Section 1

Introduction and background

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Section 1.

Introduction and background

In this section we cover:

- The purpose of a Water Resources Management Plan (WRMP)
- An overview of our water supply area and the levels of service we provide to our customers
- An outline of the statutory and policy framework which shapes the preparation of the WRMP
- The relationship between the WRMP and other plans, such as the Drought Plan and Business Plan
- Engagement with customers, regulators and stakeholders during the development of the WRMP
- Engagement with our Board and quality assurance
- Public consultation on the draft WRMP

We have made the following changes in response to points raised in the public consultation on the draft WRMP and to include new information that has become available since the draft WRMP was published.

- We have included additional information on the policy framework which influences our WRMP, namely Defra's 25-year Environment Plan and the National Infrastructure Commission's (NIC) report on the water sector. (Section D)
- We have included information on further engagement with customers since December 2017. (Section F)
- We have included additional information on the engagement with our Board in refining our plan. (Section G)
- We have included information on the public consultation on the draft WRMP, including details of the approach and number of responses received. (Section I)

A. Introduction to water resources planning

What is a Water Resources Management Plan?

1.1 A secure water supply is essential for public health, the environment and the economy. Water companies have a statutory duty to develop and maintain efficient and economical systems of water service provision which will provide security of supply for customers[1]. Every five years water companies are required[2] to produce a WRMP. Government, and regulators, publish reference documents, namely, the Guiding Principles[3] and Water Resource Planning Guideline (WRPG)[4], which provide a framework for the development of WRMPs.

1.2 The WRMP is a strategic plan which sets out how the company plans to maintain the balance between supply and demand for water for a minimum planning period of 25 years, although companies with particularly complex planning problems are encouraged to take a longer term view[4].

1.3 The main components of a WRMP, and the step-wise process to develop a WRMP, are shown in Figure 1-1.

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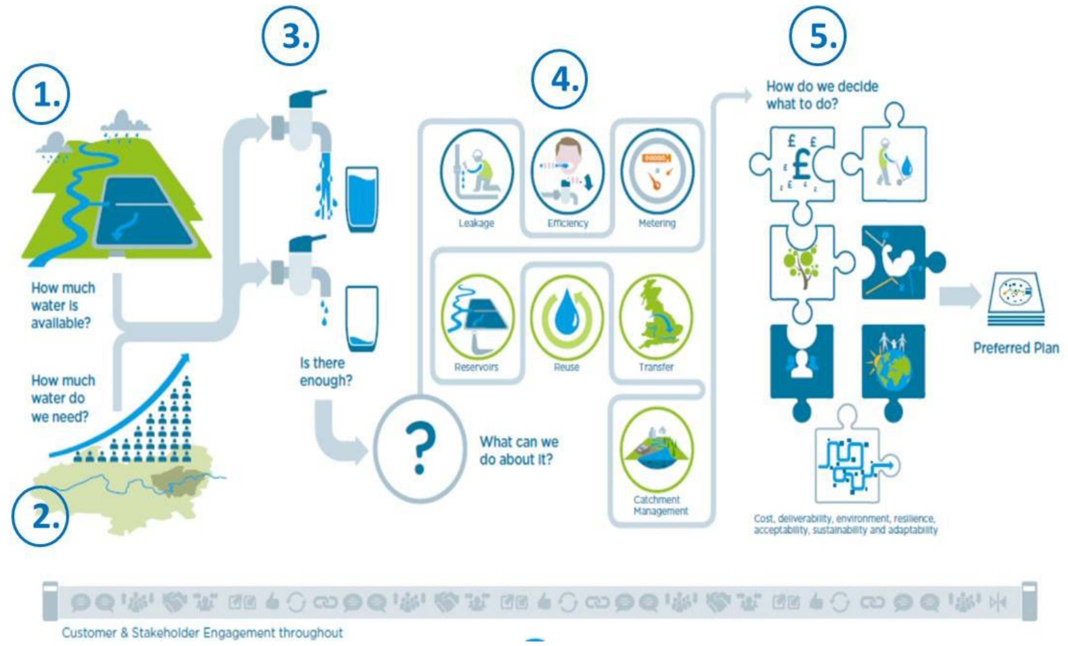
1 Water Industry Act 1991, Section 37
2 Water Industry Act 1991, Sections 37A to 37D (as amended by the Water Act 2003)
3 Defra, Guiding principles for water resources planning for water companies operating wholly or mainly in England, May 2016
4 Environment Agency and Natural Resources Wales, Final Water Resources Planning Guideline: July 2018.

Figure 1-1: The step-wise process to develop a WRMP



1) **How much water is available?** This is a forecast of the amount of water available for public water supply now and how this might change over the planning period.
2) **How much water do we need?** This is a forecast of demand for water setting out how much water customers need now and how this might change over the planning period.
3) **Is there enough?** This is the baseline supply demand balance. It is an estimate of the water resource position produced by comparing the demand forecast, including an allowance for uncertainty called headroom, and the supply forecast. This identifies if there is a surplus or deficit of water for each year of the planning period.
4) **What can we do about it?** Where a deficit is identified, a range of options to manage demand for water and provide additional water supply are assessed.
5) **How do we decide what to do?** Taking account of information including cost, environmental impact and customers' preferences we develop a programme of options to ensure a secure supply of water over the planning period.

Customer and stakeholder engagement: Throughout the process we have engaged with our customers and stakeholders to seek their input and challenge to inform the development of the revised draft WRMP19.

1.4 To ensure we can provide our customers with the best possible value over the long term we have developed our revised draft WRMP19 over an 80 year planning period and designed it to satisfy three main objectives:

- To provide a secure supply of water for our customers addressing the supply demand deficits that we forecast in our region
- To improve resilience to a severe drought
- To look beyond the needs and opportunities of our supply area alone and take into account the growing needs of the wider south east of England. In developing our plan we have worked with neighbouring companies in the south east of England to ensure an effective and efficient outcome for customers across the region.

1.5 Our approach is explained in more detail in Section 10: Programme appraisal and scenario testing.

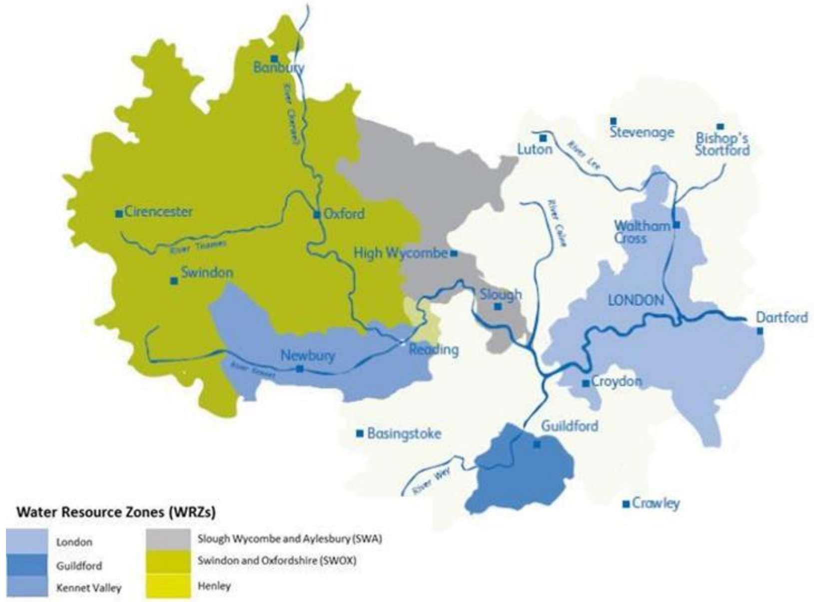
B. Our water supply area

1.6 Our water supply area extends from Cirencester in the west to Dartford in the east and from Banbury in the north to Guildford in the south and covers over 13,000 square km. Every day, we supply around 2,600 million litres of water to around 10 million people and 250,000 businesses[5]. Water supplies are derived from a mixture of surface water sources (mostly from large storage reservoirs supplied from the River Thames and River Lee) and groundwater sources. We also have a desalination water treatment works on the River Thames (Tideway) that can supplement water supplies at times of high demand and/or during drought conditions.

1.7 For planning purposes our supply area is divided into six water resource zones (WRZs) as presented in Figure 1-2. A WRZ describes an area within which the abstraction and distribution of water to meet demand is largely self-contained and all customers experience the same risk of supply failure and the same level of service. We have defined our WRZs using the Environment Agency's WRZ assessment methods[6]. We undertake the WRMP planning process for each WRZ to ensure we can provide a secure supply of water to our customers in that zone.

[5] In April 2017 a competitive retail market for water services for business customers was introduced. This means that business customers can choose which retailer they buy their water and wastewater services from. The retailer provides billing, customer service and efficiency advice to the business customer, while Thames Water, as a wholesale water provider, still has an obligation to supply the water and sewerage services and manage the infrastructure.
[6] Environment Agency, Water Resource Zone Integrity, 2016

Figure 1-2: Thames Water supply area showing the WRZs



1.8 London WRZ is the largest of the six zones and covers much of the Greater London area. The water resources for London are largely based on abstraction from the River Thames, which is stored in reservoirs, and the remainder from underground sources (aquifers) via boreholes.

1.9 The next largest zone is the Swindon and Oxfordshire (SWOX) WRZ. This zone is supplied mainly from groundwater (60%), supported by river abstraction and a reservoir, sited near Oxford.

1.10 The other zones to the west of London are Kennet Valley (includes Reading and Newbury); Henley; Slough, Wycombe and Aylesbury (SWA) and Guildford. These latter four zones are largely reliant on groundwater abstraction although there are abstractions directly from local rivers, notably the River Kennet in Reading and the River Wey near Guildford.

1.11 A more detailed map of each WRZ along with a high level description of each zone can be found in Appendix D: Water resource zone integrity.

1.12 As a part of the development of our draft WRMP19 we reviewed the WRZs with the Environment Agency and agreed that they were still the most appropriate planning units[7].

[7] Thames Water and Environment Agency Water resources update meeting, September 2017

C. Levels of service provided to our customers

1.13 In a succession of dry years, measures to reduce demand for water e.g. Temporary Use Bans (TUBs) and Non-essential Use Bans (NEUBs), and measures to allow increased abstraction, outside that permitted by an abstraction licence, may be required. Such measures are known as drought interventions. Drought interventions either have a direct effect on customers (e.g. TUBs) or the environment (e.g. drought permits for temporary changes to abstraction licences).

1.14 We set targets regarding the average frequency with which such interventions will be implemented. These are known as levels of service. The aim of the WRMP is to ensure that we can meet customer demands for water in a dry year without the need for drought interventions at a frequency that exceeds the stated level of service. Our levels of service are shown in Table 1-1.

1.15 We consulted household and non-household customers on levels of service for water use restrictions, specifically seeking their feedback on whether the levels of service should deteriorate, be maintained or improved[8]. The main findings are summarised as:

- Overall customers indicated that they did not want deterioration in the levels of service. This was particularly strong for the more severe restrictions such as rota cuts and drought permits
- The current expected frequency of sprinkler bans, hosepipe bans, and NEUBs were not perceived to have significant impacts on customers' day-to-day activities and as such customers indicated that they were broadly satisfied with the current levels of service
- Customers did show support for improved levels of service for the more severe restrictions. For rota-cuts (Level 4 restrictions), both household and non-household customers showed some support for an improvement to a 1 in 200 year level of service (from the current 1 in 100 year). Household customers did not support improvement in service beyond 1 in 200 years

1.16 In line with customers' preferences for Level 4 restrictions, and guidelines published by the Environment Agency, our revised draft plan reduces the risk of these restrictions to a 1:200 year frequency over the next ten years. The lead time to enact this change will ensure it is deliverable and affordable for our customers.

1.17 Further information on the customer research is provided in Appendix T: Our customer priorities and preferences.

1.18 The NIC[9] suggested that there is limited public appreciation of the consequences of drought and the public find it hard to understand the risk of low probability, high impact events. Therefore, based on its understanding of the challenges and risks, the NIC has stated its support for planning for increased drought resilience for the long term by enhancing the capacity of the water supply system.

[8] Appendix T: Our customer priorities and preferences
9 National Infrastructure Commission, Preparing for a drier future, April 2018

Table 1-1: Our levels of service for water restrictions based on historic twentieth century droughts

Restriction level	Frequency of occurrence	Water use restrictions
Level 1	1 year in 5 on average	Intensive media campaign
Level 2	1 year in 10 on average	Sprinkler/unattended hosepipe ban, enhanced media campaign
Level 3	1 year in 20 on average	TUB (formerly hosepipe ban), Drought Direction 2011 (formerly NEUBs) requiring the granting of an Ordinary Drought Order. Note these would be applied in a staged manner in line with our Drought Plan[10]
Level 4	Never (In reality this equates to ~ 1 year in 100 years on average)	If extreme measures (such as standpipes and rota cuts) were necessary their implementation would require an Emergency Drought Order

D. Planning framework

Water resources long-term planning framework

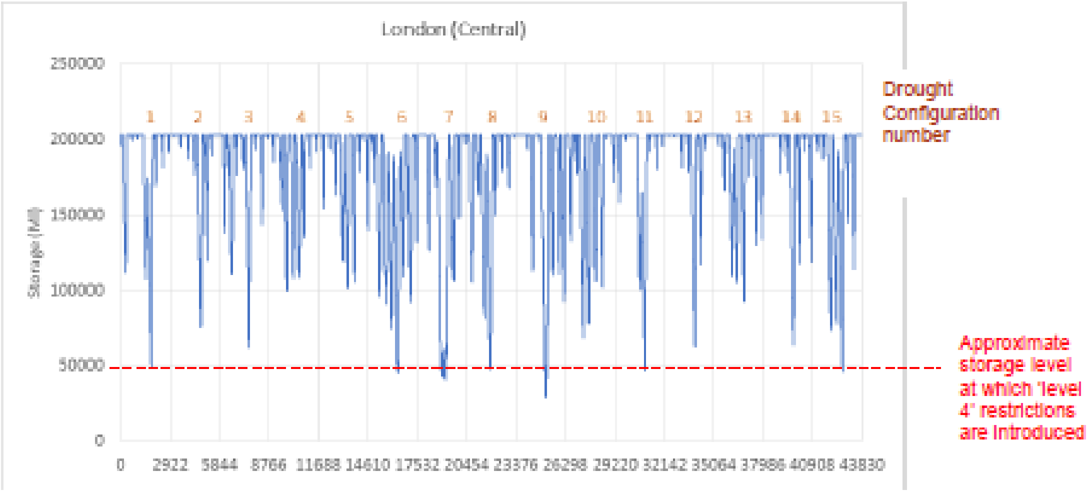
1.19 In 2015, following concern around the growing risk of drought in England and Wales, the Government asked the water industry to look at the future challenges and solutions in terms of resilience to the risk of drought. Water company's levels of resilience to drought are a matter of public interest and public policy. A study[11] was commissioned by WaterUK, the trade association for the UK Water Industry, together with water companies and regulators. The study considered the possible effects of climate change, population growth, environmental protection measures, and trends in water use to produce a wide range of potential future scenarios, looking 50 years ahead.

1.20 The results of the study showed that the problem is more pronounced than previously thought and if we carry on with "business as usual" droughts are likely to become more frequent and more geographically widespread than previously understood. Drier areas of the country, namely the south and the east of England, face a higher risk of more severe droughts than were experienced in the past. The modelling shows that measures to manage demand and enhance supplies of water are needed to contain the risk of drought.

1.21 The analysis assessed the resilience of water supplies to 15 drought scenarios (five historic and 10 modelled). Figure 1-3 presents the assessment of the resilience of water supplies in London to these drought scenarios. The graph shows that in many of the drought scenarios the levels of water storage fall to a level where the most severe water use restrictions, referred to as Level 4 restrictions, which includes rota cuts or standpipes, would be required. This is shown as the red dotted line in Figure 1-3.

[10] Thames Water, draft Drought Plan, April 2017 (available on Thames Water's website)
[11] Water UK, Water resources long-term planning framework 2015-2065 , 2016

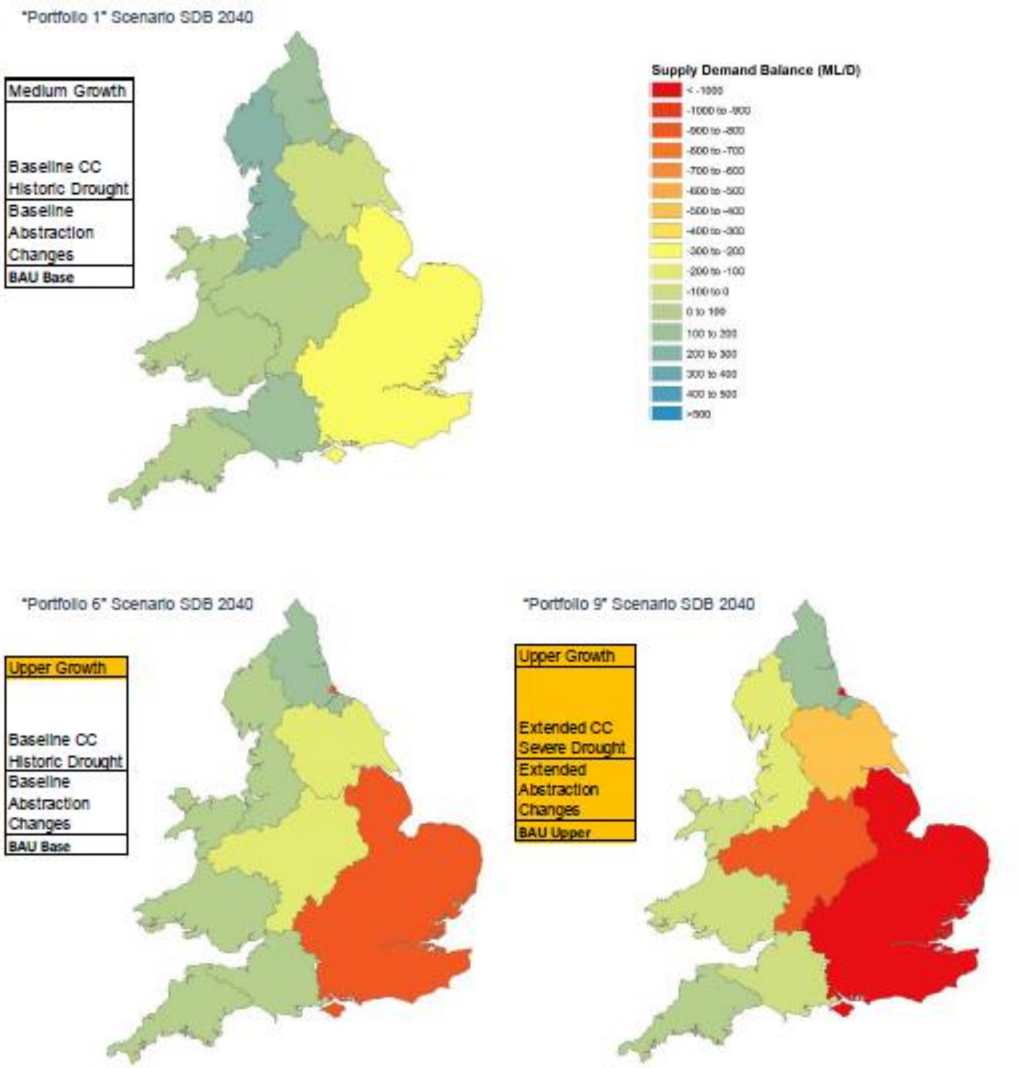
Figure 1-3: Drought resilience assessment for London



Source: Water UK, Water resources long term planning framework, 2016, Figure 6-5

1.22 The study also presented a summary of the forecast deficits by region for different scenarios for population growth, climate change, environmental protection requirements, and drought. This is presented in Figure 1-4 which shows that the biggest percentage water resource deficits are forecast across London and the south east.

Figure 1-4: Maps of forecast regional deficits by 2040 under three future scenarios



Source: WaterUK, Water resources long term planning framework, 2016, Figure 6.27

1.23 The findings of the study were provided to Government, for consideration in the development of government policy. We have also taken account of this work, in planning future water resources and developing our revised draft WRMP19; for example, we plan for the long-term, looking over 80 years for some areas, as the decisions and investments we make today will determine the levels of service we can provide to our customers in the future.

Water Resources Planning Guideline (WRPG)

1.24 The Guiding Principles and WRPG, produced by Government and its regulatory agencies respectively, provide a framework to guide the preparation of WRMPs. These documents set out good practice, the various technical approaches to follow, and the information that a plan should contain. They also give guidance on compliance with statutory requirements and government policy objectives. These documents were reviewed and revised for this round of water resource planning and included a number of significant changes to secure the long-term resilience of the water sector. We have referred to the Guiding Principles and WRPG in preparing our revised draft WRMP19.

1.25 Ofwat has also published a number of technical papers and other documents[12] which reinforce the priorities set out in the Guiding Principles and WRPG. Ofwat has placed specific focus on four key themes: resilience; affordability; innovation; and great customer service and has proposed a suite of performance measures[13] which reflect these key areas. The measures directly relevant to the WRMP are the Security of Supply Index, per capita consumption (PCC) and leakage. In addition there are performance measures covering the environment and resilience to severe droughts. We support these measures which reflect key areas of water resource planning focus, and which help to ensure high levels of customer service into the longer term.

25-year Environment Plan

1.26 In January 2018 the Department for Environment, Food and Rural Affairs (Defra) published their 25-year Environment Plan[14] which sets out the Government's goals for protecting and enhancing the environment for the next generation. The plan provides important context to planning future water supplies and includes targets relevant to our operations and long term plans, These include :

- reducing damaging abstraction of water from rivers and groundwater to achieve the objectives set out in the River Basin Management Plans (RBMP) and to support Ofwat's ambitions on leakage; and
- minimising the amount of water lost through leakage year on year, with an expectation that water companies will reduce leakage by at least an average of 15% by 2025.

1.27 The plan also has several targets focused on restoring, protecting and enhancing natural habitats and species, and on mitigating the effects of and adapting to climate change.

National Infrastructure Commission – Preparing for a drier future

1.28 The NIC published a report[15] in April 2018 which set out their recommendations on how to address England's water supply challenges and deliver the appropriate level of resilience for the long term. The Chairman of the NIC, Sir John Armitt, said "*We take for granted that we will always have a reliable water supply, but despite our reputation for rain, the country risks water shortages. Climate change, an increasing population – particularly in the drier south and east of England – and the need to protect the environment bring further challenges….If we are to avoid our taps running dry, in times of extreme drought, we need the Government to act on our recommendations without delay*."

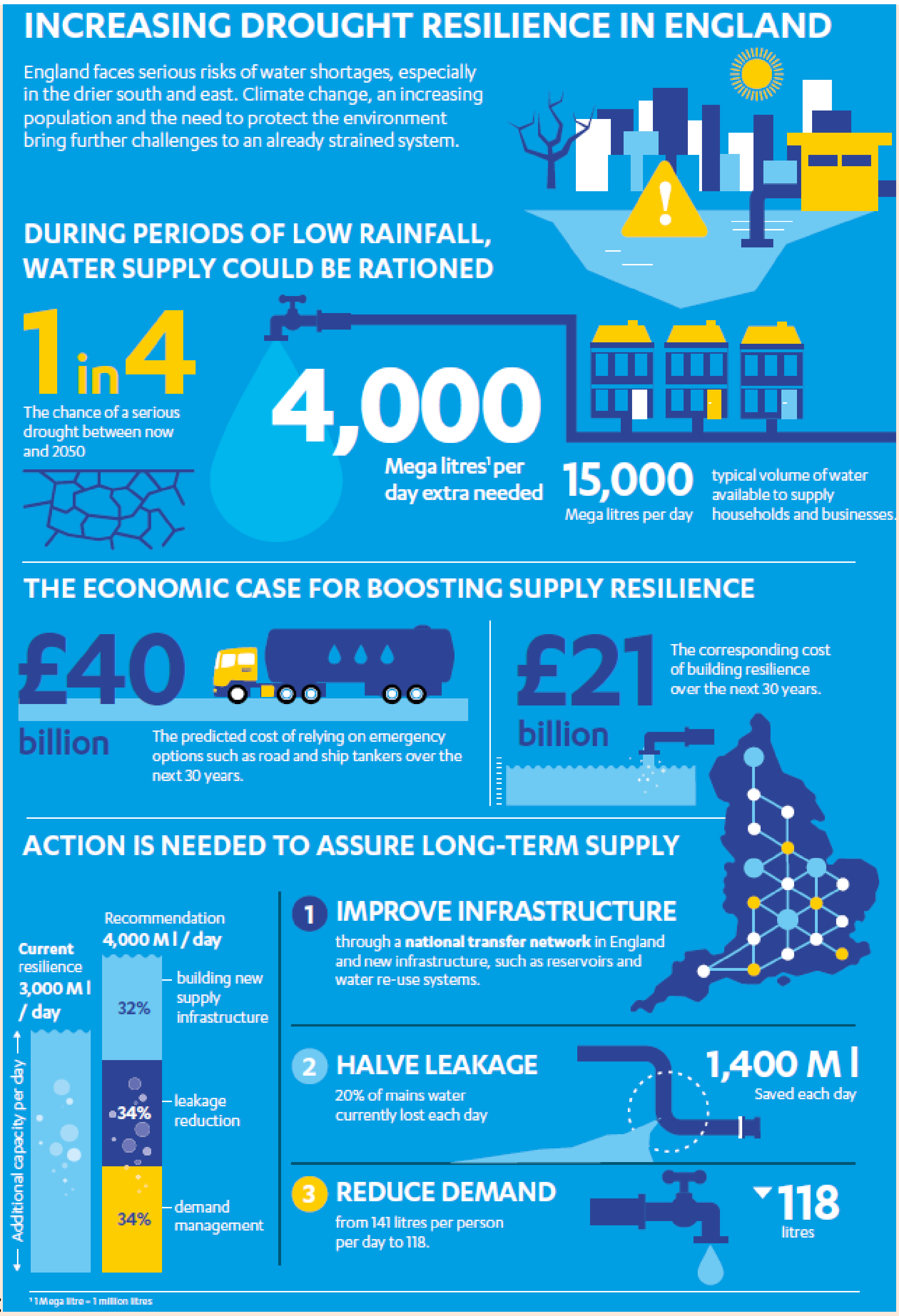
[12] Ofwat, Delivering more of water matters in PR19, July 2017
[13] Ofwat, Delivering Water 2020, Ofwat consultation document, July 2017
[14] Defra, A Green Future: Our 25 year plan to improve the environment, January 2018
[15] National Infrastructure Commission, Preparing for a drier future: England's water infrastructure needs, April 2018

1.29 The report sets out a number of measures which the NIC believes Government, water companies and regulators should take to increase investment in supply infrastructure and encourage more efficient use of water. The analysis also shows that the cost of responding to a severe drought in the UK would be very costly, tens of billions of pounds and, as such, the case for improving drought resilience is therefore compelling. The NIC published the report in April 2018 to allow water companies and the regulators to consider the recommendations as part of planning future water resources.

1.30 The main points of the NIC report are summarised below and illustrated in Figure 1-5.

- The water network is already under strain and Government should ensure increased drought resilience by enhancing the capacity of the water supply system. This will require a twin track approach combining demand management with long term investment in supply. The NIC recommend that Government should ensure plans are in place to deliver additional supply and demand reduction of at least 4,000 Ml/d.
- The report acknowledges that whilst leakage can never be fully eliminated, Defra should set an objective for the water industry to halve the amount of water lost through leaks by 2050.
- The need for a new national water network to transfer water from areas of surplus to where it is needed was proposed. This was in addition to the need to develop further infrastructure including new reservoirs and desalination plants.

Figure 1-5: National Infrastructure Commission summary of key findings



Source: NIC report, April 2018, page 4.

Main priorities in developing our plan

1.31 The main priorities presented in these documents, which have shaped our approach, are noted below.

- Understanding and delivering the outcomes that our customers want
- Involvement of interested parties in the development of future plans
- A planning period that reflects the water resources challenge faced
- A strategic approach that represents best value for our customers over the long term
- Assessment of the vulnerability of water resources to future pressures such as climate change and ensure the plan provides enhanced resilience to drought
- Flexibility to accommodate reasonably predictable changes
- Ensure a reduction in the amount of water lost through leakage
- Promotion of metering and water efficiency helping to reduce overall demand for water
- Consideration of every option to meet future public water supply needs including those outside company boundaries, plus collaboration with neighbouring water companies and other sectors
- Evaluation of resource options within a regional supply context
- Protection and enhancement of the environment

1.32 These priorities are set out in Table 1-2 alongside our response to them and reference to the relevant section of this document in which greater detail is provided.

Table 1-2: WRMP planning priorities

Priorities and policy objectives	Our response	Section of the plan
The plan must focus on delivering the outcomes that our customers want	We have undertaken a detailed programme of customer research and engagement to understand the priorities and preferences of our customers. We have worked with our Customer Challenge Group (CCG) to design and implement the programme. The output of this research and engagement has informed the development of our revised draft WRMP19 and our Business Plan.	10 and Appendix T
Involved customers, interested parties, statutory and non-statutory consultees and taken into account their views	We recognise that there is wide interest in the sustainable management of water resources and over the past three years have engaged with customers, stakeholders and regulators to share the work we have undertaken to inform our draft WRMP19, and provided the opportunity for their input into plan development. We received over 700 responses from customers and stakeholders to our public consultation on our draft WRMP19 and have taken their comments into consideration in revising our plan.	Appendix S and Statement of Response
A planning period that reflects the challenges	The statutory minimum planning horizon for water resources is 25 years. In recognition of the longer term pressures, and the time it takes to develop necessary infrastructure, Government has encouraged water companies to adopt a longer planning horizon where this is considered to be appropriate. We support this. We worked with independent consultants, NERA[16], to consider the planning horizon for WRMP19 and completed problem characterisation for each WRZ. The conclusions of this work are: London and SWOX WRZs have significant and complex water resource challenges. SWA WRZ has moderate challenges. The solutions required in these WRZs will be high cost, with long lifespans. As such, we have developed plans over an 80 year time horizon and have used advanced decision support tools for thorough analysis of the planning problem and to develop multiple feasible programmes of investment. The remaining three WRZs (Kennet Valley, Guildford and Henley) have simpler planning problems. Lower cost options are available and can be implemented relatively quickly. As such, we have developed plans over a 25 year time horizon and used less complex decision support tools.	10

[16] NERA, How Should the Appropriate Horizon for Integrated Water Resource Planning be Ascertained? September 2016

Priorities and policy objectives	Our response	Section of the plan
Strategic approach that represents best value for our customers over the long term	For many years cost has been the primary factor in devising the WRMPs, and a least cost decision support tool, called Economics of Balancing Supply and Demand (EBSD), has been used to support the development of plans. However, a least cost plan is not necessarily a resilient or robust plan and there is now support from regulators[17], stakeholders[18] and our customers[19], to develop best value plans which take account of a wider range of factors including the environment, resilience, and customer preferences. We have developed a suite of modelling and decision support tools[20] to aid the formulation of, and decision making on, the best value programme for the revised draft WRMP19. We have shared the approach and decision support tools with stakeholders to build an understanding of the process and overall stakeholders were supportive of the approach. To improve transparency and confidence in the decision making process we have set up an Expert Panel to work alongside us providing advice and challenge throughout the programme development and helping to inform the preferred programme to be promoted. The Expert Panel has written a report on their involvement in this work. We have also explored innovative water resource options including considering opportunities in growth areas for non-potable reuse of water in new buildings, planned wastewater re-use which is not widely practised in the UK, large inter-company water trades and innovative tariffs.	10

[17] Water Resources Planning Guideline, July 2018
[18] Technical Stakeholder Meetings, March 2016 and November 2016
[19] Customer research, Water resources deliberative research, February 2017
[20] UK Water Industry Research (UKWIR) WRMP 2019 Methods – Decision Making Process: Guidance Report Ref. No. 16/WR/02/10

Priorities and policy objectives	Our response	Section of the plan
Assessment of the vulnerability of water resources to future pressures such as climate change and ensure the plan provides enhanced resilience to drought	We have assessed the severity and complexity of the water resource planning problem in each WRZ in accordance with industry guidance[21]; this is referred to as problem characterisation. The assessment helps us to decide on the appropriate planning horizon, and the approach and decision support tools, to be used to develop the best value programme. Specifically on climate change, historically WRMPs have been prepared to survive a repeat of the worst drought in the 90 year historical record, at the lowest economic cost. Climate change is likely to bring different conditions such as multi-year droughts, and evidence from our own studies, the WaterUK study[6], and other companies studies show that the historical record is not an appropriate basis on which to plan. We have completed work to develop stochastic forecasting approaches for our area and generated artificial drought sequences which have been used to test the resilience of the existing system and new supply options to droughts worse than in the historical record. Our plan proposes the development of new supply infrastructure to ensure we can provide enhanced resilience to severe droughts by 2030. The need for investment in supply was supported by the analysis of the NIC.	4 and 10
Flexibility to accommodate reasonably predictable changes to regulation such as abstraction reform	Uncertainty is inherent in all forecasts. We have assessed our revised draft WRMP19 against a range of plausible future scenarios, and also used an adaptive pathways approach, to ensure it can respond flexibly to future risks, and ensure a “no regrets” approach. As part of the statutory process we undertake an annual performance review of our plan and a five-yearly review and can therefore make adjustments to our long-term strategy as needed.	5 and 10
Ensure a reduction in the amount of water lost through leakage	There is wide support from Government, stakeholders and our customers to reduce the amount of water lost through leaks in the water network. Ofwat and Defra proposed targets to reduce leakage by 15% by 2025 and the NIC proposed to Defra that they should set an objective to halve leakage by 2050. We have listened to the feedback and proposed a reduction in leakage of 15% by 2025 and to halve leakage by 2050, in line with Government’s and the NIC’s recommendations. These targets are ambitious and will require considerable focus and innovation to achieve them.	8 and 10

[21] UKWIR, WRMP 2019 Methods – Decision Making Process: Guidance Report Ref. No. 16/WR/02/10

Priorities and policy objectives	Our response	Section of the plan
Promotion of metering and water efficiency helping to reduce overall demand for water	There is wide support from customers and stakeholders for demand management activity. Regulators have also set out their expectation to see on-going reductions in household PCC. We support measures to manage water resources efficiently and effectively. In developing our revised draft WRMP19 we have explored a wide range of demand management options, we have provided more information on the options as requested by stakeholders, and demand management is the foundation of our future plan.	8 and 10
Consideration of every option to meet future public water supply needs including those outside company boundaries, plus collaboration with neighbouring water companies and other sectors	In developing our draft WRMP19 we have considered a wide range of options to both manage demand and to develop new water resources. We have engaged with stakeholders to identify and develop these options including exploration of options with other water companies and third parties. Since January 2015 we have held regular meetings, Water Resources Forums and technical stakeholder meetings, as well as individual discussions to enable stakeholder input into water resource planning. This work is continuing and we have provided updated information on the technical work completed since draft WRMP19.	7, 8 and Appendix S
Evaluation of resource options within a regional supply context	We have worked closely with the other water companies in the Water Resources in the South East Group (WRSE), engaged with Water Resources East (WRE), and other water companies and potential suppliers more widely to identify new opportunities for water supply and sharing/trading arrangements. The work of WaterUK and the WRSE has shown the significant water resource challenge facing the south east. Other water companies in the south east have indicated that they will require new water sources and we have committed to work collaboratively to provide the best solutions for our customers, and the wider south east. We have tested the implications of changes to these requirements in scenario testing.	7 and 10

Priorities and policy objectives	Our response	Section of the plan
Protection and enhancement of the environment.	There is wide recognition of the need to balance the needs of society and the economy with the environment. Defra's 25 year Environment Plan set out clear targets to restore, protect and enhance the environment, and an aspiration to put the environment first. We have assessed environmental and social impacts and benefits at all stages of the development of the WRMP including coarse screening of options, fine screening of feasible options, the assessment of the constrained options, and development of the best value programme. This ensures end-to-end consistency of approach in the appraisal process. Strategic Environmental Assessment (SEA) is the core of the environmental assessment approach of the WRMP and is supported by the statutory assessment processes relating to the Habitats Directive (Habitats Regulations Assessment (HRA) process) and Water Framework Directive (WFD)). We consulted stakeholders throughout the process, including on the scope of the SEA, methodological approaches and outputs. We received a number of comments on the environmental assessments and have worked with the Environment Agency, Natural England and Historic England to address these comments to ensure we have completed robust assessments and that our plans support the protection, and provide benefit, to the environment where possible. We have also undertaken work to explore the use of natural capital accounting to aid understanding about how to manage our environment. This concluded that the approach was not sufficiently mature at present to apply to water resource planning. Industry wide work will be completed in the next five years to develop this approach for future plans.	9, 10, Appendices B, C and BB

Public inquiry 2010

1.33 In 2010 a public inquiry was held to examine our proposed WRMP at that time (draft WRMP09). In May 2011 Defra issued instructions[22] on the amendments needed to be made to the plan (draft WRMP09) taking account of the Planning Inspector's recommendations[23]. The instructions also identified which of the Inspector's recommendations needed to be addressed as part of WRMP14 and future plans. These instructions have been addressed; those that are relevant to the WRMP19 are summarised in Table 1-3 with an update on progress.

Table 1-3: Summary of instructions from the 2010 public inquiry

Instruction	Progress update
Options appraisal	
Technical analysis to confirm feasibility and uncertainty of Severn-Thames transfer options.	We have undertaken work to examine options to transfer water from the River Severn to the River Thames. This is presented in the Raw Water Transfer Feasibility Option Report and summarised in Section 7: Appraisal of resource options.
Investigations of alternative sites for a 50 million cubic metres (Mm^3) reservoir.	We have undertaken work to investigate and assess a range of reservoir options. This is presented in the Reservoir Feasibility Option Report and summarised in Section 7: Appraisal of resource options.
Investigations into a greater range of effluent reuse schemes and alternatives to reverse osmosis technology.	We have undertaken work to investigate and assess a range of reuse options. This included consideration of potential sites and relevant technology. This is presented in the Reuse Feasibility Option Report and summarised in Section 7: Appraisal of resource options and Appendix L: Water reuse. We have engaged with the former Chief Inspector of the Drinking Water Inspectorate (DWI) as we have undertaken this work.
Update on public perception investigations and wastewater reuse trial at Deephams wastewater treatment works.	We have completed further research with customers to understand their preferences and concerns for a range of options, including wastewater reuse. This is presented in Appendix T: Our customer priorities and preferences. We have also funded an engineering doctorate to explore stakeholders' expectations for reducing risk and promoting safety linked to water reuse. This research is summarised in Appendix L: Water reuse.
Further breakdown of costs for all options and to support WRSE modelling work.	We have worked collaboratively with WRSE and provided detailed information on options for WRSE assessment. This work is discussed further in Section 7: Appraisal of resource options.

22 http://archive.defra.gov.uk/environment/quality/water/resources/documents/thames-inquiry-decision-letter.pdf
23 The Planning Inspectorate (December 2010) Water Resources Management Plan Regulations 2007, Inquiry into the Thames Water Revised Draft Water Resources Management Plan 2010-2035, September 2009

Instruction	Progress update
Consideration of how a greater range of feasible options could be provided.	We have developed and considered a wide range of resource options. We screened options to refine the options under consideration to produce a feasible option list. We have completed more detailed assessment of the feasible options. We have engaged with stakeholders throughout the option appraisal process providing opportunity for input and comment. This work is presented in Section 7: Appraisal of resource options.
Further investigate and review some of the more uncertain contingency options such as aquifer storage and recovery (ASR).	ASR is an innovative groundwater option whereby water is pumped into, and stored within, an aquifer when water is plentiful and then recovered in times of need. To investigate its potential and enable delivery of an ASR water supply scheme, we have targeted the Lower Greensand aquifer in and around Horton Kirby in the Darent Valley, in the London WRZ. We have drilled a new ASR borehole, two new observation boreholes, and constructed new pipeline connections to recharge the aquifer with potable water. During operational scale cycle testing, which is ongoing, we are recharging the aquifer to increase storage then re-abstracting the stored water, while monitoring groundwater levels and water quality to confirm its viability. This work is leading to delivery of the ASR Darent Valley (Horton Kirby) scheme, where work is in progress and currently remains on track to increase the London WRZ DO by 5 Ml/d in 2019/20. As a result of this work, a number of schemes have been included in our list of potential future resource development options.
Programme appraisal	
Apply new methodology to programme appraisal to identify our preferred strategic programme.	We worked across the industry, and with regulators, to develop new guidance to support programme appraisal, and followed this in developing our draft WRMP19. We have developed a suite of modelling and decision support tools to aid the formulation of, and decision making on, the best value programme. This involves consideration of a range of parameters including cost, environmental performance, customer preference, deliverability, inter-generational equity, resilience and adaptability. Best value planning is supported by our customers[24]. To improve transparency and confidence in the decision making process we have established an Expert Panel comprising Professor McDonald (University of Leeds), Professor Harou (University of Manchester), Dr Bill Sheate (University of London, Imperial College) and Dr Fenn, to work alongside us providing advice and challenge through the programme development.
Consideration of programme sensitivity to cost certainty.	We have refined our approach to estimating uncertainty in costing through the use of an established process, termed optimism bias. This is presented in Section 7: Appraisal of resource options and Section 10: Programme appraisal and scenario testing.

[24] Britain Thinks, Deliberative research, September 2016

Instruction	Progress update
Consideration of programme sensitivity to different potential sustainability reduction scenarios.	Programme sensitivity to different potential sustainability reduction scenarios has been considered and is presented in Section 10: Programme appraisal and scenario testing.
Consideration of programme sensitivity to actual utilisation of schemes and to Net Present Value calculation over 80 years.	The Guiding Principles set out the need to develop plans over a longer time horizon where the planning problem is significant and complex. We have adopted an 80-year planning period, for some of our WRZs, in developing our draft WRMP19. This time horizon is agreed as suitable given the significance and complexity of the planning problem.
Need to explicitly quantify the probability of the main sources of scheme timing and yield uncertainty and to include in target headroom.	Target headroom includes the main sources of uncertainty associated with schemes. We have followed industry best practice in assessing target headroom.

E. The relationship between the WRMP and other plans

1.34 Our WRMP has links with other plans. The main plans are listed below with an explanation of the relationship between the plans.

River basin management plans (RBMP)

1.35 RBMPs set out how organisations, stakeholders and communities will work together to improve the water environment. This is important context to the development of the WRMP. The SEA references the RBMPs in setting the key policy messages and establishing the environmental baseline. In addition, a specific objective is included in the water topic of the SEA to support achievement of the RBMP objectives. Furthermore, many of the sustainability reductions that we are required to make are to achieve the requirements of the WFD and are set out in the RBMP.

Business Plan

1.36 We produce a Business Plan every five years which sets out the services that we plan to provide to our customers. Funding for the Business Plan is secured through Ofwat's Price Review process. The investment required in the first five years of the WRMP is included in the Business Plan. The WRMP and Business Plan, whilst separate entities, are integrated plans. We have engaged with customers and stakeholders throughout the development of the Business Plan in co-ordination with the WRMP, where this has been appropriate, to ensure a clear and transparent approach for our customers. The Business Plan was submitted to Ofwat on 3 September 2018.

Drought Plan

1.37 The Drought Plan sets out the short-term operational steps implemented as a drought progresses to enhance available supplies, manage customer demand and minimise environmental impacts. We updated our Drought Plan in 2016 in accordance with the Drought Plan Guideline[25] and consulted on it. It covers a five year period from 2017 to 2022. There is a very close link between the Drought Plan and WRMP where we are required to demonstrate how supply will be maintained during severe drought events.

1.38 Our 2016 Drought Plan shows that, during the five year planning period, we can meet our planned levels of service for a range of severe drought scenarios, although with less resilience. However the plan does not take account of the forecast increase in population in our supply area and the associated increased demand for water, the future impacts of climate change on water available for supply, or potential future reductions in abstractions in order to provide greater protection for the environment, all of which are forecast to have a significant effect on water supply in the Thames catchment. Furthermore whilst the plan shows that we can maintain supply, it also shows that our current assets will be placed under great strain, impacting the robustness of the water system and potentially having a significant detrimental effect on the environment and ecology; and businesses which rely on water would be subject to more frequent NEUBs and TUBs.

1.39 The associated increasing demand and reduced water availability have the potential to significantly affect the underlying supply demand balance and therefore the extent to which the Drought Plan could be relied upon to robustly protect customers from Level 4 water use restrictions in future periods. These aspects are covered in Section 4: Current and future water supply.

Local plans produced by local authorities

1.40 In line with the WRPG we have based our forecasts for population and property growth on Local Plans published by the local council or unitary authority. We contacted the 95 Local Authorities across our area to obtain data to produce population and property forecasts to 2045. The Environment Agency advised that, since submission of the draft WRMP to Defra, the Greater London Authority published its draft London Plan. In this, the property figures have been revised upwards and could result in an additional 204,000 properties by 2029/30 which is significant. The Environment Agency is clear that they do not want water provision to constrain growth. We agreed with the Environment Agency that, since the data is draft[26], we would test these revisions as a scenario. We also agreed to monitor other updates to Local Authority plan figures and consider the implications for our population and demand forecasts.

[25] Environment Agency, Drought Plan Guideline, 2016
[26] TW EA Update Meeting, June 2018

F. Engagement with customers, regulators and stakeholders

1.41 We recognise that there is wide interest in the sustainable management of water resources and over the past three years have engaged with customers, regulators and stakeholders, sharing work to inform our draft WRMP19 as it is undertaken and to provide the opportunity for input and feedback.

1.42 In November 2014 we published a statement of Water Resources Stakeholder Engagement. This document set out how we planned to engage during the preparation of our draft WRMP19. The engagement framework is provided in Table 1-4. We have updated and re-published the statement on a quarterly basis up to the submission of the draft WRMP19 in December 2017.

1.43 Alongside the statement of Water Resources Stakeholder Engagement we published our water resources work programme and an accompanying report explaining the main areas of work and progress update for each of the workstreams. This was to ensure that stakeholders understood the work that was being undertaken and the timing of outputs, and provide the opportunity to input and contribute in a timely manner. This approach allowed us to understand issues and concerns and address these, as far as possible, in the development of our draft WRMP19.

Table 1-4: Engagement framework

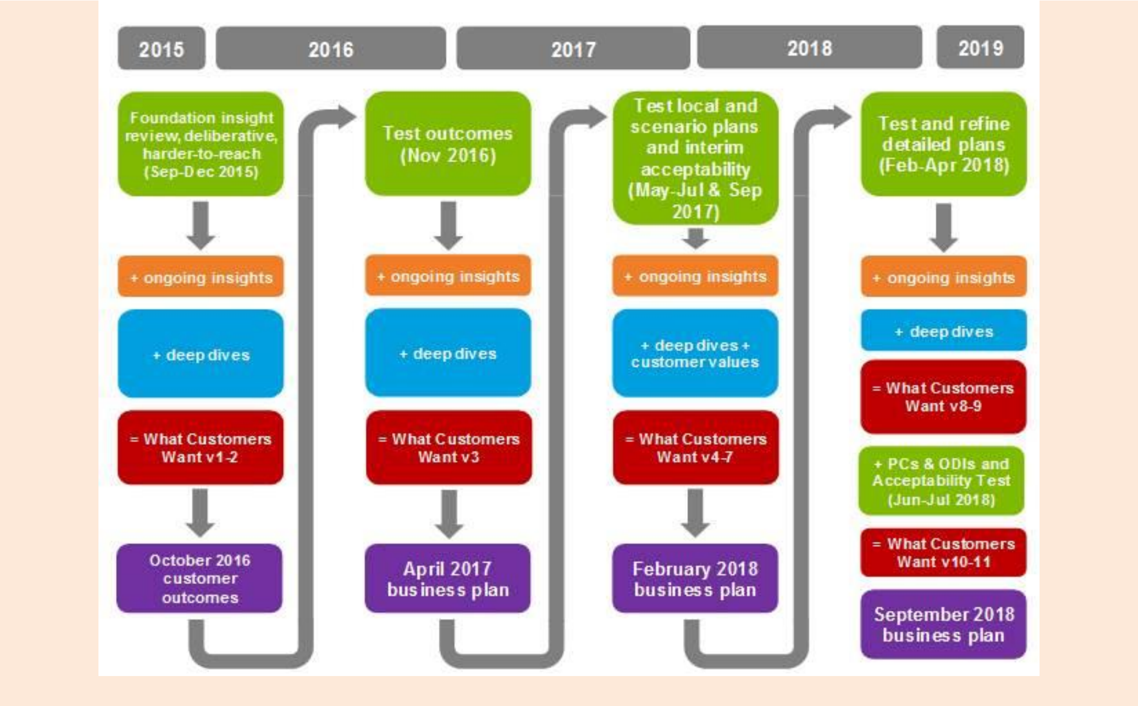
Customers	We engage with customers to understand their views on a range of water resource matters and ensure these are taken into account in developing our plan. This is aligned with engagement activity to inform the Business Plan.
Customers - CCG	The CCG was set up to test the quality of our engagement with customers and how we responded to their priorities in developing our Business Plan 2015-2020 and WRMP14. We are continuing to work with the CCG as we progress work to inform our next Business Plan and WRMP19.
Regulators - Environment Agency	We hold regular meetings with the Environment Agency to discuss water resources matters. The purpose of these meetings is to discuss technical work and to ensure the Environment Agency has the opportunity to raise concerns, contribute to the work, and to agree approaches and technical methods where required. Each quarter we provide a progress report on the water resources work programme to the Thames Water and Environment Agency Directors' meetings. The purpose of the report is to highlight any risks or issues on water resources that require discussion.
Regulators - All	We hold meetings with other regulators (Ofwat, Consumer Council for Water (CCWater), Natural England, Historic England and Natural Resources Wales (NRW) on specific topics as appropriate to ensure they are updated on technical work and to give them the opportunity to raise concerns and contribute to the work.
Regulators - All	We are involved in a number of research, technical and strategic projects such as the WRSE Group, UKWIR research, Environment Agency technical projects and the industry wide Strategic Water Resources Liaison Group. Regulators and other organisations are involved in the majority of these groups.
Stakeholders	We continue to hold forums on a regular basis to which all interested organisations are invited. The purpose of the forums is to update stakeholders on our work and to give them the opportunity to discuss and challenge our approach and to highlight issues and concerns. The agenda for these forums are aligned with the work programme and also in response to feedback from stakeholders. We regularly review the approach to engagement and seek feedback at the forum to ensure the approach is meeting the needs of stakeholders. Further information is provided in Appendix S: stakeholder engagement.
Stakeholders	We continue to convene technical meetings on specific topics that stakeholders are interested in. These meetings give stakeholders the opportunity for greater discussion and scrutiny on specific technical matters. We also hold individual meetings as needed.
Water companies and commercial organisations	We continue dialogue with water companies and external organisations to identify opportunities for collaboration and partnerships including identification of opportunities for sharing and trading resources to ensure the most effective use of available resources.

1.44 The following sections provide further information on the engagement approach with customers, regulators and stakeholders, and key issues.

Customers

1.45 Our plans and strategies are developed to reflect our customers' preferences. We have undertaken an extensive research and engagement programme to understand customers' views and expectations on all aspects of our business, and the services that we provide, as summarised in Figure 1-6. We have worked with our CCG in the design and delivery of the research and engagement programme, and how the information has been used to shape our long term plans.

Figure 1-6: Overview of the customer research and engagement programme



1.46 On water resources, we have specifically sought feedback from our customers on the following:

- the planning process and how we develop the plan
- the levels of service we provide in terms of the frequency of water use restrictions that we plan for
- the options that can be used to provide a secure supply of water, including the level of leakage that is considered acceptable.

