in sustainability research, Professor White's work focuses on achieving sustainability outcomes at least cost for a range of government, industry and community clients across Australia and internationally. This includes both the design and evaluation of programs for improving resource use efficiency and an assessment of their impact. He has co-authored several papers that assess the water industry in Australia, particularly during the Millennium Drought.
  - Webpage: https://www.uts.edu.au/staff/stuart.white
  - Email: Stuart.White@uts.edu.au
  - Phone: +61 2 9514 4944
- **Joanne Chong, Research Director, Institute for Sustainable Futures**. Jo leads inter-disciplinary research projects, in Australian and internationally, across the areas of: urban water, climate change adaptation, international development, ecosystem services, and wetland, catchment and river basin management. She has co-authored several papers that assess the water industry in Australia, particularly during the Millennium Drought.
  - Webpage: https://www.uts.edu.au/staff/joanne.chong
  - Email: joanne.chong@uts.edu.au
  - Phone: +61 2 9514 4967
- **James Horne, Researcher, Australian National University.** James's interests include infrastructure and water governance arrangements, regulatory frameworks for the interaction between water resources and 'unconventional gas' resources, and the broader issue of federal state relations in the digital age. Between 2007 and early 2011 James was a Deputy Secretary in the Australian Government with responsibility for Water. He was Chair of the MDB Basin Officials Committee and the Council of Australian Governments' Water Reform Committee.
  - Webpage: https://researchers.anu.edu.au/researchers/horne-jb
  - Email: jameshorne@iinet.net.au
  - Phone: +61 4 1269 7260

California

- **Ellen Hanak, Senior Fellow, Public Policy Institute of California**. Ellen Hanak is director of the PPIC Water Policy Center and a senior fellow at the Public Policy Institute of California. She has authored dozens of reports, articles, and books on water policy, including Managing California's Water. Her research is frequently profiled in the national media, and she participates in briefings, conferences, and interviews throughout the nation and around the world. She holds a PhD in economics from the University of Maryland.

  - Webpage: http://www.ppic.org/person/ellen-hanak/
  - Email: hanak@ppic.org
  - Phone: 415-291-4433

- **Jay Lund, Director, Center for Watershed Sciences**. Jay specialised in the management of water and environmental systems. His research has included system optimisation studies for California, the Columbia River, the Missouri River and other systems for climate adaptation, water marketing, water conservation, system reoperation, and integrated water management. He served on the Advisory Committee for the 1998 and 2005 issues of the *California Water Plan Update* and is a former editor of the *Journal of Water Resources Planning and Management*.
  - Webpage: https://watershed.ucdavis.edu/shed/lund/
  - Email: jrlund@ucdavis.edu
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Appendix E. Evidence from water company and expert consultation

E.1. Summary of comments on acceleration of capital schemes and lead times

Several water companies in drought prone areas were contacted to discuss the feasibility of accelerating different types of capital infrastructure, in the run up to and during severe droughts. The following tables summarise key comments and give some insights into the barriers and constraints involved in accelerating capital schemes.

E.1.1. South East

Scheme Category	Range of Lead Times	Range of Benefits	Comments and Flexibility
Groundwater re-instatement	SEW – 'very unlikely these would be implemented in time for a severe drought' SW – 6 to 12 months (Hampshire) PW – 3 to 6 months	SEW 2 sources using existing works with increased abstraction (4Ml/d), 3 disused sources (not stated, but relatively small, say <5Ml/d total) SW 2 sources 5Ml/d Hampshire, 2 sources Eastern @ 1Ml/d each PW 2 sources at 8Ml/d total	At least pump testing, additional pump infrastructure. Disused Re-commissioning of treatment, pump testing and then DWI approvals are the key constraints Possible hydrocarbon treatment need at one source
Temporary Desalination	SW IOW and Brighton 6-9 months *as an absolute minimum*	20Ml/d IOW 20Ml/d Brighton	Doesn't allow for pre-enabling works – *timescales down to <6 months if pipelines in place.*

Note – nothing for SESW

E.1.2. Thames

Scheme Category	Range of Lead Times	Range of Benefits	Comments and Flexibility
Groundwater re-instatement	Min 6 months (Affinity) Nitrate treatment needed for SWOX	5, 6Ml/d (Total 11 Ml/d) Nothing for London SWOX 3 options – not stated, but circa 20Ml/d total	Re-commissioning of treatment, pump testing and then DWI approvals are the key constraints
Surface abstraction	Pumps plus temporary pipeline – probably 3 months, plus temp WTW	SWOX only – bring forward the Oxford Canal scheme; 5Ml/d,	May require planning permission

	required for Blewbury (6 months)	plus extension of Blewbury	
Temporary Desalination	Not stated	London only. Not stated, but likely to be limited as it would need to supplement Beckton	
Effluent re-use	Not stated	Demand constrained	Limited to 'high value recreational users' – would need to be close to an STW

E.1.3. South West

Scheme Category	Range of Lead Times	Range of Benefits	Comments and Flexibility
Groundwater source implementation	Min 6 months (Brl) Standby source; rapid (Wessex)	2.4Ml/d (Brl) 7Ml/d (Wssx)	Requires 4km pipeline to Cheddar res for the Brl option Need to review if Wessex option is feasible to support Bristol

E.1.4. Central

Scheme Category	Range of Lead Times	Range of Benefits	Comments and Flexibility
Groundwater re-instatement	Not stated, but relatively short following enabling works.	1 source (SVT) @ 9Ml/d	May be included in the WRMP – Beechtree Lane, although will probably hold this back as an EVA support

Note – nothing for South Staffs

Severn Trent consider that re-instatement of the majority of mothballed sources is impractical and distracts time and resources, so have written off all but one option.

E.1.5. North West

Scheme Category	Range of Lead Times	Range of Benefits	Comments and Flexibility
Groundwater re-instatement	1 to 6 months, but generally 3 to 6 months	10 sources in IZ, total of 57Ml/d	Maintenance and testing programme used to keep sources viable.

E.1.6. East

Scheme Category	Range of Lead Times	Range of Benefits	Comments and Flexibility

Groundwater re-instatement	Not stated, but treatment and environmental issues indicate >6 months	Cam – 4 sites total of 7.6Ml/d	Three sites were specifically abandoned in the past due to treatment issues including Crypto– possible need for mobile plant?
Temporary Desalination	ESW indicate 8-12 months	Modular, but ESW consider up to 5Ml/d	Need to develop site and procure mobile treatment plant, timescales could be reduced slightly through enabling works, but still likely to be >6 months.

Note - Confirmed no schemes with Anglian – all options have been developed and used to support existing sources

E.2. Discussion with Albion Water

Confidential

E.3. Other Interview Evidence

Confidential

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