1.47 A summary of the views and priorities of our customers on these points is provided below with more detailed information provided in Appendix T: Our customer priorities and preferences.

Feedback on the planning process

1.48 Most customers are unaware of the challenges to our future water resources in terms of population growth, climate change and environmental protection. When they understand they want plans to ensure sufficient supply to meet future demand. They consider a secure water supply to be fundamental and they expect us to plan for this service to be resilient in the long-term.

1.49 The majority of customers support the need for us to plan for the future, considering a planning horizon of at least the next 25 years, building in flexibility to accommodate future changes.

1.50 Customers indicated that while the bill is important, and must be affordable, they support best value planning taking account of a range of factors such as the environment, deliverability and flexibility in determining the long term strategy.

1.51 Customers believed that the costs for future investment should be shared across current and future customers showing a strong sense of responsibility towards future generations.

Feedback on Levels of service - Water use restrictions

1.52 Customers indicated a preference to avoid deterioration in the levels of service.

1.53 The current expected frequency of sprinkler bans, hosepipe bans, and NEUBs were not perceived to have significant impacts on customers' day-to-day activities and as such customers indicated that they were broadly satisfied with the current levels of service.

1.54 As the severity of the water use restrictions increase, customers' views that the level of service should either be maintained or enhanced are stronger.

1.55 Water rationing, referred to as a Level 4 restriction, is the restriction that is of most concern to customers. Household and non-household customers expressed some appetite for improved levels of service, for the more severe restrictions such as rota-cuts where there is some support for an improvement to a 1 in 200 year level of service.

1.56 Views on the long-term supply of water are largely shaped by lived experience. Although aware of issues such as climate change and population growth, they do not link them to water supply. When made aware, they say planning to ensure there is enough water in the future is important. People have an expectation that water companies, Government and others will do what is needed to solve the issue of future water shortages.

1.57 We included a question on resilience to drought in the interactive customer engagement tool used during the consultation period to understand customer preferences on a range of services. We explained that our proposed plan was designed to maintain all customers' water supply, with no need for rationing during a severe drought and asked for views on how quickly we should achieve this. 55% chose a service level within a year of our proposal.

Feedback on options

1.58 Overall there is a preference for using what we already have more efficiently and effectively before we look for new sources. Customers indicated a strong preference for demand management options (leakage reduction and water efficiency) over supply options (for example new resource development). A key driver for this is avoidance of waste.

1.59 Many customers consider that the current levels of leakage are unacceptable. They understand that it is not cost effective to fix some leaks but would like to see us go beyond what we are currently doing. They call for a reduction from the current leakage level of 25% to a level that compares well with the rest of the industry and are prepared to accept some impacts on their bill and disruption from roadworks to achieve this. Customers are uncomfortable with the idea that, instead of fixing more leaks, we would seek to replace the water lost by introducing more water into the same 'broken system'.

1.60 Customers call for help to be more water efficient. They are supportive of education through schools and information, advice, advertising and 'freebies' to help customers understand the need and reduce their consumption. They also see metering as a fair way of paying for water; reducing consumption and helping customers manage their usage.

1.61 Tariffs were not as popular as other demand management measures, mainly because customers considered they were unfair to some customers.

1.62 There was a range of views on the individual resource options:

- The preferred option was transferring water at Teddington. This was understood to provide a large volume of water and to be relatively simple. However with an understanding of environmental concerns, a number of customers wanted reassurance that these issues would be addressed before this scheme was progressed.
- Reuse and reservoir were the next preferred large options
- Water transfer was identified as one of the least preferred options in all the research studies. One of the main reasons for this is customers thought that the company should be self-sufficient rather than relying on another water company for water supplies. Further research has been undertaken on transfers in collaboration with United Utilities and Severn Trent Water to explore customers concerns in more detail. This is included in Appendix T and the output will inform on-going technical work on transfers.
- The choice of energy sources was identified as a significant driver in making decisions, and customers have a strong preference for options that use renewable energy[27]

1.63 Customer research[28] completed as part of the public consultation indicated that customers were most positive about the reservoir. They saw it as an investment for the future, securing the water supply and also providing recreational and leisure activities for the local community, although they wanted reassurance that those currently living there would be treated fairly and the construction to be considerate of the local community. They were also broadly positive about Teddington abstraction as they saw it as making the most of existing resources, although there were concerns about the environmental impact. Most participants were not keen on the idea of water reuse although they became more positive as their understanding of how it would work developed. Views about water transfer were mixed, with many feeling it was a sensible solution if other regions have an excess of water, and they instinctively liked the idea of greater co-operation and partnership between companies. Some, however, raised concerns around what would happen in a drought.

[27] Note the use of renewable energy is only reported for options where it is considered to be feasible
[28] Deliberative research – Community Research April 2018

1.64 We have provided further detail on how we have used the customer research to inform the selection of our preferred plan in Section 10: Programme Appraisal and scenario testing.

1.65 Our independent CCG has a mandate to monitor our performance and whether we are meeting our commitments, reporting properly on progress, and are considering customers in our future plans. The CCG writes formally to Ofwat in response to the consultation and to questions, and also comments on our future plans. We hold regular meetings with the CCG and provided progress updates during the development of the revised draft WRMP19 and the consultation. Minutes from all our meetings with the CCG are published on our website. The CCG have also regularly attended our stakeholder meetings to ensure these are operated in a fair and transparent way, to hear from other stakeholders and to contribute to the discussions.

Regulators

1.66 We have invited Government and regulators to attend the stakeholder meetings.

1.67 We have held regular meetings with the Environment Agency throughout the development of the revised draft WRMP19. The purpose of these meetings has been to ensure that the Environment Agency is up to speed with the work being undertaken and to provide opportunities for comment, input, challenge and feedback. Overall the discussions have been helpful, although noting that all the comments provided by the Environment Agency to date are without prejudice, as the Environment Agency would not formally sign off or agree methods and approaches in advance of submission of the revised draft WRMP19.

1.68 We held meetings with Ofwat to update them on our progress in developing our draft WRMP19 and to seek their feedback and comment. In addition we have engaged with Ofwat through the development of the framework for PR19, definition of performance measures and technical issues such as direct procurement of strategic infrastructure.

1.69 In the preparation of the SEA, HRA and WFD assessment we have worked with statutory regulators Environment Agency, Natural England, Historic England and NRW) and wider stakeholders. We have completed consultation on the scope and approach of the SEA, the methodology for the HRA and WFD assessments, and the output of the assessment of options.

1.70 The primary role of the Drinking Water Inspectorate (DWI) is to ensure the safety and quality of drinking water. We have invited the DWI to join our stakeholder meetings and shared information with them on resource options under consideration. Options we consider will be of particular concern to the DWI are catchment based schemes, and options which involve the reuse of water. We commissioned the former Chief Inspector of the DWI to provide advice and feedback in respect of wastewater reuse. This is presented in Appendix L: Water reuse.

1.71 The main role of the CCWater is to ensure consumers are at the heart of the water industry in terms of the nature and quality of the service provided. CCWater has an active voice through our CCG, we regularly meet CCWater on a wide range of business issues, and we also invite CCWater to participate in stakeholder discussions and meetings to ensure we understand their views and concerns. We share with them the work that we do to engage with our customers, both day to day and also to inform future planning.

1.72 We have briefed the Welsh Government and NRW during the development of the draft WRMP19, specifically focusing on aspects which could affect Welsh resources and the people of Wales.

Stakeholders

1.73 There is wide interest in water resources from a diverse range of stakeholders, from those organisations who have interest in a specific geographical area, watercourse or single option to organisations who have a broad interest in the sustainable management of resources for the long term.

1.74 Since January 2015 we have held ten Water Resources Forums and 15 technical water resources stakeholder meetings, to update stakeholders on progress with our draft WRMP19 and to give them the opportunity to discuss and challenge our approach and to highlight issues and concerns. To ensure transparency we have published papers, presentations and minutes from these meetings on our website. These meetings have provided valuable information and input to our draft WRMP19 and have also provided a good forum for stakeholder organisations to not only hear from us, but also to hear others' viewpoints and comments. We have regularly sought feedback from stakeholders to ensure our approach is meeting their needs, which has been broadly positive.

1.75 We have also published method statements, technical reports and documents and have provided the opportunity for stakeholders to comment on these. Where comments have been received, we have ensured we have provided feedback and an opportunity for further discussion.

1.76 Further information on our engagement with stakeholders is provided in Appendix S: Stakeholder engagement. Section I on how we promoted the public consultation.

G. Engagement with our Board

1.77 The Board is accountable to shareholders, customers and other stakeholders for the performance of the company and in promoting its long-term success. As such, the Board is responsible for setting the company's strategy and for leading the development of its quinquennial business plan and the WRMP, including assuring the quality and completeness of these regulatory submissions.

1.78 The Board has provided strategic leadership throughout the business planning process by setting the governance and assurance requirements; making key strategic decisions that shape the overall direction of the longer-term strategy; monitoring the progress of preparations; and reviewing and challenging the executive team's preparations at key stages. Prior to the approval of the WRMP, the Board assessed the overall quality of the plan based on the findings of the agreed assurance activity and stakeholder feedback.

1.79 Our executive management team has engaged the Board at key stages in the development of the WRMP19 and the Board approved the draft WRMP19 in November 2017 prior to submission to the Secretary of State for Food, Environment and Rural Affairs. We have continued engagement with the Board since this time, providing updates on the feedback from the consultation, and advising of changes to the draft WRMP19 as a result of comments and new information. Members of the Board have spent time reviewing the revised WRMP in further detail as part of a deep dive into aspects of the plan. The Board will sign off the final WRMP19 plan.

H. Quality assurance

1.80 We have established a three tiered risk management and control framework to support the development of the Business Plan and the WRMP19. The framework is designed to clearly define roles and responsibilities, improve communication and coordination, and provide assurance for compliance with legal and regulatory requirements as well as efficiency and effectiveness of operations, safeguarding of assets, and reliability and integrity of reporting. Independent auditors are involved in the process to provide the Board with assurance based on independence and objectivity.

1.81 For the WRMP19 methodology statements were prepared which set out methodological approaches followed in the preparation of aspects of the draft WRMP19. To provide confidence that we complied with regulatory requirements we contracted KPMG to undertake an independent review of the data collection, calculation and controls process, and their compliance with the WRMP table instructions. KPMG undertook their review between August and October 2017. The scope of the review included reviewing the approach and processes, and testing the draft data tables for the Guildford Water Resources Zone (WRZ) as a case study. The review was subsequently undertaken for all six WRZs to ensure assurance of data quality and reporting. Feedback was provided to the Environment Agency on issues and errors identified with the data tables the 2017 assurance review.

1.82 We are undertaking a similar assurance activity for the revised draft WRMP19, again engaging KPMG to undertake a review of the preparation and population of the data tables for all six WRZs. At the end of the process KPMG will produce a report on their findings which will be available to the Board.

I. Public consultation on our draft WRMP19

1.83 We undertook a public consultation on our draft WRMP19 starting in February 2018 and ending in April 2018.

1.84 We produced a suite of documents, as noted below, to ensure information was accessible to all interested individuals and organisations:

- An overview document –a high level summary setting out the challenges, the approach we followed in developing the plan and the preferred programme, and the reasons for this
- A technical executive summary – a detailed summary of the plan with signposts to relevant sections of the detailed technical documentation
- The full technical report which comprised 11 sections and 26 appendices

1.85 We published the draft WRMP19 on our website www.thameswater.co.uk/haveyoursay and we made a paper copy available to view throughout the consultation period, by appointment, at our offices in Reading. We also made available copies of supporting technical documents that we could not publish on our website due to security restrictions. Mr John Lawson and Professor Chris Binnie, consultants working for the Group Against Reservoir Development (GARD), visited our offices to view these documents.

1.86 Consultees could submit responses through a range of channels including emailing or writing a freeform response, responding to an online survey or completing a hard copy feedback form.

1.87 We promoted the consultation through a variety of ways, and engaged on the draft WRMP19 in co-ordination with the Business Plan to ensure clear communications for customers and stakeholders.

1.88 We sent an email to all statutory consultees, stakeholder organisations who had participated in our water resources stakeholder forums, stakeholders who participated in the public consultation on our previous plan (WRMP14) and stakeholders and individuals who had expressed interest in the WRMP. We provided a link to the draft WRMP19 and details of how to participate in the public consultation.

1.89 We held a launch meeting on 5 February 2018 to raise awareness of the draft WRMP19 and the opportunity to review and provide comment on it and promoted it in the press, via media channels, community networks and stakeholder events to raise awareness and give as many people and organisations as possible the opportunity to comment on the draft WRMP19.

1.90 During the consultation period we held eight Local Engagement Forums in areas where specific issues had been identified: Abingdon, Beckton, Beddington, Bicester, Bracknell, Cirencester, Richmond and Stevenage. The forums were evening events which gave local communities and customers an opportunity to hear about our future plans and raise points that they wanted taken into consideration.

1.91 At the request of Councillors and members of the local communities we held drop in events at Oxford and Steventon, We also attended a number of Parish Council meetings in Oxfordshire and presented at the Abingdon Town Council meeting.

1.92 We hosted a stakeholder meeting in March 2018 to provide an opportunity for stakeholders to ask us questions and seek clarification and further information before submitting their final responses on our draft WRMP19.

1.93 We engaged with our customers through roadshow events at shopping centres, our online community and four deliberative research events.

1.94 We asked for feedback from customers, using our innovative interactive engagement tool, on aspects of our WRMP, namely planning for a resilient water supply and leakage.

1.95 Table 1-5 presents the number of responses received by each channel.

Table 1-5: Number of responses received to the public consultation and channel for response

Channel	Number of responses
Email or post	440 (82 written and 358 email)
Online	93
Feedback form	8
Customer research	75 deliberative workshop participants 174 online community responses 2,652 responses to the "Shape Your Water Future" engagement tool

1.96 We have reviewed all the feedback received from stakeholders and customers and prepared a document called the Statement of Response, which sets out our consideration and response to the comments received. We will publish this in September 2018. We had originally intended to publish the document on 10 August, within 26 weeks of the start of the consultation. However in view of the number and detail of the responses received to the consultation, and the importance in co-ordinating with the other water companies in the south east and nationally to ensure alignment, we agreed a later publication date with Defra[29].

1.97 The Statement of Response:

- presents the comments received during the public consultation and our consideration of the comments
- sets out changes made to the draft WRMP19 as a result of comments
- where changes have not been made as a result of comments, we have explained why not
- describes other relevant changes that have occurred during the consultation period and how these have affected parts or the whole of the plan

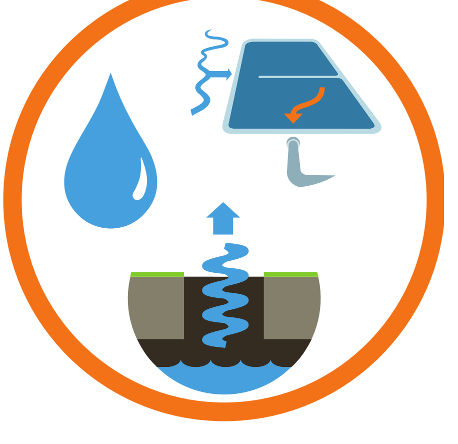
1.98 We worked with Community Research, an independent research and consultation specialist agency, to ensure the approach we adopted, the materials published, and the analysis undertaken were robust and fair. Community Research has prepared a separate report[30] on the consultation and the main issues arising to give confidence to all stakeholders that the process followed was fair and transparent. This report has been published alongside our Statement of Response.

[29] Letter from Defra to TW, 31 July 2018
[30] Community Research, Consultation on draft WRMP19, August 2018

Section 2

Water resources programme

2015-2020



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Tables

Section 2.

Water resources programme 2015-2020

In this section we set out our progress on the WRMP14 programme and the activity we will have completed by the end of March 2020, which forms part of the Price Review process undertaken with Ofwat in 2014 (PR14)

- We present how we plan to meet the supply demand gap, accounting for the challenges of growth being higher than forecast and the need to transform leakage working processes to meet the asset management plan period 6 (AMP6) target by 2019/20
- We outline the learning from the start of the roll-out of our smart metering programme, our ambition to develop a smart network, and the work we have done with customers on water efficiency to reduce their consumption, which has won national awards
- We present an overview of the supply demand studies undertaken to inform the development of our draft Water Resources Management Plan 2019 (draft WRMP19)
- We describe where we are progressing schemes to mitigate the impact of our abstractions on the environment

We have made the following changes in response to the points raised in the public consultation on the draft WRMP19, and to include new information that has become available since the draft WRMP19 was published.

- We have included updated information on our leakage, metering and water efficiency performance in 2017/18. (Section C)
- The update on leakage performance takes account of progress made on the recovery plan, the outcome of the Ofwat investigation into our missed leakage target, developments on the trunk mains investment plan and improvements made in how we respond to water supply interruption events.
- We have also updated our progress on the AMP6 resource development and environment programmes. (Sections D and F)
- Finally, we have updated Table 2-7 which presents our supply demand position for 2015 to 2020 and which illustrates that all WRZs are in surplus by 2019/20 at the latest. (Section G)

A. Summary

2.1 By the end of March 2020, we will have delivered our AMP6 water resources programme which forms the first five years of our 25 year Water Resources Management Plan 2014 (WRMP14) programme. The plan includes leakage reduction, metering and water efficiency as well as a resource development programme in the London Water Resource Zone (WRZ) to maintain supply security. All WRZs are forecast to be in a surplus at the end of the period.

2.2 We will have nearly 400,000 more people in our supply area at the end of 2017/18 than was anticipated in WRMP14. We estimate that the total number of customers in our area will grow to 10.1 million by 2019/20. This equates to growth being 4% higher than forecast in WRMP14 and approximately 39 Ml/d of additional customer demand.

2.3 We forecast that we will deliver our leakage target of 606 Ml/d at the end of 2019/20 despite missing it for the first time in 11 years in 2016/17. There have been some challenges associated with embedding a new partnership alliance at the start of AMP6 to transform leakage detection and repair working processes, including improving the impact that these activities have on customer service. A recovery plan (Environment Agency, Annual Review, June 2017) has been implemented to deliver the WRMP14 target for 2019/20.

2.4 Our programme of progressive metering is underway in London with over 243,564 smart meters installed by the end of 2017/18. Due to the property make up in London, which includes a large number of flats, approximately 60% of the installations require an appointment with a customer to install an internal meter. There are challenges associated with engaging busy and transient customers to make these appointments. As a result we have accelerated the delivery of the fixed radio network across the London WRZ to enable more external meter installations and targeted additional customer side leakage repairs from bulk metering common supply pipes to housing developments with large private mains networks.

2.5 Resource development included in WRMP14 for the London WRZ is ahead of target and is forecast to deliver an extra 46 Ml/d water into supply. The new schemes (Section D below) include water trades and groundwater development.

2.6 We have undertaken an extensive programme of supply demand studies to inform the development of the draft WRMP19. The drivers for draft WRMP19 remain largely unchanged from WRMP14, although there is an additional water industry driver focusing on security of supply resilience and the need to consider more extreme drought events than have occurred in the previously used historical record. WRMP14 highlighted the need for a new large resource scheme (>150 Ml/d) or combination of schemes from the mid-2020s, which has resulted in us undertaking a detailed programme of investigations and options appraisal in AMP6. Work is on-going to assess the wider benefits of smart metering. We have reviewed our household meter data and increased the WRMP14 estimate for customer reduction in water use after meter fit from 12% to 17%. This finding aligns with savings reported by other water companies in the South East.

2.7 The remainder of this section is structured as follows:

- Introduction
- AMP6 Demand Management Programme
- AMP6 Resource Development Programme
- Update on Supply Demand Studies
- AMP6 Environment Programme
- AMP6 Supply Demand Balance

B. Introduction

2.8 All WRMPs start from a 'base year'. The base year for the revised draft WRMP19 is 2016/17. Our activity through to 2020 was included as a part of the Price Review process undertaken with Ofwat in 2014 (PR14). In this section we set out the activity we will have completed by the end of March 2020.

2.9 Our performance each year is published on our website and reported to Ofwat in a process known as the Annual Return (AR). Further details are available on the Ofwat website. We also publish an Annual Review of the current WRMP, as required by the Environment Agency[1]. Please refer to these documents for further details on our activity in this period.

C. AMP6 Demand management programme

2.10 Demand management is any activity that reduces the amount of water we need to put into supply. This includes the reduction of losses from our distribution system in transit to customers and in how much water our customers use. Typical demand management activities include:

- Leakage reduction – fixing leaks on the distribution network and customer supply pipes
- Metering – metering helps us and customers identify leaks and can reduce demand for water by raising awareness of how much is being used. As such it is an important 'enabler' for both leakage reduction and water efficiency
- Water efficiency – activity to enable customers to be efficient in their water usage and reduce wastage. This can be device led (e.g. tap inserts, efficient shower heads, trigger nozzles for hosepipes, etc) and/or advice led, to improve awareness

2.11 To 2020 we will deliver a number of demand management outcomes, which are summarised in Table 2-1.

[1] Environment Agency, Annual Review, June 2017- https://corporate.thameswater.co.uk/About-us/Our-strategies-and-plans/Water-resources/Our-current-plan-WRMP14).

Table 2-1: Activity within the AMP6 demand management programme

Activity	Unit	2015/16 Actual	2016/17 Actual	2017/18 Actual	2018/19 Forecast	2019/20 Forecast
Reported leakage[2]	Ml/d	642.5	677.2	694.7	672.4	606.3
Leakage target[3]	Ml/d	649.0	630.4	619.5	611.4	606.3
Optant metering	Nr	18,689	19,798	16,559	17,406	14,035
Progressive metering	Nr	42,083	103,422	98,053	56,436	-[4]
Water efficiency	Ml/d	7.05	11.82	11.57	10.97	6.61

Leakage

2.12 Leakage reduction is a key element of our plan to manage the balance between supply and demand. Total leakage has been reduced by 30% since the peak in 2003/04. Our leakage reduction plan also ensures that pipe bursts do not become more frequent and customers' supplies will be interrupted less frequently. A key feature of the AMP6 plan is to reduce leakage by a further 10% (59 Ml/d) in the period 2015-20.

2.13 We currently estimate that 72% of leakage is from our water network and 28% is on customer supply pipes.

2.14 Leakage is primarily being reduced through:

- Repairing leaks reported to us by our customers
- Proactively detecting and repairing leaks on our network, hidden underground, targeted through district meter areas
- Undertaking free repairs of leaks for our customers on their underground pipework
- Installing more household meters to allow us to better target customer side leakage activity, including the use of smart meters being rolled out as part of the Progressive Metering Programme (PMP)
- Optimising pressures throughout our water network, ensuring fluctuations and excessive pressures are minimised, providing more constant pressures to our customers whilst reducing bursts
- Replacing ageing mains, targeting those that leak and burst the most. This not only helps to reduce leakage but also to reduce future disruption and inconvenience to our customers
- Introducing improvements in how we account for water use, both by our customers and by ourselves in our day to day management of the network
- Using advanced monitoring on our trunk mains to detect small leaks before they burst and cause large scale disruption

[2] These are based on the 'ODI methodology' assumptions and do not include an up-lift for the leakage consistency (shadow reporting) impact.
[3] Annual Return Table 10 consistent.
[4] To be reviewed and balanced with the revenue meter replacement programme which is prioritised in 2019/20.

- Using advanced analytics to undertake flow balances across our network from abstraction to the customers' tap and all the meters in between, identifying and resolving imbalances through improving metering, network understanding, and ultimately targeted leakage reduction with in-pipe acoustic investigations on our large trunk mains
- Through the coldest parts of the winter, injecting our network with warmer water from our desalination plant and underground reservoirs
- Trialling new approaches to leak detection including the use of satellites and drones

2.15 Although replacing the oldest and leakiest parts of our network is the best way to make long-term sustainable reductions in leakage, detecting and repairing leaks still forms a key part of the leakage strategy to offset leakage recurrence levels that are well in excess of other companies. Currently we detect and repair some 65,000 leaks per annum, with an estimated leakage benefit value in excess of 400 Ml/d.

2.16 Approximately one quarter of leakage comes from supply-pipe leaks from customers' own pipes. We offer our domestic customers a free leak repair and pipe relay service.

2.17 At the start of AMP6 we formed a new contracting partnership alliance (called the Infrastructure Alliance) to encourage better, smarter and more collaborative working. This has proved more complex than expected to implement and embed. These issues, along with the desire to always keep customers in supply throughout the leak repair process whilst working within traffic management restrictions, have hampered our ability to detect and repair leaks quickly and efficiently. In 2016/17 we missed our leakage target by 46.8 Ml/d. This was the first time we had missed the target in 11 years. Our annual average leakage for 2017/18 is 694.65 Ml/d. This exceeds our Company level performance commitment target of 620 Ml/d and reflects the difficulties experienced in 2016/17 with increasing leakage during that year.

2.18 Given the magnitude of the failure to deliver our leakage target in 2016/17, Ofwat launched an investigation into our performance. In June 2017 we welcomed the conclusion of the investigation and as part of the agreement between Thames Water and Ofwat, £65 million will be paid back to customers, on top of £55 million in automatic penalties, making a total of £120 million returned to customers from our shareholders.

2.19 We have a detailed plan[5] to address the leakage shortfall and deliver the 2019/20 target. We have committed additional funding on activities such as further leakage detection and repair, including the use of more advanced technologies, further pressure management and optimisation, and more investment into improving understanding and accounting for water use which is drawing heavily on the increasing numbers of smart meters being installed. This is all supported by improved governance and clearer accountability

2.20 Following endorsement by Thames Water's Board in July 2018, in August 2018 we committed to steps in relation to leakage reduction performance and management of leakage reduction operations with Ofwat as part of our undertaking for the purpose of section 19 of the WIA 1991[6].

[5] https://www.thameswater.co.uk/Help-and-Advice/Leaks/our-leakage-performance
[6] https://www.ofwat.gov.uk/investigation-thames-waters-failure-meet-leakage-performance-commitments

2.21 Additional funding has also been committed to trunk mains rehabilitation in AMP6. After a series of bursts on our trunk mains network in 2016, we committed to undertake an independent Forensic Review (March 2017) and a Trunk Mains Strategic Review (October 2017) which are published on our website. The strategic review includes a high level implementation plan to improve monitoring, asset information, risk management and event response. We continue to work with partners to develop our trunk mains investment programme. Our CEO is the water sector representative on the London Mayor's Infrastructure High Level Group (IHLG) and we support the formation of the proposed Infrastructure Coordination and Delivery Unit (ICDU) that promotes collaborative working between statutory undertakers. In September 2018 we will set out our trunk mains investment plan in our PR19 Business Plan submission to Ofwat.

2.22 In March 2018 we experienced freeze / thaw supply interruptions during the extreme cold weather. As part of our learning from this event we have installed a customer incident team in June 2018 to respond to all such events, updated our phone systems and social medial channels and enabled consistent messaging. The team will provide dedicated face to face support to customers 24/7 during supply interruption incidents with an explicit focus on proactively contacting vulnerable customers to provide support and bottled water until supplies are restored. We are also working with partners, including Local Authorities and AgeUK, to improve our Priority Services Register (PSR) which holds the contact details of vulnerable customers. The focus of these initiatives is to enable us to work together during an event both in using the data we hold and in giving our customers the support they need as promptly and effectively as possible.

2.23 Due to missing our leakage target in 2016/17, and with leakage increasing over the year, the recovery plan does not envisage us meeting our WRMP14 leakage targets fully until 2019/20. The first year of the plan focussed on stabilising leakage prevention performance and on re-organising the delivery model with the detection and repair service providers. The second year of the plan principally concerns driving down leakage to ensure we meet the 2019/20 leakage target and are back on track for the next AMP period. The recovery plan therefore forms a key part of the base plan for WRMP19 and we have reported in the Environment Agency Annual Review 2018 that our performance is on-track despite the period of particularly cold weather at the start of March 2018.

2.24 In July 2017 Ofwat introduced the requirement to report leakage following the newly defined guidance developed by UKWIR[7]. This reporting is to be in the form of shadow reporting for the remainder of AMP6, 2016/17 to 2019/20, with the requirement that companies' leakage performance commitments will be set based on the new reporting methodology for AMP7. We have estimated that our reported leakage levels will increase by approximately 40 Ml/d using the new methodology. It should be noted that not all the changes specified in the UKWIR report have been fully incorporated into our provisional estimate as we need to install additional pressure and flow monitoring equipment in the field as well as implement software upgrades before this can be achieved. We will be undertaking further works in AMP6 to become compliant with the new requirements by AMP7.

[7] UKWIR, Consistency of Reporting Performance Measures, July 2017,Report Ref No. 17/RG/04/5

2.25 For further information on the leakage reduction options considered in our plan, see Section 8: Appraisal of demand options and Appendix M: Leakage.

Metering

2.26 Smart meter data supports demand management, water efficiency and leakage improvements. Smart meters provide greater insight into asset performance, improving the speed and effectiveness of decision making and enabling investments to be made more wisely. From a customer's perspective, smart meters put them fully in control of their bill. They help meet an increasing customer expectation to access services digitally and will change our role in the relationship from being just water supplier to trusted advisor on water and energy use.

2.27 In 2014 we started our transformation journey to deliver an industry leading smart metering programme. Key milestones of this transformation included:

- Appointing a new meter installation partner
- Creating a smart metering operations centre to manage the millions of meter reads we would start to receive
- Procuring a new meter, radio network and data capture supplier and starting to build our radio network
- Developing a new customer journey and training our teams to become smart metering experts

2.28 Table 2-2 presents the total number of optant, progressive and bulk meters installed in AMP6 compared to the anticipated outputs over the period.

Table 2-2: Meter installations in AMP6

New meter installations		2015/16	2016/17	2017/18	2018/19	2019/20	AMP6 total
Optant metering	Target	34,089	34,089	34,089	34,089	34,089	170,445
	Actual/ forecast	18,689	19,798	16,559	17,406	14,035	86,487
	Difference	-15,400	-14,291	-17,530	-16,683	-20,054	-83,958
Progressive metering	Target	40,000	110,000	109,990	109,990	71,020	441,000
	Actual/ forecast	42,083	103,428	98,053	56,436	-[8]	300,000
	Difference	2,083	-6,572	-11,937	-53,554	-71,020	-141,000
Bulks	Actual/ forecast	1,086	1,080	556	960	960	4,642

[8] To be reviewed and balanced with the revenue meter replacement programme which is prioritised in 2019/20.

Progressive metering programme

2.29 In WRMP14 we planned to install 441,000 smart domestic water meters by the end of AMP6 as part of the Progressive Metering Programme (PMP), in order to contribute towards delivering 33.7 Ml/d of demand related savings.

2.30 Under the PMP we have installed 243,564 meters in the first three years of AMP6. This is in line with our revised delivery programme. However, the programme requires significantly more internal installations than originally envisaged, presenting challenges with respect to generating appointments with our customers. It was assumed that the majority of our meters would be fitted externally in the footpath. We have quickly learnt, however, that this is not the case and in fact, due to the property profile in London, approximately 60% of our meter fits require an appointment with a customer. Trying to engage a busy, transient population living largely in rented accommodation has been challenging. Our biggest obstacle to overcome is customer engagement; customers do not know who their water supplier is, let alone if they have a meter. Renters do not understand their responsibility in terms of getting a meter fitted and a small group of customers actively object to having a meter fitted. We have had to innovate and learn to develop our communication techniques quickly to open up new channels to enable customers to engage with us. One of our recent improvements has been launching an online appointment booking platform which has helped us digitalise our reach out to a wider demographic.

2.31 As a result of the challenges associated with internal meter installations the PMP is expanding into more London Boroughs than originally planned to progress external meter installations. This has required an accelerated roll-out of the fixed radio network across the London WRZ. The forecast number of progressive meter installations in AMP6 has been reduced to account for this issue and the number of targeted bulk meter installations has been increased to make up for the shortfall in demand reduction benefits by identifying and repairing additional customer side leaks. Work is currently in progress to develop and trial a more cost effective internal meter installation journey.

2.32 Our smart meters are helping us pinpoint leaks on customers' pipes more accurately than ever before. The data they collect alerts us to continuous flow, which is where the flow does not drop to zero over a sustained period of time, indicating that there could be a leak. We are now receiving more than six million reads per day through the fixed network, benefiting the wider business with increased data on consumption.

2.33 A number of customers will see an increase in their bill after the meter is installed. To manage this 'bill shock' we allow customers two years to switch over to a metered bill. We have now activated over 184,865 customers' accounts onto their two year bill comparison journey. We are using smart meter data to write to customers after three months, six months, 12 months and 18 months to let them know what their metered bill is likely to be compared to their current bill which is based on the rateable value of their home. The meter reads are also being used by our online customer platform 'my meter online', to populate daily usage graphs allowing customers to log in online regularly and view their water use. Work is in progress in 2018/19 to trial a shorter one year customer journey. Educating our customers on how much water they use, when they use it and how they can reduce it is a hugely important part of our programme. Smart water meter data allows us to engage with customers in many different ways which will be critical to our success in reducing water use. Updated analysis of our historic metering data shows that customer reduction in water use after a meter fit is approximately 17% which is higher than the 12% forecast for WRMP14. The benefits from the new smart metering programme data will be evaluated from the summer of 2018 when the first customers complete their two year journey and convert to a metered bill.

2.34 After fitting the meter we offer all our customers water efficiency advice and a personalised Smarter Home Visit. During this visit we spend time with the customer understanding their current water use behaviour, what they can do to reduce the amount of water they use and fit free water saving devices. The smart water meter data is highly influential in supporting this water efficiency message and it can be used to help customers understand their before and after water use. It also has the potential to be used in future water efficiency programmes, such as gamification, to help push water use savings even further.

2.35 We are not only using the smart meter data to detect leaks and reduce customer water use. We're also starting to build our first smart District Metered Areas (DMAs). These are areas within our water network where we know the amount of water we are pumping into it but not necessarily where the water then goes. By installing smart meters, our intelligence on where water is going (i.e. whether it is being used or lost through leakage) will vastly improve. This will help us plan for future investment and ensure we target leakage repair and mains replacement work in the areas with the largest benefit. Smart DMAs will also help us:

- Significantly improve the accuracy of our water balance calculations
- Make sure we quantify customer side leaks better
- Improve our understanding of night time consumption
- Predict leaks before they become visible
- Make better informed investment decisions with regard to the water network

2.36 There are also many indirect benefits of our smart water metering programme that we are only just starting to realise. For example, for customers to view their water use online they have to sign up for an online account. By driving sign ups we are helping to reduce the retail cost of our service as customers can make payments online, change billing details and access their bills etc. without having to call us.

2.37 We have saved nearly 13 Ml/d in the first three years of the programme through a combination of locating and fixing leaks on our customers' pipes, fixing internal wastage problems in their properties and by enabling customers to reduce their water usage as a result of having a meter.

2.38 The proportion of billed measured households is 40% of all households at the end of 2017/18 compared with 34% at the start of 2015/16.

Bulk metering

2.39 The bulk metering programme was developed to better understand demand and leakage on private mains networks. The programme is currently over-achieving as regards its leakage reduction targets and has saved 13.2 Ml/d in the first three years of AMP6 through detection and repair of leaks on supply pipes to large blocks of flats.

2.40 The team has been working with specialist consultants to target bulk meter installations where there is a higher chance of customer side leaks being identified to improve the cost efficiency of the programme. The current threshold is blocks of flats in London with over 50 dwellings per building.

2.41 There are a limited number of these types of buildings with private mains networks within our supply area, so this benefit cannot be relied upon as continuing to be delivered in the long term. The programme is being extended to buildings with over 35 dwellings to make up for the shortfall in benefits from the progressive metering internal meter installations.

2.42 An Information Systems (IS) change project will provide the ability for bulk meters to be connected to the fixed radio network, allowing for improved ongoing data capture from the spring of 2017.

Optant metering

2.43 It was assumed that, with increased awareness of the benefits of metering through the roll-out of the PMP in London, there would be an uplift in applications from customers wanting to have a meter installed during AMP6 (25% in London and 5% in Thames Valley), compared to AMP5, leading to a total of 170,445 in AMP6 (approx. 34,000 / year).

2.44 The current optant meter installation rate is however, significantly below the WRMP14 forecast. During 2016/17 we successfully started the roll out of smart meters on the optant programme to utilise the benefits of the fixed radio network in London.

2.45 It is intended to use the historic optant approach to help drive successful internal installations. Customers who have opted for a meter will be more likely to provide us access to enable the installation. It is also proposed that the optant meter installations are rolled up into the PMP in London to ensure a more efficient delivery approach.

2.46 For further detail on metering see Section 8: Appraisal of demand options and Appendix N: Metering.

Water efficiency

2.47 Water efficiency is an essential part of our long-term plans to sustainably manage water usage. We are delivering the UK's largest ever water efficiency programme of nearly 40 Ml/d in AMP6.

2.48 We are developing water efficiency initiatives for households, businesses, schools, local authorities and housing associations. Our customer engagement efforts include home visits, websites, multiple social media platforms, regional campaigns and online calculator tools.

2.49 We promote water efficiency to encourage our customers to save water, energy and money in a variety of different ways, and we work directly with our household and non-household (business) customers via a number of projects, including third party partnership schemes. These include:

- **Smarter home visits (SHVs):** The UK's largest in-home specific advice and fitting of water saving products for customers. The award winning scheme offers our customers a range of free water-saving products and tailored behaviour change advice to save water, energy and money. During the visits we also fix leaking toilets, plus offer selected customers free Benefit Entitlement Check and debt advice

- **Wastage fixes**: Wastage fixes of leaking toilets and taps, as identified through our SHV programme, have ramped up this year. A leaking toilet will waste between 200 – 400 litres a day, on average, and we have a programme running alongside our SHVs to do a one off free fix to households with 'leaky loos'
- **Smarter business visits:** We are offering business customers smarter business visits to fit free water saving devices (including urinal controls) and wastage fixes
- **Water saving freebies:** We offer all our water supply customers free water-saving products – including showerheads and timers, tap inserts, and toilet cistern devices
- **Water energy calculator:** We also provide a free to use water and energy calculator via our website (https://www.thameswater.co.uk/Be-water-smart). The calculator helps households to quantify how they use water in the home and their potential savings
- **Water efficiency schools programme:** We have one of the UK's largest schools education programmes for water efficiency, running across 40 to 80 schools each year
- **Water matters:** This is our schools and community engagement programme based in the River Kennet catchment, in partnership with an environmental group Action for the River Kennet (ARK)
- **Local authorities and housing associations:** We are working with a number of local authorities and housing associations and delivering inhome water saving device installation, including a trial with Zap carbon linking it to an existing in-home energy and benefits programme being rolled out with London and Quadrant housing in London
- **Save water South East (SWSE)**: This is a two year collaboration between Waterwise, the Environment Agency and six water companies in the South East. We have joint funded this partnership to promote water efficiency and increase awareness of water as a finite resource and create a water saving culture in the South East of England. This year, SWSE has started to build relationships with key stakeholders, run the innovative #Thinkwater campaign and also set up a water saving conference with local authorities and housing associations
- **Oxford water efficiency campaign** – during 2016/17 we ran two campaigns in Oxford to raise awareness of the supply demand deficit issue *"More people, less water to go around"*. This consisted of radio adverts, local media, posters at bus stops, and direct mail to households. The pre and post-campaign market research showed a very positive response to the campaign and helped to raise awareness of the water issues faced. We are using the results to help feed into future campaigns, and in autumn 2017 we developed the campaign further to show 'There's no substitute for water', to help customers really value water
- **Why be water smart animation -** We have produced a simple animation to help explain the complex issues around supply/demand deficit and to help our customers understand the wider issues around water resources and why it is important for us all to be water smart (https://www.thameswater.co.uk/Be-water-smart/Why-be-water-smart).

2.50 After three years of the AMP6 programme we have exceeded our target savings based on the Ofwat assumed savings methodology. However, we are aware that measured savings will be lower than the reported figure which includes an element of assumed water savings. To address the issue of the lower savings figures recorded from measured flow rates/volumes we have increased the scale of our core on-ground water efficiency initiatives with the aim of achieving the AMP6 targets using a greater share of programmes that can support a measured savings methodology. When we have robust water efficiency measured savings from our smart meter data we will change to measured savings and retrospectively adjust for the whole AMP.

2.51 Our efforts to improve the quality and increase the quantity of our water efficiency delivery were rewarded in 2016 with four national awards.

2.52 Our SHV programme won:

- Water Industry Achievement Award for Water Resource Management Initiative of the Year
- UK Water Efficiency Award for Built Environment
- UK Customer Experience Award for Utilities and Team- Customer at the Heart categories

2.53 We were also shortlisted in the Sustainability Leaders Awards and the Utility Week Awards for SHVs.

2.54 Our Clearwater Court bathroom refurbishment project (Propelair toilets, Cistermiser tap and urinal sensors) and large-scale rollout across our office buildings won the Institution of Civil Engineers – Chris Binnie award for sustainable water management.

2.55 In December 2017 we received the UK Eco Friendly Toilet of Year Award. Our SHV were also shortlisted in the SHIFT sustainable housing and EDIE Sustainability Leaders Awards.

2.56 In addition to promoting water efficiency activity to help customers use water wisely we committed to undertaking a trial of innovative tariffs in AMP6. The objective of the trial was to understand and quantify customers' responses to alternative tariffs and different communication approaches, as well as helping to understand the logistics, systems, and technology requirements and full costs of implementing tariffs in preparation for their roll-out in the period 2020-2025.

2.57 We have undertaken two studies to inform the innovative tariff trial:

- a desk based review of tariffs which have been trialled and adopted internationally[9]
- an assessment of innovative charging options for Thames Water[10]

2.58 We also engaged customers, regulators and stakeholders, including Waterwise and the Greater London Authority (GLA), on our proposed approach. The key findings were to first prioritise measures which would positively engage customers on efficient water use. We have subsequently started an incentives scheme pilot in Reading targeting 3,000 homes. This is the first ever non-financial water efficiency incentives pilot, linked to smart meter data and a web based site. The scheme has been developed with Greenredeem, a recycling reward specialist. The pilot will test whether we can encourage households to reduce their water use

[9] RPS Literature Review, October 2017
[10] Review of Innovative Tariff Options, Nera, April 2015

in return for points and rewards vouchers. In 2017/18 we expanded the incentives scheme by offering it to over 140,000 customers with a smart meter in London. The learning from the incentive scheme will inform the development of future innovative tariffs which could be adopted in AMP9 when household meter penetration is greater than 65%, to ensure fair imposition on our customers.

2.59 Average household per capita consumption (PCC) has been reduced by over 20% since 2002/03. Average PCC is forecast to reduce to approximately 141 l/h/d by 2019/20, which will be 9 l/h/d lower than the WRMP14 estimate. In addition to the impact of metering and water efficiency interventions, reported PCC has been affected by the change in categorisation of large blocks of flats due to the introduction of the non-household commercial market in 2016. Historically a large block of flats, billed as a single entity, was counted as a single non-household property. These flats are now counted as household properties, in line with Ofwat's new eligibility criteria in 2016, and the number of the flats in the building (subsidiary properties) is included within the property count.

2.60 For further details see Section 3: Current and future demand for water, Section 8: Appraisal of demand options, Appendix M: Leakage, Appendix N: Metering and Appendix O: Water efficiency.

D. AMP6 Resource development programme

2.61 Resource development is any activity that increases the amount of water available for supply.

2.62 In AMP6 we are delivering a number of resource development schemes in the London WRZ. The schemes are a combination of groundwater development and water trades. By the end of the period we forecast we will be able to deliver an extra 46 Ml/d water into supply during a dry year. Table 2-3 presents progress against targets for the delivery of our water resources development programme for AMP6:

- **Bulk transfer RWE Didcot:** 17 Ml/d, resulting from an agreement with RWE npower to utilise water not abstracted following the closure of Didcot Power Station A. The scheme delivered a deployable output (DO) gain of 17 Ml/d earlier than planned and was included in the 2013/14 London DO as reported in the AR14 Environment Agency Review

  BT Essex and Suffolk Water (ESW) Chingford reduction: 17 Ml/d, resulting from a new water trading agreement to reduce the volume of the existing raw water transfer to Essex and Suffolk Water (Northumbrian Water South), was delivered in 2014/15. This delivered a DO gain of 17 Ml/d during periods of drought and low flow. This increase was included in the 2014/15 London DO as reported in the AR15 Environment Agency Review. Subsequently, a further 5 Ml/d reduction in the export to ESW has been agreed in 2016/17. This has delivered a corresponding benefit of 6 Ml/d to the London WRZ DO

- **Groundwater (GW) Tottenham borehole** delivers additional water from an existing private borehole. Delivery of the output was delayed from the original target date of 2015/16 due to access and construction challenges, but has since delivered an increase of 6 Ml/d to the London WRZ DO in 2016/17. This is a significant increase against the original target DO benefit of 1.4 Ml/d programmed in WRMP14

- **GW ELRED** will not now be delivered during AMP6. More detailed investigations have demonstrated that high turbidity in the raw groundwater requires a reduction of the ELRED source DO. As the scope of any solution has changed significantly, the original scheme has been deferred. A new solution is not currently included in our list of options for the revised draft WRMP19, but the reduction in the ELRED source DO is reflected in our revised draft WRMP19 base position for London WRZ DO. This reduction is compensated by the increased output from the GW Tottenham Borehole scheme
- **Aquifer storage and recovery (ASR) Darent Valley (Horton Kirby)** is an innovative groundwater option whereby water is pumped into, and stored within, an aquifer when water is plentiful and then recovered in times of need. We have drilled a new ASR borehole to the south of Horton Kirby and two new observation boreholes. We have constructed new connections to the ASR boreholes that enable the Lower Greensand aquifer to be recharged with potable water and abstracted. Using these new assets we have carried out operational scale cycle testing, recharging the aquifer to increase storage then re-abstracting the stored water, while monitoring responses in the catchment. During the testing, which is ongoing, we are collecting hydraulic and water quality data to confirm the operational viability of ASR. The scheme has been deferred from AMP6 and is being re-evaluated as part of WRMP19 to increase the London WRZ DO by 5 Ml/d
- **GW Honor Oak** was programmed to deliver an increase of 1.48 Ml/d at the existing Honor Oak water treatment works in 2019/20. During development of the design for the scheme the scope of the solution required to deliver this output has increased significantly. As a result, the cost has increased significantly and the scheme has been deferred and re-evaluated as part of WRMP19

Table 2-3: AMP6 resource development schedule

London – AMP6 increases in WAFU	WRMP14 Ml/d	Forecast Ml/d	Actual/Forecast delivery (x)		AMP6 delivery schedule (x- planned, x- delayed)					Actual/Forecast delivery
			2013/14	2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	
GW Tottenham BH	1.4	6			X	**X**				**Benefit claimed**
GW Honor Oak	1.48	0							X	**Deferred**
GW ELRED	0.95	0			X					**Deferred**
BT RWE Didcot	17	17	**X**		X					**Benefit claimed**
ASR Darent Valley (Horton Kirby)	5	5							X	**Deferred**
BT ESW Chingford reduction	17	17		**X**	X					**Benefit claimed**
Additional ESW reduction		**6**				**X**				**Benefit claimed**
Total AMP6 actual/*forecast*	**42.83**	**51**				**12**			***17***	
Cumulative total (target)			0	0	36.35	36.35	36.35	36.35	42.83	
Cumulative total actual/*forecast*			17	34	34	46	46	46	46	

E. Update on supply demand studies

2.63 We have undertaken a range of complex technical supply demand studies in AMP6 to refine our water resources planning for the revised draft WRMP19.

2.64 We have held 29 forums and technical meetings with stakeholders to review and explain our approaches to develop our plan against the guidelines provided.

Demand forecast

2.65 Two UKWIR projects on forecasting household demand and developing population and property forecasts were completed in 2016[11]. We have used the output from these studies to inform our approach to develop the baseline demand forecasts.

We commissioned Edge Analytics to work with Local Authorities to develop 'plan based' population and housing forecasts for the period 2016 - 2045 and the University of Leeds to develop longer term 'trend based' forecasts from 2045 - 2100. With the publication of ONS2016 Nation Population Projection in November 2017 we commissioned Edge Analytics to produce a new 2045 – 2100 forecast for the revised draft WRMP19.

2.66 New Multivariate Linear Regression household consumption forecasting models were developed with Artesia Consulting for each WRZ. These models have replaced the micro-component models used in WRMP14.

2.67 Servelec Technologies working with Teccura were commissioned to develop non-household forecast consumption for each WRZ.

2.68 For the detail of our demand forecast see revised draft WRMP19 Section 3: Current and future demand for water, Appendix E: Population and property projections, Appendix F: Household water demand modelling and Appendix G: Non-household water demand modelling. The results of these studies have illustrated that demand for water is forecast to significantly increase in our region, mainly driven by population growth.

Assessment of available resource

2.69 We have improved our water resources management system model, WARMS2, which is the tool we use to assess water resources Deployable Output (DO). The tool has been reviewed by recognised independent industry experts, HR Wallingford, and we have commissioned periodic audits to ensure the model remains fit for purpose, and have provided assurance to this effect for external stakeholders.

2.70 Sensitivity testing of WRMP14 showed vulnerability of the preferred plan to severe droughts not present in the historic record from 1920. For draft WRMP19 we commissioned Atkins to generate spatially and temporally coherent artificial drought data that models the current

[11] UKWIR (2016) WRMP19 Methods – Household Consumption Forecasting. UKWIR (2016) Population, household property and occupancy forecasting.

climate and can be used to evaluate the sensitivity of our current water resource system and water resource options to different drought types than those in the historical record. The work was used to assess our resilience to more extreme drought events and to assess the reliable yield of new surface water resource options. The results illustrated that we were resilient to a worst historic drought in all WRZs but not resilient to a more severe 1:200 drought in London, SWOX, SWA or Kennet Valley. For further details see revised draft WRMP19 Section 4: Current and future water supply.

2.71 We are seeing changes to the raw water quality in our large raw water storage reservoirs supplying London and predict that this will continue with the increasing effects of climate change. Deeper reservoirs have better control measures to manage the raw water quality and therefore are more resilient to the impacts of climate change. Therefore any drawdown of the reservoirs will impact our treatment capability. This, coupled with our increasing concern with our ability to treat water in the lower levels of our reservoirs, is likely to reduce our DO by a notable amount, with algal blooms impacting a normal year and total reservoir water quality in a dry year. We have engaged the services of independent experts to undertake a quantitative assessment of the impact of these changes in raw water quality and quantity on the treatment capability as described in revised draft dWRMP19 Appendix K: Process losses.

2.72 Our 'stock' of raw water storage reservoirs is very different to that of other water companies in the UK in that they generally comprise embankments with thin clay cores supported by sand and gravel shoulders. Two independent studies have been undertaken by Atkins[12] and AECOM[13] to review the probability of failure of this type of constructed reservoir. The analysis was to assist in the prediction of an event which would result in the 'loss' of a reservoir, either through failure or the need to drawdown a reservoir for a significant period of time, affecting the storage capacity and consequent resource availability. The results illustrated that due to the age and construction of this type of reservoir, the risk to loss of storage to undertake remedial repairs is 2.5 times higher than the UK average. The impact of any failure resulting in the requirement to draw down any one of the twenty five raw water storage reservoirs will have a significant impact on our DO, placing our customers at risk of a supply shortage during dry periods.

Water resource options

2.73 In WRMP14 we set out that a new large resource scheme (>150 Ml/d), or combination of schemes, is highly likely to be required to maintain security of supply in the region from the mid-2020s. In autumn 2014 we started a programme of work to examine resource schemes. The programme comprises multiple phases and we have worked extensively with regulators and stakeholders as we progress the work.

2.74 The process to develop our Constrained List of resource options is explained in detail in revised draft dWRMP19 Section 7: Appraisal of resource options, Appendix P: Options list tables, and Appendix Q: Scheme rejection register.

[12] Atkins Reservoir Longevity report, April 2016
[13] AECOM Reservoir Longevity report review, February 2017

Demand management options

2.75 We are implementing a large programme of demand management activity from 2015 - 2020, comprising leakage reduction, metering and the promotion of water efficiency. The programme is planned to deliver approximately 107 Ml/d of savings. We are monitoring this programme as it is rolled out to ensure we are taking lessons learned into account in planning future activity.

2.76 In August 2016 we published our approach for developing demand management options for the draft WRMP19[14]. We have considered a wide range of demand management options and screened the options to produce a shortlist of feasible options. We have engaged with stakeholders throughout this work. In March 2017 we published an updated screening report[15], including comments from stakeholders, and set out the final constrained list of feasible options. The options are categorised into five areas:

- Metering
- Water efficiency
- Leakage
- Incentive schemes
- Non-potable options

2.77 We have undertaken a detailed feasibility study[16] on the opportunities for the use of non-potable water to help to manage demand in London, and specifically the Opportunity Areas in London identified by the GLA. Further detail on this study is included in revised draft WRMP19 Appendix L: Water Reuse.

2.78 In June 2017 we published an updated feasibility paper[17] setting out the costs and benefits of the feasible options and sought feedback from stakeholders on these.

2.79 The feasible options have been input into the DMA based Integrated Demand Management model to develop optimised demand management portfolios to input to the programme appraisal decision support tools alongside the resource options.

2.80 For more detail, see revised draft WRPM19 Section 8: Appraisal of demand options, Appendix P: Options list tables, Appendix Q: Scheme rejection register and the reports available on our website https://corporate.thameswater.co.uk/About-us/Our-strategies-and-plans/Water-resources/Document-library/Past-meetings-minutes-and-presentations.

Developing our preferred programme

2.81 Our WRMP14 method of programme appraisal found only a small pool of potential solutions to the supply-demand problem, using least-cost optimisation as the primary driver for the search and modifying the solutions in terms of other values including environmental and social costs. Sensitivity testing to different futures was carried out on the preferred plan.

[14] Demand management options screening report, August 2016
[15] Demand Management Options Screening report update, April 2017
[16] Non-potable water reuse feasibility report, June 2017
[17] Demand Management Feasibility paper, June 2017

2.82 For draft WRMP19 we have enhanced our decision making process based on UKWIR guidance[18] to include for a longer planning horizon where appropriate and worked with Decision Lab Ltd (EBSD) and the University of Manchester (IRAS-MCS) to improve the functionality of our decision support tools such that they will generate a large number of potential investment programmes which will be optimised in terms of cost, but also with consideration of other parameters (referred to as metrics), including resilience, environmental effects, customer preference, intergenerational equity and deliverability, to ensure a best value programme is taken forwards.

2.83 We have also developed a new tool, PolyVis, to show how the different programmes perform against the range of metrics, improving the transparency of the process.

2.84 For the detail of this work, see revised draft WRMP19 Section 10: Programme appraisal and Appendix W: Programme appraisal.

Water Resources South East

2.85 We continue to work with Water Resources in the South East (WRSE), a collaboration of water companies, located predominantly in the South East of England, and regulators. The objective of WRSE is to develop a flexible and robust water resources strategy for the region.

2.86 WRSE has undertaken modelling to investigate the resilience of the region to a range of possible futures. The modelling has highlighted the vulnerable zones in the region, considered opportunities for transfers and greater connectivity to share resources across the region, and identified potential regional infrastructure investment. The output has been reviewed and commented on by WRSE members and it is intended that the output will be used to inform individual water companies' plans.

2.87 We requested that companies set out their future requirements from us and we have used this information in the development of the revised draft WRMP19.

Market development

2.88 Ofwat has identified over recent years that the development of markets may be beneficial in stimulating the efficient use of existing resources to support resource development and in encouraging more innovation and involvement of third parties in demand management. There have been several developments in AMP6 to support the development of markets, which we have actively supported.

2.89 Ofwat introduced financial incentives for trades in AMP6, which requires companies to have an approved trading and procurement code. We were one of the early adopters of this approach and our code was approved by Ofwat in May 2016.

2.90 Ofwat have also introduced, following development via an industry working group which we actively supported, a requirement for water companies to publish market information using a

[18] UKWIR (2016) WRMP19 Methods – Decision Making Process: Guidance Report Ref. No. 16/WR/02/10

common framework on their website. We published the first version of our market information alongside the draft WRMP19[19].

2.91 Further innovations to encourage increased use of existing water resources include:

- the development of a bid assessment framework to create more clarity and confidence to third parties that their bids to supply water resources, leakage or demand management services will be assessed fairly consistent with the principles of transparency, equal treatment/non-discrimination and proportionality
- development of access pricing for the bi-lateral market

2.92 We are supportive of these developments as we seek to make maximum use of the resources available and have been active in evaluating trading opportunities as set out in the revised draft WRMP19 Section 7: Appraisal of Resource Options.

F. AMP6 Environment programme

2.93 This section discusses progress on schemes to reduce the environmental impact of public water supply. Water companies undertake these schemes through working closely with the Environment Agency to identify where abstraction may be having an adverse environmental impact and putting plans in place to address this impact if it is necessary to do so.

2.94 The mechanism by which this is achieved is through the Water Industry National Environment Programme (WINEP), through which the Environment Agency identifies and prioritises its requirements for water companies to undertake measures to improve the environment.

2.95 The process by which adverse environmental impact is assessed as present or likely is as follows:

- Firstly, the Environment Agency (EA) identifies sites where it has a concern that the impact of abstraction may be adversely affecting the environment
- Secondly, once the sites of concern are identified, an investigation is undertaken by the water company to determine the exact impact of the abstraction on the flow in a river or the water level in a wetland. This requires an understanding of the hydrology of the source, if the abstraction is from a surface water source, and of both the hydrology and the hydrogeology if the abstraction is from a groundwater source. If a significant hydrological impact is identified then the impact of the flow or water level in the water body on the ecology supported by that water body is assessed. This process of investigation may be undertaken quite quickly in simple cases where there is clear evidence of a direct impact or may take several years if the impact is complex, and it may require a programme of measurement and monitoring of hydrogeological and hydrological variables as well as ecology
- Thirdly, if an adverse impact on the environment is clearly demonstrated through this process of investigation, or in cases where it is not possible to demonstrate that no adverse impact is caused and the site is very sensitive (e.g. a site designated under

[19] https://corporate.thameswater.co.uk/About-us/our-strategies-and-plans/water-resources/water-resources-market-information

the European Habitats Directive), then the next stage is to assess all the options available to address the impact. This is termed an options appraisal and is undertaken by the water company if the investigation concludes that it is necessary.

- Finally, if the options appraisal identifies that a feasible option is available to address potential or actual adverse environmental impacts caused by abstraction, it will be put forward for implementation. The decision as to whether the feasible option is implemented will normally need to take account of the costs and benefits of the option to determine whether it is cost-beneficial. In cases relating to abstraction sites in areas designated under the European Habitats Directive, a cost benefit assessment is not applied, although if the option has a high cost or is 'disproportionately costly' then consideration may have to be given to a different option or mitigation option as an alternative.

2.96 The WINEP sets out the requirements for investigations, options appraisals and scheme implementations that water companies are required to undertake.

2.97 During AMP6 a number of sustainability reductions, investigations and options appraisals have taken place or are currently taking place, in response to concerns raised by the Environment Agency regarding the impact of abstractions on the environment. These are identified and described below.

2.98 For information on future sustainability reduction schemes, see revised draft WRMP19 Section 4: Current and future water supply. There is considerable uncertainty as regards the long-term programme of sustainability reductions particularly in relation to the potential need for licence reductions to meet the requirement for 'no deterioration' in the quality of water bodies under the Water Framework Directive (WFD). We have not included an allowance for these in the baseline forecasts in the revised draft WRMP19, but we have included scenario tests on how sustainability reductions, including 'no deterioration' measures, may affect our plan in revised draft WRMP19 Section 10: Programme appraisal. As part of this testing we have included scenario analysis to assess the impact of reducing abstractions at our water sources that are perceived to adversely affect chalk streams.

Licence reductions and mitigation schemes

2.99 The schemes identified by the Environment Agency as needing specific reductions or mitigation schemes during AMP6 are related to our abstractions at Axford, Ogbourne, Childrey Warren and Pann Mill. Additionally, a mitigation scheme to address the impact of abstraction from the Lower Thames is required to be implemented.

Axford

2.100 The sustainability reduction for Axford was identified following an investigation undertaken in AMP3 and options appraisal undertaken in AMP4. The required solution reduces the licence in low flow periods from 13 Ml/d to 6 Ml/d average and peak. This licence reduction required a network infrastructure solution and incorporates the delivery of the Ogbourne sustainability reduction (discussed below), the solution being common to both reductions.

2.101 The construction of this scheme commenced in AMP5 and was successfully completed to allow the reduction in the Axford licence from 1 April 2017. An allowance for emergency abstraction in the event of infrastructure failure, such as a burst in the main transferring water from Farmoor to Swindon, has been included on the licence.

Ogbourne

2.102 The requirement for a sustainability reduction at Ogbourne was identified following an investigation in AMP4 followed by an options appraisal in AMP5 which was completed in 2013. The requirement identified was to reduce the licence at Ogbourne to zero Ml/d. The scheme to deliver this licence reduction required a similar network modification to the licence reduction for Axford and so the solution for Axford incorporated the requirements for the licence reduction at Ogbourne, with the two reductions delivered to the same timescale. The Ogbourne abstraction licence was revoked from 1 April 2017. As for Axford, an allowance for emergency abstraction in the event of infrastructure failure has been included on the licence.

Pann Mill

2.103 A scheme for licence reduction at Pann Mill is required to reduce the risk of abstraction impacts on the River Wye in High Wycombe. The requirement for a sustainability reduction at Pann Mill was identified following an investigation and options appraisal in AMP5 which was completed in 2015. The licence reduction required is to reduce the average and peak licence from 22.73 Ml/d to 9.5 Ml/d. This will reduce the DO at Pann Mill from 16.8 Ml/d to 9.5 Ml/d. This scheme requires no infrastructure modification. However, in order to ensure the SWA WRZ retains sufficient supply/demand surplus to allow the licence reduction to take place, the average licence reduction will be accommodated by transfer of the licence volume to Medmenham. This will mean that the average licence limit at Medmenham will be increased from 45 Ml/d to 52.3 Ml/d. It is expected that this licence transfer will be completed by the end of March 2020. We are currently in discussion with the Environment Agency regarding the peak licence volume that we will retain at Pann Mill.

Lower Thames

2.104 The requirement for a mitigation solution to address the impact of abstraction from the Lower Thames was identified following an investigation and options appraisal in AMP5. The investigation identified that the Lower Thames abstractions had an impact on the ecology of the Thames Tideway, however the options appraisal and cost benefit assessment concluded that it was not cost beneficial to reduce the abstraction from the Lower Thames. The options appraisal identified the requirement to investigate further the oxygen levels in the reach of the Thames Tideway in the vicinity of the discharge from Mogden sewage treatment works (STW) and, if necessary, to develop a scheme to increase oxygenation during periods of low flow. Investigations and monitoring have been undertaken to assess the oxygen levels in the Thames Tideway and to identify the best mechanism to deliver the requirement for increased oxygenation. Work undertaken to improve the quality of the discharge from Mogden STW has been undertaken since the completion of the investigation and this has been taken into account in the determination of the scheme requirement. Water quality modelling of the Thames Tideway has been undertaken to determine whether a scheme is required, and it has been confirmed that a scheme is required and will be designed and implemented by March 2020.

Site investigations and options appraisals

AMP6 investigations

2.105 A number of investigations at abstraction sites within areas with no statutory designation for environmental protection were initiated in AMP6 to identify the potential environmental impacts caused as a result of abstraction. Table 2-4 outlines the investigations. Regular progress updates have been provided to the Environment Agency and these investigations are due to be completed in 2018 with the exception of the Darent river review which will be extended to allow it to take account of the conclusions of the Sundridge investigation. The Environment Agency has used the interim findings of these investigations to inform the requirement for sustainability reductions and included this in the WINEP. The requirement for further option appraisals has also been confirmed following the outcome of these investigations.

2.106 The AMP6 investigations to date have led to a requirement for potential sustainability reductions for Bexley and Hawridge abstractions and these have been identified in the WINEP. These investigations have been assessed as sufficiently certain to be included in the WRMP baseline. These sources are currently at the options appraisal stage and this process will include a cost benefit assessment of the licence reductions and this may mean that an alternative solution is implemented, for example, river restoration or augmentation. Our approach has been agreed with the Environment Agency. The confirmation of the requirement for any sustainability reduction will be determined following completion of options appraisals in each case. We have completed investigations for the Lower Lee and the Upper Darent (Sundridge and Westerham) and these have proceeded to option appraisals. For both these cases it has been confirmed that sustainability reductions are not required. Similarly, for the Upper Darent (because no adverse impact is demonstrated to be caused by the abstraction), and for the Lower Lee (because it would not be cost beneficial to make any reduction), no sustainability reductions are proposed. The investigations at Sundridge and Hawridge were undertaken with South East Water and Affinity Water respectively, as they also operate sources that have the potential to have an impact on the watercourses being investigated.

Table 2-4: Environmental investigations in AMP6

Investigation	Water body	Completion date	WRZ
Lower Lee	Lower Lee	31/04/2017	London
Sundridge and Westerham	Upper Darent	31/03/2017	London
Bexley	River Cray	31/12/2018	London
Hawridge	River Chess	31/09/2018	SWA
Darent Review	River Darent	31/12/2018	London

AMP6 options appraisals

2.107 The investigations described above to determine the impact of water abstraction at sites in non-statutorily designated areas have been or are being carried out to determine whether our abstractions may be contributing to adverse environmental impacts and whether option appraisals are required. Work to date has confirmed that options appraisal is required in most cases. In addition an options appraisal is required for Waddon which was investigated in AMP5 and has an adverse environmental impact on the Waddon Ponds. Table 2-5 outlines the options appraisals underway or likely to be required in the current period. Some further work is required beyond March 2018 in some cases.

Table 2-5: Environment options appraisals in AMP6

Options appraisal	Water body	Completion date	WRZ	Status
Lower Lee	Lower Lee	31/12/2018	London	Ongoing
Bexley	River Cray	31/12/2018	London	Investigation and OA Ongoing
Sundridge and Westerham	Darent	31/12/2018	London	Ongoing
Waddon	Waddon Ponds and River Wandle	31/06/2018	London	Ongoing
Hawridge	River Chess	31/09/2018	SWA	Ongoing

Eel screens

2.108 There is a requirement[20] to install screening at all water abstraction intakes where the abstraction has the potential to result in the entrainment of eels and where it is cost beneficial and feasible to do so.

2.109 The 2009 Regulations require all abstraction intakes to be reviewed to determine the requirement for screening protection and to implement a screening solution by an agreed date. It has been confirmed that the majority of our intakes on the Lower Thames and Lower Lee will require screening with other intakes in the Thames Valley also likely to require screening, but at a greater aperture size. The implementation of these requirements must be carried out in such a way that they do not affect abstraction volumes. Where compliance with the regulations was not possible by 2015 the Environment Agency has issued an exemption to allow implementation of a suitable solution at an agreed date. In the interim period mitigation measures may be required.

2.110 We have investigated specific requirements for all our intakes and developed detailed environmental and engineering design specifications to enable the screening programme to be rolled out during AMP6. The installation of these screens will need to be undertaken having regard to the Water Framework Directive requirement to improve the status of fish

[20] Under the Eel (England and Wales) Regulations 2009, which arise from European Commission's Eel Recovery Plan 2007

where the water body is not achieving good status as a result of entrainment at abstraction intakes.

2.111 The first screen to be installed was at Walton and was completed in March 2017. It is being used as a pilot to enable experience to be gained through its operation to inform the design of the other screens to be rolled out by the end of AMP6. Installation of the screen at Hampton was completed in April 2018.

2.112 The cost of these screens was not included in the WRMP14 but was included in our Business Plan for PR14.

River restoration

2.113 We are required to undertake river restoration at a number of sites in AMP6 as a result of environmental obligations identified in the WINEP. This requirement arises as a result of water abstractions adversely impacting on watercourses and the need to mitigate this impact. We will undertake river restoration at eight sites where we are either undertaking sustainability reductions or where an adverse impact caused by abstraction on a watercourse has been identified but it is not cost beneficial to implement a sustainability reduction. These river restoration requirements are shown in Table 2-6 and will be completed by March 2020.

Table 2-6: River restoration required in AMP6

Abstraction source leading to river restoration requirement	Water body	Completion date	WRZ	Status
New Gauge	River Lee distributary	31/03/2020	London	Ongoing
North Orpington	River Cray	31/03/2020	London	Ongoing
Waddon	Wandle	31/03/2020	London	Ongoing
Pann Mill	River Wye	31/03/2020	SWA	Ongoing
Farmoor	River Thames	31/03/2020	SWOX	Ongoing
Ogbourne	River Og	31/03/2020	SWOX	Ongoing
Childrey Warren	Letcombe Brook	31/03/2020	SWOX	Ongoing
Pangbourne	Sulham Brook	31/03/2020	Kennet	Ongoing

Heavily modified and artificial water bodies

2.114 We are required to undertake mitigation works at a number of Heavily Modified and Artificial Water Bodies (HMWBs) in AMP6 as a result of obligations identified in the WINEP. HMWBs are sites designated under the WFD for the heavily modified nature of the water body due to measures such as flood defence, navigation or water supply. The requirement is to undertake works where it has been identified as beneficial to enable the water body status to be as close to good potential as possible. The works required are to improve habitat at a number of our reservoirs and aqueducts where it is possible to do so without compromising the water supply function of the water bodies. The assessments so far undertaken have identified the requirement to install floating reed beds at a number of our reservoirs in the Lee Valley.

Assessment has also been undertaken for the potential to address vegetation growth, spread of Invasive Non-Native species, and sedimentation in the New River and Staines aqueduct. This assessment has shown that it is not necessary to implement any measures in the Staines aqueduct and that weed removal needs to be continued on the New River; but that it can be implemented in a more efficient manner to minimise weed regrowth.

Abstraction incentive mechanism

2.115 Since 2016/17 we have implemented the Abstraction Incentive Mechanism (AIM). AIM's objective is to encourage water companies to reduce the perceived impact of water abstraction at sites that are considered environmentally sensitive and is designed to complement existing management tools e.g. NEP Sustainability Reductions and Hands-Off Flows. Implementing AIM should not impact security of supply or DO and there is no capital investment for the scheme. We have implemented AIM at five sites where it was not cost beneficial to undertake licence reductions using the existing management tools or licence reductions have been implemented but reduced abstraction rates could be implemented earlier during the onset of low flows.

2.116 The five sites included in AIM are: Pangbourne, Axford, Pann Mill, North Orpington and New Gauge. These sites were selected in consultation with the Environment Agency, Ofwat, local stakeholders and the Customer Challenge Group.

2.117 During the first year of implementation, 2016/17, river flows remained above the AIM constraints and therefore no abstraction reductions were implemented. During 2017/18 all of the five sites have been triggered at various points throughout the summer/autumn and we have been able to reduce abstractions at each source such that we were compliant with AIM at all our sources for 2017/18.

G. Supply demand balance from 2015/16 to 2019/20

2.118 The supply demand balance for AMP6 is shown below, taking into account the impact of the demand management programme, the resource development programme and the sustainability reductions resulting from the WINEP.

2.119 There have been some notable changes in the supply demand positions from that forecast in the WRMP14, principally in London, where leakage levels and overall demand are higher than planned.

2.120 Population growth at the end of 2017/18 is higher than forecast in WRMP14, with approximately 400,000 more people requiring water in our region. Most of this growth is in the London WRZ. Based on the local authority plans, we estimate that the number of customers in our area will grow to over 10.1 million by 2019/20 (+4%).

2.121 The 2017/18 reported leakage was 75.2 Ml/d above the 2017/18 target. A recovery plan has been implemented, with the aim of achieving the WRMP14 leakage target by 2019/20 at the latest which will support reducing some of the deficit.

2.122 There are nearly 200,000 fewer measured properties than forecast in WRMP14. This reflects both delays experienced with the conversion of properties where meters have been installed as part of the progressive metering programme to a measured bill account, and a lower uptake of Optant meters than forecast. Work is underway in 2018/19 to reduce the two year customer journey to a measured bill account to one year.

2.123 The supply demand balances presented in Table 2-7 reflect the best information available at April 2018 for the revised draft WRMP19 baseline data lockdown. The data is based on AR17 and includes for a forecast of our position to the end of the AMP6 period. All WRZs are in surplus by 2019/20 at the latest.

2.124 Following the work undertaken for the revised draft WRMP19, and as part of the Environmental Performance Assessment, a review of the supply demand balance in London was undertaken. The review identified a number of areas for improvement that could be implemented during the 2018/19 report year that would lead to the supply demand position in London returning to a surplus in the year. The results are published in the Environment Agency Annual Review, June 2018[21].

[21] Environment Agency, Annual Review, June 2018 - https://corporate.thameswater.co.uk/About-us/our-strategies-and-plans/water-resources/our-current-plan-wrmp14

Table 2-7: AMP6 supply demand position

WRZ	Item	Volume				
		2015/16	2016/17	2017/18	2018/19	2019/20
London (DYAA)	Demand	2079	2114	2119	2070	2020
	Headroom	81	89	80	106	122
	Supply	2171	2166	2165	2160	2155
	Balance	11	-37	-34	-16	12
SWOX (ADPW)	Demand	326	329	332	331	330
	Headroom	10	11	13	14	16
	Supply	370	369	359	358	355
	Balance	34	30	14	14	9
SWA (ADPW)	Demand	167	176	182	176	170
	Headroom	5	4	5	6	6
	Supply	194	197	197	197	190
	Balance	22	17	11	16	14
Kennet Valley (ADPW)	Demand	120	122	125	124	122
	Headroom	4	4	4	5	6
	Supply	152	152	152	151	151
	Balance	27	25	22	23	23
Guildford (ADPW)	Demand	62	62	63	63	63
	Headroom	2	2	2	2	3
	Supply	68	68	68	68	68
	Balance	5	5	3	3	3
Henley (ADPW)	Demand	19	19	19	19	19
	Headroom	1	0	1	1	1
	Supply	26	26	26	26	26
	Balance	6	6	6	6	6

Section 3

Current and future demand for water

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Section 3.

Current and future demand for water

This section explains how we calculate current and forecast future demand for water. This is one of the foundations of our plan as it provides the information that enables us to define the supply-demand balance we need to manage in the future.

- ‘Demand’ is composed of five elements:
  - Household water use
  - Non-household water use (water used by businesses)
  - Operational use (water used in maintaining the network)
  - Water taken unbilled (water used legally or illegally without charge)
  - Leakage (from our pipes and also those belonging to our customers’).
- We estimate that in our ‘base year’ (2016/17), we supplied water to nearly 3.7 million households and 215,000 businesses. The average current household demand is 145.3 litres per person per day. The average current metered non-household demand is 478 litres per day.
- The base year presents our current level of demand and is reported as part of our Annual Return. Part of this reporting is accounting for the weather conditions of the base year. We do this through the use of scenarios and we produce forecasts for ‘Dry Year Annual Average’ (DYAA) and ‘Average Day Peak Week’ (ADPW) scenarios.
- We are required to plan for the property growth projected by the 95 local authorities in our area. Based on their plans, we estimate that the number of customers in our area will grow by more than two million people to 11.8 million by 2045.
- Because local authority plans only plan 15-20 years into the future, we have worked with demographic experts to develop our own projections to the end of the century. We forecast that the number of people in our area could reach up to 15.4 million by 2100.
- Finally we forecast demand for each of the five water balance components for each of our six water resource zones (WRZs). The uncertainty regarding the demand forecasts is then estimated in Section 5: Allowing for risk and uncertainty, before the supply-demand balance is calculated in Section 6: Baseline water supply demand position.

We have made the following changes in response to points raised in the public consultation on the draft WRMP, and to include new information since the draft WRMP was published.

- Central population and property forecasts updated to August 2017 Edge Forecasts
- New post 2045 population and property forecasts produced by Edge Analytics using information from the ONS 2016 nation population projections (NPP) and sub national population projections (SNPP)
- Inclusion of alternative population and property forecasts for the purposes of comparison with central estimates
- Discussion of alternative population and property forecasts
- Update to base year values due to further improvements to UKWIR consistency of reporting measures project
- Update of all graphs and tables to align with changes caused due to revised base year values and change population and property forecasts

A. Introduction

3.1 We are responsible for the supply of wholesome water to more than 9.8 million customers in over 3.9 million properties. Over the past ten years the population we serve has been growing at average rate of more than 100,000 people a year. This is the equivalent of the population of Birmingham, more than 1 million people, moving into our supply area in the last decade.

3.2 To ensure we are able to provide a safe and secure supply of water to all our customers, we produce forecasts of what the likely demand for water will be.

3.3 'Demand' is the term we use to describe the water that is supplied through our network to households, workplaces and schools; water taken illegally and legally unbilled; water used by industry; water used in maintaining the water network; and water that is lost through the distribution systems.

3.4 Demand forecasting is the method by which we estimate future demand for water. We use mathematical models which use information such as population and property projections, water use data and trends, and a range of other information to forecast how the components of demand for water are likely to vary over the next 80 years.

3.5 Over the planning period we face continued growth in demand. Upward pressures include:

- Population increase
- Decreasing household size (occupancy), as occupancy decreases per person water use increases
- Climate change

3.6 These upward pressures are partially offset by downward pressures from:

- The improving efficiency of water fixtures and fittings such as toilets, dish washers, washing machines, etc.

- Water efficient new housing resulting from design requirements of building regulations
- Customers opting for a meter to better manage their consumption
- Customers being more efficient in their use of water

3.7 For the draft Water Resource Management 2019 (draft WRMP19), we have developed a new forecasting model using the methods identified from the UKWIR project "WRMP19 Methods – Household Consumption Forecasting"[1]. Using this model, we estimate an increase in household demand of more than 241 Ml/d by 2045 and a total increase of approximately 429 Ml/d by 2100.

3.8 Non-household water use is forecast to decline by approximately 3% over the planning period to 2045 and continues to decline by 5% in 2100, although it should be noted there are differing trends across our six WRZs. Generally, increases in water use from service industries (e.g. offices, call centres) are being offset by reductions in demand from non-service industries (e.g. industrial sites, breweries).

3.9 The baseline demand forecast is the starting position for the future supply demand balance without any planned interventions from 2020. It includes demand reductions from the promotion of water efficiency, leakage reduction and metering activities assumed in price limits up to 2019/20, i.e. the demand management practices in place at the beginning of the new planning period.

3.10 Water taken unbilled, operational use and leakage are forecast to remain at current levels in the baseline forecast.

3.11 Overall, the total baseline demand forecast (before intervention) is expected to increase by 241 Ml/d in the period of 2017-2045 and by 429 Ml/d by 2100. This represents a significant challenge, particularly in the face of reductions in our supply capability (Section 4: Current and future water supply). As part of our plan we have looked at the potential to reduce demand and show how different levels of demand management affect the cost and performance of future plans and strategy. This is in accordance with the 2018 Water Resources Planning Guideline[2] (WRPG) which states that the plan should address government policy including reducing the demand for water.

3.12 The remainder of this section is structured as follows:

- An introduction to what is 'demand'
- Guiding principles and drivers of demand
- Annual water balance – reporting the components of the water balance relevant to the base year, 2016/17
- Demand forecasting – how we forecast demand to 2045 and then to 2100

[1] UKWIR 2015 WRMP19 Methods – Household Consumption Forecasting 15/WR/02/9
[2] Environment Agency and Natural Resources Wales and also produced in collaboration with Defra, the Welsh Government, and Ofwat, Final Water Resources Planning Guideline, July 2018

What is 'demand'?

3.13 'Demand' is the term we use to describe the water that we use that is supplied through Thames Water's network.

3.14 When reporting demand for water it is split in to the following categories:

- Household Use - water used in the home and garden
- Non-household Use - water used by businesses
- Operational Use - water used maintaining the network
- Water Taken Unbilled - water used without charge either legally (e.g. fire hydrant use), or illegally (e.g. usage in a property declared as void (empty)).
- Leakage - water lost from the distribution system

3.15 We calculate and report these components on an annual basis in a process known as the 'water balance'.

3.16 Demand forecasting is the method by which water companies estimate future demand for water. We use mathematical models which use information such as population and property projections, water use data and trends, and a range of other information to forecast how the components of demand for water are likely to vary over the next 80 years. We produce updated forecasts every five years, with an annual review in the intervening period. We follow industry guidelines supplemented with our own detailed analysis.

Guiding principles

3.17 The WRPG sets a clear framework for developing a demand forecast. We have followed the latest UKWIR guidance[3] in developing our forecasts.

3.18 For the baseline forecasts it is assumed that beyond 2019/20 water efficiency activity will continue at approximately 3 Ml/d of activity per year. We have also assumed that meters will only be fitted where customers request a meter and in new properties, and that there will be no additional leakage reduction, although activity to maintain leakage at current levels continues.

3.19 AMP6 activity includes the progressive household metering programme in London to 2020, where we will fit meters to properties including those that have not requested a meter. Our progressive metering programme assumes that after a two year adjustment period the customer will be switched over to a measured tariff. This will deliver benefits through demand reduction and leakage detection and repair, as well as delivering long term efficiencies for network maintenance in metered areas.

3.20 Once all the steps in the water resource planning process have been completed, a range of demand reduction options will be included in the demand forecast, such as further leakage reduction, progressive household metering and additional water efficiency measures (Section 8: Appraisal of demand options, Section 10: Programme appraisal and Section 11: Preferred

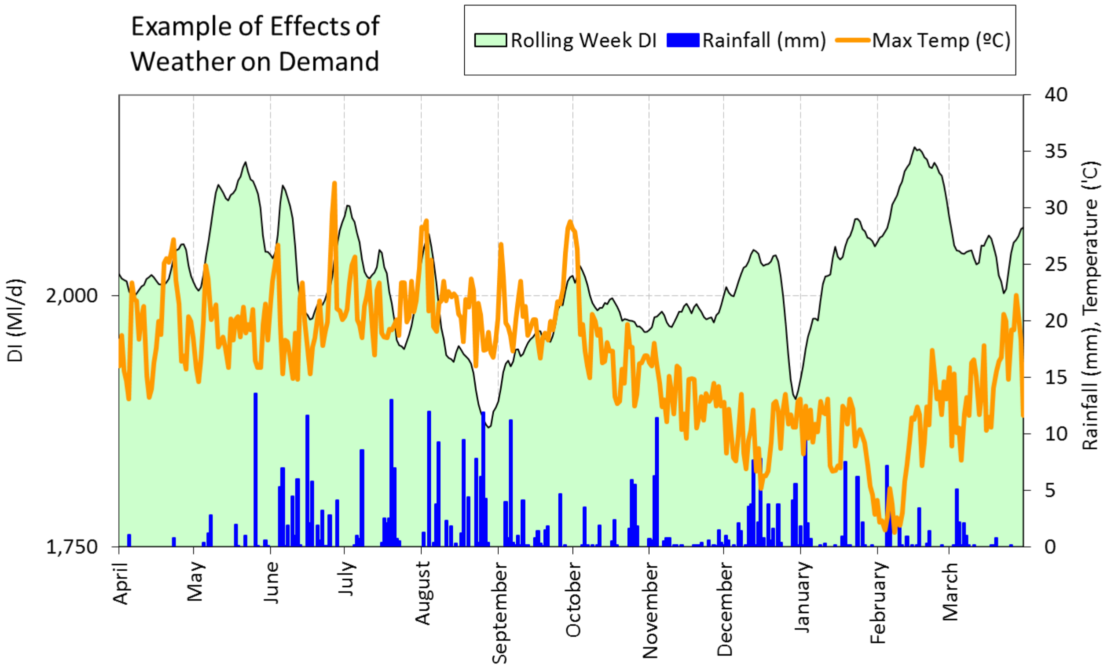
[3] UKWIR, WRMP19 Methods – Household Consumption Forecasting, 15/WR/02/9, 2015

programme). We call this final demand forecast the 'Final Plan' forecast to differentiate it from the 'Baseline' forecast described above.

Demand drivers

3.21 Demand for water varies due to a number of factors. One of the most important of these factors is the weather. In hot dry weather, customer use more water is used for activities such as garden watering or filling paddling pools. On the other hand, in cold weather, leakage will rise, because pipes can contract and leak. The effect of weather on demand is shown in Figure 3-1.

Figure 3-1: Effect of weather on demand (measured by Distribution Input)



3.22 Demand will change over time in response to a range of drivers which also change over the planning period. The main drivers, which are included within demand forecasting models, are:

- Population and property growth, in line with the plans developed by local authorities
- Effects of climate change
- Changes in non-household consumption, including industrial and commercial use
- Trends in household water use linked to behaviour and technological development of water using devices

3.23 Agricultural water use does not feature as a driver for demand due to the relatively small volume of water that is used for this purpose within the Thames Water supply area. Currently it is estimated that approximately 0.7% of all non-household demand within the Thames Water supply area is for agricultural water use.

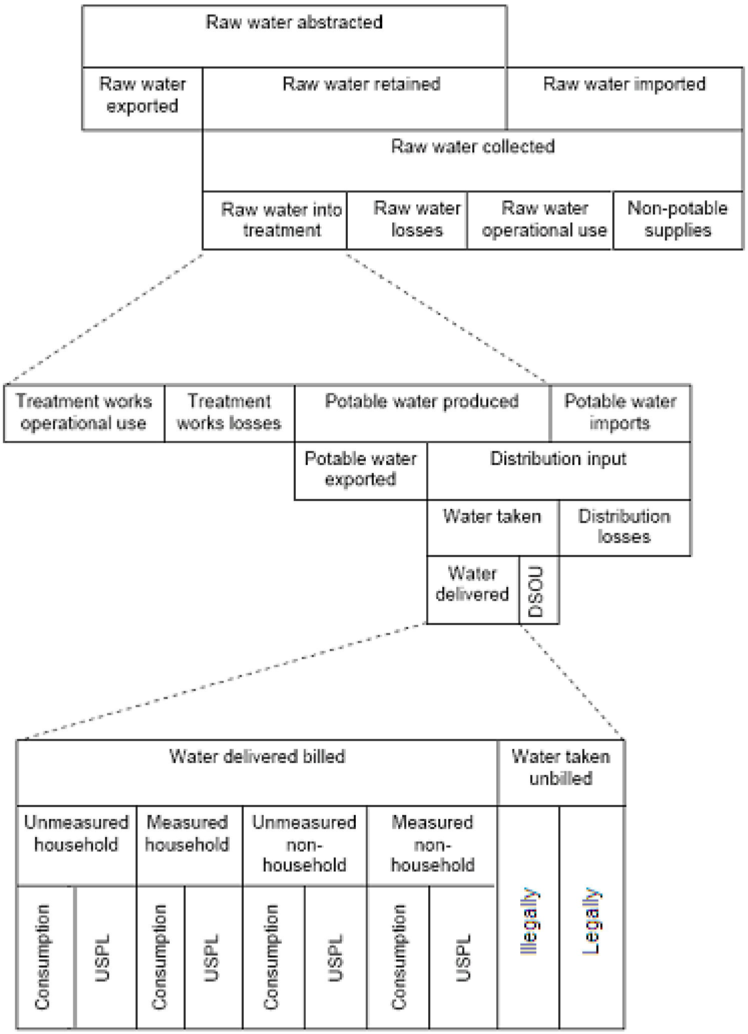
3.24 Leakage is an important element of demand but in our baseline scenario leakage remains constant at its base year value across the entire forecast period.

3.25 These demand drivers are discussed in more detail within the remaining sections of this document and in Appendix E: Populations and property projections, Appendix F: Household water demand modelling, Appendix G: Non-household water demand and Appendix H: Dry year and critical period forecasting.

B. Current demand

The water balance

Figure 3-2: Overview of water balance



DSOU – distribution system operational use
USPL – underground supply pipe losses

Base year properties

3.26 Company level property numbers by type (measured/unmeasured, household/non-household, void[4] household/void non-household) are derived from our Customer Information System (CIS). These include adjustments to the unmeasured and measured household and non-household figures for missing properties. They also take account of properties that have moved to a measured tariff due to optant metering as well as the addition of new properties to the count of measured households.

3.27 The numbers of properties within each WRZ are then calculated using a database called Netbase. Netbase takes property information from CIS and geo-references it, firstly to District Meter Areas (DMAs), a discreet area of the network where water supplied is measured by a district meter, then to Flow Monitoring Zones (FMZs), discreet areas of the network where the water supplied is measured by a zonal meter, and finally to WRZs. The proportions from this exercise are then used to apportion the property numbers from CIS to each WRZ.

3.28 The base year property values are summarised in Table 3-1.

Table 3-1: Base year properties

WRZ	Households			Non-households		
	Unmeasured	Measured	Void	Unmeasured	Measured	Void
London	1,817,250	912,337	76,433	33.635	912,337	15,099
SWOX	152,244	273,437	7,134	1,511	22,805	1,709
SWA	98,954	106,686	3,563	665	9,691	969
Kennet Valley	71,727	87,337	2,686	610	6,941	731
Guildford	29,131	32,506	1,083	342	3,346	325
Henley	7,066	14,226	360	97	1,001	81
Thames Water	**2,176,371**	**1,426,528**	**91.260**	**36.861**	**159.074**	**18.914**

Base year population

3.29 The starting point for estimating base year population is the mid-2015 population estimates published by the Office for National Statistics (ONS). This data was then updated to the base year of 2016/17 using projections from expert consultants, Edge Analytics, and the Greater London Authority (GLA) for areas within London. Edge Analytics have worked with us to develop a more granular distribution of population for the draft WRMP19. This has been done using census output areas giving a better occupancy distribution and population split across WRZs. This work has been incorporated in our plan.

3.30 Not all population is accounted for in official statistics. To take account of "hidden" population, short-term migrants and second addresses we apply an additional allowance, based on a

[4] Void properties which are households and commercial buildings that are not occupied or being used

study by Edge Analytics[5]. This allowance totals an additional population of 517,228, the majority of which are considered to be within London.

3.31 Non-household population is comprised of population residing in communal establishments; based on the Ofwat eligibility criteria released in July 2016.

3.32 The total household population is derived by subtracting the total non-household population from the total population. This year, the number associated with communal establishments has been updated at 103,843. The unmeasured non-household population remains at zero.

3.33 The population split between measured and unmeasured households uses data obtained from occupancy questionnaires which were sent to 49,028 households, both unmeasured and measured, as research to inform our June Return 2010 (JR10) regulatory reporting, of which 11,482 were returned with valid data. All responses could be classified by property type, metering type, ethnicity and region enabling us to scale up responses according to the effective sampling rates of each category. We also adjusted for any occupancy bias in the responses by comparison with profiles of occupancy classes obtained from the Census 2011 for regions covering our London and Thames Valley zones.

3.34 To update population splits between measured and unmeasured households this year we have used the movement in properties, reductions in unmeasured properties as customers opt for a meter, and increases in measured properties associated with the optants, in addition to newly built properties. It is assumed that the occupancy of the additional measured properties is the same as the occupancy of the existing measured properties. This plan also considers the impact of population in bulk billed blocks of flats (subsidiary properties), taking account of the population in the measured unmeasured household split rather than in non-household population. This should provide a more reflective view of the population distribution. The residual movement in population is assumed to be in the unmeasured population base. Base year populations are summarised in Table 3-2. As with any company, large changes in government statistics on population estimates would affect our plan.

Table 3-2: Base year population 2016/17 (000s)

WRZ	Populations	
	Unmeasured	Measured
London	5,226,919	2,368,700
SWOX	436,344	585,481
SWA	301,178	247,666
Kennet Valley	211,881	189,855
Guildford	86,763	73,423
Henley	22,339	28,562
Thames Water	**6,285,422**	**3,493,687**

[5] Clandestine and Hidden Populations Edge Analytics October 2016

Household demand

3.35 Household demand is normally described by the volume of water used per person each day, and is called ‘Per Capita Consumption’ or PCC. Unmeasured customer PCC is calculated from our Domestic Water Use Survey (DWUS), a panel of approximately 1,600 customers who have, voluntarily, had meters installed but are charged on an unmeasured basis. Measured customer PCC is calculated by totalling the volume recorded by all customer meters, allowances are then applied for supply pipe leakage, which is subtracted, and meter under-registration, which is added. This total volume of water is then divided by the total number of measured customers to give a measured customer PCC.

3.36 For 2016/17 the PCC for measured, unmeasured and average for each WRZ is shown in Table 3-3.

Table 3-3: Per capita consumption (l/person/d)

WRZ	Unmeasured PCC	Measured PCC	Average PCC	% Metered
London	159.46	120.16	147.20	33.42%
SWOX	149.12	129.32	137.77	64.24%
SWA	151.87	125.46	139.95	51.88%
Kennet Valley	143.23	125.73	134.96	54.91%
Guildford	155.90	137.91	147.66	52.74%
Henley	141.66	144.95	143.51	66.81%
Thames Water	**157.72**	**122.95**	**145.30**	**39.59%**

Non-household demand

3.37 The vast majority of the non-household demand is measured. It is primarily water used by commercial, industrial and agricultural premises, though there is a small population whose consumption is included within the non-household category as they live in properties classified as ‘mixed’ (e.g. a flat above a shop).

3.38 Assessed non-household[6] usage is estimated using a matrix which looks at the size of the property supply and the number of full time employees as well as the business type, calculating an estimated daily consumption. Unmeasured non-household usage is assigned by billing band type and number of billed units supplied by the Central Market Operating System (CMOS).

3.39 Non-household demand was reported as shown in Table 3-4 for 2016/17.

[6] Non-household properties where it is impractical to fit a meter

Table 3-4: Non household consumption (Ml/d)

WRZ	Measured	Unmeasured
London	350.99	14.93
SWOX	58.47	0.64
SWA	19.79	0.27
Kennet Valley	18.64	0.23
Guildford	7.57	0.16
Henley	1.74	0.04
Thames Water	**457.21**	**16.26**

Leakage

3.40 The reported leakage value for our 2017 Annual Return (AR17) was 667.84 Ml/d. For the revised draft WRMP19 we have used a different value which is consistent with the guidance contained within the 2017 UKWIR report "Consistency of Reporting Performance Measures" (17/RG/04/5). Using this new method results in a Dry Year Annual Average (DYAA) leakage value of 741.16 Ml/d for Thames Water and will form the basis of water industry leakage reporting from 2020 onwards.

3.41 Leakage is split into two categories.

- Distribution losses: these are leaks on our own infrastructure and make up approximately 72% of total leakage
- Supply pipe leakage: this is water leaking from customer supply pipes, which is the responsibility of customers, although we offer a free leakage repair service to household customers who meet the eligibility criteria

3.42 Leakage for each WRZ, as reported within our Appendix A of AR17, is shown in Table 3-5.

Table 3-5: Actual leakage (Ml/d)

WRZ	Total Leakage
London	524.45
SWOX	61.32
SWA	42.81
Kennet Valley	24.10
Guildford	12.16
Henley	3.01
Thames Water	**667.84**

Minor components

3.43 Minor components include the demand taken from the distribution system for our operational use and any water which is taken but unbilled. Operational use includes water used by a company to maintain water quality standards in the distribution system such as mains flushing. Water taken unbilled includes public supplies for which no charge is made (sewer flushing etc.), fire training and fire-fighting supplies; it also includes water taken illegally.

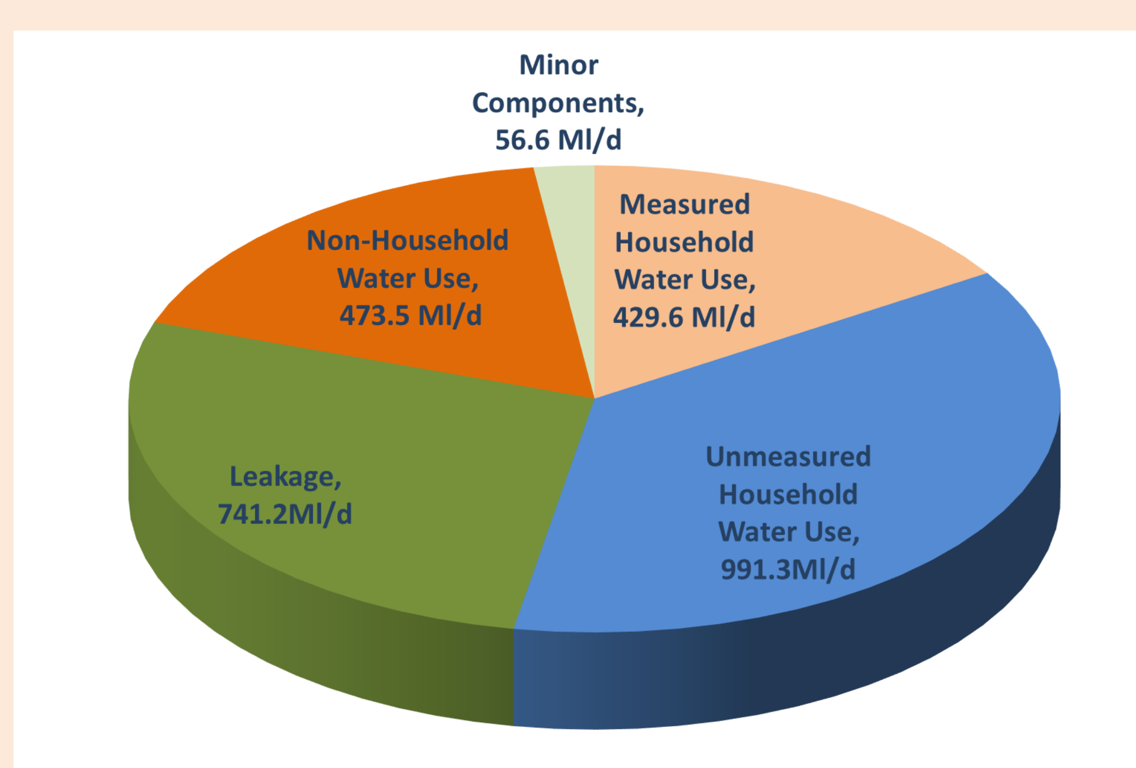
3.44 At the company level, minor components add up to approximately 57 Ml/d.

Summary for 2016/17

3.45 Figure 3-3 shows the breakdown of the total demand reported in the water balance for 2016/17 by component. Overall household water use accounts for 53%, leakage for just over 27% and non-household demand accounting for approximately 18% of total demand. The remaining 2% is accounted for by the minor component of water take unbilled and operational uses.

3.46 This split of total demand and its sub-components forms the base position for the demand forecast.

Figure 3-3: Dry Year Annual Average demand[7]



[7] Consistent with 2017 UKWIR report “Consistency of Reporting Performance Measures” (17/RG/04/5)

C. Future demand – the demand forecast

Planning scenarios

3.47 The water balance reflects the conditions experienced in that year. It may have been, looking at the year as a whole, wet, dry, hot, cold or somewhere in the middle. From a planning perspective, we are interested in the demand that would be expected to be met up to the point that the system becomes stressed, as set out in our level of service. Therefore, we need a demand forecast which is reflective of that level of service. We use planning scenarios to recreate anticipated demand levels.

3.48 Demand forecasts are developed for different conditions which describe demand in an average year and in the Dry Year Critical Period (DYCP). For us the DYCP scenario is defined as the Average Day Peak Week (ADPW) for our Thames Valley zones, i.e. all zones except for London. Table 3-6 summarises the scenarios constructed for each of our WRZs. The table describes two different scenarios:

- The DYAA scenario: this is the forecast for a dry year (a period of low rainfall) where there are no constraints on demand; and
- The ADPW scenario: this describes the average daily demand during the peak week for water demand. The peak week is the critical period of demand which drives the need for water resource management options to be implemented.

Table 3-6: Planning scenarios used in each of our WRZs

WRZ	Baseline		Final Plan	
	DYAA	ADPW	DYAA	ADPW
London	✓	×	✓	×
SWOX	✓	✓	✓	✓
SWA	✓	✓	✓	✓
Kennet Valley	✓	✓	✓	✓
Guildford	✓	✓	✓	✓
Henley	✓	✓	✓	✓

3.49 We do not report on ADPW demand for the London WRZ. This is because peak demands in London can be met through the relatively large volume of surface (raw) water storage (reservoirs) and treated water in the London Ring Main. The ability to meet peak demands is therefore not a resource availability issue at present but dictated by treatment and transmission capabilities.

3.50 All other zones are driven by summer weather-related peak demands and thus the ADPW scenario is the main driver for water resource investment.

3.51 All scenarios are produced by factoring up or down the demand reported in the base year, the approach used is described below.

Peaking factors

3.52 Peaking factors are used to uplift or reduce out-turn demand in any year to the DYAA and ADPW planning scenarios. They are calculated using a model called OMSPred which uses historic weather conditions and the current year's base demand to recreate how current demand would vary in different weather conditions. We have refined our uplift process so that we are now able to uplift water usage and leakage separately. The model uses the peaking factors to uplift or reduce base year leakage and usage to the desired level of service, and then calculates uplift volumes that are applied to base usage and leakage volumes.

3.53 Comparing London's annual average demand for 2016/17 with the modelled demand using weather data from the last 69 years demonstrates that the levels in 2016/17 have been below that of a normal year, and a dry year, being ranked 12th of the 69 available years.

3.54 Thames Valley's annual average demand for 2016/17 is ranked 18th of 49 available years. The peak week in 2016/17 occurred very early in May and was below both the 1 in 10 and in the 1 in 2 year peak week coming in 12th of the 49 available years.

3.55 The uplift volumes, for each component, are shown in Table 3-7.

Table 3-7: Distribution input uplift volumes (Ml/d)

WRZ	DYAA Uplift			ADPW Uplift		
	Usage	Leakage	Total	Usage	Leakage	Total
London	9.18	23.32	32.50	N/A	N/A	N/A
SWOX	1.61	0.89	2.50	58.70	N/A	58.70
SWA	0.85	0.28	1.13	32.50	N/A	32.50
Kennet Valley	0.60	1.03	1.63	21.48	N/A	21.48
Guildford	0.51	0.14	0.65	16.96	N/A	16.96
Henley	0.14	0.08	0.23	6.55	N/A	6.55

3.56 These uplifts result in the overall demand, measured in terms of distribution input, shown in Table 3-8.

Table 3-8: Overall demand (Distribution Input) post uplift

WRZ	DYAA (Ml/d)	ADPW (Ml/d)
London	2,114.05	N/A
SWOX	272.78	328.79
SWA	144.83	176.07
Kennet Valley	102.15	121.91
Guildford	45.64	61.93
Henley	12.63	18.94
Thames Water	**2,679.99**	**N/A**

3.57 The impact on leakage values for the different forecast scenarios in each WRZ is given in Table 3-9.

Table 3-9: Uplifted leakage 2016/17 (Ml/d)

WRZ	Shadow Leakage DYAA
London	582.76
SWOX	68.04
SWA	46.04
Kennet Valley	27.56
Guildford	13.35
Henley	3.40
Thames Water	**741.16**

3.58 More information can be found on peaking factors in Appendix H: Dry year and critical period forecasting.

Population and property forecasts

Introduction

3.59 Throughout this section, the term 'forecast' is used as a generic term to encompass both population projections (trend-based outcomes) and population forecasts (policy-based outcomes, e.g. housing-led forecasts).

3.60 Robust population and property forecasts are a key underpinning of the draft WRMP19 process. A sustained period of new housing growth, ageing population profiles and an uncertain future for international migration are key considerations for industry planners.

3.61 The WRPG produced by Defra, in conjunction with the Environment Agency, Welsh Government, Natural Resources Wales and Ofwat, include guidance on the key requirements for population, property and occupancy forecasts to support the draft WRMP19. This guidance has formed the basis for the development of the forecasts presented here.

3.62 Given our requirement for an extended forecast we commissioned two separate components to our forecasting evidence:

1) the *core* forecasts relate to the 2016-2045 planning horizon based on local authority plans; and
2) the *longer-term* outlook considers the extended 2045-2100 planning horizon which used trend-based methods.

3.63 In the draft WRMP19 (published in February 2018), population and property output from the University of Leeds' demographic forecasting model was used as the basis for the long-term growth outlook. Since completion of the draft WRMP19, the ONS has published a new 2016-

based, long-term projection, the first release of future population growth estimates since the Brexit referendum in June 2016.

3.64 To ensure alignment with the latest ONS evidence on the likely trajectory of growth during the second half of the 21st century, we commissioned updated population and property forecasts for our WRZs for the extended, 2045-2100 horizon.

3.65 Whilst the core and long-term forecasts have used consistent methodologies, the long-term forecasts have been formulated using trend-based inputs and assumptions that are consistent with the ONS 2016-based NPP; this contrasts to the housing-led approach used in the development of the core, 2016-2045 forecasts.

3.66 All forecasts have been produced for us by Edge Analytics Ltd who are experts in demographic analytics and scenario forecasting. They are contracted by the Local Government Association (LGA) to support and develop the POPGROUP suite of forecasting models used by planners, analysts and researchers across the UK.

3.67 These core forecasts have been produced in line with the requirements of the WRPG, with 'plan-based' population and property growth estimates underpinned by published evidence on local authority housing plans. The longer-term outlook has been underpinned by the latest evidence from the ONS on growth projections to 2100[8].

3.68 The remainder of this section provides a summary of the methodology and outcomes of these forecasting approaches. Further detail is provided in Appendix E: Property and population projections.

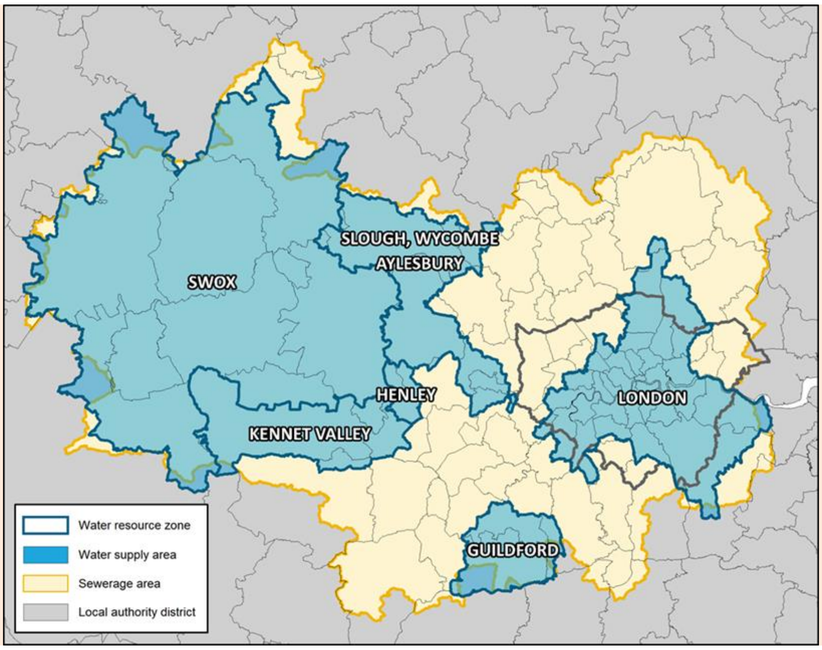
Area definition

3.69 The Thames Water area of operations in which it provides its water and sewerage services encompasses a total of 95 local authority areas (either in full or in part); a mix of London Boroughs, Unitary Authorities and non-metropolitan districts.

3.70 The six WRZs are covered by a sub-set of these local authority areas, as shown in Figure 3-4, again either in full or in part. This sub-set of local authority areas has provided the basis for the development of our draft WRMP19 population and property forecasts.

[8] ONS 2016-based NPPs
https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/bulletins/nationalpopulationprojections/2016basedstatisticalbulletin#things-you-need-to-know-about-this-release

Figure 3-4: Area definition of Thames Water operational areas and local authorities



3.71 Population and property forecasts developed for each local authority area have been scaled to ensure consistency with the WRZ geography. This scaling process has been based upon the proportional distribution of properties, using digital map data and Geographical Information System (GIS) technology to ensure the most accurate process of estimation.

Regulatory guidance

3.72 In developing population and property forecasts for the draft WRMP19, the WRPG published by Defra *et al* mandates the use of housing growth evidence from Local Plans to inform the core 2016-2045 scenarios:

> *'For companies supplying customers wholly or mainly in England you will need to base your forecast population and property figures on local plans published by the local council or unitary authority.' (p. 21)*[9]

3.73 The WRPG acknowledges that councils may be at different stages of Local Plan development but has required population and property forecasts to be aligned to the best-available evidence. Where plan evidence does not exist, the WRPG advises the use of the ONS and Department for Communities and Local Government (DCLG) official statistics as an alternative.

3.74 To support the WRPG documentation, UKWIR has produced a suite of documents which provide additional guidance on the development of population, property and occupancy forecasting. The UKWIR documentation is in three forms: a Guidance Manual; a Worked Example; and a Supplementary Report that includes a review of stakeholder engagement and a technical review of forecasting approaches.

[9] Final Water Resources Planning Guideline 2018 Environment Agency, Natural Resources Wales, Defra, Ofwat

3.75 The UKWIR Guidance Manual is not prescriptive in terms of methodological recommendations for forecast development but it does identify six key 'tasks' required to complete the process:

1) Assess needs and make choices
2) Assess Local Development Plans
3) Calculate population and household forecasts
4) Calculate occupancy forecasts
5) Analyse uncertainty
6) Review and finalise population, household and occupancy forecasts

3.76 Whilst the core (2016-2045) and long-term (2045-2100) forecasts use different data inputs and assumptions, their underpinning demographic modelling methodology and principles are the same and align with methods employed by the ONS and the GLA. The following sub-sections first provide a short summary of generic demographic methods, and then describe the particular approaches adopted for the development of the core and long-term forecasts.

Demographic forecasting methodologies

3.77 Population forecasts have been developed using a cohort-component methodology, the universal standard for demographic analysis. The cohort-component method models the annual growth in the size and age-sex structure of a population over time, taking account of fertility, mortality and migration, as follows:

$$Pop_{(a,s,t+n)} = Pop_{(a,s,t)} + B_{(s)} - D_{(a,s)} + InUK_{(a,s)} - OutUK_{(a,s)} + InOV_{(a,s)} - OutOV_{(a,s)}$$

where:

Pop(a,s,t) = the population at time (t), by age (a) and sex (s)

B(s) and D(a,s) = number of births and deaths occurring between t and t+n.

InUK(a,s) and OutUK(a,s) = domestic in- and out-migration during the period t to t+n.

InOV(a,s) and OutOV(a,s) = immigration and emigration during the period t to t+n.

3.78 Household forecasts have been developed using a 'household representative rate' (also known as 'household headship rate') model that is consistent with approaches applied by the ONS, GLA and the Welsh, Scottish and Northern Ireland national statistical agencies. The annual growth in the number and profile of households over time is calculated as follows:

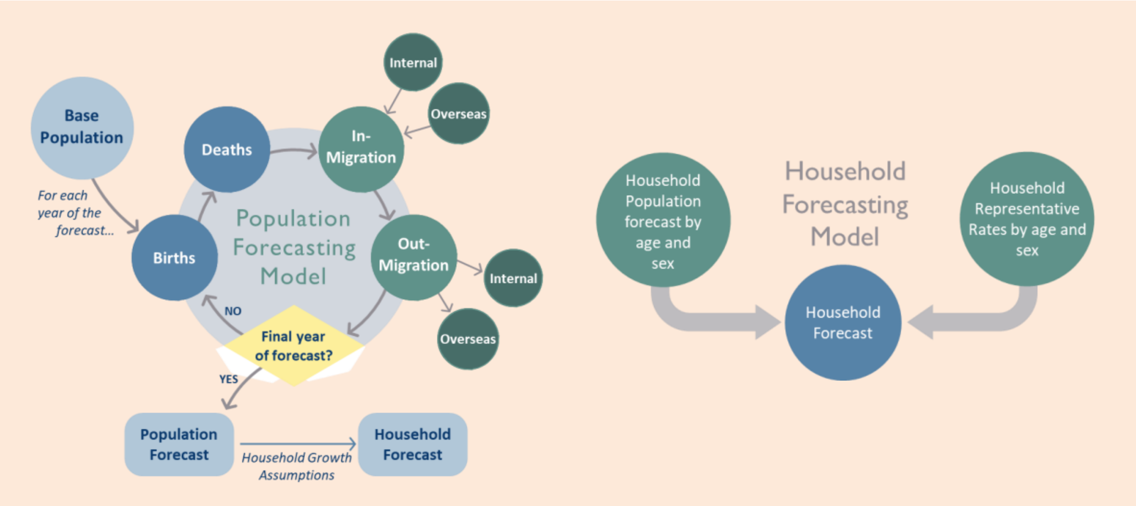
$$H_{(a,s,d,t)} = HPop_{(a,s,t)} * R_{(a,s,d,t)}$$

where:

$H_{(a,s,d,t)}$ = Households at time (t), by age (a), sex (s) and household type (d)
$HPop_{(a,s,t)}$ = Household Population at time t by age and sex
$R_{(a,s,d,t)}$ = Household Representative Rate at time t by age, sex and household type

3.79 The population and household models can work independently or in tandem. When operating together, the models can be used to evaluate 'housing-led' growth scenarios, whereby population change is determined by a forecast growth in the number of new homes. This functionality has been key to the development of the 'plan-based' forecasts for our 2016-45 planning horizon and is summarised in Figure 3-5.

Figure 3-5: Population and household forecasting methodologies



Core forecasts (2016-2045) – Plan-based

3.80 Using a combination of its demographic modelling expertise in conjunction with an extensive Local Plan data collection and validation exercise, Edge Analytics has derived a 'plan-based' forecast of population and property growth for our WRZs to 2045. In achieving this objective, Edge Analytics has sought to ensure that the draft WRMP19 requirements detailed by Defra *et al* in its WRPG documentation have been met and that the technical approach has aligned with UKWIR's recommendations for the development of population and property forecasts. Appendix E: Population and property projections, provides a full technical report provided in support of the delivery of the plan-based forecasts.

3.81 Key to the development of the plan-based forecast was the collection of Local Plan housing evidence from all local authorities within our area of operations. Edge Analytics liaised directly with local authorities to collect both 'macro' and 'micro-level' detail on planned new housing developments. The macro-level information has provided the overall housing growth trajectory for each local authority's chosen plan period. Where available, the micro-level information has provided the detail on the geographical distribution of planned new homes. The combination of macro- and micro-level information has enabled the development and alignment of 'top-down' and 'bottom-up' forecasts to inform the draft WRMP19.

3.82 Edge Analytics used a combination of its POPGROUP and VICUS technology to develop the plan-based forecasts. POPGROUP is the industry-standard, cohort-component and headship rate model that is managed by Edge Analytics on behalf of the LGA and used by planners across the UK. VICUS is Edge Analytics' micro-forecasting model, enabling the population impact of the most geographically-detailed housing growth plans to be derived. The VICUS micro-level detail aligns directly to the local authority-level forecasts derived from the POPGROUP model.

3.83 The base-year of the plan-based forecasts was 2016, with base-year property numbers aligning to those in the Royal Mail's Address Based Premium dataset. The forecast horizon was 2045, with underpinning demographic assumptions on fertility, mortality, domestic and international migration drawn from published ONS statistics. Household representative rate statistics and estimates of non-household populations were derived from DCLG evidence. Vacancy rates, enabling the calculation of property numbers from household totals were derived from the 2011 Census.

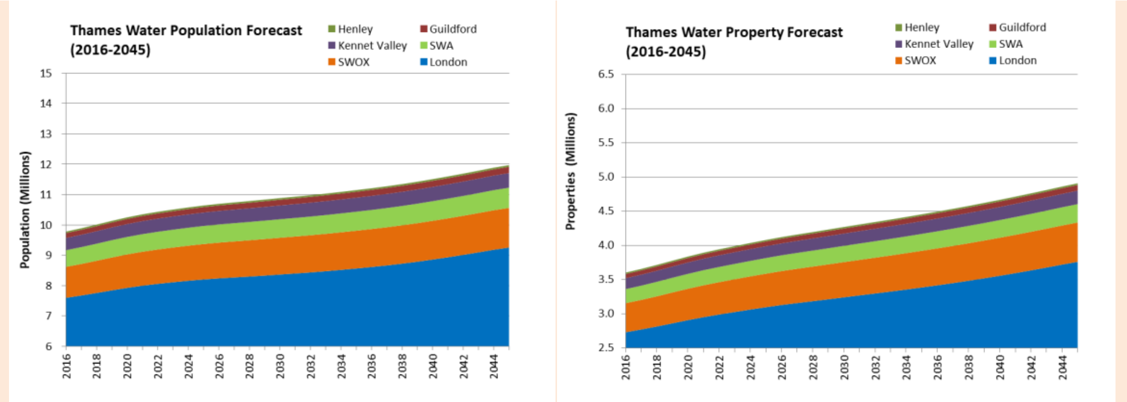
3.84 For each local authority, planned housing growth was used as the key determinant of future population change, with net-migration used to balance the relationship between population size and property numbers. Using the cohort-component functionality, the forecasting model considered not only the planned housing growth but also the changing age-sex profile of the population and the forecast changes in household headship representative rates by age and sex.

3.85 Local Plans typically have a 15-20 year horizon, with most housing growth trajectories ending in 2030-35. The plan-based forecasts have assumed that, at the end of the Local Plan period, housing growth makes a gradual return to the trend evident in the ONS 2014-based projections, achieving the average annual trend growth by 2045.

3.86 Aligning with base-year totals, we have used the plan-based output to derive population and property forecasts by WRZ, illustrated below. The rate of population change is relatively high in the short-term (approximately 2016-2025), consistent with higher housing growth in Local Plans, reducing towards the end of the Local Plan periods (2030-2035). Population growth is higher thereafter as housing growth totals return to the trend evident in the ONS 2014-based projection.

3.87 For the six WRZs in combination, the plan-based forecast estimates a population growth of 2.1 million (21.5%) for the 2016-2045 plan period. In terms of properties, the plan-based forecast estimates a growth of 1.26 million (34.9%) over the same time-period. The growth across this period is shown in Figure 3-6.

Figure 3-6: Growth in population and properties, 2016-2045



3.88 The population and property growth forecasts are presented for each individual WRZ. The population of the London WRZ is forecast to increase by 1.58 million (20.9%) by 2045, with a total property growth of 0.99 million (36.3%).

3.89 The lowest percentage change in population is forecast for the smallest WRZ, Henley at 11.6%, with an associated property growth of 14.1%. The highest percentage growth is evident in the Guildford and Swindon and Oxfordshire (SWOX) WRZs at 27.5% and 27.4% respectively, with associated property growth of 33.6% and 34.3%. This growth is summarised in Table 3-10.

Table 3-10: Growth in population and properties for each WRZ, 2016-2045

WRZ	Total Population	Change in Population from Base Year				% Change in Population from Base Year to 2044/45
	2016/17	2019/20	2024/25	2029/30	2044/45	
London	7,595,624	246,205	562,497	733,487	1,584,089	20.9%
SWOX	1,021,824	62,121	134,637	182,091	279,508	27.4%
SWA	548,844	21,152	42,819	58,582	114,509	20.9%
Kennet Valley	401,735	16,666	37,731	49,905	76,506	19.0%
Guildford	160,186	4,909	14,426	24,605	44,019	27.5%
Henley	50,901	2,237	3,698	4,132	5,895	11.6%
Total	**9,779,115**	**353,289**	**795,807**	**1,052,801**	**2,104,527**	**21.5%**

WRZ	Total Properties	Change in Properties from Base Year				% Change in Properties from Base Year to 2044/45
	2016/17	2019/20	2024/25	2029/30	2044/45	
London	2,729,586	131,218	332,222	482,909	989,749	36.3%
SWOX	425,681	25,148	59,520	84,705	145,951	34.3%
SWA	205,640	9,339	20,717	30,318	61,080	29.7%
Kennet Valley	159,064	4,855	13,083	19,096	37,080	23.3%
Guildford	61,637	2,081	6,045	10,455	20,709	33.6%
Henley	21,292	508	875	1,290	3,011	14.1%
Total	**3,602,900**	**173,148**	**432,463**	**628,774**	**1,257,580**	**34.9%**

3.90 The evaluation of the level of uncertainty associated with these plan-based forecasts is a key component of the draft WRMP19 process. Section 5: Allowing for risk and uncertainty, considers this uncertainty, using UKWIR's technical guidance to inform the calculation of a Target Headroom allowance.

Long-term forecasts (2045-2100) – Trend-based

3.91 The plan-based forecasts provide a growth perspective to 2045. A second key component of our demand forecasting process has been the consideration of longer-term forecasts of population and property growth, with a horizon that stretches to 2100.

3.92 In the draft WRMP19, published in February 2018, population and property output from the University of Leeds' demographic forecasting model was used as the basis for the long-term growth outlook. Since completion of the draft WRMP19 the ONS has published a new 2016-

based, long-term projection, the first release of future population growth estimates since the Brexit referendum in June 2016.

3.93 To ensure alignment with the latest ONS evidence on the likely trajectory of growth during the second half of the 21st century, updated population and property forecasts for the WRZs have been formulated.

3.94 Whilst the core and long-term forecasts have used consistent methodologies, the long-term forecasts have been formulated using trend-based inputs and assumptions that are consistent with the ONS' 2016-based NPP; this contrasts to the housing-led approach used in the development of the core, 2016-2045 forecasts.

3.95 A summary of the long-term forecasting approach and analysis is provided here, with further detail and analysis provided in Appendix E: Population and property projections.

3.96 At the end of 2017, the ONS published a 2016-based 'national' population projection for the UK and its constituent countries. The Principal projection for the UK, estimates substantially lower population growth than each of its 2010-based, 2012-based and 2014-based predecessors. The UK's population is projected to increase to 83 million by 2100 under the 2016-based growth trajectory, compared to 91 million under the previous, 2014-based scenario. The lower rate of growth in the 2016-based scenario is driven by a combination of: lower international migration; lower fertility rates; and a slower rate of increase in life expectancy.

3.97 In addition to its 2016-based Principal projection, the ONS also published a number of variant UK national projections which consider alternative assumptions for future fertility, mortality and migration. A selection of the UK growth variants illustrates the impact of higher or lower levels of international migration. These international migration variants have provided the basis for the long-term scenario analysis for each of our WRZs. These scenarios have included the 2016-based fertility and mortality differentials applied to all local authority areas and assumptions on the long-term effect of domestic migration to and from London.

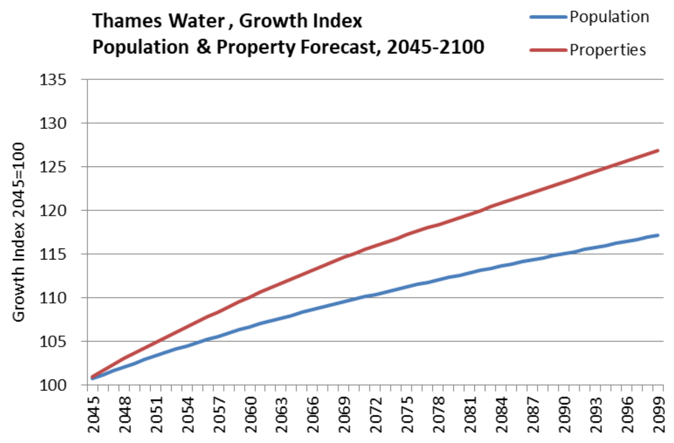
3.98 A total of seven variants of higher/lower international migration were presented, with a 'Principal-2016' scenario recommended for inclusion in the WRMP. Post-2045 this is driven by a UK net international migration total of approximately +165,000 per year, plus a domestic net migration outflow from London that reverts to pre-2007 levels over the course of the forecast period.

3.99 The UK's planned exit from the EU points towards lower rather than higher international migration, so the high-migration variants represent a less likely outcome for our WRZs over the long-term horizon. However, whilst lower international migration is a likely consequence of exit from the EU, the UK's economy will require a constant and ready supply of labour both from the UK and overseas.

3.100 For WRMP purposes, the 'Principal-2016' scenario presents an appropriate balance between the higher-growth scenario and the low migration options presented by the ONS.

3.101 A summary of the long-term population and property forecasts is presented below, in Figure 3-7, for the six WRZs in total, illustrating an *index* of growth over the 2045-2100 plan period.

Figure 3-7: Growth index, population and properties, 2045-2100



3.102 Population is forecast to grow by 2.04 million to 2100, a 17.1% rate of growth from 2045. Associated property numbers are forecast to grow by 1.3 million, a 26.8% growth rate from 2045.

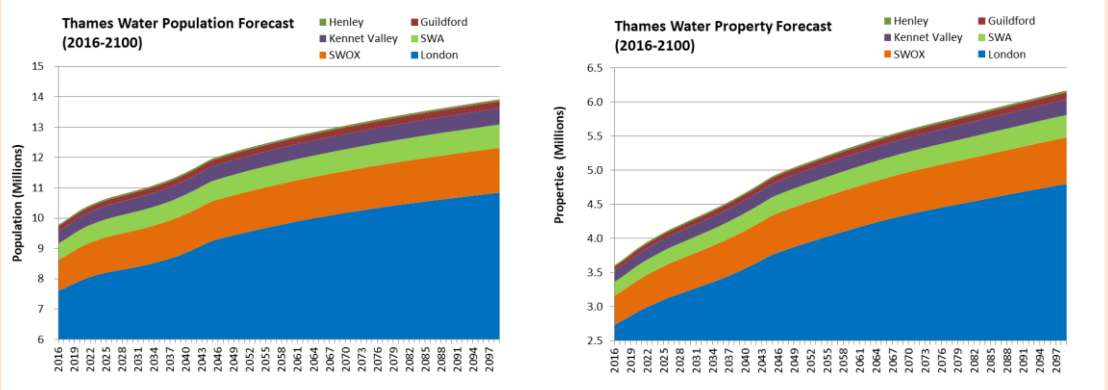
Final forecast

3.103 Evidence from the plan-based and long-term population and property forecasts have been used to inform our *final* forecast. The final forecast used to produce our baseline household demand forecast was calculated as follows:

- Both the plan-based forecast and the long-term trend forecast were converted to growth profiles
- The plan-based growth profile for the period from 2016 to 2045 was applied to our base year values for population and properties
- This has produced a forecast for populations and properties to 2045 which is based on the plan-based analysis completed by Edge Analytics
- Beyond 2045 the Principal-2016 projection, underpinned by key ONS long-term assumptions on growth, has been utilised
- The growth between 2045 and 2100 from Edge Analytics' Principal-2016 projection has been applied from the end of the plan-based forecast
- This extends the population and property forecasts to 2100.

3.104 A summary of the combined plan-based and long-term population and property forecasts is presented below, in Figure 3-8. For the six WRZs in combination, the forecast estimates a population growth of 4.14 million (42.3%) for the 2016-2100 plan period. In terms of properties, the forecast estimates growth of 2.56 million (71.1%) over the same time-period.

Figure 3-8: Growth in population and properties, 2016-2100



3.105 Growth by WRZ is illustrated in Table 3-11, providing an indication of population and property growth for the initial, plan-based horizon and for the longer-term, trend-based outlook to 2100.

Table 3-11: Growth in population and properties for each WRZ, 2016-2100

WRZ	Total Population	Change in Population from Base Year			% Change in Population from Base Year to:	
	2016/17	2044/45	2069/70	2099/100	2044/45	2099/2100
London	7,595,624	1,584,089	2,545,741	3,241,288	20.9%	42.7%
SWOX	1,021,824	279,508	357,072	460,410	27.4%	45.1%
SWA	548,844	114,509	167,337	220,443	20.9%	40.2%
Kennet Valley	401,735	76,506	99,949	132,995	19.0%	33.1%
Guildford	160,186	44,019	57,398	72,616	27.5%	45.3%
Henley	50,901	5,895	8,824	12,791	11.6%	25.1%
Total	**9,779,115**	**2,104,527**	**3,236,321**	**4,140,543**	**21.5%**	**42.3%**

WRZ	Total Properties	Change in Properties from Base Year			% Change in Properties from Base Year to:	
	2016/17	2044/45	2069/70	2099/100	2044/45	2099/2100
London	2,729,586	989,749	1,601,449	2,066,895	36.3%	75.7%
SWOX	425,681	145,951	192,349	256,414	34.3%	60.2%
SWA	205,640	61,080	91,172	123,453	29.7%	60.0%
Kennet Valley	159,064	37,080	50,770	70,795	23.3%	44.5%
Guildford	61,637	20,709	28,172	37,537	33.6%	60.9%
Henley	21,292	3,011	4,870	7,427	14.1%	34.9%
Total	**3,602,900**	**1,257,580**	**1,968,783**	**2,562,521**	**34.9%**	**71.1%**

3.106 The evaluation of the level of uncertainty associated with the combined plan-based and long-term forecasts is a key component of the revised draft WRMP19 process. Section 5: Allowing for risk and uncertainty, considers this uncertainty, using UKWIR's technical guidance to inform the calculation of a Target Headroom allowance.

Draft WRMP19 representations and new evidence

3.107 Following the submission of the draft WRMP19 in December 2017, we received formal feedback, both from regulatory bodies and from other stakeholder organisations. A number of points were raised with regard to the demographic evidence supporting the draft WRMP19, identifying the availability of new housing and demographic evidence and the need for us to compare the draft WRMP19 growth forecasts with this new evidence.

3.108 Since the draft WRMP19 was first submitted the ONS has published its 2016-based population projections, the first release of future SNPP growth estimates since the Brexit referendum in June 2016[10]. A new Draft London Plan[11] has advocated higher housing growth across the 33 London Boroughs over the next ten years, with demographic evidence to inform these new housing numbers provided by the GLA[12]. Finally, new Local Plan evidence has been published by local authorities outside London, with revisions to the housing growth trajectories that informed the core draft WRMP19 demographic forecasts.

3.109 In response to these specific points of representation we asked Edge Analytics to consider the new housing and demographic evidence in order to establish its comparability with our 'final forecast' presented above.

3.110 The full report on this review of evidence is provided in Appendix E: Population and property projections (Part C). A summary of the key components of the evidence is presented here.

Latest ONS evidence

3.111 Every two years, the ONS publishes its national and sub national population projections. The 2016-based NPP was released in October 2017[13]. The 2016-based suggests a *lower* rate of population growth than under the earlier NPPs, driven by assumptions on lower natural change (i.e. increased deaths and fewer births) and lower net international migration

3.112 In May 2018, the ONS released its 2016-based -S*NPP*s, providing a new suite of 'official' statistics for all local authority areas in England. These are 'trend' based projections, aligning to the NPP and do not take account of any planned trajectories of housing growth for individual local authorities. However, the 2016-based SNPPs provide an important benchmark against which to compare the 'core' Baseline scenario.

3.113 The latest 2016-based scenario evidence from the ONS has been considered alongside the Baseline scenario. ONS-2016 High and ONS-2016 Low scenarios have been formulated,

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10 https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/bulletins/subnationalpopulationprojectionsforengland/2016based

11 Mayor of London, December 2017. The London Plan: The spatial development strategy for Greater London (Draft for Public Consultation) https://www.london.gov.uk/what-we-do/planning/london-plan/new-london-plan

12 https://data.london.gov.uk/dataset/projections/

13 https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/bulletins/nationalpopulationprojections/2016basedstatisticalbulletin#quality-and-methodology

which consider the potential for higher or lower international migration growth over the 25-year projection horizon.

3.114 The analysis has also considered how the latest ONS assumptions on population growth influence the 'return-to-trend' assumptions, which are a key component of the plan-based scenarios for non-London local authorities over the second half of the core WRMP plan period, 2030-2045.

London Plan and GLA projections

3.115 In December 2017, the GLA published a draft update to the London Plan, setting out revised 10-year targets for net housing completions by Borough. Totalling approximately 64,935 homes per year over the 2019/20-2028/29 period, the new housing target is informed by an updated range of evidence, including 2016-based population and household projections, the 2017 Strategic Housing Market Assessment (SHMA) and 2017 Strategic Housing Land Availability Assessment (SHLAA) .

3.116 The latest GLA 2016-based growth projections include its 'Housing-led' scenario, informed by housing growth data drawn from the latest SHLAA for London. For all London Boroughs, the latest GLA housing-led scenario has been combined with updated Local Plan evidence from non-London local authorities, to produce a revised plan-based population and housing growth outcome for the London WRZ.

New Local Plans

3.117 In response to the draft WRMP19 representations, Local Plan housing evidence published since the Baseline forecast was formulated has been collected and reviewed. This process has focused only on those local authorities within the supply area (not the extended waste-water geography) which excluding the London Boroughs, represents a total of 31 local authorities.

3.118 The final report presented in Appendix E: Population and property projections (Part C) provides a comparison of previous and revised housing growth totals for the core 2016-2045 WRMP plan period and annual growth for 2016-2030 and 2030-2045.

3.119 The revised housing totals include a 'return-to-trend' assumption to estimate housing growth beyond each local authority's Local Plan horizon (typically from approximately 2030 onwards, although sometimes earlier). Housing totals used in the Baseline scenario, include a 'return-to-trend' assumption based on ONS 2014-based population projections. Updated housing totals presented for August 2018, include a 'return-to-trend' assumption based on ONS 2016-based population projections.

3.120 There are changes in the housing growth trajectories associated with individual local authorities but in total (taking account of both Local Plan and 'return-to-trend' evidence) the overall difference is just +225 in favour of the August 2018 evidence.

3.121 Generally the pattern is for higher housing growth in the 2016-2030 time period; reducing in 2030-2045 beyond the Local Plan horizons. With the ONS 2016-based projections generally resulting in lower growth than their 2014-based equivalents, the revised 'return-to-trend' assumptions will invariably result in a dampening of estimated housing growth for most local authorities beyond the end of each Local Plan period.

3.122 These new Local Plan housing trajectories in conjunction with the new ONS and London Plan / GLA evidence, have been used in the formulation of an updated Plan-based (August 2018) scenario.

Summarising the Evidence

3.123 In the new Plan-based (August 2018) scenario, population and property growth evidence from the GLA's 2016-based Housing-led projection has replaced the original London Borough forecasts from the Baseline scenario. Updated Local Plan evidence for non-London districts has provided the basis for a revised housing-led growth scenario in these areas. Additionally, the original 'return-to-trend' assumptions that were based on ONS 2014-based evidence and applied to all local authority areas where plan-based evidence was not available, have been replaced with equivalent ONS 2016-based assumptions for the non-London Boroughs.

3.124 Population growth profiles are presented for the supply area, in total, and for each individual WRZ. The Baseline scenario and the updated Plan-based scenario are illustrated alongside trend-based projections. The ONS 2016-based projection is presented alongside two variant 2016-based projections (ONS-2016 High and ONS-2016 Low). An ONS 2014-based scenario (ONS-2014) is included to illustrate how the official projections have altered in the latest round.

3.125 For the supply area, the latest evidence, presented in the Plan-based (August 2018) scenario estimates slightly higher population growth (22.8%) than the previous Baseline scenario (21.5%), and an additional +120,300 population (Table 3-12).

Table 3-12: Growth in population and properties for each All WRZs, 2016-2045

All WRZs	Total population		Change in population	
	2016/17	2044/45	Absolute	%
Baseline	9,779,115	11,883,642	2,104,527	21.5%
August 2018	9,779,115	12,003,988	2,224,874	22.8%

All WRZs	Total Properties		Change in Properties	
	2016/17	2044/45	Absolute	%
Baseline	3,602,900	4,860,480	1,257,580	34.9%
August 2018	3,602,900	4,770,650	1,167,750	32.4%

3.126 This higher population growth is achieved on a lower property growth total: 32.4% in the latest evidence, versus 34.9% in the Baseline scenario. The Plan-based (August 2018) scenario records higher property growth than the Baseline scenario in the first half of the core 2016-2045 WRMP plan period, but lower growth thereafter. This trend is a reflection of two key factors:

- Higher property growth totals in the new Draft London Plan and in the latest Local Plan statistics for non-London local authorities, both of which primarily relate to the period prior to 2030.

- Lower property growth totals associated with the GLA's Housing-led scenario for London Boroughs post-2030, plus lower property growth totals in non-London local authorities resulting from the dampened 'return-to-trend' assumptions to 2045.

3.127 Population projection evidence from the ONS has been considered alongside the Baseline and Plan-based (August 2018) scenarios. For the supply area in total, the Plan-based (August 2018) scenario follows a similar trajectory to the ONS-2014 projection. The ONS-2016 projection estimates lower overall population growth at just 16.5%, reflecting the lower international migration assumptions and the altered fertility and mortality outlook that are implied by this projection. The High and Low variants of the ONS-2016 projection, based on higher and lower international migration assumptions, suggest a growth range of 10.9%-22.1% by 2045 (1.1 million-2.2 million additional people), each lower than the Plan-based (August 2018) evidence.

3.128 The relationship between the scenarios varies by WRZ. The growth in the London WRZ drives the overall profile for the supply area, although its Plan-based (August 2018) scenario outcome is lower than the ONS-High, in contrast to all other WRZs. The new evidence and assumptions driving the Plan-based (August 2018) scenario result in an additional 110,000 population growth in the London WRZ compared to the Baseline scenario.

3.129 In the SWOX and Henley WRZs, the Plan-based (August 2018) scenario results in a higher population growth outcome than the Baseline scenario. The Plan-based (August 2018) and Baseline scenarios produce similar outcomes for the Kennet Valley WRZ, whilst the newer evidence suggests slightly lower growth in the Slough, Wycombe Aylesbury (SWA) and Guildford WRZs. In all non-London WRZs, the new Plan-based evidence exceeds the growth outcomes of the latest ONS trend scenarios.

Figure 3-9: Population growth summary: WRZ total

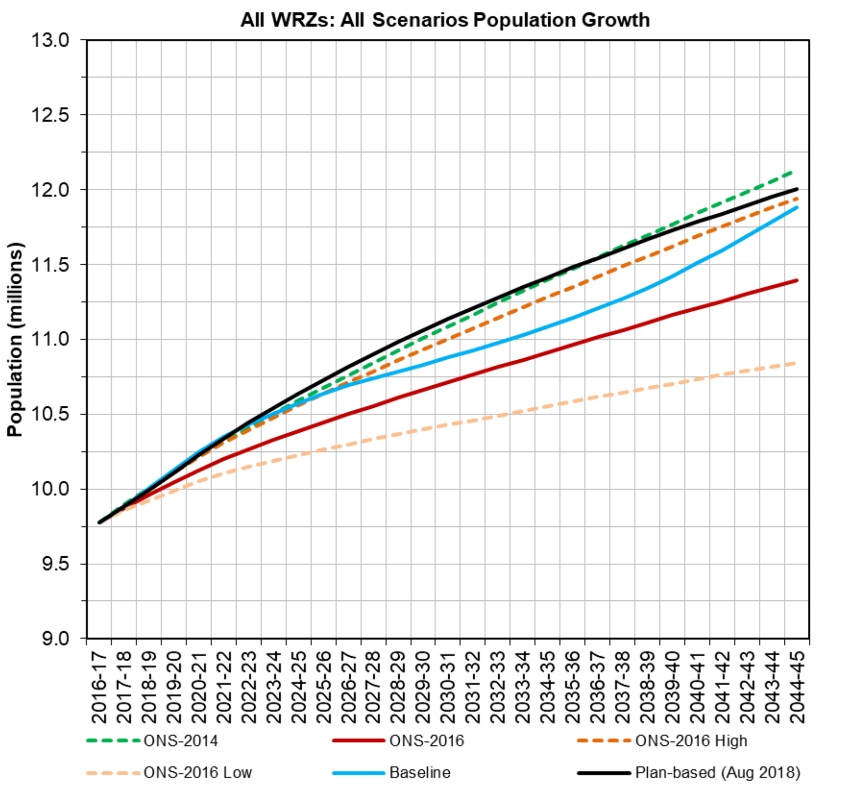


Table 3-13: Population growth summary: WRZ total

All WRZs	Total population		Change in population	
	2016/17	2044/45	Absolute	%
ONS-2014	9,779,115	12,130,067	2,350,953	24.0%
Plan-based (Aug 2018)	9,779,115	12,003,988	2,224,874	22.8%
ONS-2016 High	9,779,115	11,941,524	2,162,409	22.1%
Baseline	**9,779,115**	**11,883,642**	**2,104,527**	**21.5%**
ONS-2016	9,779,115	11,390,784	1,611,669	16.5%
ONS-2016 Low	9,779,115	10,843,156	1,064,041	10.9%

Figure 3-10: Population growth summary: London WRZ

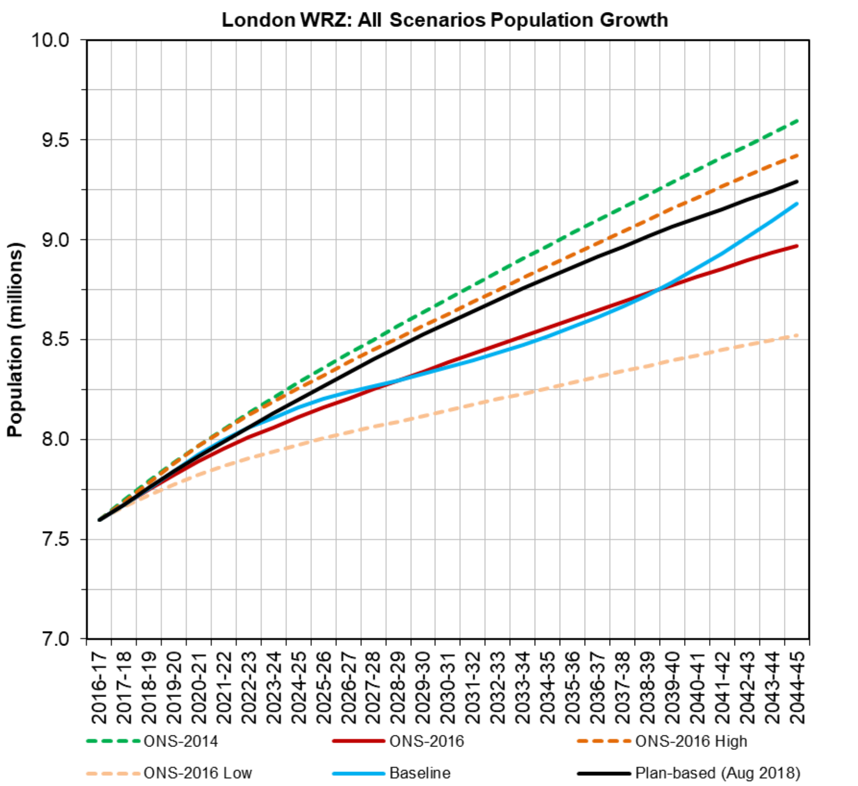


Table 3-14: Population growth summary: London WRZ

London WRZ	Total population		Change in population	
	2016/17	2044/45	Absolute	%
ONS-2014	7,595,624	9,593,722	1,998,098	26.3%
ONS-2016 High	7,595,624	9,422,978	1,827,354	24.1%
Plan-based (Aug 2018)	7,595,624	9,289,686	1,694,062	22.3%
Baseline	**7,595,624**	**9,179,714**	**1,584,089**	**20.9%**
ONS-2016	7,595,624	8,970,567	1,374,943	18.1%
ONS-2016 Low	7,595,624	8,520,185	924,561	12.2%

Figure 3-11: Population growth summary: SWA WRZ

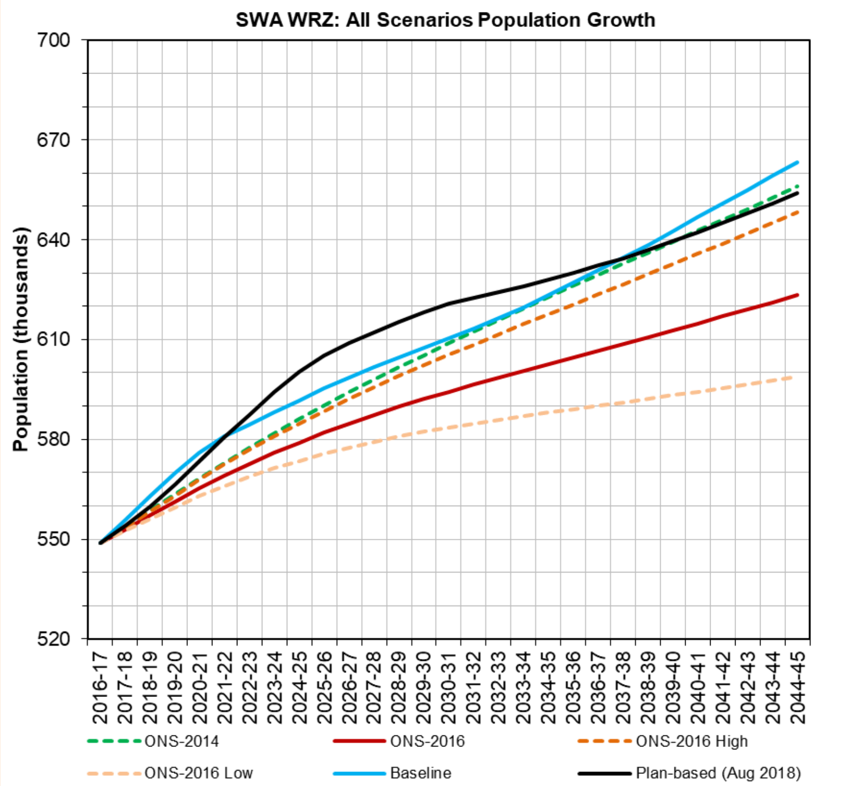


Table 3-15: Population growth summary: SWA WRZ

SWA WRZ	Total population		Change in population	
	2016/17	**2044/45**	**Absolute**	**%**
Baseline	**548,844**	**663,353**	**114,509**	**20.9%**
ONS-2014	548,844	655,950	107,106	19.5%
Plan-based (Aug 2018)	548,844	654,035	105,191	19.2%
ONS-2016 High	548,844	648,113	99,269	18.1%
ONS-2016	548,844	623,372	74,528	13.6%
ONS-2016 Low	548,844	598,948	50,104	9.1%

Figure 3-12: Population growth summary: SWOX WRZ

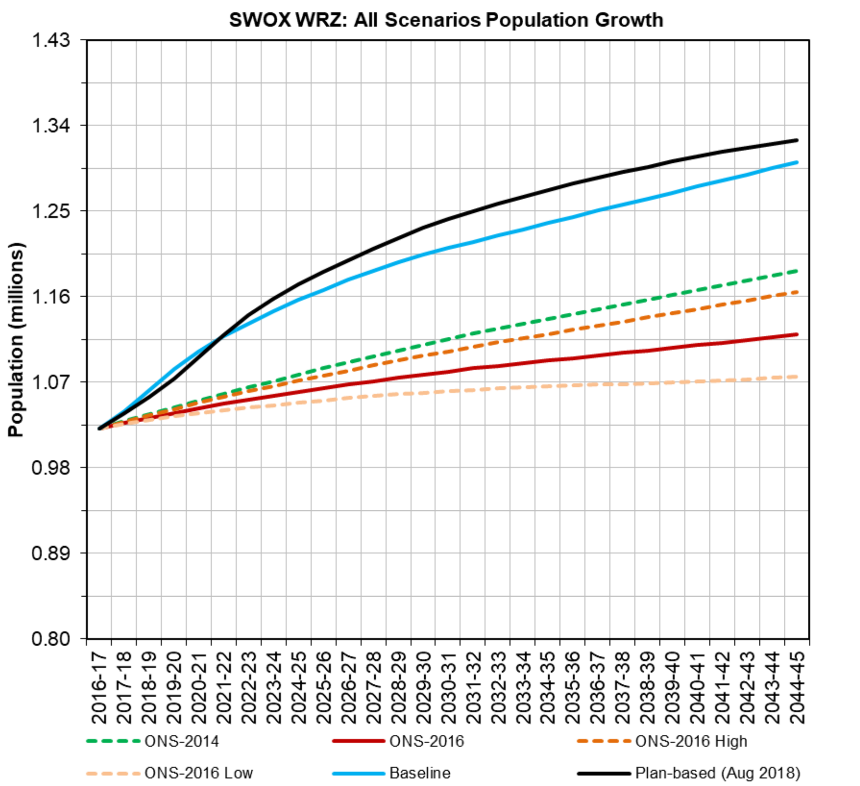


Table 3-16: Population growth summary: SWOX WRZ

SWOX WRZ	Total Population		Change in Population	
	2016/17	**2044/45**	**Absolute**	**%**
Plan-based (Aug 2018)	1,021,824	1,324,389	302,564	29.6%
Baseline	**1,021,824**	**1,301,332**	**279,508**	**27.4%**
ONS-2014	1,021,824	1,186,855	165,031	16.2%
ONS-2016 High	1,021,824	1,165,421	143,597	14.1%
ONS-2016	1,021,824	1,120,320	98,496	9.6%
ONS-2016 Low	1,021,824	1,075,615	53,790	5.3%

Figure 3-13: Population growth summary: Guildford WRZ

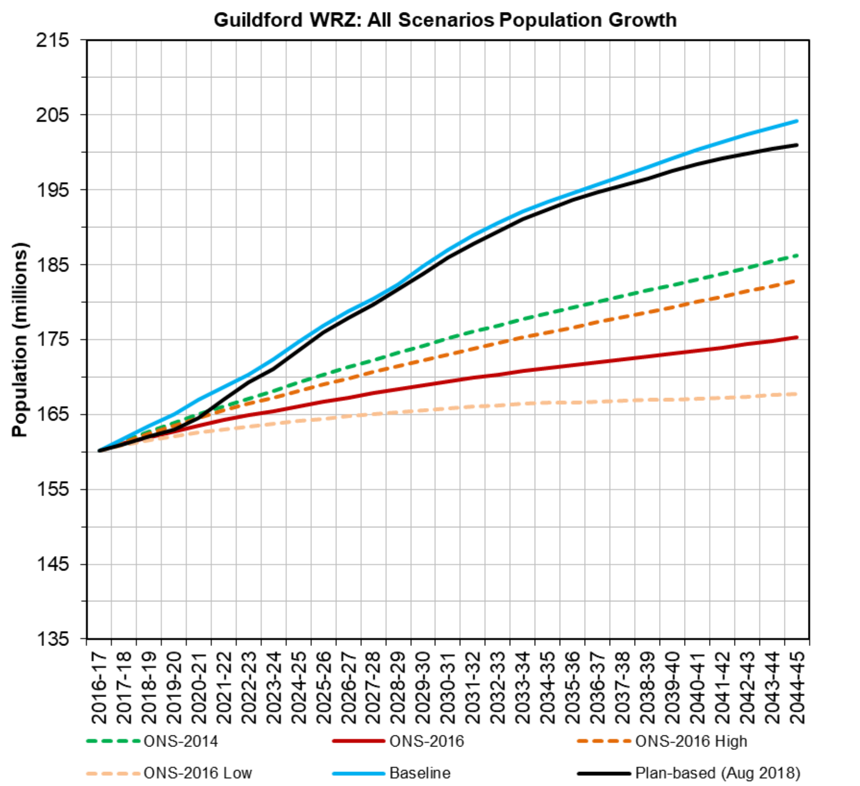


Table 3-17: Population growth summary: Guildford WRZ

Guildford WRZ	Total population		Change in population	
	2016/17	2044/45	Absolute	%
Baseline	**160,186**	**204,205**	**44,019**	**27.5%**
Plan-based (Aug 2018)	160,186	200,952	40,766	25.4%
ONS-2014	160,186	186,181	25,996	16.2%
ONS-2016 High	160,186	182,889	22,703	14.2%
ONS-2016	160,186	175,278	15,092	9.4%
ONS-2016 Low	160,186	167,717	7,531	4.7%

Figure 3-14: Population growth summary: Kennet Valley WRZ

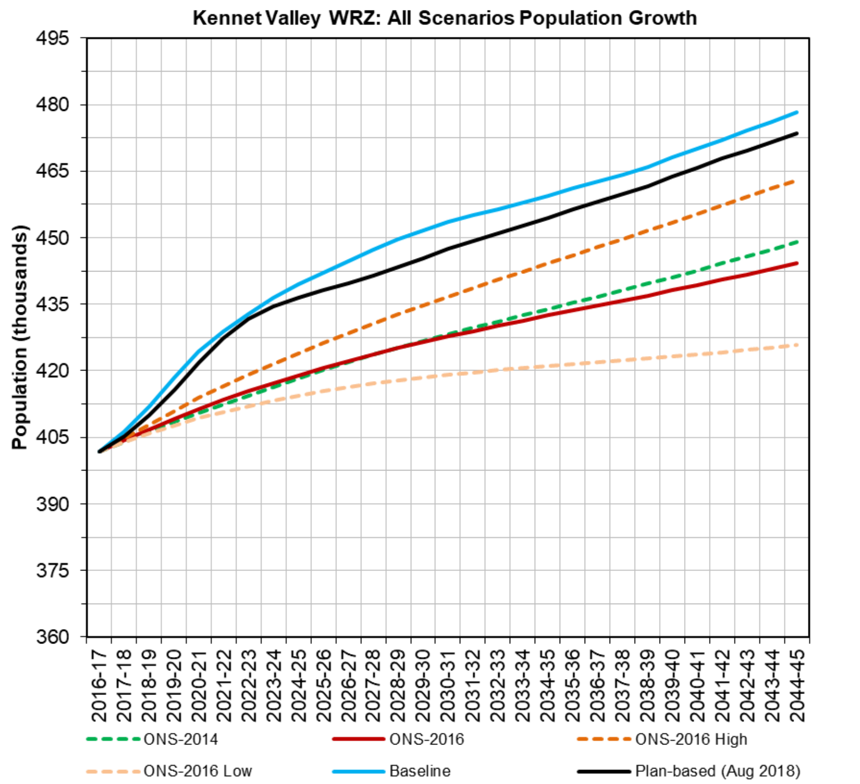


Table 3-18: Population growth summary: Kennet Valley WRZ

Kennet Valley WRZ	Total population		Change in population	
	2016/17	2044/45	Absolute	%
Baseline	**401,735**	**478,241**	**76,506**	**19.0%**
Plan-based (Aug 2018)	401,735	473,456	71,721	17.9%
ONS-2016 High	401,735	462,978	61,243	15.2%
ONS-2014	401,735	449,032	47,297	11.8%
ONS-2016	401,735	444,228	42,492	10.6%
ONS-2016 Low	401,735	425,776	24,041	6.0%

Figure 3-15: Population growth summary: Henley WRZ

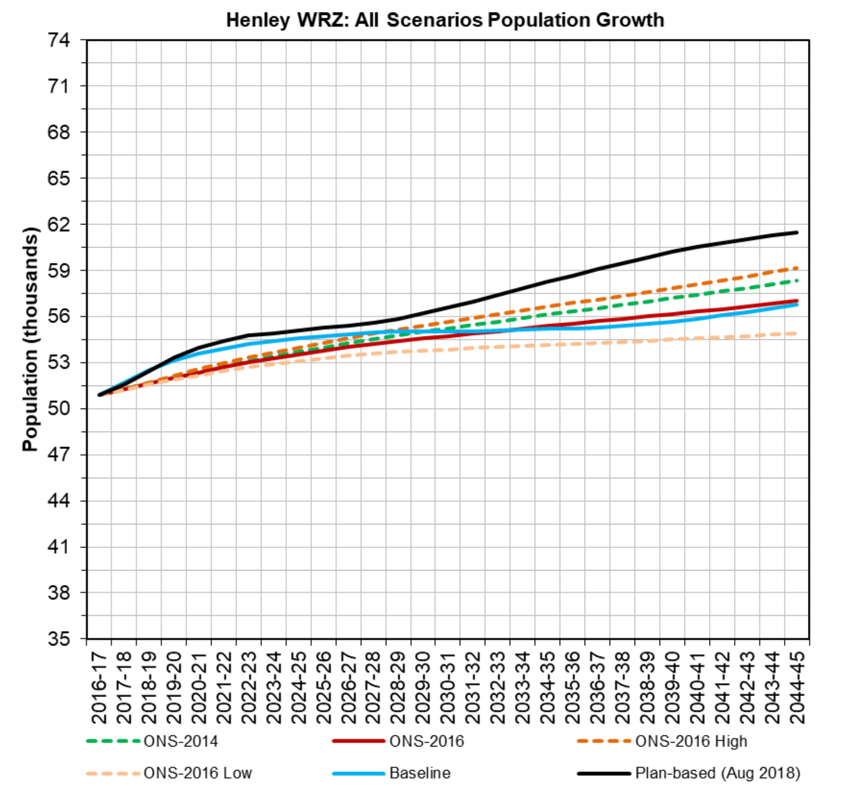


Table 3-19: Population growth summary: Henley WRZ

Henley WRZ	Total population		Change in population	
	2016/17	**2044/45**	**Absolute**	**%**
Plan-based (Aug 2018)	50,901	61,471	10,570	20.8%
ONS-2016 High	50,901	59,145	8,244	16.2%
ONS-2014	50,901	58,327	7,426	14.6%
ONS-2016	50,901	57,019	6,118	12.0%
Baseline	**50,901**	**56,796**	**5,895**	**11.6%**
ONS-2016 Low	50,901	54,914	4,013	7.9%

Measured and unmeasured property forecasts

3.130 Now that we have a total population and property forecast for each WRZ we look to disaggregate this to produce estimates for measured and unmeasured household properties, and measured, unmeasured and non-household populations for the baseline forecast.

3.131 The first stage in this process is to calculate the change in measured and unmeasured households each year which is done using simple arithmetic.

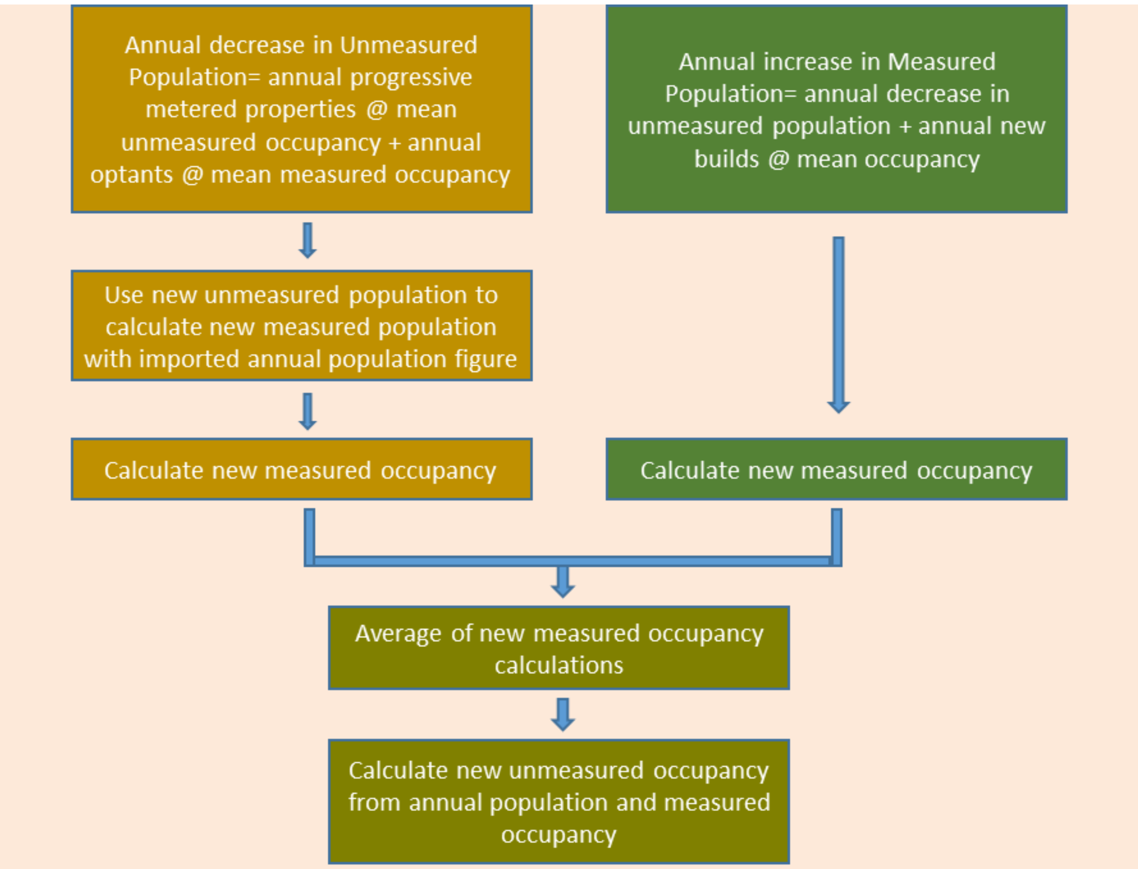
3.132 The increases in the total number of household properties each year is attributable to new households being built and, as all new household properties have a meter, these are added to the measured category.

3.133 The effects of metering are also accounted for. The total of optant and progressive meters are calculated for each year and this number is subtracted from the unmeasured household category and added to the measured household category.

3.134 These simple calculations allow us to produce household property forecasts segmented by their metering status.

3.135 The calculation of populations for metered and unmetered properties is more complex. Forecasts of population are not available for measured and unmeasured property types and therefore are required to be calculated. An algorithm, shown in Figure 3-16, to forecast the changing occupancy for measured and unmeasured population as metering progresses has been developed. This algorithm is initiated by calculating the change in population expected from shifts in metering status and new build properties for both measured and unmeasured populations. These are then used with forecast population changes to reconcile the two calculations against total population on an annual basis. Figure 3-16 shows how this algorithm calculates these values.

Figure 3-16: Occupancy recalculation algorithm



3.136 The calculated occupancy can then be multiplied by the total number of households in each segment giving a total population value for each. Population totals for each segment and their associated occupancy are shown in Table 3-20. Now we have forecasts of properties and population for each WRZ and each segment this information can now be used in the production of demand forecasts.

Table 3-20: Population, properties and average occupancy forecasts for each WRZ (baseline)

WRZ	Parameter	Type	2016/17	2019/20	2024/25	2029/30	2044/45	2069/70	2099/2100
London	Population (000s)	Measured	2,368,703	3,243,969	3,820,970	4,251,849	5,754,967	7,694,249	9,433,457
		Unmeasured	5,226,922	4,597,860	4,337,151	4,077,262	3,424,747	2,447,117	1,403,456
		Non Household	51,443	52,434	55,201	58,649	74,688	102,642	129,122
	Properties (000s)	Measured	912,337	1,245,432	1,502,105	1,708,461	2,382,308	3,272,353	4,071,813
		Unmeasured	1,817,250	1,615,373	1,559,704	1,504,035	1,337,028	1,058,683	724,669
	Occupancy	Measured	2.60	2.60	2.54	2.49	2.42	2.35	2.32
		Unmeasured	2.88	2.85	2.78	2.71	2.56	2.31	1.94
		Overall	2.78	2.74	2.66	2.59	2.47	2.34	2.26
SWOX	Population (000s)	Measured	585,481	664,365	771,289	854,607	1,063,930	1,233,050	1,355,299
		Unmeasured	436,344	419,581	385,172	349,308	237,402	145,847	126,935
		Non Household	32,589	33,110	34,271	35,774	40,717	46,059	52,145
	Properties (000s)	Measured	273,437	304,042	351,874	390,533	492,202	573,632	637,698
		Unmeasured	152,244	146,787	133,327	119,853	79,431	44,398	44,398
	Occupancy	Measured	2.14	2.19	2.19	2.19	2.16	2.15	2.13
		Unmeasured	2.87	2.86	2.89	2.91	2.99	3.29	2.86
		Overall	2.40	2.40	2.38	2.36	2.28	2.23	2.17
SWA	Population (000s)	Measured	247,666	282,045	327,001	366,610	491,620	636,759	701,676
		Unmeasured	301,178	287,951	264,662	240,816	171,733	79,422	67,611
		Non Household	5,281	5,491	5,896	6,422	8,331	11,076	13,915
	Properties (000s)	Measured	106,686	119,271	138,656	156,273	211,081	274,838	307,119
		Unmeasured	98,954	95,707	87,701	79,686	55,639	21,974	21,974
	Occupancy	Measured	2.32	2.36	2.36	2.35	2.33	2.32	2.28
		Unmeasured	3.04	3.01	3.02	3.02	3.09	3.61	3.08

WRZ	Parameter	Type	2016/17	2019/20	2024/25	2029/30	2044/45	2069/70	2099/2100
		Overall	2.67	2.65	2.61	2.57	2.49	2.41	2.34
Kennet Valley	Population (000s)	Measured	189,855	212,623	247,545	275,301	353,346	430,066	470,219
		Unmeasured	211,881	205,778	191,921	176,339	124,895	71,618	64,511
		Non Household	6,791	6,910	7,203	7,581	8,902	10,540	12,187
	Properties (000s)	Measured	87,337	94,711	109,151	121,383	158,023	192,858	212,883
		Unmeasured	71,727	69,208	62,996	56,777	38,120	16,976	16,976
	Occupancy	Measured	2.17	2.24	2.27	2.27	2.24	2.23	2.21
		Unmeasured	2.95	2.97	3.05	3.11	3.28	4.22	3.80
		Overall	2.53	2.55	2.55	2.54	2.44	2.39	2.33
Guildford	Population (000s)	Measured	73,423	81,918	97,411	113,838	153,704	192,645	211,422
		Unmeasured	86,763	83,178	77,201	70,952	50,501	24,939	21,379
		Non Household	7,468	7,535	7,704	7,905	8,588	9,682	10,928
	Properties (000s)	Measured	32,506	35,566	41,946	48,775	66,284	83,421	92,786
		Unmeasured	29,131	28,151	25,736	23,317	16,062	6,388	6,388
	Occupancy	Measured	2.26	2.30	2.32	2.33	2.32	2.31	2.28
		Unmeasured	2.98	2.95	3.00	3.04	3.14	3.90	3.35
		Overall	2.60	2.59	2.58	2.56	2.48	2.42	2.35
Henley	Population (000s)	Measured	28,562	31,141	33,736	35,881	43,099	49,023	53,885
		Unmeasured	22,339	21,997	20,863	19,152	13,697	10,702	9,807
		Non Household	271	324	429	542	896	1,248	1,618
	Properties (000s)	Measured	14,226	15,014	16,071	17,177	20,971	23,936	26,492
		Unmeasured	7,066	6,786	6,096	5,405	3,332	2,226	2,226
	Occupancy	Measured	2.01	2.07	2.10	2.09	2.06	2.05	2.03
		Unmeasured	3.16	3.24	3.42	3.54	4.11	4.81	4.41
		Overall	2.39	2.44	2.46	2.44	2.34	2.28	2.22

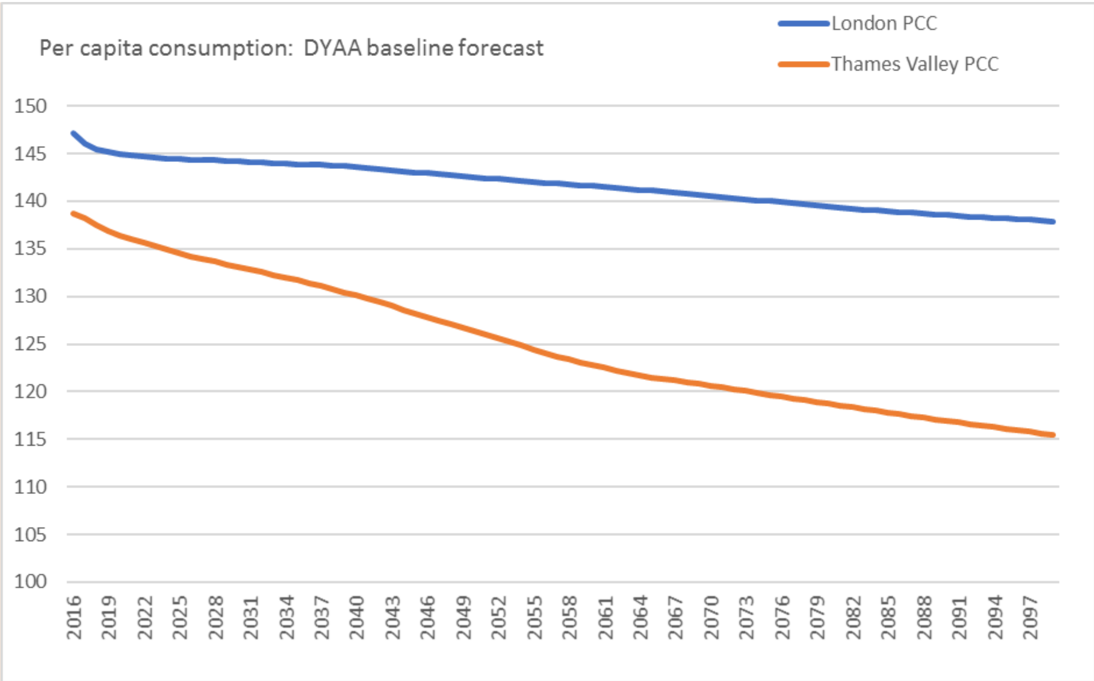
D. Household water use

Introduction

3.137 For the draft WRMP19 we developed a forecast for household consumption that shows baseline PCC across the region declining from the base year through to 2100. This is illustrated in Figure 3-17. The figure presents the DYAA PCC for the London region and for the remaining WRZs (collectively referred to as 'Thames Valley'). From the figure we can see that the projections for average PCC for the two regions are different, with the London region starting with a higher PCC that reduces at a lower rate than the PCC for the Thames Valley region. The difference in scale and trend in PCC in the London region is due to a number of factors:

- Lower metering penetration, London has only 33% metering penetration in the base year compared to ~59% for Thames Valley
- The larger proportion of rented properties results in less interest in water saving. Tenants are also reluctant to change fittings or install water efficiency devices as it is not their property
- There is a larger number of Indian, Pakistani and Bangladeshi households in London compared to most of our other areas. Indian, Pakistani and Bangladeshi households have been observed to have significantly higher usage than other households and these differences are thought to be cultural. This in combination with London's lower metering penetration results in higher PCC
- The higher proportion of flats within London also results in few opportunities for saving water due to lack of garden usage

Figure 3-17: Overview of household consumption forecasting process



3.138 The household consumption forecasts for both regions have been developed using multiple linear regression models. This is a different approach to the forecast developed for WRMP14, when the forecast was developed using micro-component models. Updating of the industry best practice for household demand forecasting[14], introduced the option to select from a range of forecasting methods based on an analysis of the planning challenges in each WRZ.

3.139 After careful consideration and peer review, we decided to move to a forecasting method based on multiple linear regressions for all WRZs. The detailed reasons for this are explained below and in Appendix F: Household water demand modelling, but in summary:

- the forecasts could be built on good quality historic household consumption
- the availability of demographic and housing type data from across the Thames Water region
- the models are based on demographic and housing factors that are known to influence household consumption
- the models could be constructed using standard statistical method that allow the robustness and uncertainties of the models to be quantified
- the models could be validated using historic and regional data

3.140 The sections below provide an overview of the modelling approach and each of the steps in the process for developing the household demand forecasts, shown in Figure 3-18, and further detailed explanation is included in Appendix F: Household water demand modelling.

[14] UKWIR 2015 WRMP19 Methods – Household Consumption Forecasting 15/WR/02/9

Demand forecasting model

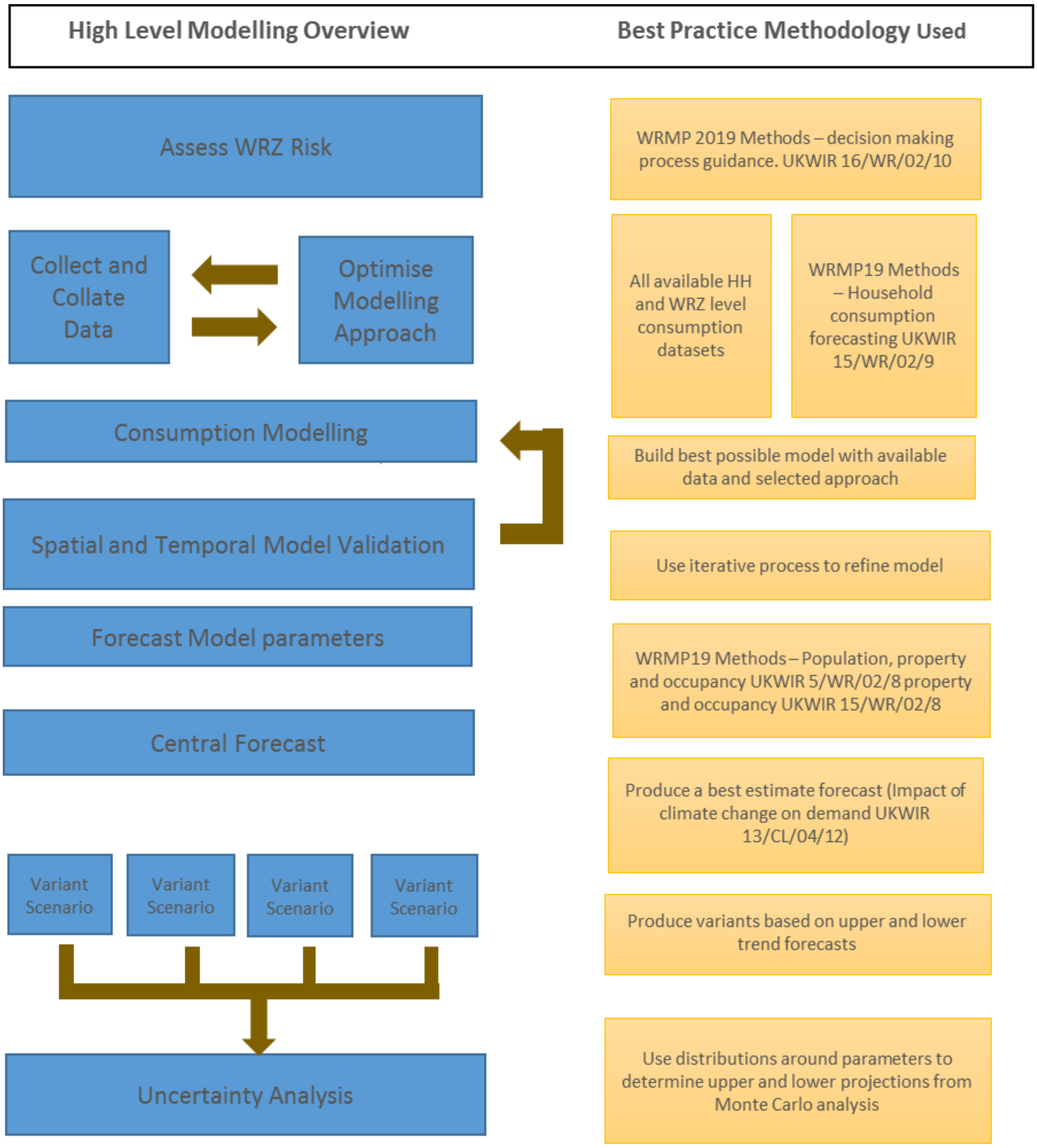
3.141 For the draft WRMP19 we have developed a new model for the purposes of forecasting future household consumption.

3.142 In line with the methods set out by "WRMP19 Methods – Household Consumption Forecasting" we have developed a household consumption model. We tasked Artesia Consulting with developing and delivering a model to produce a baseline household consumption forecast, which could be projected forward to the year 2100.

3.143 We are required to use the most appropriate forecasting method for household consumption in each of our WRZs. This identified that the London WRZ required a bespoke model due to the importance of this area. Separating the Thames Valley dataset from the London modelling mitigated the risk of potentially skewing the model for the largest area (London) by the five Thames Valley WRZs.

3.144 The high level modelling process used to develop the model is shown in Figure 3-18.

Figure 3-18: Overview of household consumption forecasting process



3.145 Section 5 of the WRPG describes the approaches that water companies should take to forecast demand, including household consumption. In particular, section 5.4 of the guidelines states that:

> *'You should select demand forecasting methods appropriate to the data available and the supply-demand situation in individual WRZ'.*

3.146 To identify the most appropriate method for forecasting household consumption we need to consider how the differing options address the regulatory, business, stakeholder and risk requirements so that it provides a sound foundation for our draft WRMP19.

3.147 The first stage is to determine in water resource planning terms, the planning challenges that exist, how they differ between WRZs, the length of forecast required, what data is available and which method or methods will be most suitable for the household consumption forecast.

3.148 The draft outputs from the UKWIR 'Decision making process' framework[15] were used to characterise the water resources planning challenge in each of our WRZs, as shown in Table 3-21. More information on problem characterisation of our WRZs can be found in Appendix D: Water resource zone integrity.

Table 3-21: Problem characterisation based on WRMP14

Zone	Problem characterisation
London	High
SWOX	High
SWA	Medium
Kennet Valley	Low
Guildford	Low
Henley	Low

3.149 The UKWIR household consumption forecasting guidance identifies the following methods for forecasting household consumption:

- Use existing study data
- Trend based models
- Per-capita methods
- Variable flow methods
- Major consumption groups
- Micro-components
- Regression models
- Proxies of consumption
- Micro-simulation

3.150 A full review of these methods can be found in the UKWIR Household consumption forecasting guidance.

3.151 The following criteria, shown in Table 3-22, were developed in the UKWIR consumption forecasting guidance to assess the forecasting methods.

[15] WRMP 2019 Methods – decision making process guidance. UKWIR. 2016. Ref: 16/WR/02/10

Table 3-22: Criteria for evaluation consumption forecasting methods

Criteria	Comment
Acceptance by stakeholders	The method should stand up to scrutiny from the regulators and other external stakeholders, including customers.
Explicit treatment of uncertainty	The method should recognise that there will be uncertainty around the forecast, and should quantify the level of uncertainty.
Underpinned by valid data	The method should be based on data that is valid for the area under consideration.
Transparency and clarity	The method needs to be understood and should be able to be replicated by others.
Appropriate to level of risk	The method should be appropriate in terms of cost and data requirements for the planning problem being addressed; i.e. the degree of vulnerability to a supply demand deficit.
Logical and theoretical approach	The method should command confidence to practitioners and decision makers. It should address those factors that people believe drive water demand, and it should be relevant to historical trends.
Empirical validation	The method should enable comparison to outturns or past projections. It should be possible to test the method on past data to predict demand, and predict any explanatory factors used in the forecast.
Explicit treatment of factors that explain household consumption	The method should be able to take account of the different factors which drive household demand, and different segments of consumers with respect to household water use.
Flexibility to cope with new scenarios	The method should be flexible enough to run different household consumption forecasts.

3.152 UKWIR best practice guidance for forecasting household consumption recommends the use of a Red Amber Green (RAG) matrix to identify the most suitable consumption forecasting methodologies. These are presented in Appendix F: Household water demand modelling for WRZs with High, Medium and Low problem characterisations.

3.153 The analysis of the RAG matrices showed that regression models scored highly across all levels of problem characterisation. Major consumption group (MCG) modelling generally came second, although for the low vulnerability zones, this was a marginal second place and MCG modelling could potentially be used in these zones.

3.154 However, there is a benefit in terms of consistency and efficiency of analysis if a single robust method for forecasting consumption across all WRZs is used. It also allows spatial validation and residual analysis of the model across WRZ’s which proved instrumental in model development. Therefore multiple linear regression (MLR) modelling was chosen as the method to be used for all six of our WRZs.

3.155 A range of potential data sources were identified at the start of the project, shown in Table 3-23.

Table 3-23: Potential data sources

UKWIR customer behaviour study	New data from smart meters
Market transformation programme	Thames Water research and development studies
DWUS	Smarter Home Visit data – skewed dataset. Water efficiency visits
VMR and meter trial data	Wastage study
Peak factors study	Multi faith water use studies
Micro-component studies	

3.156 Potential sources of data were identified and discussed with Artesia Consulting. The following data sets were considered to be the most useful due to the demographic information captured, sample size and amount of historic data:

- The DWUS:
  - Largest number of demographics
  - Representative sample
  - Consumption data from multiple zones
  - Large sample size
  - 10 year timeline
  - Data fairly new at six months old.
- Smarter home visits:
  - Good sample size
  - Average quality consumption values.
  - Smart metering data:
  - Useful for checking range of data (per household consumption and leakage) against DWUS.

3.157 Of these, the DWUS data was likely to be most useful as it:

- Contained a representative sample of our household customers due to the way in which the sample was derived.
- Included a long-period of quality checked consumption data;
- Provided information on individual properties; and
- Collected annual survey data on their occupants, and the ownership and frequency of use of water using devices.

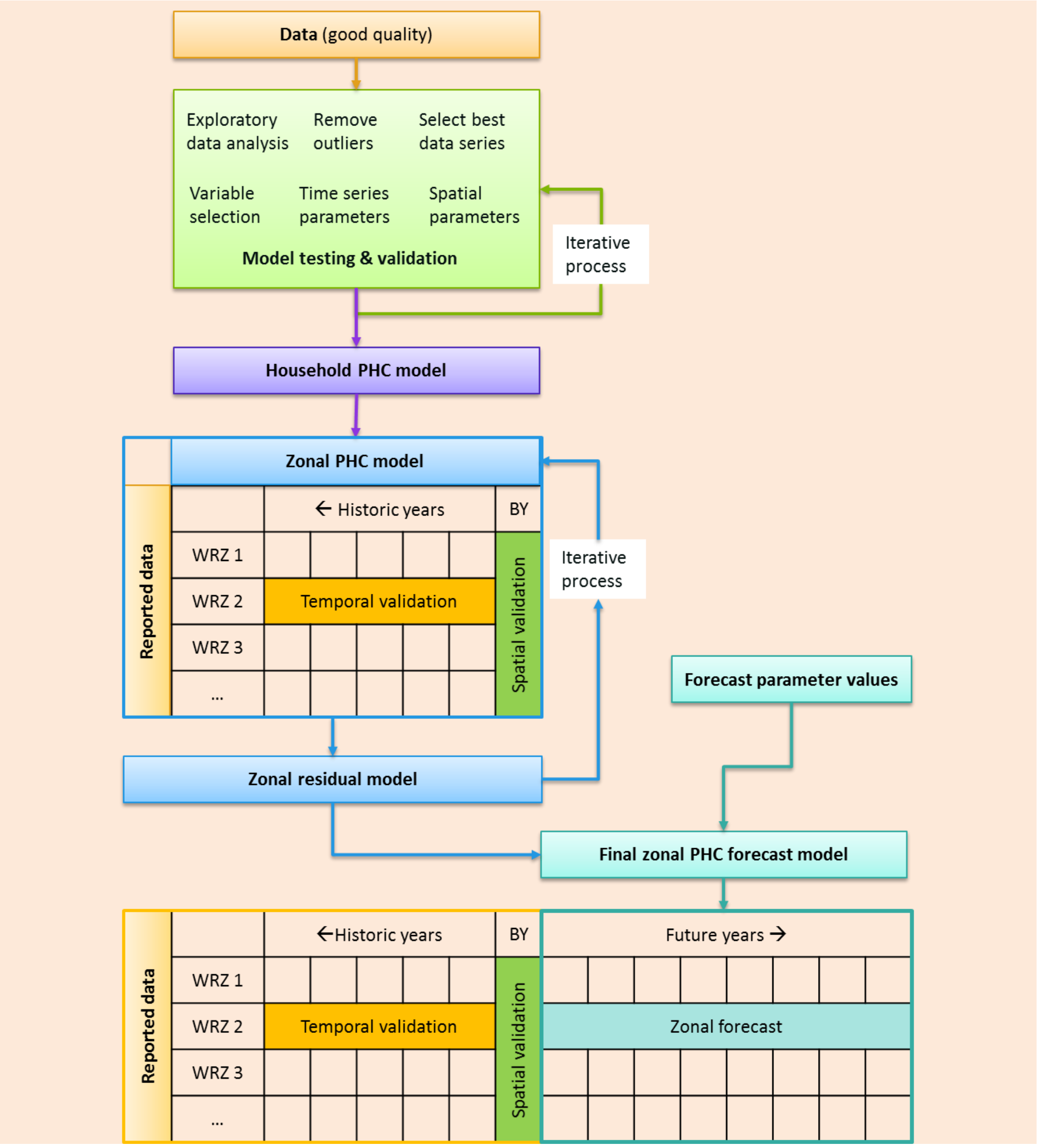
3.158 Therefore, the DWUS data became the principal focus of analysis for this project.

3.159 For the previous three WRMPs we used a micro-component modelling approach. The switch to a different method places a greater emphasis on validation of the new model. It is not possible to directly compare the outputs between the previous micro-component model and the new approach. Therefore, we have validated the MLR models using three different approaches:

1) The models are constructed using standard statistical methods from which the uncertainty can be quantified.
2) Temporal validation by using historic data as a model input and forecasting forwards to the current year. The outputs can then be compared with reported figures.
3) Spatial validation by applying the model to approximately 240 sub-zones across the Thames Water region and comparing with reported data. This is a level of validation that could not be carried out with previous micro-component based models.

3.160 Development of a MLR based model is a long and complicated process, therefore, only an outline of process is given here. However full details of the development can be found in Appendix F: Household water demand modelling. The process is summarised in Figure 3-19.

Figure 3-19: MLR household demand modelling and forecasting process



3.161 A more detailed description of the Figure 3-19 is described in the following steps:

1) **Obtain data** and explanatory variables from the Water Company.
2) **Select data** with which to build the model, based on:
    - Sample size – sample needs to be sufficiently large so that extremes of the distribution can be modelled
    - Amount of historic data – long term availability of data is important for modelling trends, calibrating the base year against annual weather effects and for testing data stability
    - Representativeness of population – does the sample adequately reflect the characteristics of the population it is trying to model?
    - Number of explanatory variables – is there a sufficient amount of demographic data collected at household level?
    - Age of data – has the data been recently collected, and could external drivers have caused bias in the data since its collection?
3) **Exploratory data analysis** on the selected data set, to determine:
    - The presence of outliers and how to deal with them
    - The distributions of the data, specifically the response variable
    - If missing values are present, and how to deal with them
    - The presence and removal of duplicate observations
4) **Selection of variables** for inclusion within the model. Once the data has been analysed, and outliers and missing data are removed, both automatic and manual variable selection techniques, e.g. stepwise selection, are performed to identify variables which are significant in the model build
5) **Identify variables which can be forecast,** and remove other variables from the model. It is likely that the 'ideal' model includes variables which cannot be forecast into the future, for example dishwasher usage. Therefore, a secondary version of the model is created which includes all significant parameters which can be forecast into the future
6) **Test model assumptions** and validate the usage of MLR modelling. Using MLR requires that the data be tested for:
    - A linear relationship between the response variable and the explanatory variable. This is verified by analysing a plot of the residuals versus the fitted points
    - The expectation of the error term is zero for all observations, i.e. $\mathbb{E}(\varepsilon_i) = 0$ for all i
    - Homoscedasticity – the variance of the error term is constant across the variables and over time. A plot of the standardised residuals versus the predicted values can show whether the points are equally distributed or not. If the variance is not constant, then the model uncertainty will vary for different observations leading to heteroscedasticity

- No multicollinearity, which assumes that the explanatory variables are not highly correlated with one another. Again, this can be determined using the standard residuals as well as looking at variance inflation factors

7) **Model testing and validation** at household level, by way of coefficient resampling, and cross validation
8) **Aggregate model to zonal level** so that zonal consumption figures can be derived as per the WRMP requirements
9) **Zonal model validation,** similar to the household level validation, but using zonal reported figures. Again this is done using cross validation by excluding data by time period (years) and by zone to test the model spatially and temporally
10) **Residual analysis** to determine if other factors which cannot be considered at household level (such as weather or climate effects) can be incorporated into a secondary model which will act upon the initial outputs
11) **Trends and scenarios** are finally applied to the forecast based on the most likely scenarios for future behavioural and technological changes
12) **Uncertainty** calculations are performed on the final forecast to give a 95% confidence interval for future predictions

3.162 The resulting model has a number of model variables; each has a coefficient that is derived from the model and there is a residual error term. The residual is essentially the consumption component that cannot be explained by the model variables. Residuals are used for estimating error and developing further modelling refinements.

Final unmeasured household model

3.163 Following a thorough analysis of model parameters, their interaction with other explanatory variables and their ability to be forecast, the final model is given below.

$$Consumption = \alpha + \beta x_1 + \gamma x_2 + \boldsymbol{\delta} x_3 + \boldsymbol{\eta} x_4 + \upsilon x_5 + \varepsilon$$

where:

x_1 Number of adults
x_2 Number of children
x_3 South Asian Ethnic Group flagged property type flag; either Semi-detached, terraced, flats, flat block or detached
x_4 Non-IBP flagged property type flag; either Semi-detached, terraced, flats or flat block
x_5 Rateable value (RV)

and the coefficients:

α Intercept
β Number of adults
γ Number of children
$\boldsymbol{\delta}$ Vector of coefficients for South Asian Ethnic Group property types; Semi-detached, terraced, flats, flat block and detached. The appropriate coefficient is used dependent on the value of x_3
$\boldsymbol{\eta}$ Vector of coefficients for South Asian Ethnic Group property types; Semi-detached, terraced, flats, flat block and detached. The appropriate coefficient is used dependent on the value of x_4
υ Rateable value (RV)
ε Error term

3.164 These parameters are the same for both the London and Thames Valley data sets.

3.165 The coefficients of the final model are shown in Table 3-24.

Table 3-24: Final model output and coefficients

Residuals:	Minimum	1Q	Median	3Q	Maximum
	-1479	-104	-26	74	1440

Coefficients:	Litres/prop/day	Standard error	T value	P-Value	Rating
(Intercept)	52.32	10.35	5.06	0.0000	***
Number of adults	102.73	1.92	53.41	0.0000	***
Number of children	73.68	1.85	39.90	0.0000	***
Non South Asian Ethnic Group Semi-detached	-21.62	6.72	-3.22	0.0013	**
Non-South Asian Ethnic Group Terraced	-11.23	6.83	-1.65	0.0999	.
Non-South Asian Ethnic Group Flat	-47.92	7.94	-6.04	0.0000	***
Non-South Asian Ethnic Group Flat block	-18.24	8.05	-2.27	0.0234	*
South Asian Ethnic Group Detached	262.77	18.69	14.06	0.0000	***
South Asian Ethnic Group Semi-detached	88.04	15.29	5.76	0.0000	***
South Asian Ethnic Group Terrace	316.89	11.83	26.78	0.0000	***
South Asian Ethnic Group Flat	-59.34	20.49	-2.90	0.0038	**
South Asian Ethnic Group Flat block	-0.43	19.60	-0.02	0.9825	
Rateable value	0.27	0.02	11.91	0.0000	***

Notes:

i. Residual standard error: 184.4 on 11843 degrees of freedom
ii. (10,813 observations deleted due to missingness)
iii. Multiple R-squared: 0.4236, Adjusted R-squared: 0.423
iv. F-statistic: 725.3 on 12 and 11843 DF, p-value: < 2.2e-16

Base year normalisation

3.166 The base year for calibration is financial year (FY) 2016/17; selected as the most recent year for which a full data set was available, at the time the model development was being performed, in terms of both reported consumptions and associated demographics.

3.167 If the model is to correctly forecast a 'normal' year, then the base year consumption must also be normal.

3.168 The uncalibrated temporal residuals are modelled against weather parameters using a secondary model. The model is built by first selecting the most appropriate variable from a selection including temperature, rainfall and sunshine hours. Once the variables have been selected and the model built, the resultant weather-consumption model is applied to the base year weather parameters to produce a base year consumption correction for a normal year, which is fed back into the model for base year calibration on future projections.

3.169 In the case of the London model the weather normalisation is 2.5 l/property/day, which approximates to 0.5%. This is effectively a normal year as 0.5% is within modelling error that would be expected.

Developing a metered property model

3.170 When analysing the available data for creating the demand forecast, it was noted that the measured set of properties in the DWUS comprised a 'self-selecting' group, in the sense that these people chose metering with a much larger prior knowledge than the standard optant or progressive metered households. For this reason, these properties were excluded from the analysis and an unmetered model was derived to model consumption (paragraph 3.133).

3.171 However, comparing outputs of the model with reported metered consumption revealed the need to create a metering coefficient to adequately model metered consumption.

3.172 Building a model using unmeasured consumption enables the behaviour of the unmeasured properties to be built into the model. The unmetered population of today is the metered population of tomorrow, so understanding the drivers of consumption in this cohort is a useful and necessary task for predicting metered consumption. As we move through time, metered homes will become the dominant cohort, so future forecasts will need to gather and analyse data from the progressive metered households to understand the drivers of consumption in these new cohorts.

3.173 Once metered, behavioural tendencies tend not to alter very rapidly, with the majority of savings stemming from reduced losses/leakage. Therefore, introducing a simple coefficient to scale the consumption values which have been modelled from the unmeasured behaviour, to a level consistent with the reported metered consumptions is a logical approach.

3.174 The 'self-selecting' metered group is therefore unsuitable to build an independent model, but is perfectly sufficient for understanding the potential savings, or scale difference, compared with the unmetered group.

3.175 To validate this approach, the derived metering coefficient was tested using k-fold cross validation. This process involves splitting the data into the water supply zones, and using k-1 samples to build the model, using the kth sample as the test set in which predictions of metered consumption are made using the new coefficient. The different zones all have varying meter penetrations, and provide a good measure of how the coefficient performs using areas with differing levels of metering. This exercise found that the coefficient improved the model in all regions, providing a way to forecast metered consumption without the need to build a separate metered model.

3.176 The resulting metered coefficients for the metered household model were:

- Thames Valley metered: -101 l/prop/day
- London metered: -61 l/prop/day

Trends

3.177 The household consumption model residuals from previous years produce a significant trend in time series, indicating that some of the projected change in consumption is not accounted for by dynamic time series parameters within the model such as occupancy rates and meter penetration.

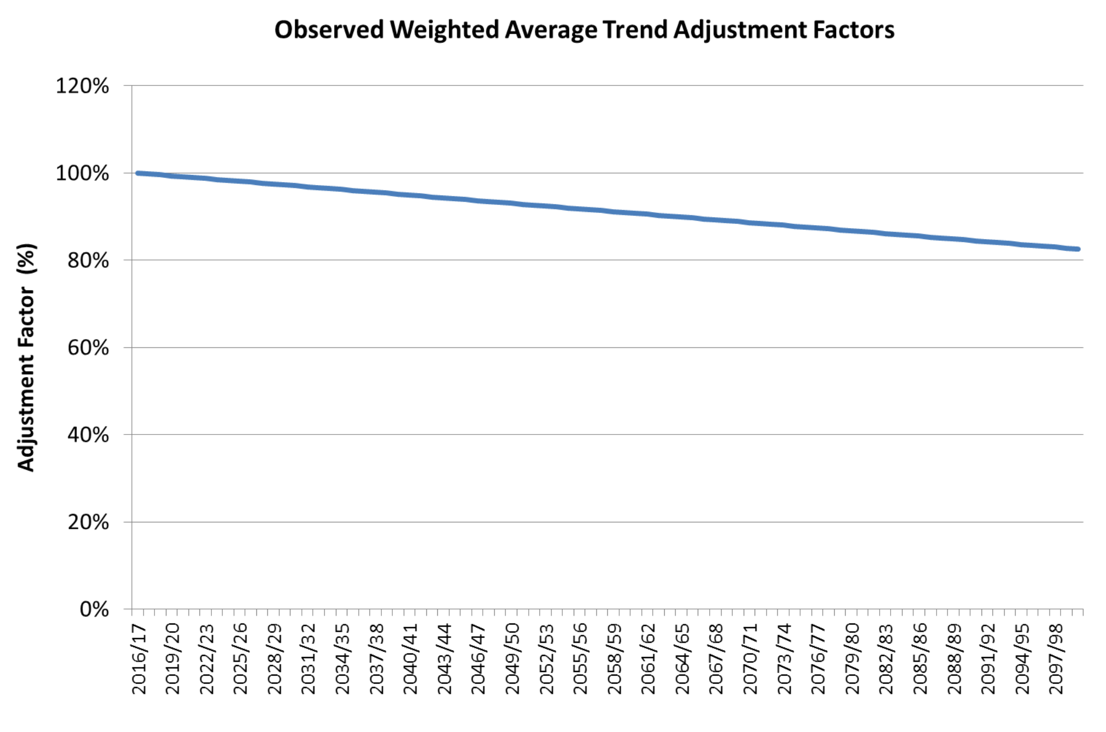
3.178 This observed un-modelled trend is thought to be driven by technological and behavioural changes.

3.179 Separate trends were derived for both London and Thames Valley data sets. The trend was observed over a ten year period and is derived from model residuals. The trend was generally downward and stronger for winter; the year round trend was applied to the initial forecast period to 2045 and also for a ten year initial period.

3.180 It is possible that the strong Thames Valley and weak London trends could switch because evidence showed more efficient appliances are installed in Thames Valley, thus leaving a greater potential for consumption reduction in the London area.

3.181 Therefore, we have used a weighted average of the two observed trends for use in the demand forecasts. The trend is presented as a percentage which is used to factor the household demand. This trend has then been linearly extrapolated to 2100. The resultant trend across the whole forecast period is shown in Figure 3-20.

Figure 3-20: Household demand trend adjustment factor



Uplifts AR17 outturn, dry year and critical period

3.182 To align with the base year reported position for the base year of 2016/17 a peaking factor is used. This peaking factor represents the difference between the outturn year and the modelled consumption from the model. Once this is done the same peaking factors as used for AR17 can be applied to uplift to dry year and the critical period.

Climate change

3.183 We commissioned the consultants HR Wallingford to carry out a study[16] to estimate the likely impacts of climate change upon household demand. No climate change effects are assumed for other components of demand based on the findings of the UKWIR report on the impacts of climate change on demand[17].

3.184 HR Wallingford undertook a statistical analysis of available data in order to derive empirical relationships that describe how weather and other factors affect household demand for water in our supply area.

3.185 We provided the following data sets:

- DWUS Unmeasured PCC by property type (2000-2010)
- PCC by property type for testDWUS[18] panel (2002-2004)
- Demand data (distribution input – minimum night line, 1998 onwards)
- Climate data (temperature, rainfall and sunshine hours, 1998 onwards).

3.186 Three climate variables were considered in the statistical analysis; temperature, rainfall and sunshine hours. However sunshine hours were removed as it was found to be highly correlated with temperature, and temperature provided a stronger and better understood climate change signal which would increase confidence in the model. Including both sunshine hours and temperature could have resulted in instability within the model. For the DYAA model both rainfall and temperature were included. For the ADPW model only temperature was included as an explanatory variable, this was due to insufficient data as for most years there was no rainfall in the peak period.

3.187 To estimate the impacts of climate change, the full sample of 10,000 UKCP09 climate change projections for maximum temperature and rainfall in the Thames Valley basin in the 2030s; medium emissions scenario, was used. These scenarios provide climate change factors that are applied to the regression models.

3.188 The climate change factors are reported as the change between the baseline period (1961-1990) and the future period (2021-2050). As the baseline for the revised draft WRMP is 2016/17 a scaling factor was calculated:

$$ScalingFactor = \frac{2035 - BaseYear}{2035 - 1975}$$

[16] HR Wallingford (2012) EX6828 Thames Water Climate Change Impacts and Water Resource Planning. Thames Water Climate Change Impacts on Demand for the 2030s
[17] UKWIR 2013 Impact of Climate Change on Water Demand 13/CL/04/12
[18] testDWUS – A temporary panel of unmeasured customers used to validate DWUS

3.189 As the base year is 2016/17 this results in a scaling factor of 0.4, i.e. 60% of the climate change between 1975 and 2035 has already been assumed to have occurred.

3.190 These factors were then used to provide estimates of PCC change due to climate change in the 2030s. The results of this gave 10,000 potential future PCC factors. The 10th, 50th and 90th percentiles of these factors were extracted to represent lower, mid and upper estimates of impact on PCC. The mid estimate was used in the demand forecasting models while the upper and lower estimates have been used in headroom modelling (see Section 5: Allowing for risk and uncertainty).

3.191 The climate change profiles for lower, mid and upper estimates are shown for the DYAA and DYCP scenarios in Figure 3-21 and Figure 3-22.

Figure 3-21: The impacts of climate change for the DYAA scenario

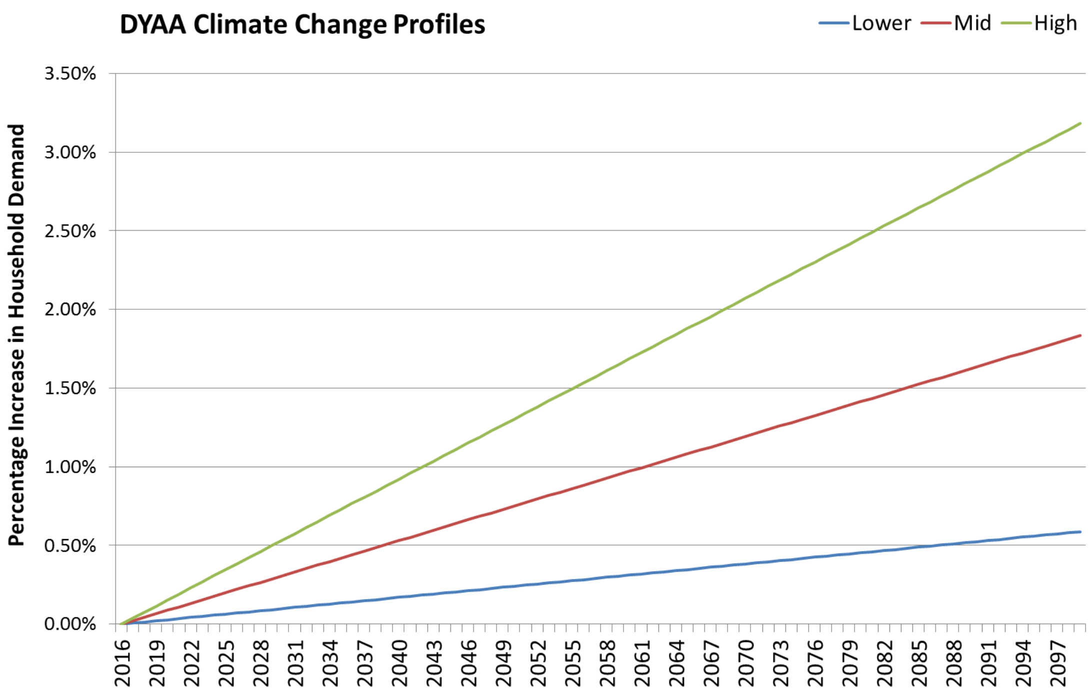
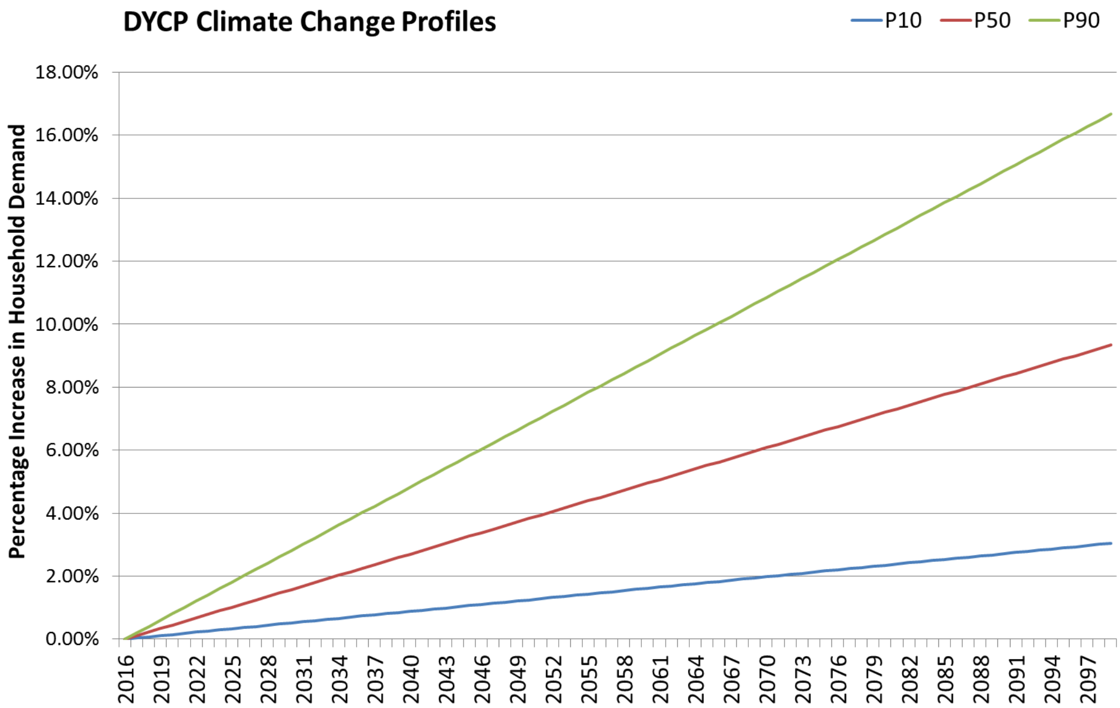


Figure 3-22: The impacts of climate change for the DYCP scenario



3.192 The volume impact of these climate change profiles for DYAA is shown in Table 3-25 and for ADPW in Table 3-26.

Table 3-25: DYAA additional demand due to climate change

Units Ml/d	2016/17	2024/25	2034/35	2044/45	2054/55	2074/75	2099/2100
Guildford	0.0	0.0	0.1	0.2	0.2	0.4	0.5
Henley	0.0	0.0	0.0	0.0	0.1	0.1	0.1
Kennet Valley	0.0	0.1	0.2	0.4	0.5	0.7	1.1
London	0.0	2.1	4.9	8.1	11.4	18.2	26.9
SWA	0.0	0.1	0.3	0.5	0.7	1.1	1.6
SWOX	0.0	0.3	0.6	1.0	1.4	2.1	3.1

Table 3-26: ADPW additional demand due to climate change

Units Ml/d	2016/17	2024/25	2034/35	2044/45	2054/55	2074/75	2099/2100
Guildford	0.0	0.3	0.8	1.2	1.7	2.5	3.6
Henley	0.0	0.1	0.2	0.3	0.5	0.7	1.0
Kennet Valley	0.0	0.7	1.6	2.6	3.5	5.2	7.6
SWA	0.0	1.0	2.3	3.7	5.1	7.8	11.4
SWOX	0.0	1.9	4.5	7.2	9.6	14.8	21.6

Water efficiency

3.193 For AMP7 onwards it has been assumed that there would be ongoing baseline water efficiency activity of approximately 0.85 Ml/d per annum across all zones. Once decay is factored in this equates to an ongoing saving of 3.4 Ml/d across the forecast period. This total saving has then been factored across all zones based on the proportion of total population in each zone. The water efficiency saving for each zone can be seen in Table 3-27.

Table 3-27: Baseline water efficiency savings (Ml/d)

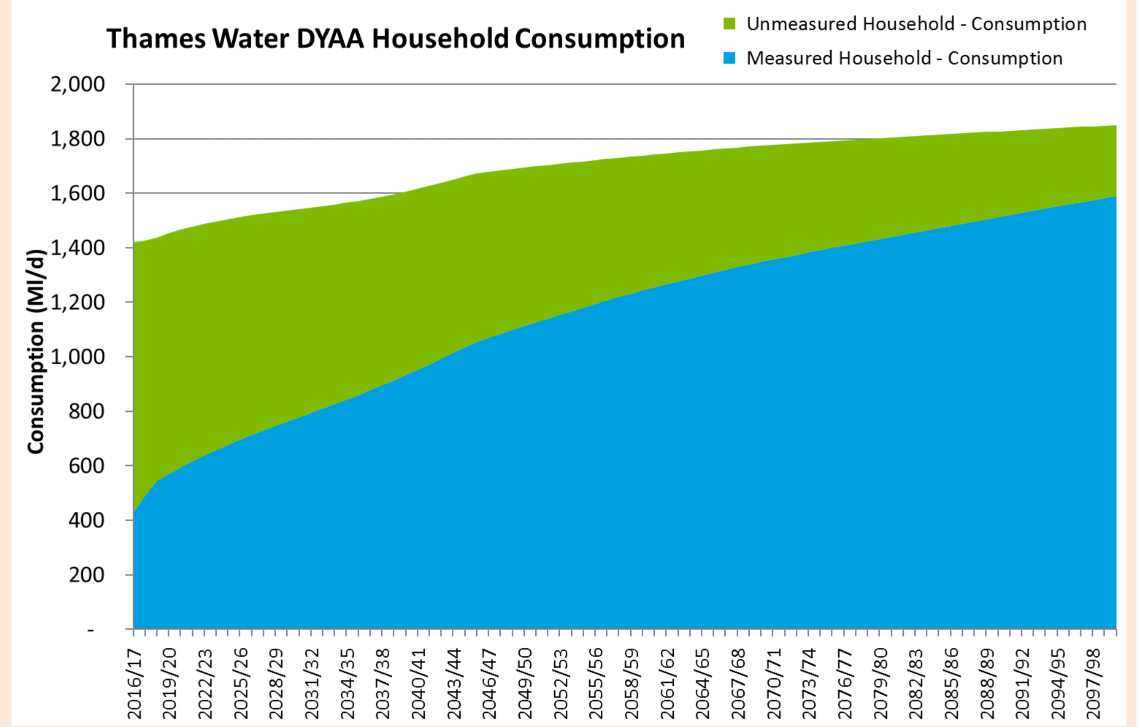
WRZ	Water efficiency saving
London	2.63
SWOX	0.36
SWA	0.19
Kennet Valley	0.14
Guildford	0.06
Henley	0.02
Total	3.4

Household forecasts

3.194 Household forecasts can now be produced for all WRZs. The charts in the sections below show total household demand in each WRZ for DYAA and ADPW where applicable. All zones show the same trend in that measured household demand increases both in absolute terms but also relative to the proportion of unmeasured household demand. This is due to two factors. The first is that all new properties are built with a meter installed and therefore drive an increase in measured demand. The second is the effect of metering (based on the AMP6 projections for the progressive metering programme, and thereafter the baseline optant and new forecasts to 2100). This continues across the forecast period until 90% of all properties are metered in the Thames Valley and 80% of all properties are metered in London.

3.195 This can be clearly seen in Figure 3-23 which shows total household demand for our whole water supply area.

Figure 3-23: Thames Water DYAA household consumption



London

3.196 London is forecast to start AMP7 with a total household demand of approximately 1,118 Ml/d. This is forecast to increase to approximately 1,314 Ml/d by 2045 and 1,494 by 2100. This change is driven by the forecast increases to population.

3.197 Unmeasured PCC is forecast to remain stable over the forecast period, from 159 l/person/d in 2016/17 to 159 l/person/d in 2044/45 and 160 l/person in 2100.

3.198 Measured PCC is forecast to increase over the forecast period from 120 l/person/d to 134 l/person/d in 2045 and to 135 l/person/d. There are several reasons for this forecast increase. Firstly, household occupancy continues to decrease across the period. In addition to this the number of adults is also continuing to grow as a percentage of the population and the modelling showed higher consumption for adults than children.

3.199 A significant factor is the change in the categorisation of large blocks of flats due to the introduction of the non-household commercial market. Historically a large block of flats, billed as a single entity, was counted as a single non-household property. These are now counted as household properties, in-line with Ofwat's new Eligibility Criteria 2016[19], and the number of flats in the building (subsidiary properties) included within the property count. The largest impact of this change was seen in London where the total number of 133,714 subsidiary properties are now included in the measured property count.

[19] Eligibility guidance on whether non-household customers in England and Wales are eligible to switch their retailer, Ofwat 2016

3.200 As our household forecast models use property type as a parameter this movement has a significant impact on our base PCC. Properties which fall into the category of “Large Blocks of Flats” have the lowest water use of all property types. Therefore the movement of this large number of flats has resulted in a substantial reduction in average measured household PCC from 130 l/person/d for AR16 to 119 l/person/d for AR17.

3.201 As new properties are built and progressive and optant metering continues other property types will move into our measured households category which will have higher average usage than these large blocks of flats and as a result will drive up measured consumption across the forecast period.

3.202 The result of this is a forecast increase in baseline measured household PCC. Figure 3-24 to Figure 3-26 show London DYAA household consumption and also PCC for both measured and unmeasured households.

Figure 3-24: London DYAA household consumption

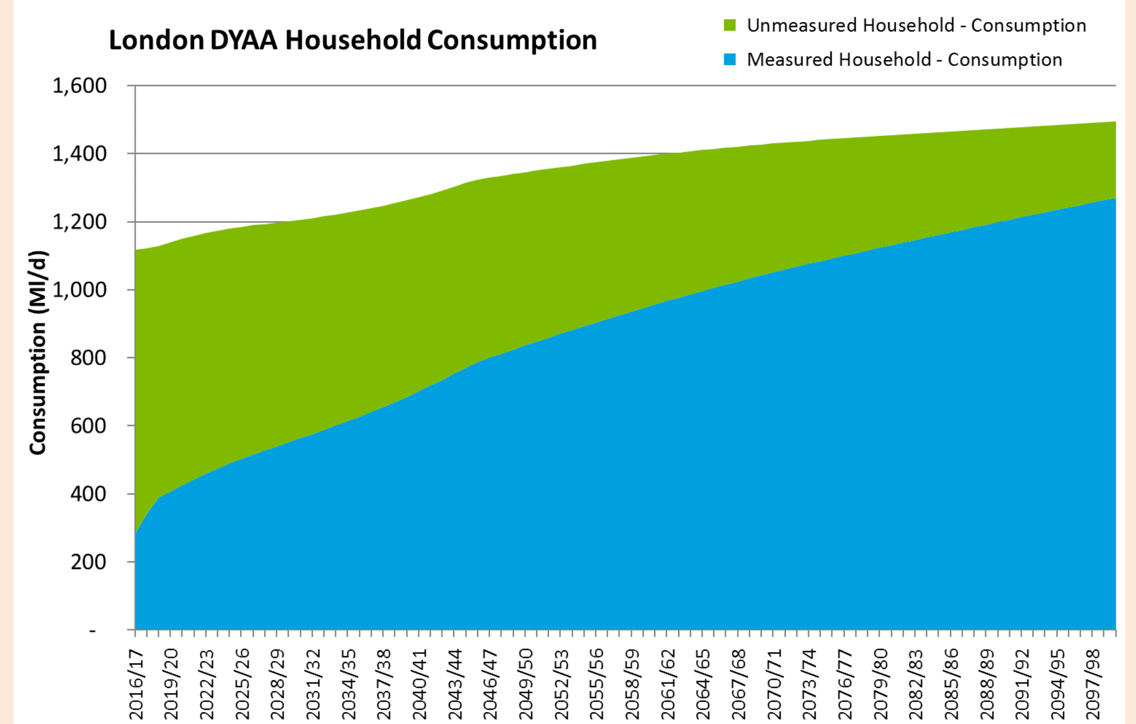


Figure 3-25: London unmeasured PCC

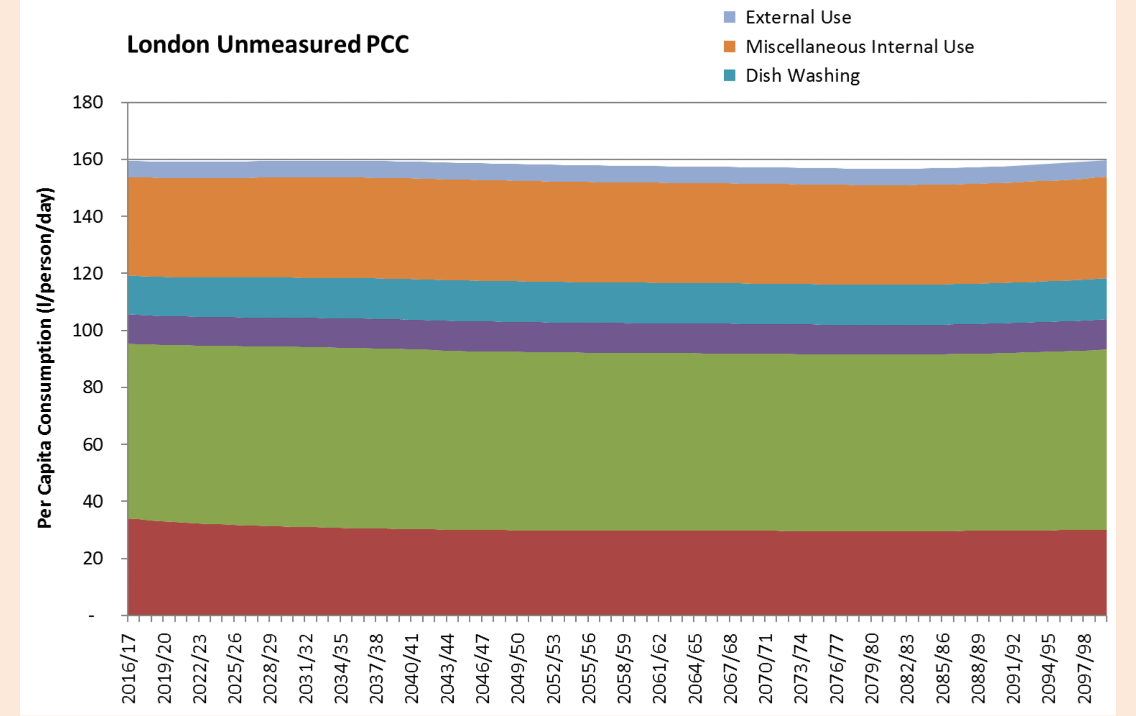
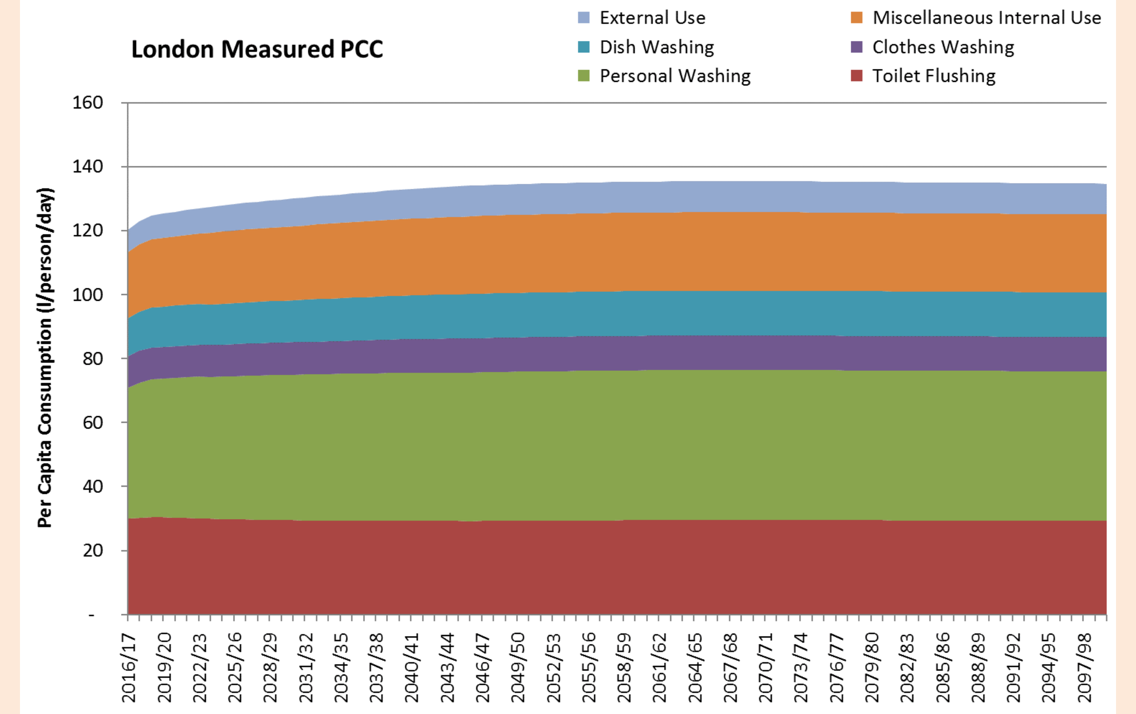


Figure 3-26: London measured PCC



SWOX

3.203 Total household consumption increases in SWOX from 141 Ml/d in 2016/17 to 170 Ml/d in 2044/45 and then remains flat for the remaining forecast period to 2100.

3.204 The increases in household consumption are driven by increases to population from the plan based population forecast. After 2045 we switch to the trend based population forecast which has a slower rate of growth. At this point population continues to increase, albeit at a slower rate, but this is offset by decreases in both measured and unmeasured PCC. This PCC reduction is a result of the trend adjustment that forms part of the household consumption forecasting model. Figure 3-27 to Figure 3-29 show SWOX DYAA household consumption, unmeasured PCC and measured PCC respectively.

Figure 3-27: SWOX DYAA household consumption

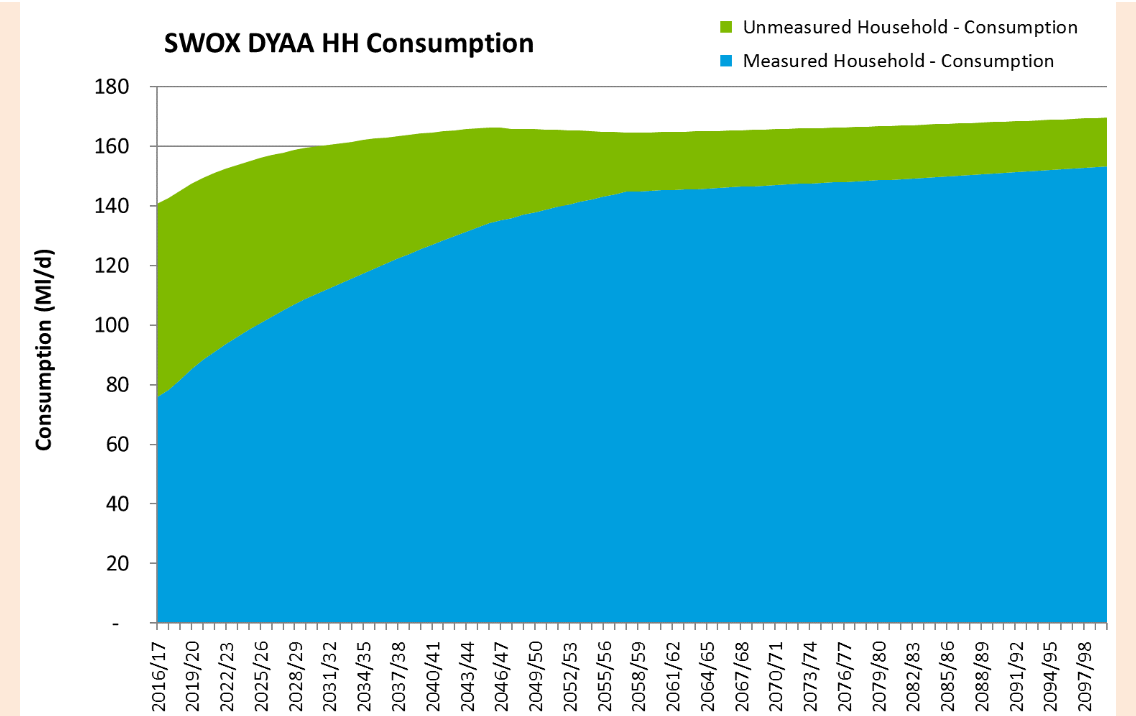


Figure 3-28: SWOX unmeasured PCC

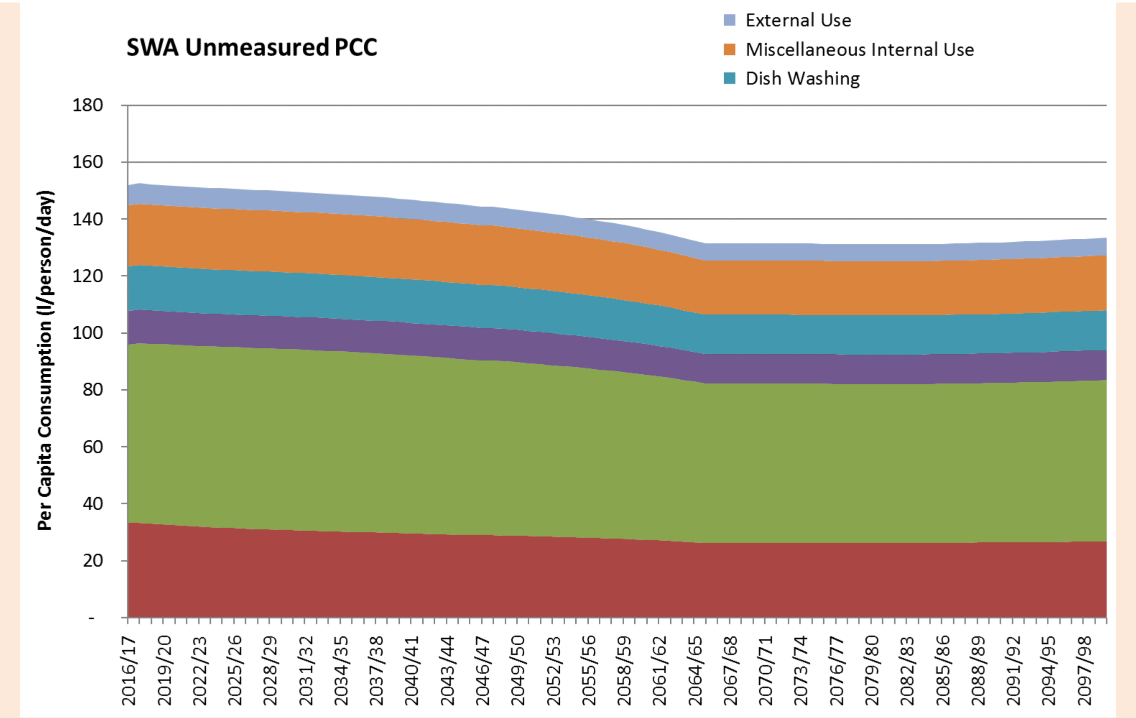
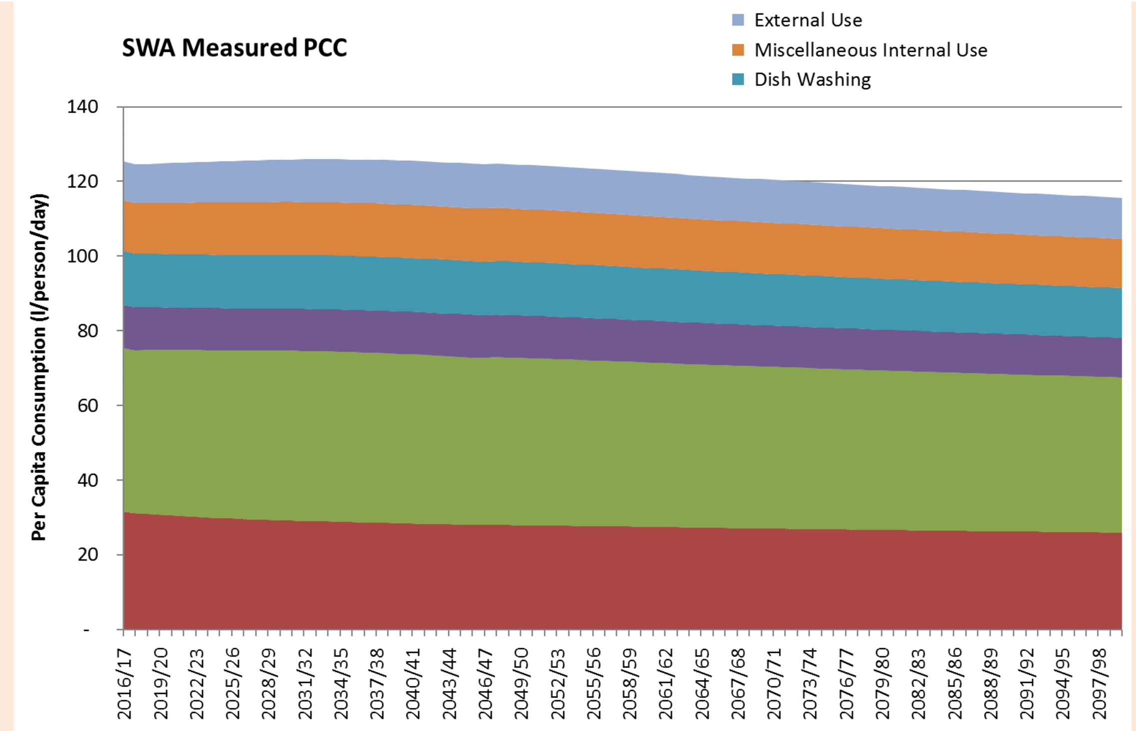


Figure 3-29: SWOX measured PCC



SWA

3.205 Total household consumption increases in SWA from 77 Ml/d in 2016/17 to 86 Ml/d in 2044/45 and then 90 Ml/d in 2100.

3.206 The increases in household consumption are driven by increases to population from the plan based population forecast. After 2045 we switch to the trend based population forecast which has a higher rate of growth. Some of this growth is offset by reducing PCC across the forecast period however substantial increase in household demand remain being forecast. This higher growth rate is driven by the Indian, Pakistani and Bangladeshi population that lives within the SWA WRZ. Figure 3-30 to Figure 3-32 show SWA DYAA household consumption, unmeasured PCC and measured PCC respectively.

Figure 3-30: SWA DYAA household consumption

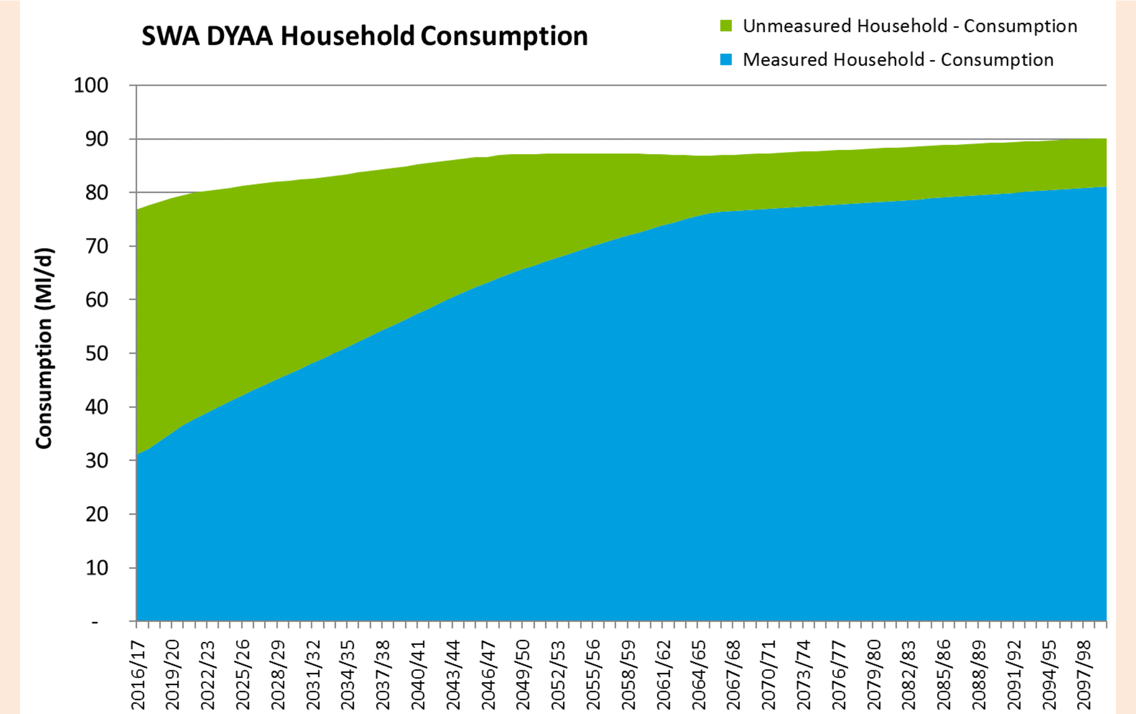


Figure 3-31: SWA measured PCC

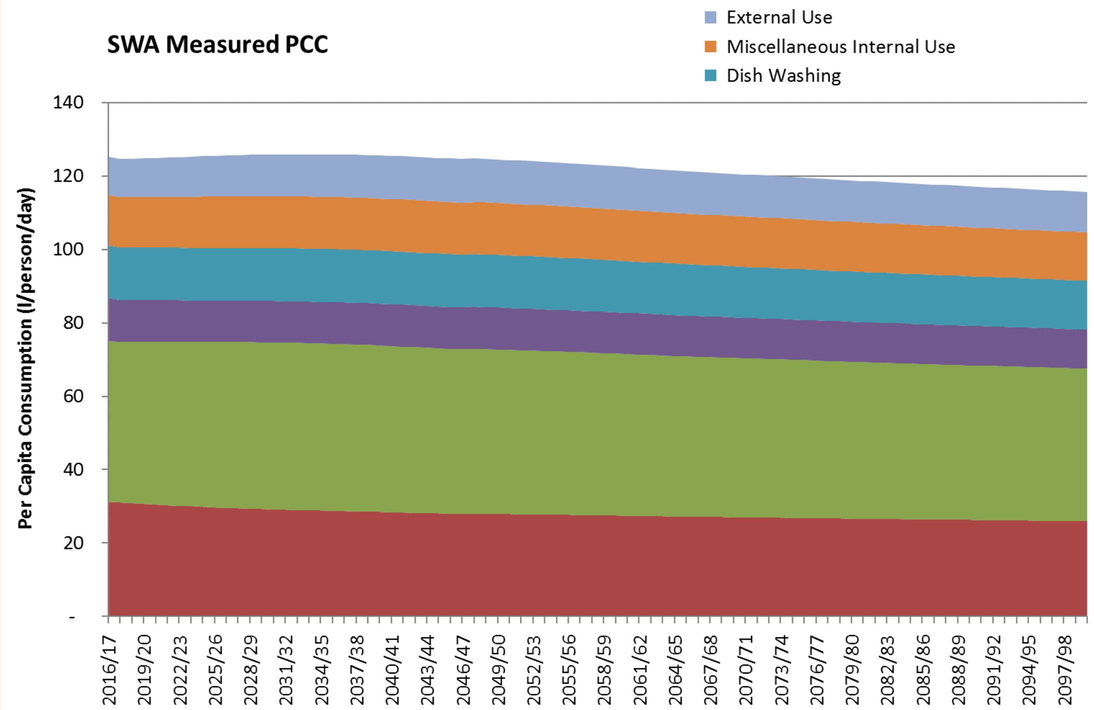
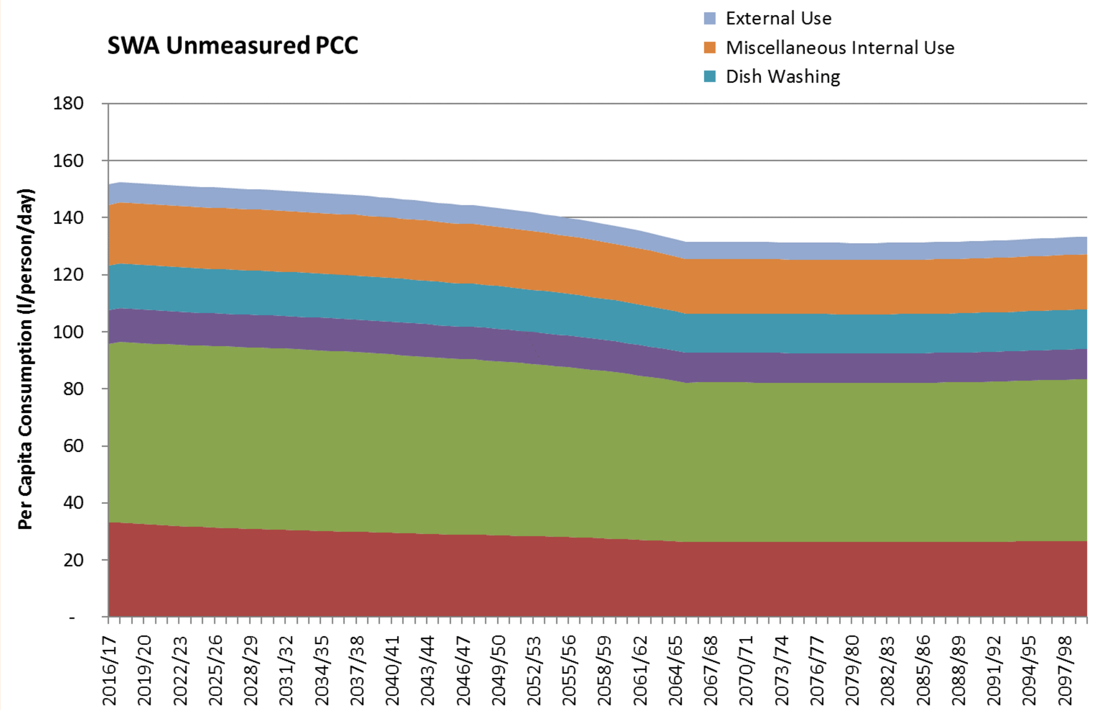


Figure 3-32: SWA unmeasured PCC



Kennet Valley

3.207 Total household consumption increases in Kennet Valley from 54 Ml/d in 2016/17 to 60 Ml/d in 2044/45 and then remains flat for the remaining forecast period to 2100.

3.208 The increases in household consumption are driven by increases to population from the plan based population forecast. After 2045 we switch to the trend based population forecast which has a slower rate of growth. At this point population continues to increase, albeit at a slower rate, but this is offset by decreases in both measured and unmeasured PCC. This PCC reduction is a result of the trend adjustment that forms part of the household consumption forecasting model. Figure 3-33 to Figure 3-35 show Kennet Valley DYAA household consumption, unmeasured PCC and measured PCC respectively.

Figure 3-33: Kennet Valley DYAA household consumption

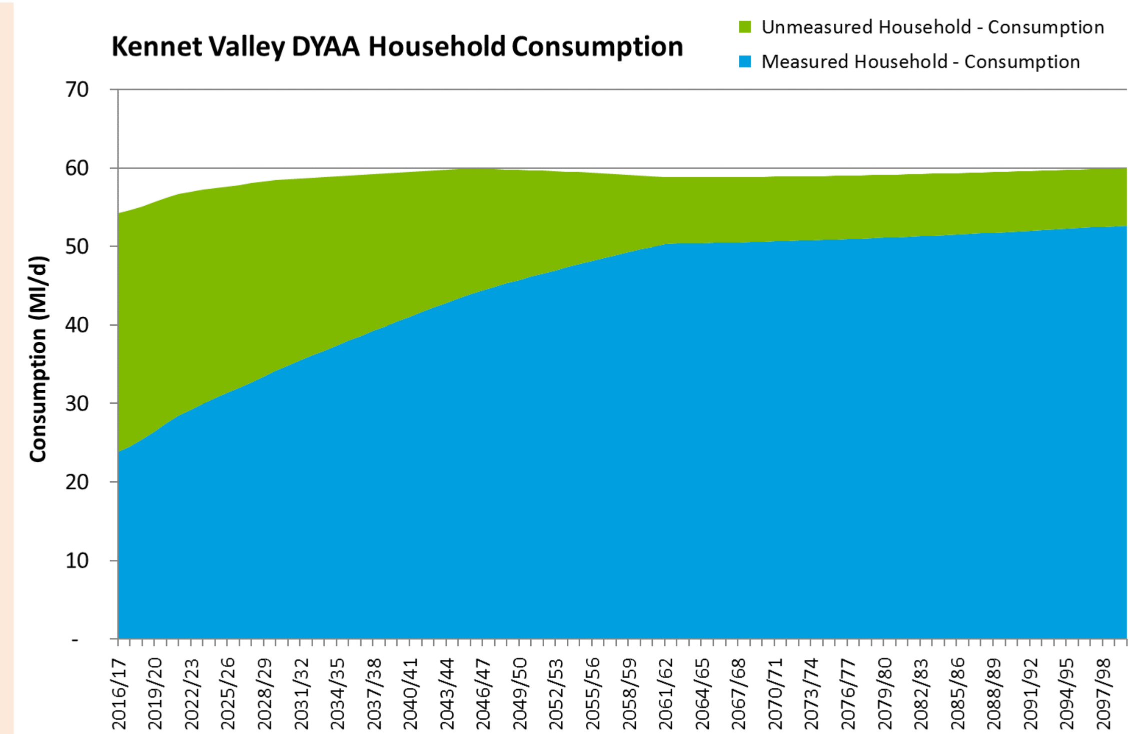


Figure 3-34: Kennet Valley unmeasured PCC

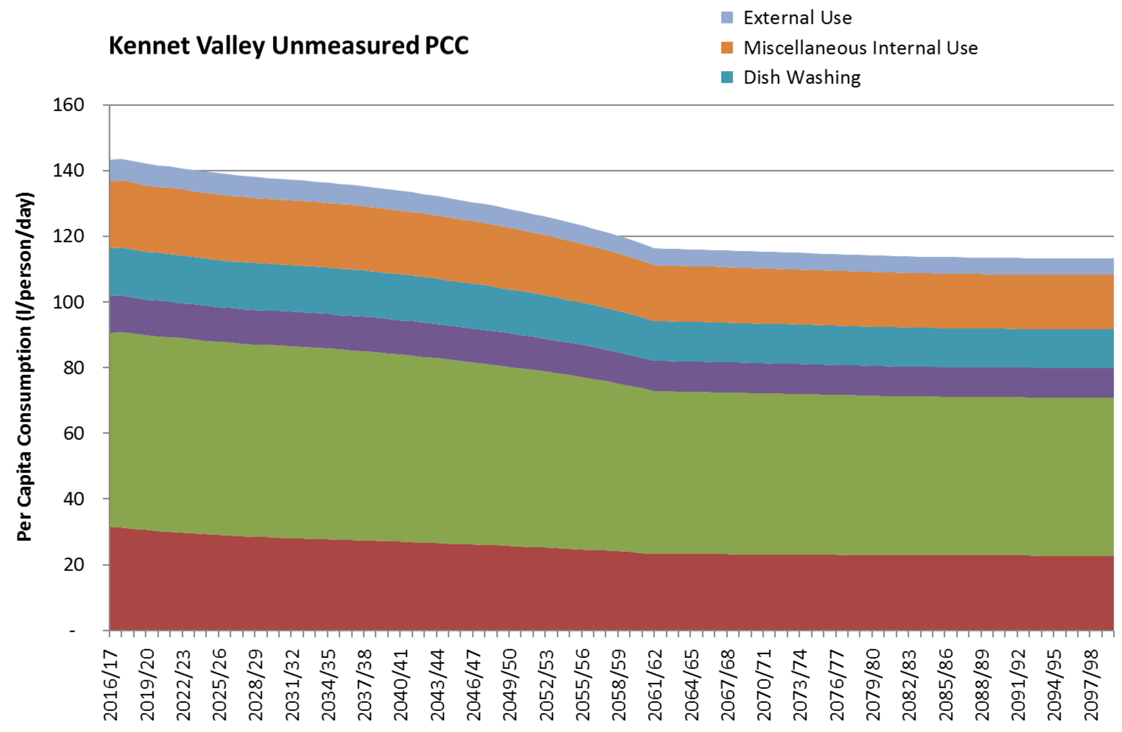
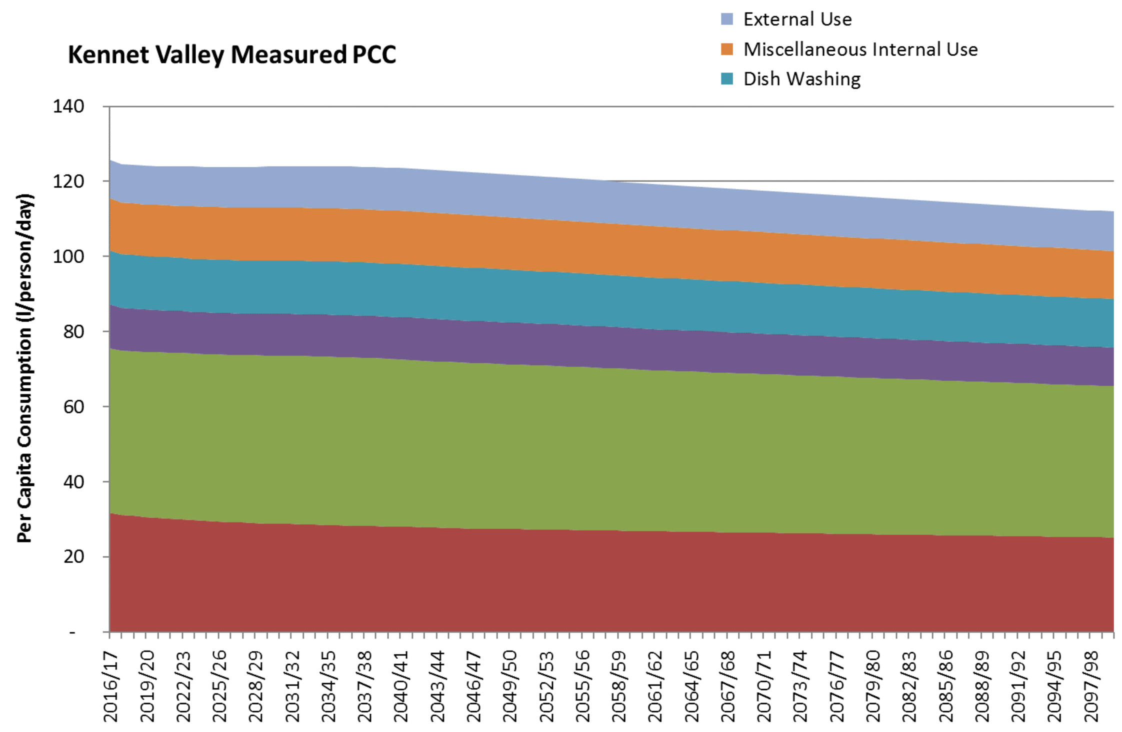


Figure 3-35: Kennet Valley measured PCC



Guildford

3.209 Total household consumption increases in Guildford from 24 Ml/d in 2016/17 to 28 Ml/d in 2044/45 and then remains flat for the remaining forecast period to 2100.

3.210 The increases in household consumption are driven by increases to population from the plan based population forecast. After 2045 we switch to the trend based population forecast which has a slower rate of growth. At this point population continues to increase, albeit at a slower rate, but this is offset by decreases in both measured and unmeasured PCC. This PCC reduction is a result of the trend adjustment that forms part of the household consumption forecasting model. Figure 3-36 to Figure 3-38 show Guildford DYAA household consumption, unmeasured PCC and measured PCC respectively.

Figure 3-36: Guildford DYAA household consumption

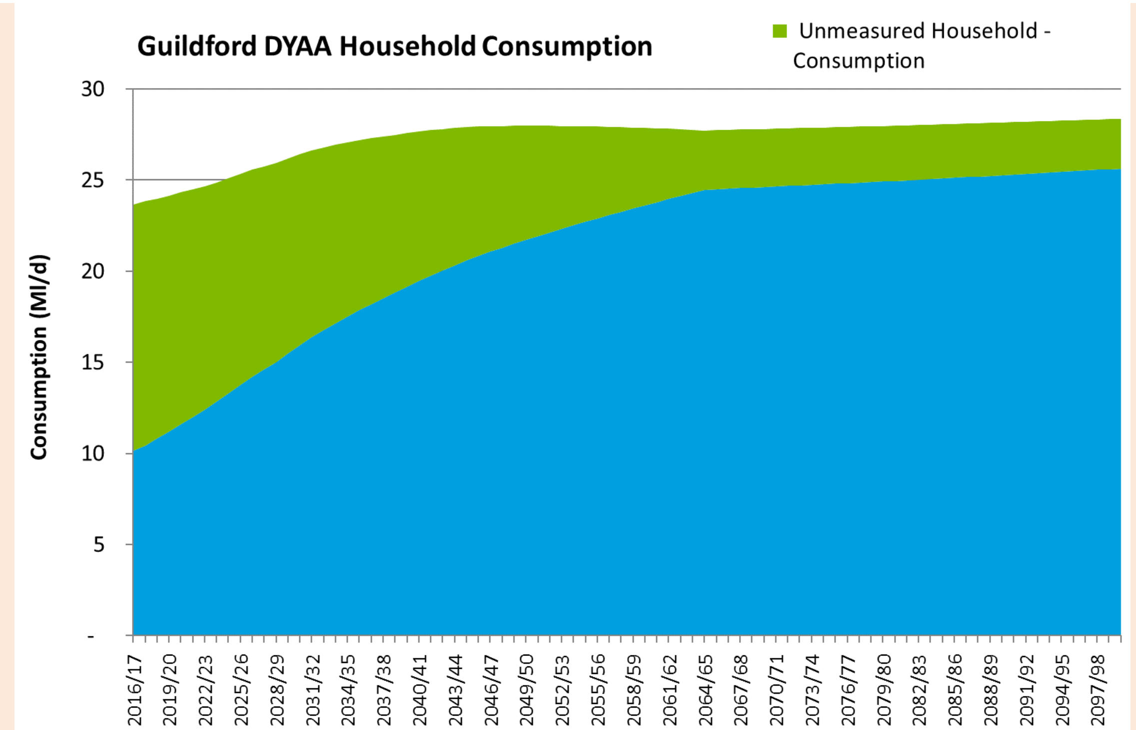


Figure 3-37: Guildford unmeasured PCC

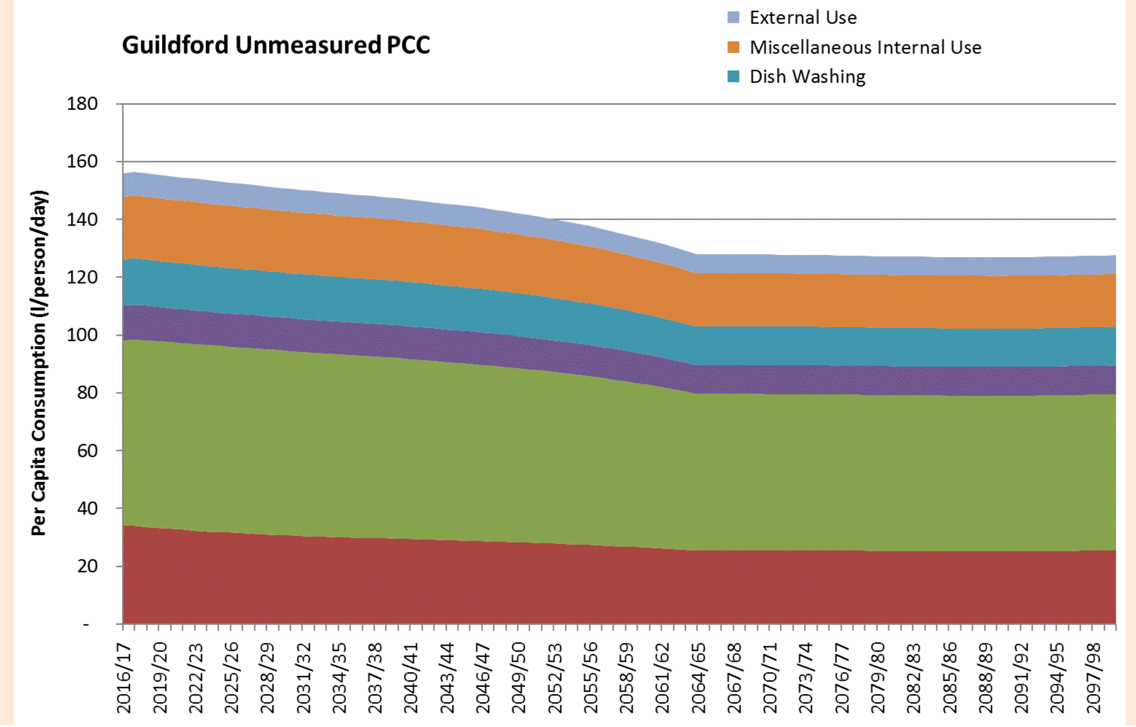
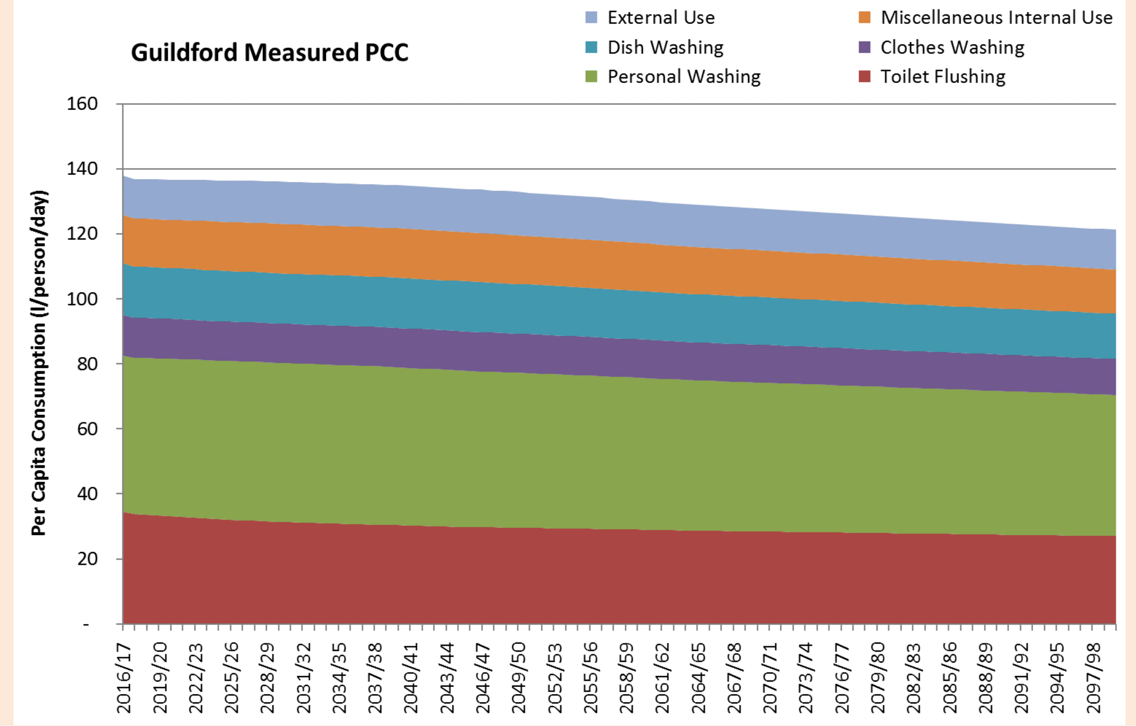


Figure 3-38: Guildford measured PCC



Henley

3.211 Total household consumption increases in Henley from 7 Ml/d in 2016/17 to 8 Ml/d in 2044/45 and then remains flat for the remaining forecast period to 2100.

3.212 The increases in household consumption are driven by increases to population from the plan based population forecast. After 2045 we switch to the trend based population forecast which has a slower rate of growth. At this point population continues to increase, albeit at a slower rate, but this is offset by decreases in both measured and unmeasured PCC. This PCC reduction is a result of the trend adjustment that forms part of the household consumption forecasting model. Figure 3-39 to Figure 3-41 show Henley DYAA household consumption, unmeasured PCC and measured PCC respectively.

Figure 3-39: Henley DYAA household consumption

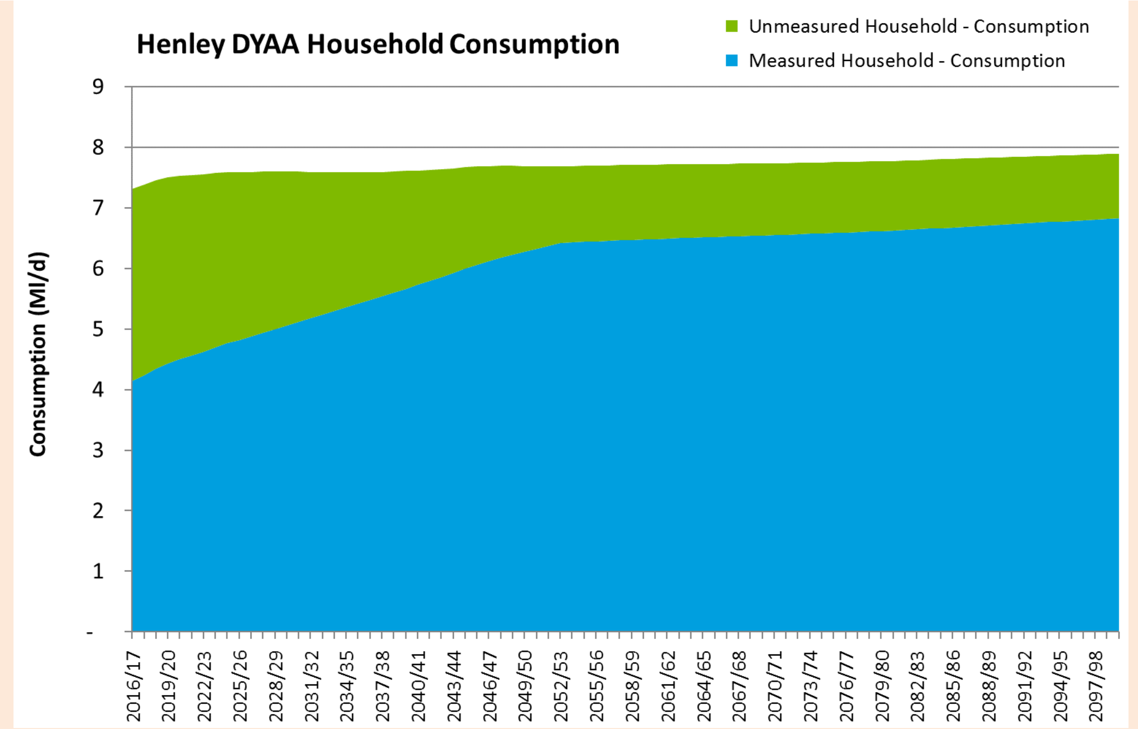


Figure 3-40: Henley unmeasured PCC

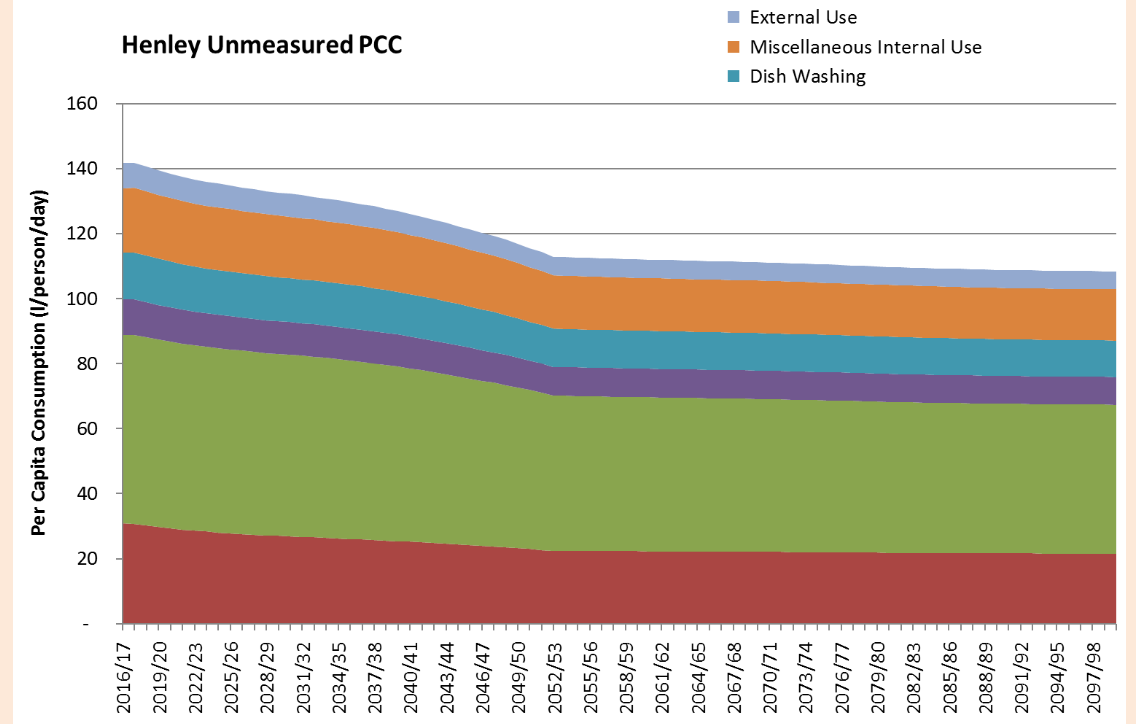
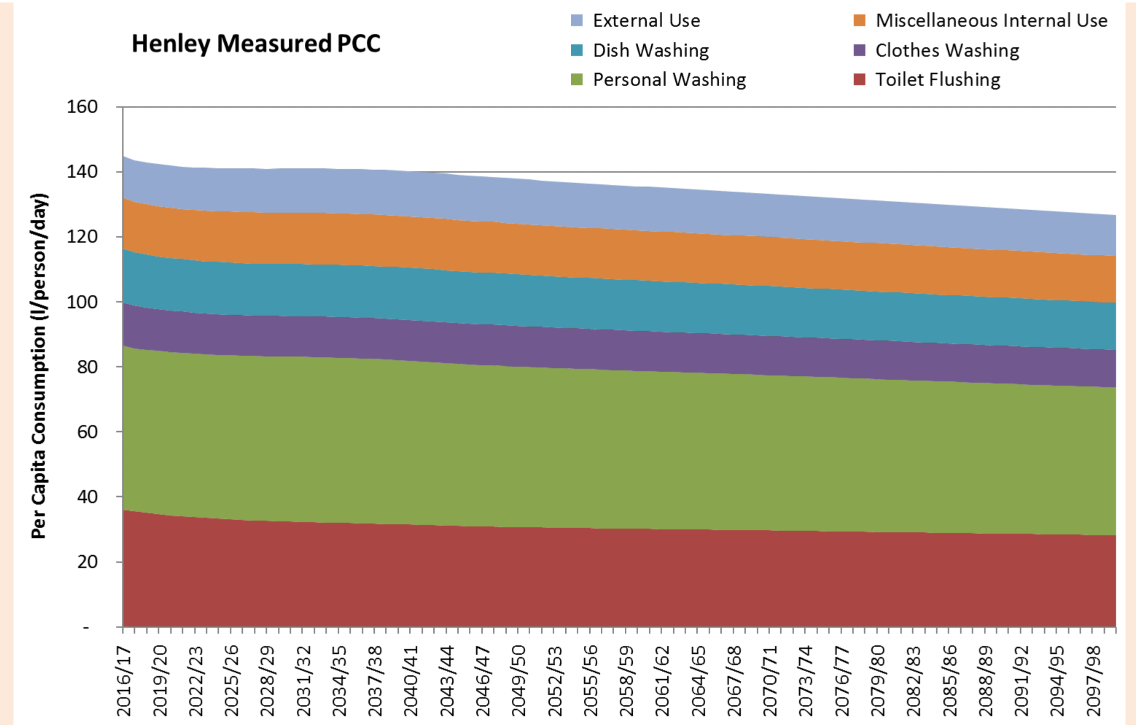


Figure 3-41: Henley measured PCC



3.213 A summary of the change in PCC for DYAA across all our zones is shown in Table 3-28

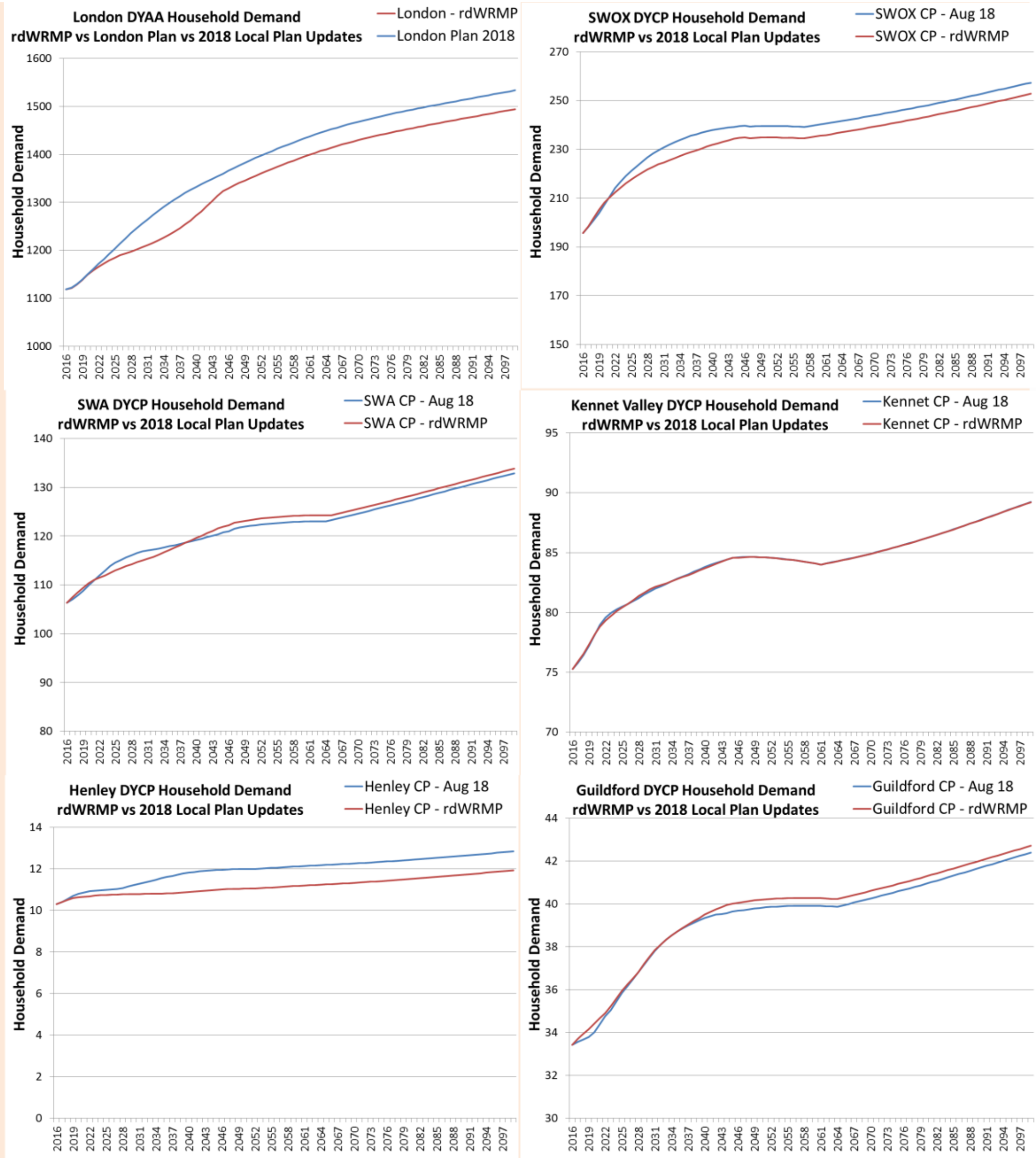
Table 3-28: Summary of forecast PCC (litres/person/day)

WRZ	2016/17	2044/45	2099/2100
London	147.2	143.1	137.9
SWOX	137.8	127.5	114.4
SWA	140.0	130.2	117.2
KV	135.0	125.1	112.1
Guildford	147.7	136.7	121.8
Henley	143.5	135.0	123.9

August 2018 household demand reforecast

3.214 Using the household and population forecasts from the August 2018 update to local authority plans we have rerun the household demand forecasting model. This data was received after production of the supply demand balances used to generate our preferred programme and, accordingly, was not available for use for this purpose. Instead we have used this data to determine if recent updates to local plans, by local authorities, produce a material change in household demand forecasts.

Figure 3-42: Comparison of demand profiles



3.215 The London WRZ demand forecast shows material increases in demand starting from around 2025. These are due to the increased rate of house building in the London Plan. The demand increases across the period of 2020 to 2045 with the largest difference in demand being in 2037 where household demand is forecasted to be approximately 67 Ml/d higher than the baseline forecast used in our revised draft WRMP. By 2044 this difference has reduced to approximately 36 Ml/d. Beyond 2044 there are minor yearly increases up to a 39 Ml/d increase above the revised draft WRMP baseline.

3.216 These increases in demand would result in a deficit in our preferred programme and within Section 10: Programme appraisal we set out how these increases in demand would change our preferred programme.

3.217 Outside of our London WRZ none of the changes in household demand are considered material. The largest change in demand, outside London, is seen in SWOX where an increase in demand of approximately 6 Ml/d is predicted from the updated forecast. When tested against our preferred plan, Section 10, all five Thames Valley zones would remain in surplus.

E. Non-household demand

3.218 Non-household water use in our supply area tends to follow wider economic trends. We do not have a large agricultural sector, as is found for example in East Anglia or a significant, declining industrial sector as has occurred in some other areas of the country. Consequently, our forecasts of non-household water use have remained fairly flat.

3.219 We commissioned Servelec Technologies to develop a non-household demand forecasting model. Servelec Technologies used multiple linear regression to formulate the model. Full details of the model development and methods used can be found in Appendix G: Non-household water demand.

3.220 Non-household customers were divided by geographical area and industry sector, and then separate models developed to forecast consumption based on one or more explanatory factors.

3.221 Explanatory factors (e.g. numbers in employment or the level of economic activity) are selected that best account for variation seen in consumption. A regression model is then developed using these factors. This allows forecasts of consumption based upon forecasts of the explanatory factors. The sensitivity of the result can then be assessed by examining different scenarios for the explanatory factors.

3.222 The historical consumption and sector allocation was provided by Teccura. They used raw billing data, matched it with their database of customer sectors, and validated the raw reading data to give the best estimate of true consumption for each year from FY2006 to FY2015.

3.223 The historical consumption data provided was then reconciled to the reported non-household consumption figures, and after an allowance for meter under-registration and other adjustments, and a small variation to account for differences in the allocation of properties to either household or non-household status, there is general agreement.

3.224 Data received from Teccura analysis/ obtained from public domain sources:

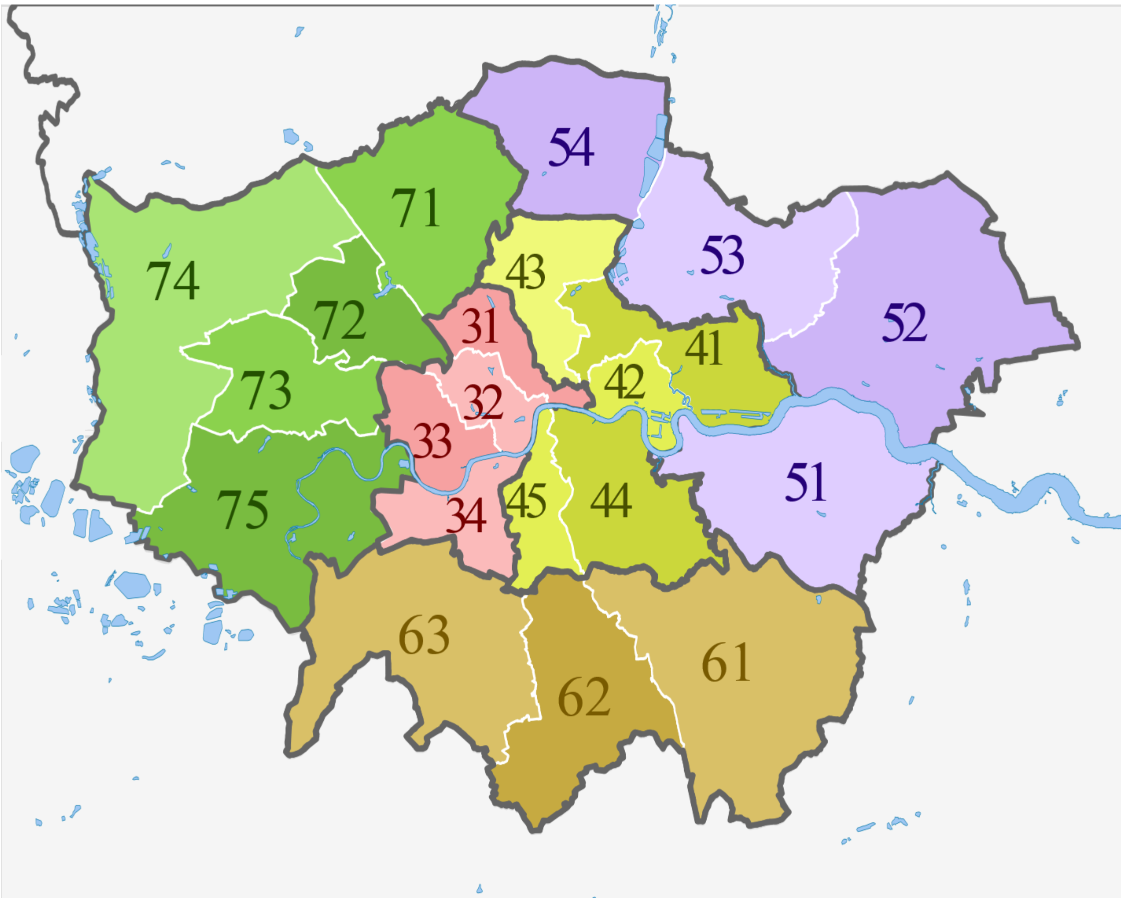
- Annual consumption for each FMZ broken down by sector for the period FY2006-FY2015
- Individual annual consumption for major customers (high users)
- Details of customers that fall into the ‘unknown sector’ type in the Teccura data set
- Gross Value Added (from the ONS)
- Employment data (from the UK commission for employment and skills)
- Population data used in household consumption forecasting

3.225 The five WRZs outside London were modelled as individual areas. The London WRZ broken down into three areas:

- Inner West (authorities 31-34)
- Inner East (authorities 41-45)
- Outer (all other London areas including those in the London WRZ that fall outside of the London Nomenclature of territorial units for statistics (NUTS) Area)

3.226 The location of each area is shown in Figure 3-43.

Figure 3-43: NUTS level 3 authorities[20]



3.227 There are strong arguments for modelling the London areas separately, given the different ways in which they have developed over the last ten years. Further subdivision is unlikely to lead to an increase in accuracy since issues around the alignment of FMZ and Nomenclature of Territorial Units for Statistics (NUTS) area boundaries will become more significant, and the model application will increase in complexity.

3.228 The industry sectors provided in the raw data set are a bespoke set of detailed industry codes. These have been mapped to Standard Industrial Classification (SIC) codes to allow alignment with publically available data for Gross Value Added (GVA) and employment levels.

[20] Dr Greg and Nilfanion. Contains Ordnance Survey data © Crown copyright and database right 2010

3.229 The SIC groups have been further grouped to give five groups for each WRZ as follows:

- Group 1 – SIC groups P, Q and O – “Education”, “Human health and social work activities”, “Public administration and defence”
- Group 2 – SIC groups R, S and T – “Arts, entertainment, recreation”, “Households” and “Other service activities”
- Service industries – the remaining SIC groups that relate to service industries. This tends to be dominated by groups M and I, “Professional, scientific and technical activities” and “Accommodation and food service activities”
- Non-service industries – the remaining SIC groups that relate to non-service industries. This tends to be dominated by food manufacturing or waste services depending on the WRZ

3.230 Explanatory factors, such as numbers in employment or the level of economic activity, are selected that best account for variation seen in consumption, and a regression model developed. This allows forecasts of consumption based upon forecasts of the explanatory factors. Each of the parameters selected are set out below.

Demand forecasting model

Population

3.231 Population forecasts are the same as those discussed above and which are used in the household demand forecasts.

3.232 The overall population is expected to steadily increase across all our WRZs over the forecast period.

Employment

3.233 The projection of employment in London is obtained from GLA Economics London labour market projections from 1971 to 2041[21] and an average growth rate of 0.8% has been used from 2016 to 2041. The forecast growth rates are assumed to be decreasing from 0.7% in 2042 to 0.5% in 2100 because of differing levels of growth in different industry sectors. Employment in London is projected to reach 9.3 million by the end of the 21st century.

3.234 The projection of employment in the south east, excluding London, is obtained by extrapolation of the UK Commission for Employment and Skills (UKCES) forecast from 1990 to 2024 (where employment has been disaggregated by industry sectors, but not by local authorities). An average growth rate of 0.6% has been used between 2015 and 2024. This rate is assumed to decrease from an average of 0.8% in 2025 to an average of 0.5% in 2100. Employment in the south east is projected to reach 7.2 million by the end of the 21st century.

[21] https://www.london.gov.uk/business-and-economy-publications/london-labour-market-projections-2016

GDP

3.235 The review of the historical Real GDP since 1830 to 2009 by the Bank of England[22] concluded that, under the central scenario (crises-free) an average annual growth of 2.0% is appropriate for the forecast period.

3.236 This assumption aligns with the reported UK total GDP growth rate forecast by HSBC Global Research[23] which is forecast to increase from 1.7% per annum in 2020 to 2.2% by 2050. The UK GDP average growth rate estimated by the Environment Agency for the UK is 2%, under the 'Restoration' scenario (sustainability-led governance, dematerialised UK consumption), whereas under the 'Alchemy' scenario (sustainability-led governance, material consumption) the annual growth is estimated at 2.5%.

3.237 The GVA growth rate in each of the WRZs in the our supply area has therefore been assumed at 2%, with the exception of London whose regional economy is expected to grow faster in which the GVA growth rate is assumed 2.5%.

Model

3.238 The general model previously used for each sector group in each area has been retained, with the following form:

$$\ln(Consumption_i) = C + \alpha_1 Empl_i + \alpha_2 \ln(GVA_i) + \alpha_3 Pop_i + \alpha_4 Year_i + \alpha_5 Tariff_i$$

where:

Consumption$_i$ - the consumption in year *i* for the particular sector group in the particular area

Empl$_i$ – the number of employees in the sectors modelled (in London for the three London areas and in south east England for the other WRZs) in year *i*

GVA i - the GVA in £million for the relevant SIC groups in the relevant area in year *I*

Pop i - the population resident in the relevant area in year i

Year i - the year, which is used to give an absolute trend to the model

Tariff i - the general user water tariff in £/m3 in year *i*

$\alpha_{1\text{-}5}$ are the coefficients determined through linear regression

C – a constant term determined by the regression analysis

Non-household forecasts

London

3.239 As per the previous modelling, the population figures in London Outer East and West refer to the Inner London East and West NUTS areas, and the population in London Outer. Outer refers to the Outer London NUTS area. Water demand in London is forecast to rise in nearly

[22] www.bankofengland.co.uk/Fpublications/Documents/quarterlybulletin/threecenturiesofdata.xls
[23] http://www.gbm.hsbc.com/solutions/global-research

all service sectors. The non-service sector and unknowns are forecast to decrease over the forecast period. The overall combined demand from London Overall East, West and Outer London is shown in Figure 3-44, and this has been compared with a single model of the demand in London as a whole. The two graphs generally agree until the 2050s, then diverge and follow different trends until 2100. This difference is due to a slight loss of detail in the London single model, requiring two assumptions to balance demand between the non-service and unknown sectors:

- Non-services in the London single model was assumed to remain relatively constant, whereas decreasing trends are assumed in the London Inner East and West regions for the combined model. Unknowns sector from the two models show decreases in demand, however the London single model is showing a much faster fall. The service industries are projected nearly exactly the same in both models, they are forecast to gradually increase their water demands over the forecast period. The main difference in the two models is therefore the handling of the non-service industries (which have downward trends in all London Overall, East, West and Outer) and unknown sectors.
- Demand in the London WRZ is projected to see alternate successions of increases and decreases. Increases of demand are driven by the service sector, whereas the non-service and unknown sector demands are expected to decrease over the forecast period.

London Inner East

3.240 Water demand from service industries is projected to increase. The non-service sector is decreasing by 22.8% in 2050 and by 48.5% in 2100.

3.241 The overall non-household demand generally increases, driven by service industries. Service industry demand is expected to rise by about 17.3% in 2050 and 62.7% in 2100 compared to the level in 2015. The overall magnitude of increase in 2050 is 15.1 Ml/d, and by 2100 an increase of 25.5 Ml/d will be achieved.

London Inner West

3.242 The overall demand will see an overall decrease. Demand will increase by about 9 Ml/d in around 2030 compared to the 2015 level; whilst the magnitude of the decrease from 2015 to 2100 is estimated at about 18 Ml/d.

Outer London

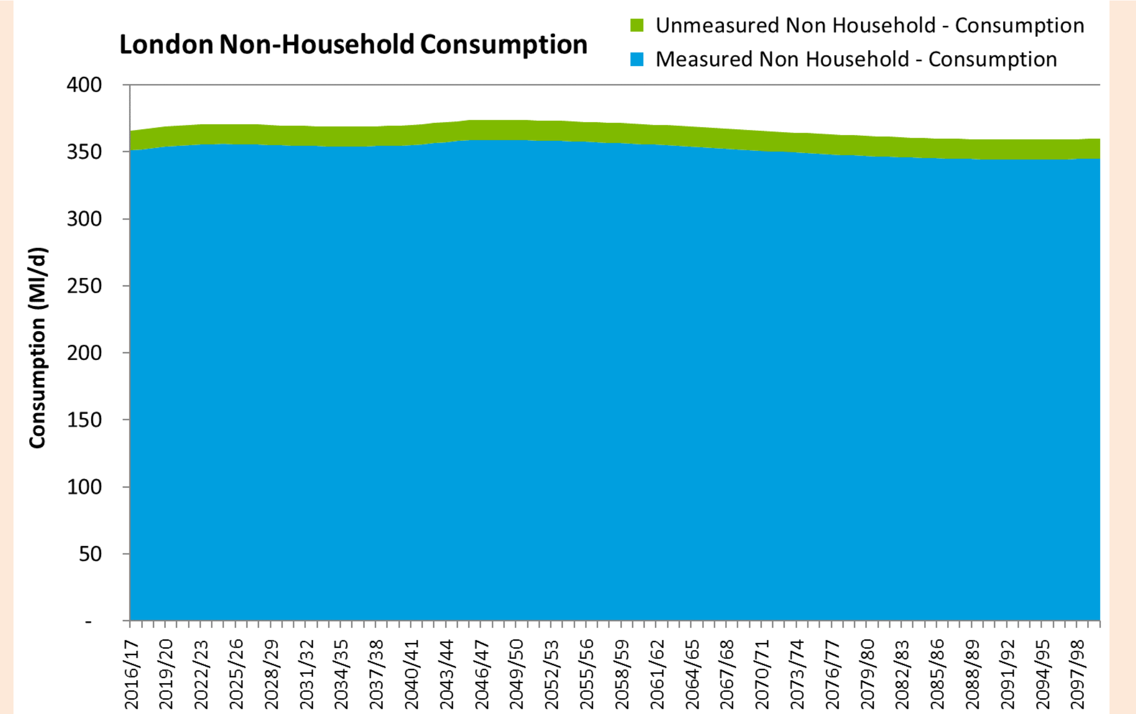
3.243 The overall demand will slightly decrease until the 2050s, and then slightly increase during the remaining period to 2100. The decreases are driven by the non-service industries. The non-service model forecasts a decrease by 21.2% in 2050 and a decrease about 62.7% by 2100 compared to level in 2015.

3.244 Demand from service industries is projected to continue its growth and will ultimately overcome the offsets from the non-service industries. The projected demand in the Outer London regions in 2100 will only be about 8.0 Ml/d lower than the level in 2015.

London overall

3.245 The overall non-household forecast for London is shown in Figure 3-44.

Figure 3-44 London non-household consumption



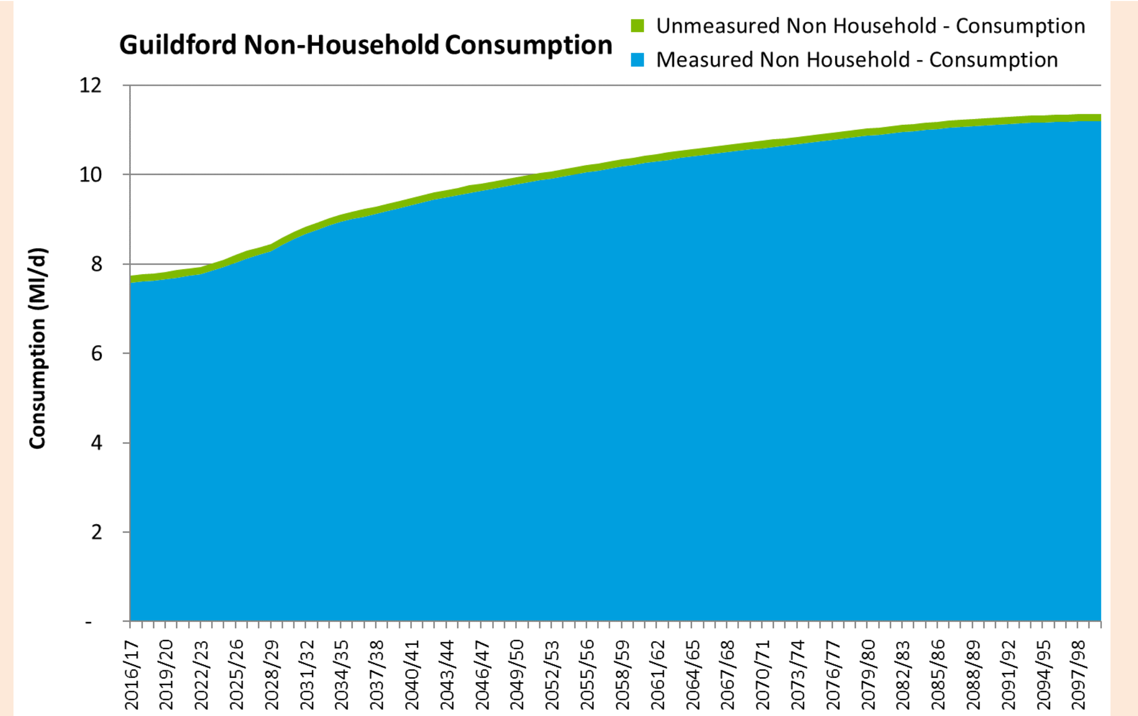
Guildford

3.246 The overall demand will increase in general, driven by the service sectors except the Group 2 (SIC groups R, S and T) group (Other Services and Household activities), whereas the non-service sector is a small demand compared to the overall service sector in Guildford.

3.247 A demand increase by 24.1% in 2050 is expected compared to 2015, and by 2100 demand will rise to about 3 Ml/d.

3.248 Overall non-household demand for Guildford is shown in Figure 3-45.

Figure 3-45: Guildford non-household consumption

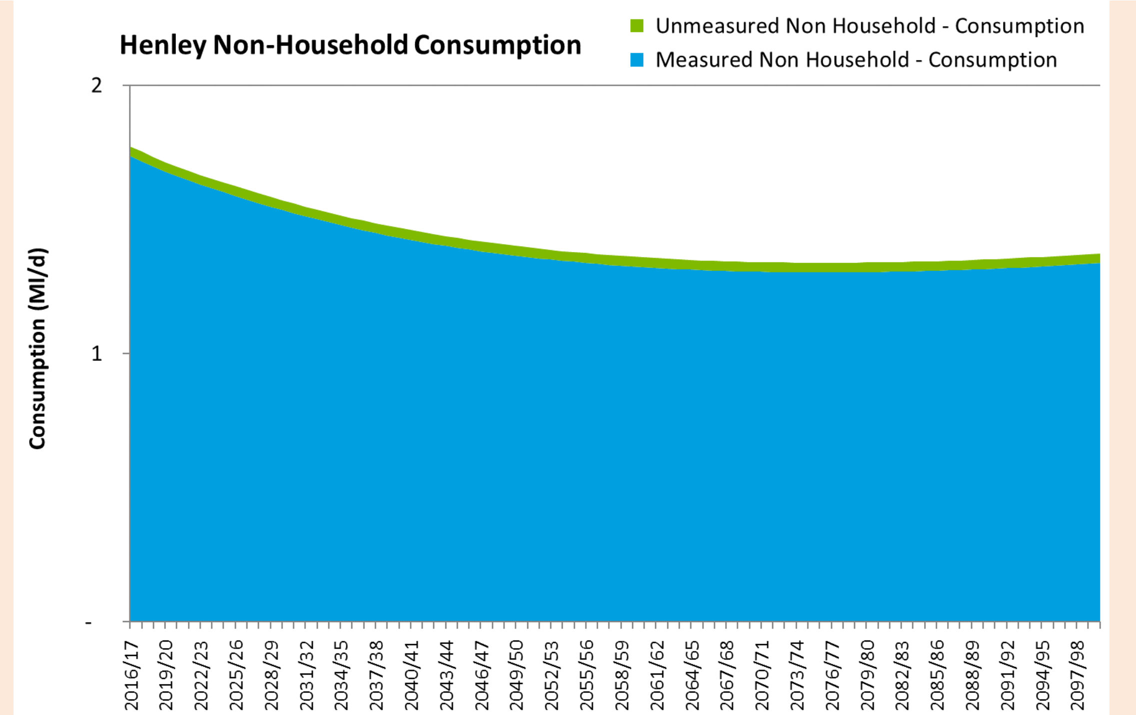


Henley

3.249 The overall demand in Henley is forecast to decrease till the 2060s and then stay level throughout the remaining period. Only the service sector demand from SIC groups G, H, I, M, N and J is forecast to increase, but will not make any significant effect in the long term. The non-household water demand in Henley is negligible compared to the overall company demand, and thus will not change much the general forecast trend at the company level.

3.250 Overall non-household consumption for Henley is shown in Figure 3-46.

Figure 3-46: Henley non-household consumption

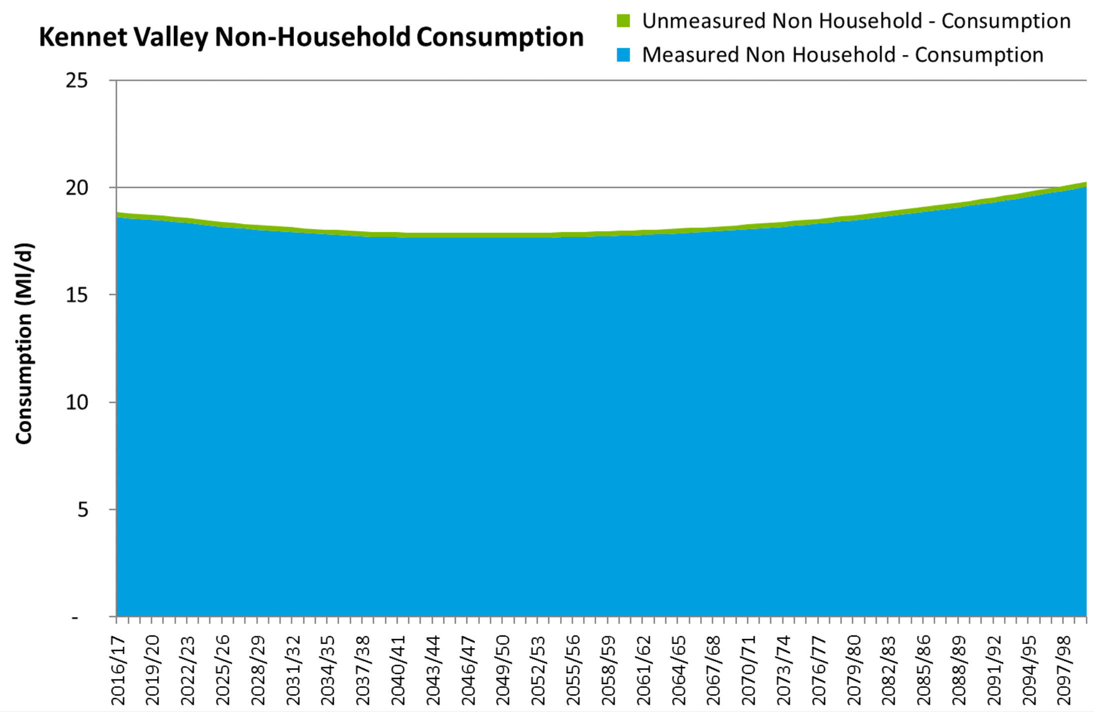


Kennet Valley

3.251 Water demand is expected to increase in the service sector, whereas the non-service sector is forecast to remain level throughout. Demand will marginally decrease until mid-century, decreasing by 5.9% in 2050 compared to 2017 level, and then slightly increasing throughout the remaining period to 2100. However, the magnitude of increase between 2050s and 2100 is only about 2.4 Ml/d.

3.252 Overall non-household consumption for Kennet Valley is shown in Figure 3-47.

Figure 3-47: Kennet Valley non-household consumption

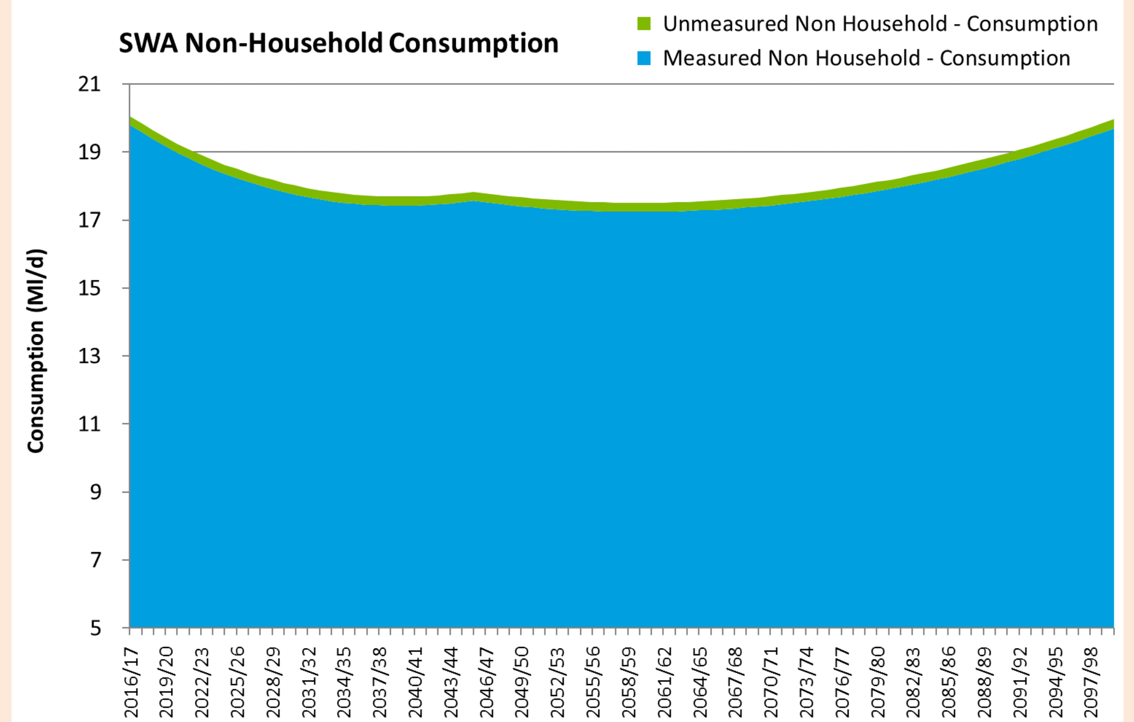


SWA

3.253 The combined sector consisting of the groups Group 1 and Service is forecast to decrease over the forecast period. The non-service sector is assumed to rise. Demand is projected to decrease till the 2050s, decreasing by 13.2% in 2050 compared to 2015 level, and then increasing throughout the remaining period to 2100, reaching 20 Ml/d. The first half decrease is driven by demand from service industries in Group 2 and unknown sector, whereas the second half increase is driven by the demand from the remaining service industries and the non-service sector. The magnitude of increase between 2050 and 2100 is estimated at about 2.3 Ml/d. The increase of demand in the non-service sector has been driven by the demand from Arla Foods Plc. However, we have assumed demand for the non-service sector will remain constant over the second half of the forecast period. We do not believe it is appropriate to continue a trend based on such a localised significant driver.

3.254 Overall Non-household consumption for SWA is shown in Figure 3-48.

Figure 3-48: SWA non-household consumption

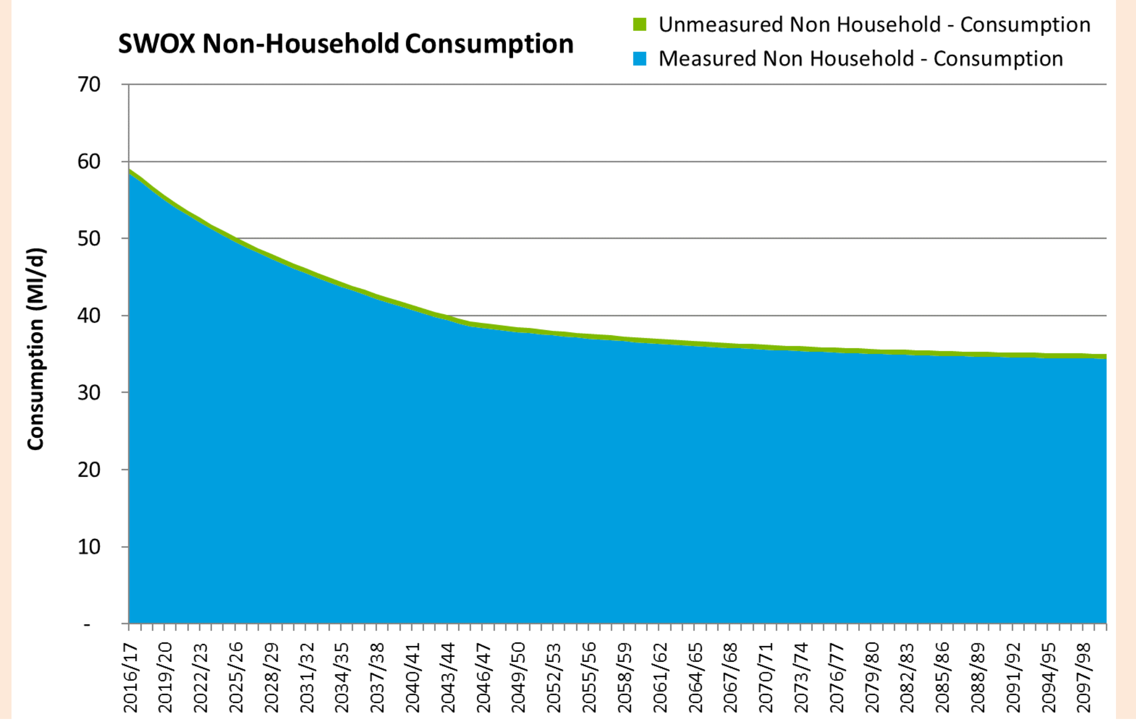


SWOX

3.256 Only the Group 1 (SIC groups P and Q) group is forecast to increase its demand over the forecast period. Demand from the service SIC groups G, H, I, M, N and J is expected to decrease by 32.9% in 2050 and by 58.3% in 2100 compared to 2015 level. The decrease of demand in the Group 2 (SIC groups R, S, T and O) is driven by the closure of Didcot power station, and the reduction of demand from defence (MOD) sites. However, it can be argued that a continued decline will not be sustained for such a group of service industries. Hence a constant demand is assumed over the second half of the forecast period. The overall demand will decrease till mid-century, with 36% decrease in 2050 compared to 2015. Then, demand will slowly decrease throughout the remaining period to 2100.

3.257 Overall non-household consumption for SWOX is shown in Figure 3-49.

Figure 3-49: SWOX non-household consumption



3.258 A summary of forecast non-household demand across all our WRZs is shown in Table 3-29.

Table 3-29: Summary of non-household demand (Ml/d)

WRZ	2016/17	2044/45	2099/2100
London	365.92	372.87	359.79
SWOX[24]	59.11	39.61	35.04
SWA[25]	20.06	17.79	19.96
Kennet Valley	18.87	17.89	20.28
Guildford	7.74	9.71	11.36
Henley	1.77	1.43	1.37

Summary

3.259 The modelling has developed forecasts of areas and groups of industry types, showing a wide variety of different patterns. The model shows slight decreases in non-household demand until the 2080s, then slight increases until the 2100s. Increase of demand in the service sector, notably in London, has been forecast, whereas demand from the non-service sector is projected to remain relatively constant over the forecast period. The unknown sector demand, i.e. demand where there is insufficient information to classify the user into either category, is forecast to largely decrease by the end of the forecast period.

F. Baseline leakage and minor components

3.260 In line with the requirements of the WRPG, leakage in the baseline demand forecast remains flat across the forecast period with an end of AMP6 value in 2019/20 consistent with the value stated in our 2014 Final Determination[26].

3.261 We also forecast minor components as unchanged over the planning period due to no satisfactory method by which to forecast these.

3.262 The values for leakage and minor components across the planning period can be seen in Table 3-30.

[24] SWOX WRZ
[25] Slough, Wycombe and Aylesbury WRZ
[26] Note that our 2014 Final Determination (FD) as published shows a 2019/20 target figure of 606 Ml/d. Table 3-30 shows a figure of 646 Ml/d. The difference between these numbers is that the 2014 FD is stated using the current leakage reporting methodology. We are also shadow-reporting using a new methodology which will replace the current methodology in 2020. This change is explained further in section D of Appendix M: Leakage.

Table 3-30: Leakage, operational usage and water taken unbilled

WRZ	London	SWOX	SWA	Kennet Valley	Guildford	Henley	Total
Leakage	493.90	63.40	37.40	26.20	13.40	3.58	637.88
DSOU	6.86	0.74	0.47	0.23	0.18	0.03	8.50
Water Taken Unbilled	40.42	4.12	1.44	1.27	0.73	0.12	48.10

G. Summary of our baseline demand forecasts

3.263 The baseline DYAA demand forecast for each WRZ and the DYCP forecast for Thames Valley zone are shown in the following figures.

Figure 3-50: London DYAA distribution input

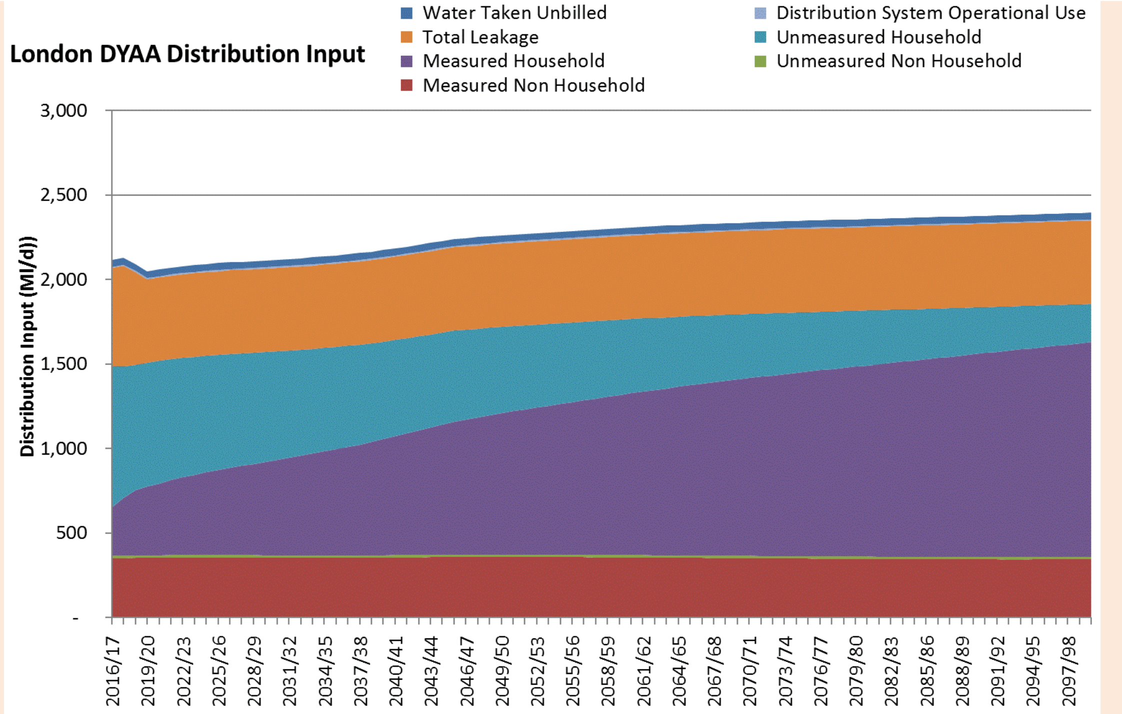


Figure 3-51: SWOX DYAA distribution input

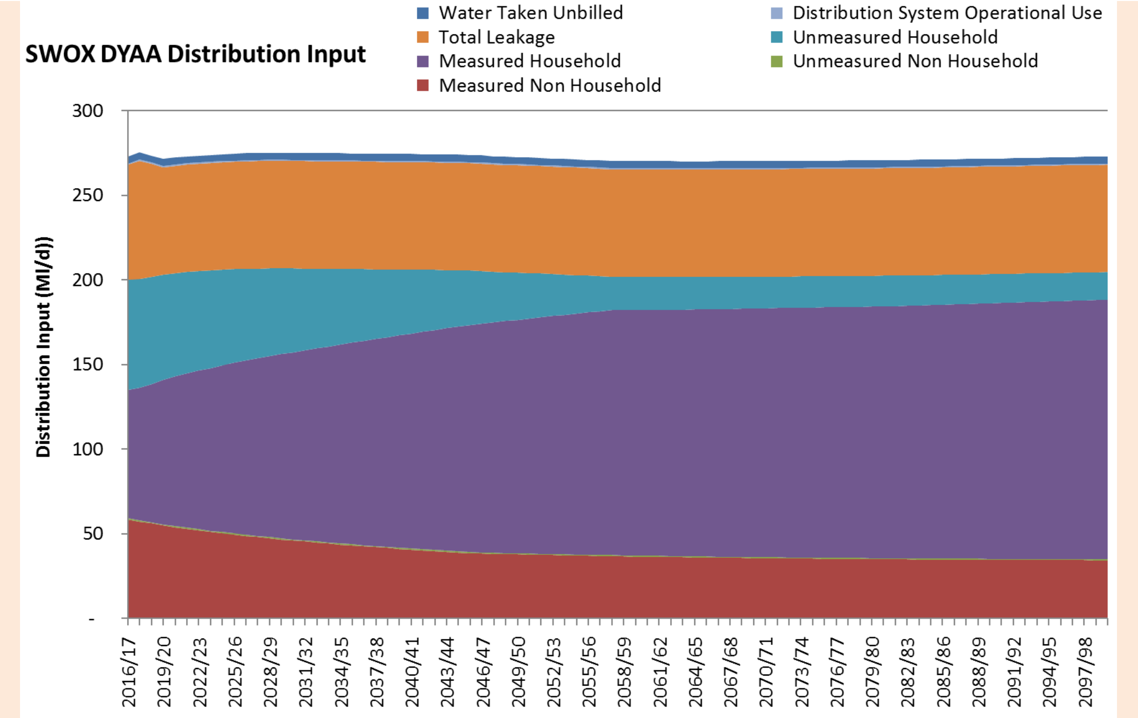


Figure 3-52: SWOX DYCP distribution input

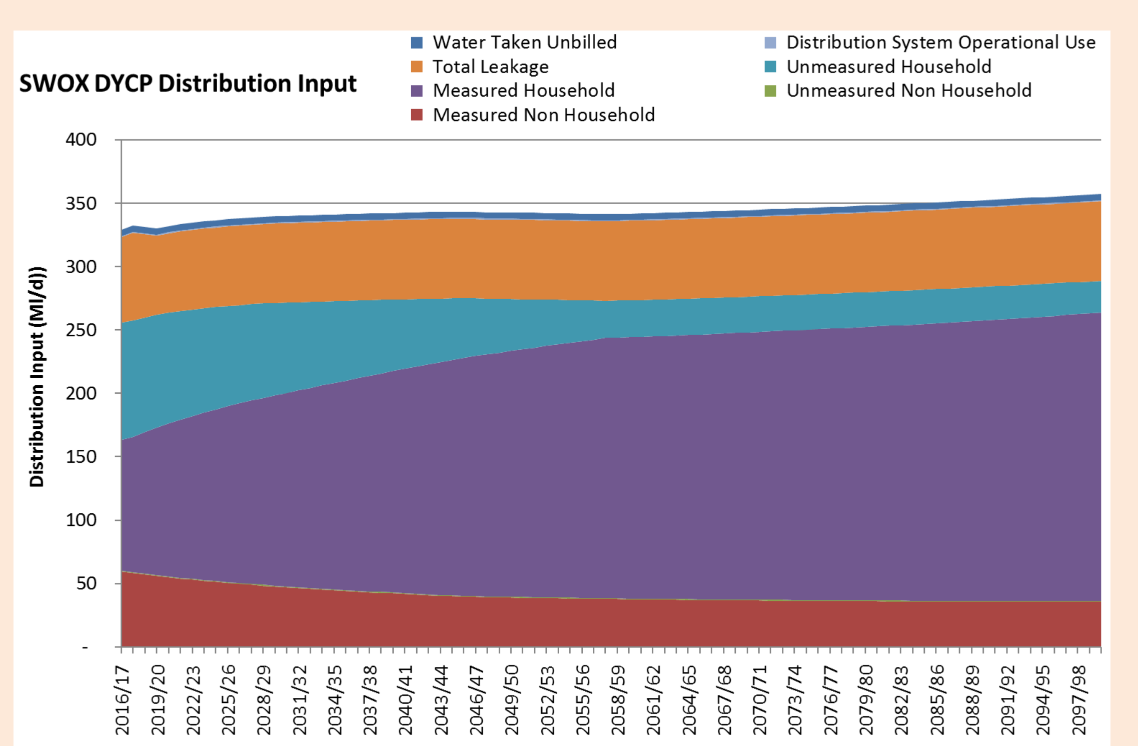


Figure 3-53: SWA DYAA distribution input

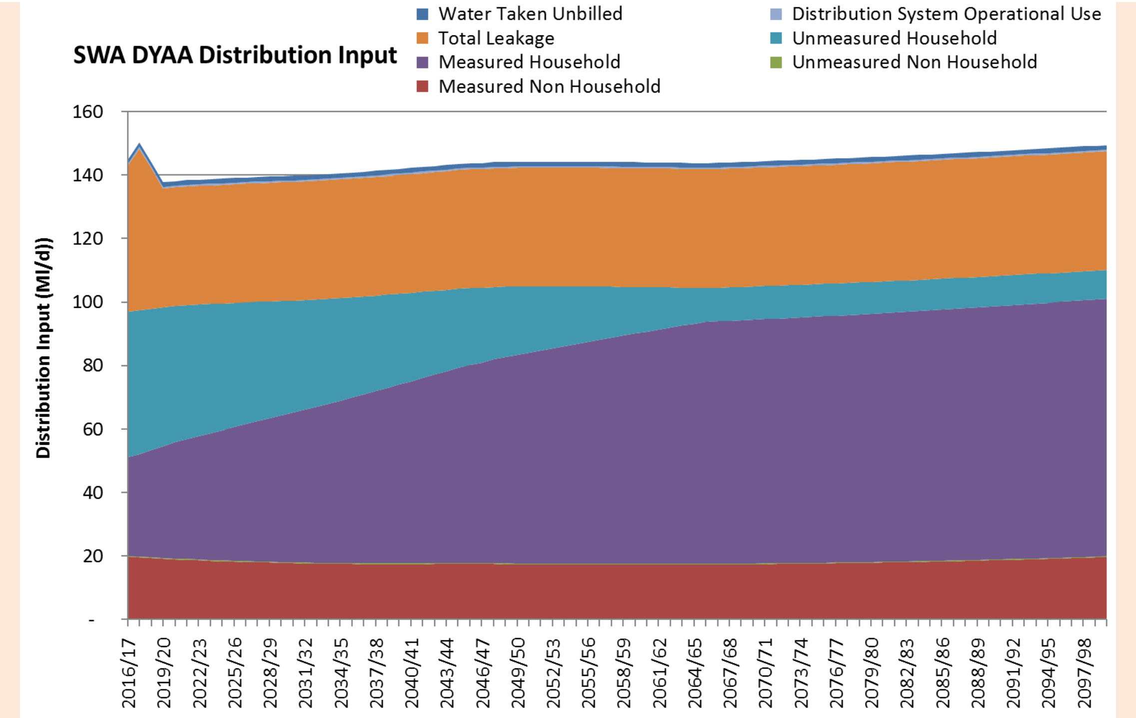


Figure 3-54: SWA DYCP distribution input

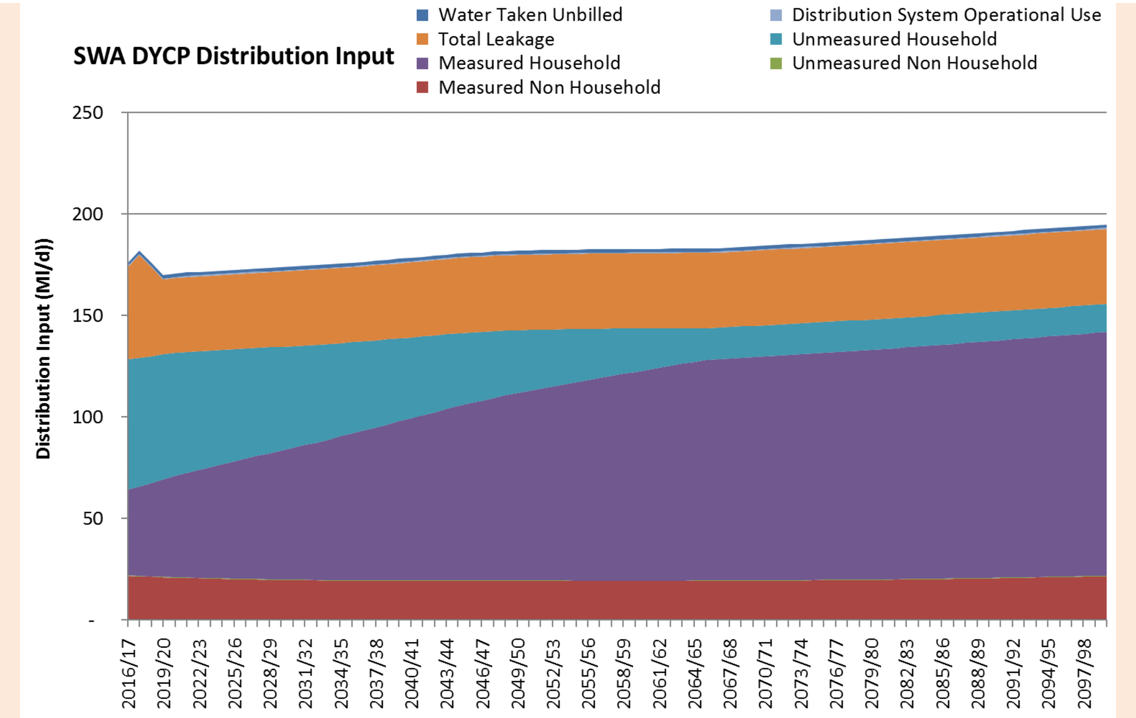


Figure 3-55: Kennet Valley DYAA distribution input

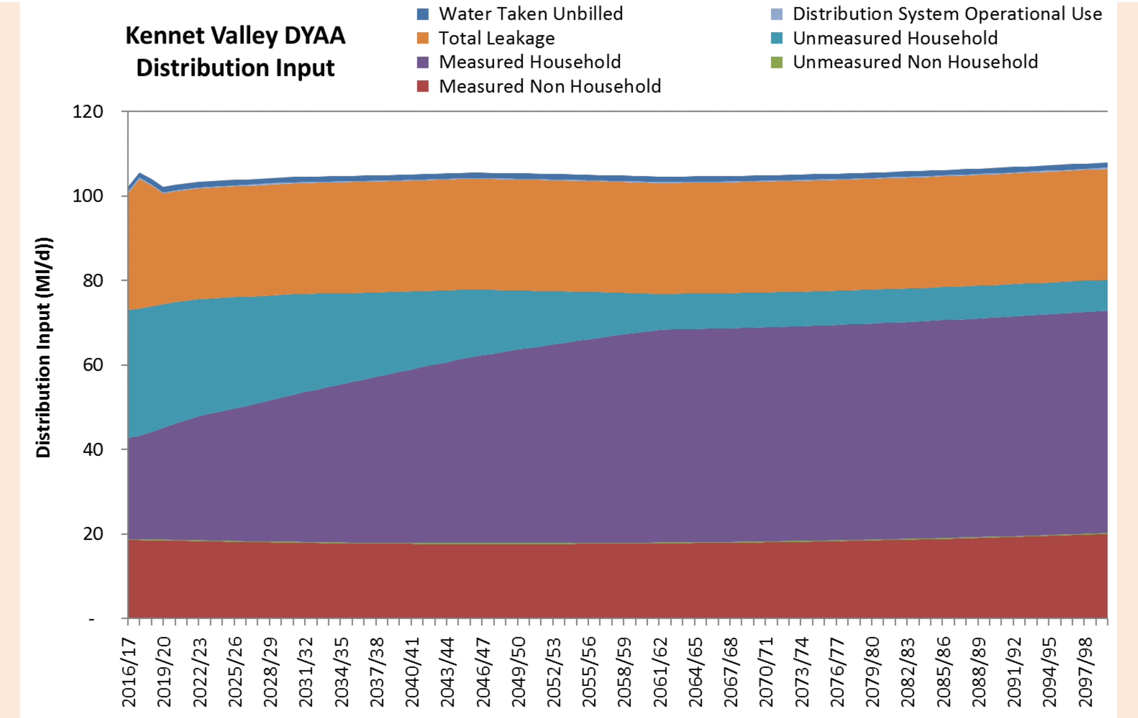


Figure 3-56: Kennet Valley DYCP distribution input

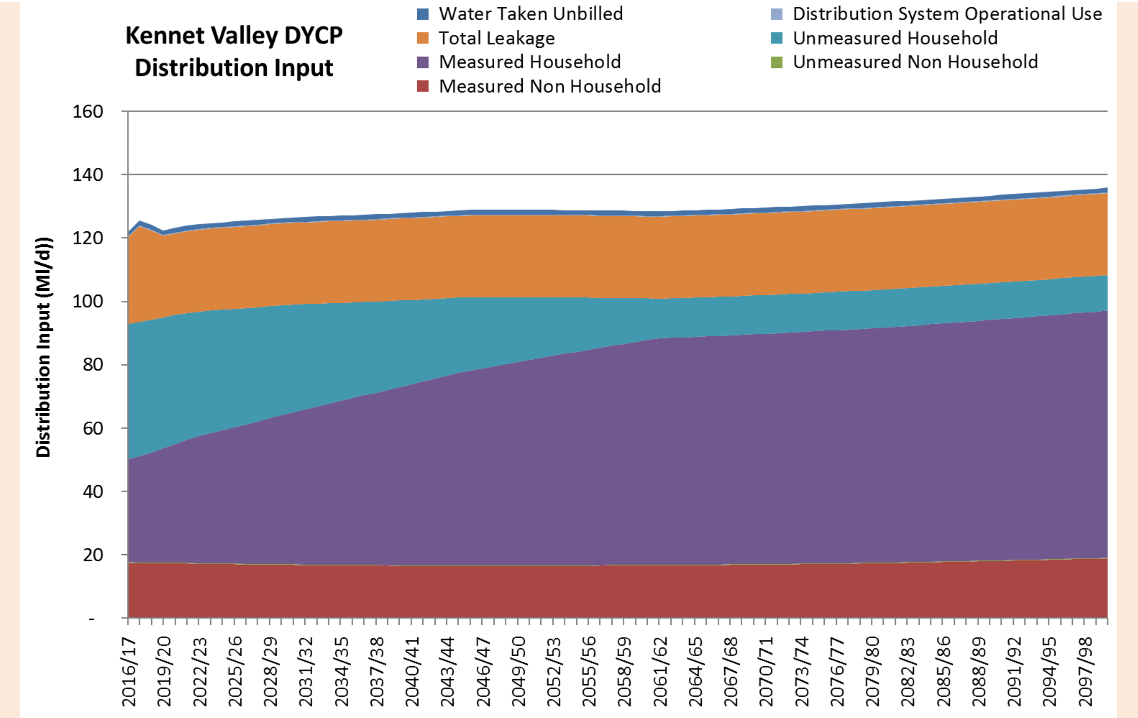


Figure 3-57: Guildford DYAA distribution input

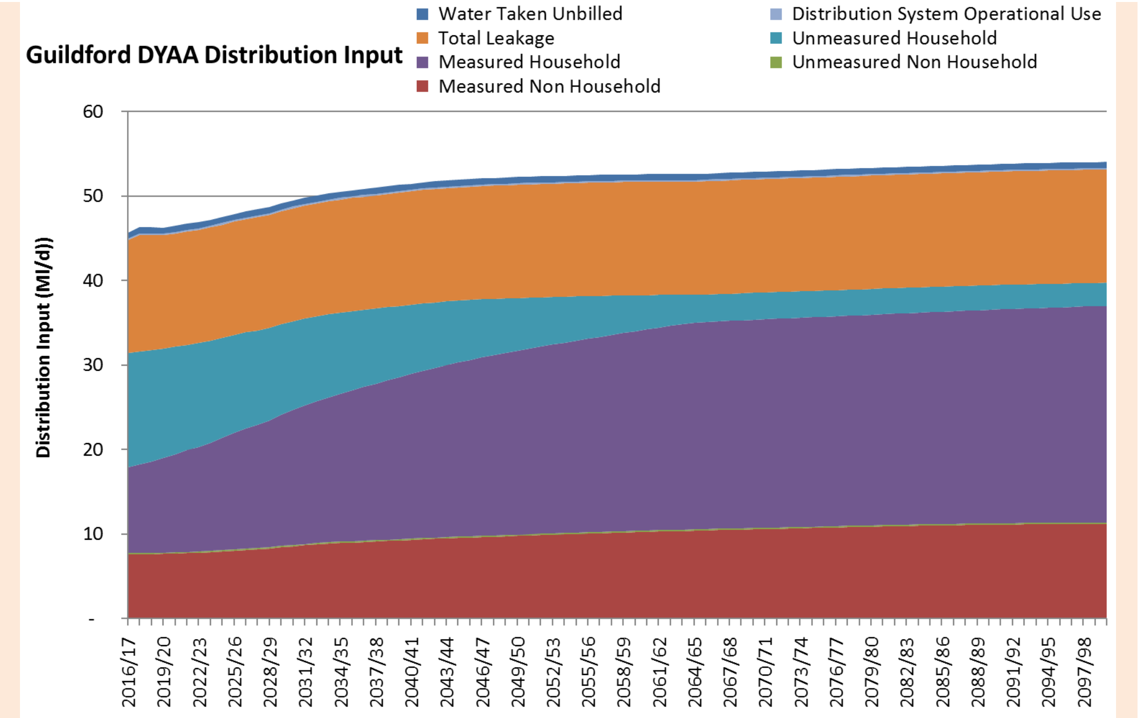


Figure 3-58: Guildford DYCP distribution input

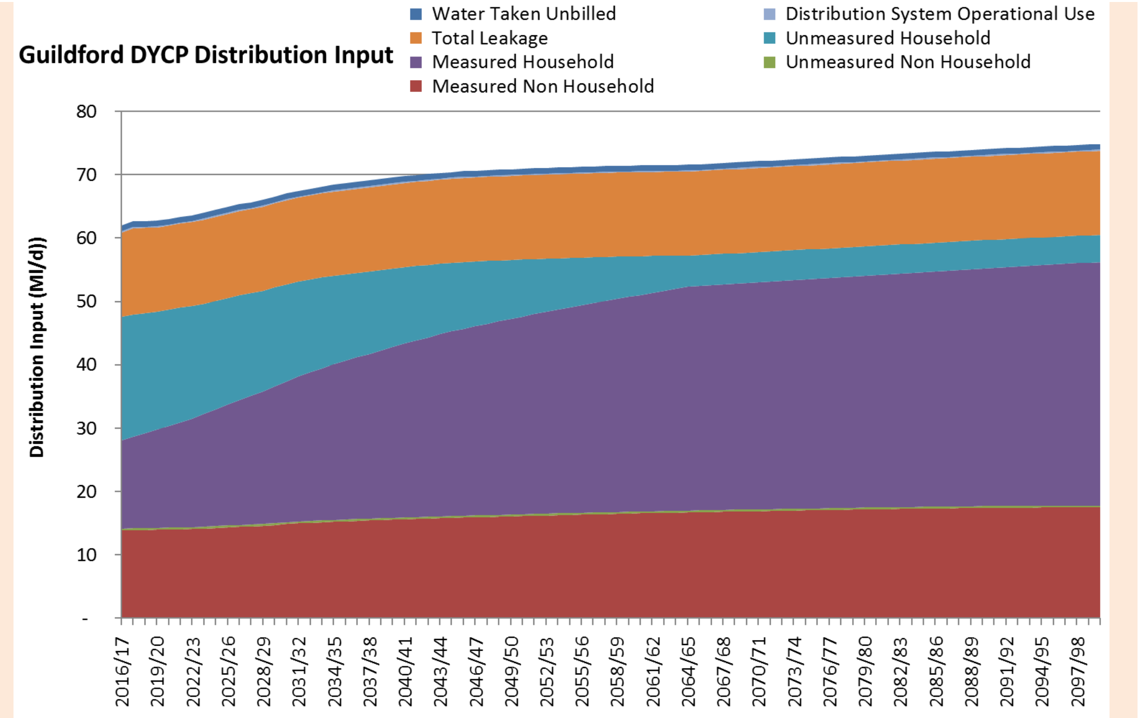


Figure 3-59: Henley DYAA distribution input

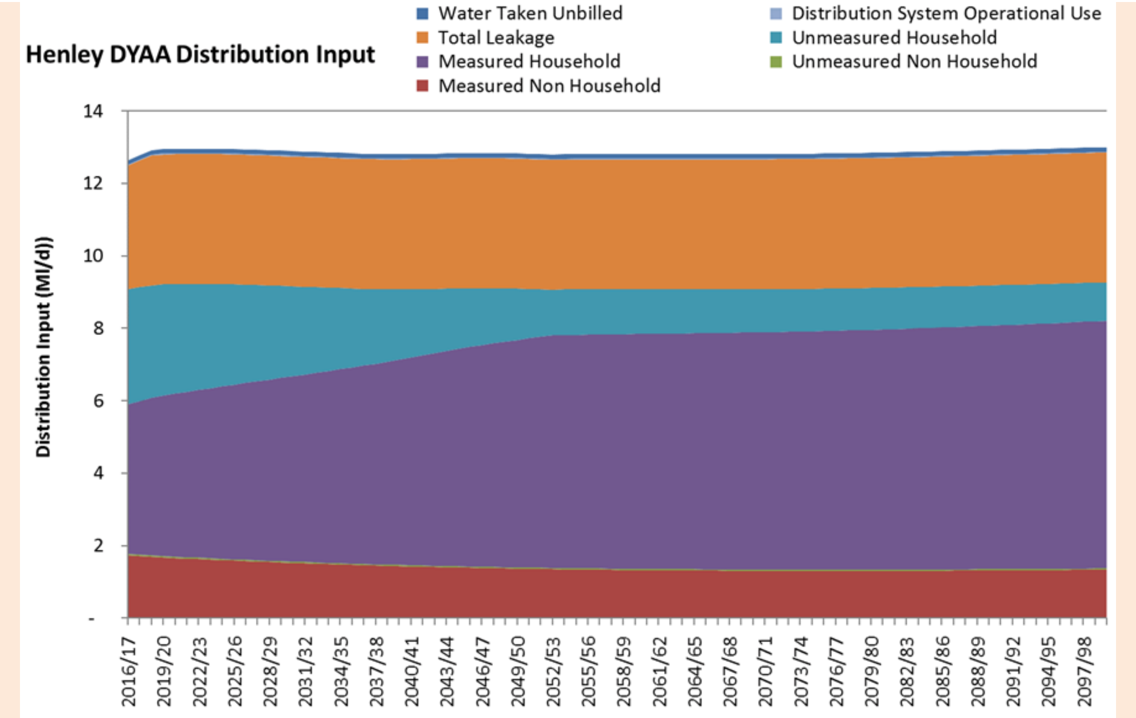
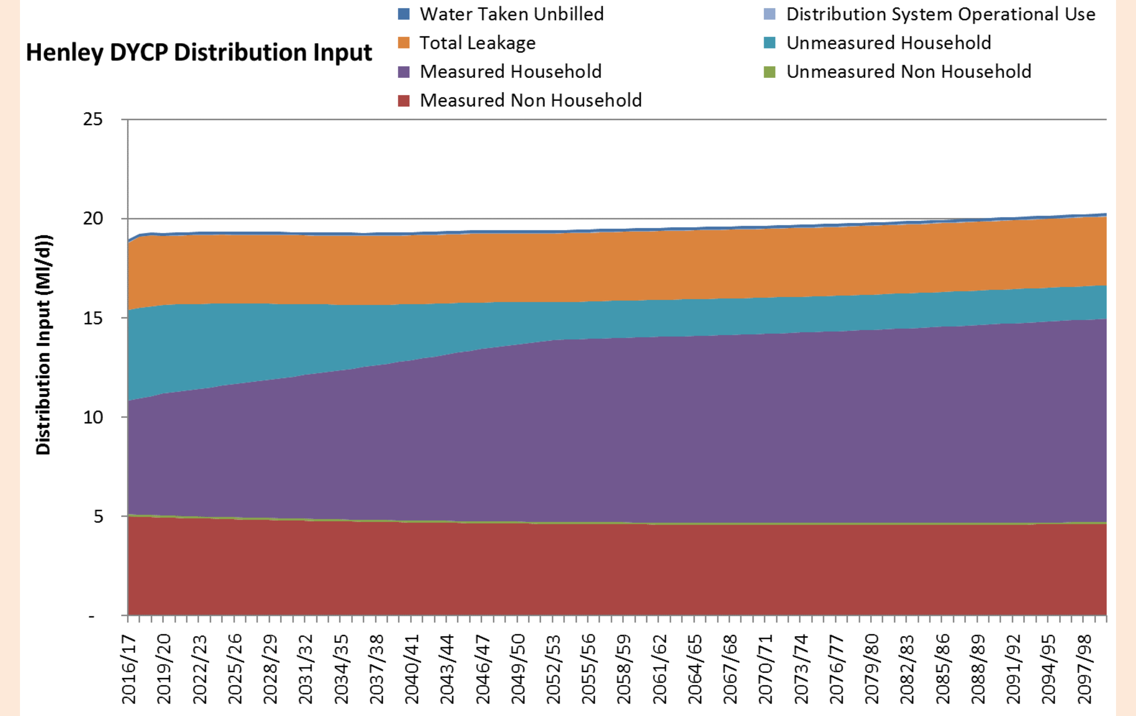


Figure 3-60: Henley DYCP distribution input



Section 4

Current and future water supply

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Section 4.

Current and future water supply

- Our water supplies are derived from a combination of surface water (from rivers) and groundwater (underground water holding rock formations, known as aquifers).
- In this section we describe the amount of water which is currently available for water supply, Deployable Output (DO), and how this has been assessed. The components of the term Water available for use (WAFU) are explained and the base year values for the year 2016/17, updated using the best available up-to-date information between draft and revised draft WRMP19 (referred to as AR17+ figures here), are shown.
- We describe the forecast of supply and the dual pressures affecting water supply of climate change and reductions in abstraction licence capacity to achieve for environmental improvements.
- We have included sustainability reductions in line with the Water Industry National Environment Programme (WINEP3) published by the Environment Agency (March 2018).
- We explain our involvement in the Water Resources in the South East (WRSE) Group and its examination of the potential for a regional water resources solution; and set out our bulk transfers with neighbouring water companies.

In response to feedback received as part of the public consultation on the draft WRMP19 and the availability of new information, the following changes between the draft and revised draft WRMP19 Section 4 have been made:

- **DO Modelling:** Further justification is provided of the modelling approaches employed including clarification on DO assessment in the Thames Valley for zones with a mix of source types (groundwater, surface water with associated reservoir storage and run of river). Description of how demand restrictions and strategic schemes are triggered. Further details on triggering drought actions and benefit to the London Water Resource Zone (WRZ) DO have been added to Appendix I. Risk around the longevity of the West Berkshire Groundwater Scheme (WBGWS), one example of a strategic scheme, has been included as a 'what-if' scenario as part of programme appraisal in Section 10: Programme appraisal and scenario testing.
- **Treatment Works Losses:** Clarification that process losses are included within the DO calculation.
- **Bulk Supplies and Inset Appointments (NAVs):** Bulk supplies and inset appointments are consistent between draft and revised draft WRMP19 including the export to Fortis Green. For the Fortis Green export, Affinity Water did not provide a confirmed revised profile for use within our revised draft WRMP19 profile so we have carried forward the draft WRMP19 profile. Affinity Water have however sent through a provisional revised profile which is included as a 'what if' scenario in Section 10: Programme appraisal and scenario testing.

- **Outages:** Additional information is provided on: Changes to the period of record used resulting in an outage increase; use of residual outages; baseline outage being consistent with final plan outage throughout the 80 year planning period; the reason for annual average being the same as critical period, consideration of outages longer than 90 days and options to reduce outage.
- **Sustainability Reductions:** Updated information on sustainability reductions is included to take account of the recent Environment Agency WINEP3 publication with the result that the sustainability reductions included in the baseline have been updated to include Hawridge and Bexley abstraction licence, and therefore DO, reductions. We have also added two more scenarios to assess impacts from potential sustainability reductions associated with no deterioration obligations. These compliment the two scenarios considering our long term aspiration to cease abstraction from vulnerable chalk streams where there is shown to be an adverse impact from abstraction.
- **Stochastic Modelling:** Additional information is provided explaining the PET data used for stochastic modelling relied on with further details included in Appendix I. Modelling 1 in 200 droughts in WARMS2 (Water Resources Management System) and comparing DOs generated to those from Integrated River Aquifer System (IRAS) has justified the appropriateness of using IRAS as a screening tool for WARMS2 with details of the analysis provided in Appendix I. Further evidence provided supportive of the estimation of more extreme drought event DO using Extreme Value Analysis (EVA) in the Thames Valley as introduced and detailed within Appendix I. Further explanation provided as to how a range of drought profiles have been considered across all WRZs including the addition of Drought Vulnerability Surfaces (DVSs) for London shown to be the most vulnerable WRZ.
- **WRSE Modelling:** Responding to stakeholder requests for a regional plan in addition to the company plan; in WRMP24 we expect to produce a regional WRMP for the South East Region in combination with other WRSE companies.

In addition there have been further changes made to this section including:

- **Current WAFU:** AR17 2016/17 figures for DOs, water treatment works' (WTW) capabilities, process losses and Outage Allowance updated between the draft and revised draft WRMP19 using the best available up-to-date information; these figures are referred to as AR17+ figures and compared to AR18 figures.
- **Climate Change:** The climate change assessment has not been updated between the draft and revised draft WRMP19; however, the climate change impact on DO has changed marginally due to updated AR17+ baseline DO figures being used to assess the impact. In addition, a climate change emissions sensitivity analysis has been carried out by assessing the High Emissions UKCP09 climate scenario for the 2080s in the London WRZ and comparing the impacts with the Medium Emissions 2080s scenario used for the baseline supply forecast; the results show only a marginal difference.
- **Stochastic Modelling:** Consideration is given to the return period of the worst historic 20th century drought refined to 1:100 years and the London WRZ DO impact of a 1 in 500 return period drought to 250Ml/d. Statement included to show that the company will increase drought resilience from 1 in 100 year drought to 1 in 200 year drought in 2030. Furthermore a 1 in 200 drought resilience timing of delivery and 1 in 500 'what-if' scenario is included as part of programme appraisal in Section 10: Programme appraisal and scenario testing.

A. Introduction

4.1 The Thames basin is one of the most intensively used water resource systems in the world. Around 55% of effective rainfall is licensed for abstraction[1] and 82% of that is for public water supply (Figure 4-1).

4.2 Our baseline water supplies are derived mainly through surface water abstraction in London (supported by a series of large bunded storage reservoirs) and groundwater abstraction in the Thames Valley. The proportions of supply are as follows:

- **London:** 80% surface water and 20% groundwater
- **Thames Valley:** 30% surface water and 70% groundwater

4.3 In a dry year we supply 2,100 Ml/d of water in London and 780 Ml/d in the Thames Valley at peak times.

4.4 Our baseline water supplies are forecast to reduce over the planning period to 2100. The main cause is the impact of climate change (~134 Ml/d by 2044/45 increasing to ~241 Ml/d by 2099/00). A lesser cause is due to trading agreements expiring, which amount to 40 Ml/d over the period to 2099/00.

4.5 Together with growing demand as set out in Section 3: Current and future demand for water, this leaves us with a considerable challenge to balance supply and demand over the 80 year planning period in some zones, London in particular.

4.6 The remainder of this section is structured as follows:

- Introduction
- Current WAFU
- Baseline supply forecast
  - Sustainability reductions
  - Climate change (further information in Section 5: Allowing for risk and uncertainty and Appendix U: Climate change)
- WRSE (further information in Section 7: Appraisal of water resource options).

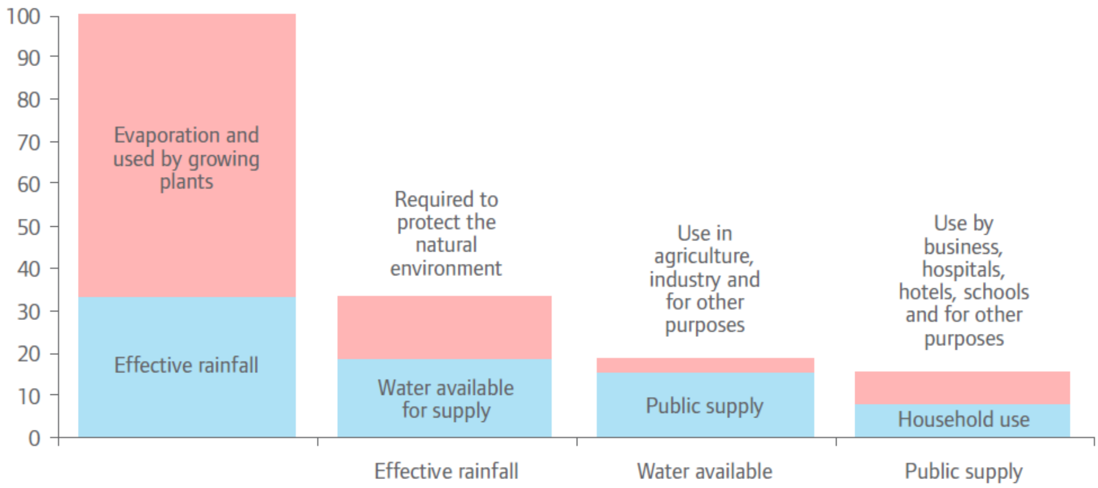
[1] Environment Agency, Thames Catchment Abstraction Management Strategy, May 2014, section 2, page 8

The Thames basin

4.7 The Thames basin is the largest river basin in the south east of England. The average rainfall for the Thames catchment is 739mm[2] in a year, substantially less than the average for England and Wales, 919mm[3]. (Note this is derived from the records from 1883 to 2011.)

4.8 Of the rain that falls, two-thirds is either lost to evaporation or transpired by growing vegetation (Figure 4-1). Of the remaining one-third, which is 'effective' rainfall, approximately 55% is abstracted for use, making it one of the most intensively used river basins in the world. Of all the water abstracted, 82% is for public supply.

Figure 4-1: What happens to water in the Thames basin



Source: Taken from GLA Securing London's Water Future - The Mayor's Water Strategy for London, 2011

[2] "Thames 12 Station average" data from the Environment Agency and averaged over 131 years
[3] Defra, Official Statistics for England and Wales

Where we get our water supplies

Figure 4-2: Existing water resources in the Thames catchment

4.9 The amount of water we can put into supply (i.e. leaving our WTWs and into our distribution network), is called WAFU and is a function of many factors.

4.10 WAFU in the base year (2016/17) is evaluated according to the relationship below and describes the amount of water available to supply the demand for water:

WAFU = Deployable Output – Climate Change Impacts – Constraints – Outage +/− Bulk Supply Imports/Exports (including Inset Arrangements).

4.11 Each of these components is described further below.

4.12 We take into account increases and decreases to these components when forecasting WAFU over the 80 year planning period. Principally these are:

- The impact of climate change
- Changes as a result of trading agreements expiring
- New schemes coming online and
- Changes to abstraction licences in the period to 2019/20 (as discussed in Section 2: Water resources programme 2015-2020.

4.13 WAFU is then assessed against demand (Section 3: Current and future demand for water) plus Target Headroom (Section 5: Allowing for risk and uncertainty) to understand whether a WRZ is in surplus or deficit (Section 6: Baseline water supply demand position).

B. Current water available for use (2016/17)

4.14 The individual components to calculate the amount of WAFU are discussed briefly below.

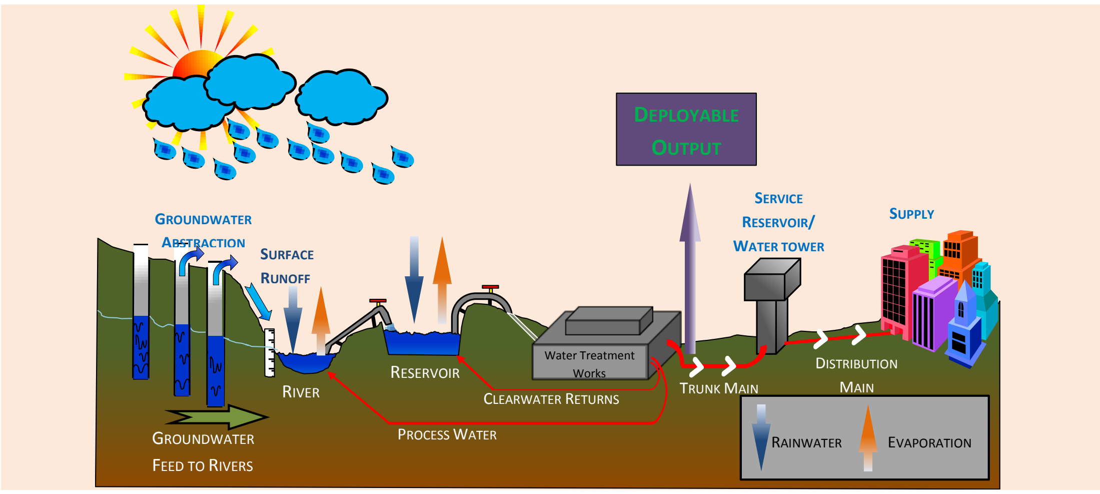
Deployable Output

4.15 DO is the building block on which the assessment of WAFU is based. It is defined as the output of a commissioned water source or group of sources or of a bulk supply for a given Level of Service as constrained by:

- Hydrological yield;
- Licensed quantities;
- Environment (through licence constraints);
- Pumping plant and/or well/aquifer properties;
- Raw water mains and/or aquifers;
- Transfer and/or output main;
- Treatment;
- Water quality.

4.16 This is shown in Figure 4-3 below:

Figure 4-3: Definition of DO



Source: Based on Water Resources Planning Tools 2012 Definitions and Environment Agency Guidelines May 2016

4.17 DO is calculated using prescribed methodologies for surface and groundwater sources.[4,5,6,7,8] The assessment of DO also follows the principles for DO derivation as outlined in the 2012 UKWIR/Environment Agency report on Water Resources Planning Tools[9].

4.18 We have a complex supply system where, in many areas, surface and groundwater are mixed and operated together to maintain yields over the year in reaction to antecedent weather and demand patterns. These are known as conjunctive use systems.

4.19 London's water comes from many sources but most is abstracted from the River Thames and stored in raw water reservoirs before being treated and put into supply. The raw water reservoirs provide a buffer for use in dry periods when abstraction from the River Thames is restricted. The quantities that can be abstracted from the river depend on the relationship between the quantities stored in the reservoirs, the need to ensure a residual freshwater flow in the River Thames over Teddington weir, and the time of year. This is governed by the formal operating agreement between Thames Water and the Environment Agency under Section 20 of the Water Resources Act 1991, called the Lower Thames Operating Agreement (LTOA).

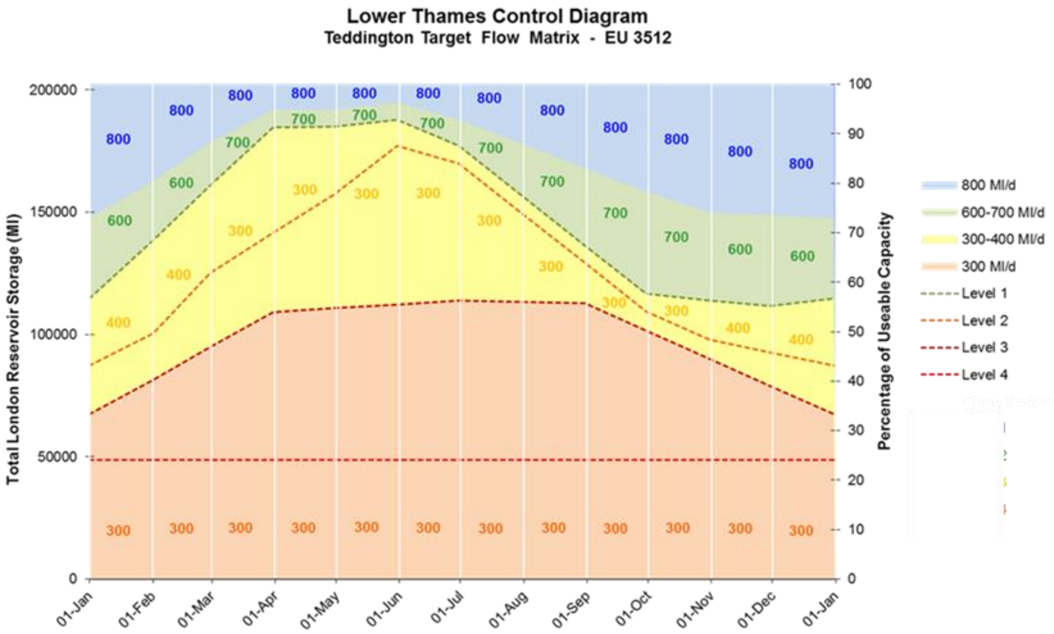
4.20 DO for the London conjunctive use zone (CUZ) is calculated using a simulation model entitled WARMS2, which is an enhancement of the original WARMS used for our Water Resources Management Plan 2014 (WRMP14). The LTOA is fundamental to the calculation of DO because it determines the relationship between the flow in the River Thames and the amount of water available to abstract for given levels of raw water storage in the London water storage reservoirs. This in turn defines how the abstractions from the Lower Thames are managed and therefore determines the supply capability for London. Due to the interconnectivity across London it also influences the operation of other strategic sources. Key to the LTOA is the Lower Thames control diagram (LTCD), which sets the rules by which the level of flow over Teddington weir is set, known as the Teddington Target Flow. It also provides River Thames flow / London raw reservoir storage trigger levels which place actions on us that are aimed at reducing demands and providing a DO benefit, for example a media campaign or hosepipe ban and supporting yields by operating strategic schemes, including, as an example, the WBGWS, during a dry year as detailed within Appendix I: Deployable output.

4.21 Following the re-development of the WARMS2 an update of London's DO was calculated for the Annual Review 2016 (AR16).The calculation assumes the preferred version of the optimised LTCD and the Teddington Target Flow matrix (TTFM), agreed with the Environment Agency. The re-development of WARMS and the introduction of an optimised LTCD resulted in a significant change in London's DO as seen in Table 4-1. The updated optimised LTCD is shown in Figure 4-4, with details in Appendix I: Deployable Output.

[4] Drayton and Lambert ,1995, Surface Water Yield Assessment
[5] Environment Agency, 1997, Reassessment of Water Company Yields
[6] Beeson, van Wonderen and Mistear, 1995, Assessing the Reliable Outputs of Groundwater Sources
[7] UKWIR and Environment Agency, 2000, A Unified Methodology for the Determination of Deployable Outputs from Water Sources
[8] UKWIR, 2014, Handbook of Source Yield Methodologies
[9] UKWIR and Environment Agency, 2012, Water WR-27 Water Resources Planning Tools

4.22 With regard to the future operation of the WBGWS, we will await the Environment Agency's national review of their environmental augmentation schemes, to be completed by March 2019, which will address their longer term availability, including that of the WBGWS. This will be followed up by discussion of the scheme ownership and operation beyond 2031. To assess the potential future water supply impact for the London and Kennet Valley WRZs, the WBGWS has been included within the Economics of Balancing Supply and Demand (EBSD) model as a 'what-if' scenario as part of programme appraisal as detailed in Section 10: Programme appraisal and scenario testing.

Figure 4-4: Lower Thames control diagram



4.23 The groundwater source DO (SDO) numbers that contribute to the current WAFU for the revised draft Water Resources Management Plan 2019 (revised draft WRMP19) and input to WARMS2 are those reported in the Annual Review 2017 (AR17) as adjusted for the impact of updates to groundwater SDOs (following an internal review of constraints) and revised treatment works throughput capabilities and treatment works loss figures (using our WTW Process Models) between draft and revised draft WRMP19. The 2016/17 values within the revised draft WRMP19 are therefore referred to within this document as AR17+ figures.

4.24 The calculation of these groundwater SDOs is in accordance with good practice, ensuring consistency in their assessment and enabling a coherent assessment of our DO. In particular, the approach defines source DOs for a single drought year for all sources in each WRZ. In addition, the groundwater source DOs are arrived at by defining: a Dry Year Critical Peak (DYCP) DO that reflects a demand driven peak DO for Average Day Peak Week (ADPW) at the time of peak summer demand in July/August; a Dry Year Annual Average (DYAA) DO that reflects an average over 12 months; as well as a minimum DO that accounts for the lowest groundwater levels in the drought year.

4.25 The Swindon and Oxfordshire (SWOX) WRZ is the other CUZ within the Thames Water area where the DO is also modelled using WARMS2. The current assessment for SWOX WRZ DO follows best practice (WRPG) because WARMS2 models the Upper Thames strategic reservoir/groundwater source conjunctive use system, with the South Oxfordshire (SOX) source DOs and transfers to the Upper Thames added as a post-processing step to calculate the WRZ DO.

4.26 The remaining four zones of Kennet Valley, Henley, Guildford and Slough, Wycombe and Aylesbury (SWA) derive raw water supplies predominantly from groundwater sources, although Kennet Valley and Guildford have significant run of river surface water sources at Fobney and Shalford, respectively. The Kennet Valley and Guildford WRZs have not been assessed as CUZs because they do not have any strategic reservoir storage; rather they are served by a combination of run of river sources and groundwater sources.

4.27 The DO calculation for run-of-river surface water sources with no raw water storage (Fobney, Kennet Valley WRZ and Shalford, Guildford WRZ) follows the approach outlined in the UKWIR Handbook of Source Yield Methodologies (2014). This relies on flow data provided by the Environment Agency, rather than model outputs.

4.28 The mechanism by which demand restrictions are triggered in the Thames Valley WRZs is set out in detail in our draft Drought Plan 2017. Drought management decisions must start with a consideration of the impact the drought is having on the supply capability within each WRZ and the approach taken in formulating the drought management protocol is dependent upon the nature of the water resources system within each WRZ. Because of the dominant nature of the London WRZ, it will generally be the case that the water use restrictions introduced in the London WRZ will also be applied to the rest of our supply area. Nonetheless, the Drought Plan recognises that there may be situations in which more local measures may need to be introduced for the other WRZs. Consequently, protocols have also been developed for these zones. The protocol for each zone is included in further detail in Appendix I: Deployable Output.

4.29 Further information and discussion on the methodology for calculating DO, DO sensitivity analysis and the impacts of Levels of Service, including the DO benefit of demand restrictions and strategic schemes and details of how these drought actions are triggered, is provided in Appendix I: Deployable Output.

4.30 The DYAA and DYCP DOs for 2015/16 (AR16) and 2016/17 (AR17), which are included in the Annual Review to the Environment Agency, are shown in Table 4-1 below as are the values at WRMP14 based on Annual Review 2013 (AR13) data; the DO for our London WRZ is assessed for DYAA only due to both London's reservoirs and ring main providing a buffer during peak periods. Changes to the DOs between reporting years are explained as part of the Annual Review reporting process. Further details of our Annual Review process can be found on our website. The AR17+ figures are also shown in Table 4-1. These figures reflect the best information available at the time of producing the revised draft WRMP19 between AR17 and AR18.

Table 4-1: DO WRMP14, 2015/16 (AR16) and 2016/17 (AR17+).

WRZ	Deployable Output (Ml/d)							
	DYAA WRMP14	DYAA AR16	DYAA AR17	DYAA AR17+**	DYCP WRMP14	DYCP AR16	DYAA AR17	DYCP AR17+**
London*	2144	2305	2305	2302	--	--	--	--
SWOX	319.5	319.2	329.2	329.2	373.9	373.7	385.4	385.4
Kennet Valley	137.1	133.1	135.8	143.9	160.1	155.1	157.8	155.4
Henley	25.7	25.7	25.7	25.7	26.3	26.3	25.9	25.9
SWA	186.3	186.3	183.3	185.1	215.1	216.2	213.3	214.4
Guildford	65.0	65.4	65.4	65.8	71.2	72.9	71.3	71.7
Total	2877.6	3034.7	3044.4	3051.7	846.6	844.2	853.7	852.9

**The DO for our London WRZ is assessed for DYAA only due to both London's reservoirs and ring main providing a buffer during peak periods.*

***Note A17+ figures have been used in the revised draft WRMP19. These are the AR17 figures adjusted to take account of the impact of updates to SDOs (following internal review of constraints) and revised treatment works capabilities and treatment works loss figures (using our WTW Process model) between the draft and revised draft WRMP19.*

4.31 AR18 DOs are consistent with the AR17+ DOs with the exception of SWOX which is +1 Ml/d DYAA and +1.19 Ml/d DYCP due to a refinement to the Chingford WTW capability.

Treatment works losses

4.32 An important element in the calculation of DO is the amount of water used at treatment works. Abstracted water is treated within a WTW before disinfection and being put into the supply network. There is inevitably a loss of water in this process.

4.33 Many groundwater sources are good quality and may need only a simple treatment process with negligible waste. However, the large surface WTWs that treat water from our London raw water reservoirs necessitate the employment of a variety of treatment processes. Treatment processes and WTWs also require additional 'process water' for cleaning and maintaining the plant.

4.34 The process for treating water means that there are potential losses of process water to the system unless there is an opportunity to re-cycle the water.

4.35 This 'process water' contains contaminants and is either treated and discharged to the river, or discharged to a sewer or, where possible, further treated and re-cycled back to the "head of the works" for re-use.

4.36 The route for disposal of process water depends upon the nature of the WTW, the source and quality of the raw water.

4.37 The opportunity to recycle process water can be achieved by a number of routes:

- Directly, as at the Coppermills WTW, which recovers the majority of process water by treatment and recycling
- Indirectly via discharge into a watercourse or river, where it contributes to the flow available for abstraction or the "hands off flows", as on the Lower Thames
- Indirectly via a sewage treatment works, which in turn may support downstream water available for abstraction or the "hands off flows", as on the Lower Thames

4.38 Process losses are included in WARMS2 and therefore included in the calculation of DO.

4.39 The modelling of the water resources system through WARMS2 assumes that a percentage of additional water is needed to deliver a specific quantity into supply. For example to put 100 Ml/d into supply with a 10% process water requirement means that 110 Ml/d would need to be transferred to the WTWs and results in a 10 Ml/d process water loss (calculated in WARMS2 as 10% of 100 Ml/d output from the WTW into supply).

4.40 As noted the percentage of process water losses differs between works due to varying raw water quality and treatment processes.

4.41 Note the Coppermills WTW has the facility to transfer 35 Ml/d of process water back upstream of the process plant for re-use.

4.42 The process water losses percentages assumed for each WTW in WARMS2 for AR17 and for AR17+, the figures used in the revised draft WRMP19 and consistent with AR18, are shown in Table 4-2.

4.43 AR17 process losses at the large surface WTW have been reviewed since submission of the draft WRMP19. This review has used our WTW Process Models. The AR17+ process losses now range from around 1% up to almost 16%, but with most being less than 7%. At the treatment works with losses of almost 16%, i.e. Coppermills WTW, facilities exist for recycling some of the process water as noted about, which reduces net process losses to 7.4%. The updated AR17+ process losses used for the revised draft WRMP19 are documented in Table 4-2 and these are consistent with the figures used for AR18. The analysis and calculation for the key WTW in each WRZ discussed in Appendix K: Process losses.

Table 4-2: Process water losses assumptions in WARMS2

WRZ	WTWs	Process water losses (%)	
		AR17	AR17+
London	Ashford Common	3.0	2.3
	Hampton	6.1	3.4
	Kempton Park	7.2	1.1
	Walton	14.2	6.7
	Coppermills	8.0	7.4
	Hornsey	3.0	4.6
	Chingford	3.5	0.7
SWOX	Farmoor	8.4	6.9
	Swinford	3.3	5.7
Kennet Valley	Fobney	7.0	5.9
Guildford	Shalford	12.0	5.3

4.44 We will continue to examine the potential for reducing process water losses at our WTW sites as part of our maintenance plans and our efforts to continuously improve our processes, reducing waste and enhancing water supply benefit from our WTWs.

Constraints

4.45 Constraints occur where existing infrastructure is not capable of distributing or treating all of the raw water that can be produced at a site. In AMP5 several schemes were completed to remove a number of identified network constraints leaving just a few limitations where schemes are being pursued. The remaining constraints have been assessed to ascertain whether it is cost effective to implement schemes to remove them. Most network constraints are associated with small rural sources on the edge of our distribution network, feeding areas of local demand. All constraints within the existing supply system have been examined for their potential to increase water availability, and therefore to be taken forward to programme appraisal as scheme options, however these will decrease as demand increases and water is used locally.

4.46 Network constraints are deductions from DO (in the same way as outage is deducted) and are not included as an integral part of the DO assessment, as was the case for the WRMP14.

4.47 A summary of constraints for 2015/16 (AR16) and 2016/17 (AR17 and AR17+) is shown in Table 4-3 below. AR17+ figures have been used in the revised draft WRMP19 and these figures are consistent with AR17 and AR18. A review of constraints was undertaken for AR17, which shows marginal reductions in the constraints from AR16 due to variation in demand.

Table 4-3: Constraints by WRZ

WRZ	Constraints (Ml/d)					
	DYAA AR16	DYAA AR17	DYAA AR17+**	DYCP AR16	DYCP AR17	DYCP AR17+**
London*	0	0	0	N/A	N/A	N/A
SWOX	0.30	0.28	0.28	1.23	1.19	1.19
Kennet Valley	0	0	0	0	0	0
Henley	0	0	0	0	0	0
SWA	5.2	2.0	2.0	5.2	2.0	2.0
Guildford	0	0	0	0	0	0

**Constraints data for London WRZ under DYCP is blank as the London WRZ is assessed for DYAA only due to both London's reservoirs and ring main providing a buffer during peak periods.*

***Note A17+ figures have been used in the revised draft WRMP19 these figures are consistent with AR17 and AR18.*

Outage

4.48 Outages are temporary reductions in DO, which can be caused by factors such as mechanical failure or pollution events. The methodology used for evaluating the Outage Allowance is compatible with and computationally identical to the latest UKWIR methodology used for assessing Headroom Uncertainty - see Appendix V: Risk and uncertainty. The method enables an assessment of the uncertainty surrounding outage within the supply demand balance, with a range of probabilities and confidence limits. This calculation is based on the analysis of historical events, updated annually in light of new data and information, and reported as part of the Annual Review to the Environment Agency. The Outage Allowance is calculated in accordance with the original UKWIR methodology (1995), which is consistent with more recent guidance updates, including the Risk Based Planning Methods (UKWIR, 2016), which states that the 1995 methodology remains acceptable.

4.49 Our outage model concentrates on the 'critical month' in each WRZ, with this month having the highest calculated Outage Allowance. As a result, 'residual outages' could be considered to exist outside the 'critical month', but they do not contribute to the Outage Allowance unless the month they occur in later became the 'critical month'. As the existing outage methodology is conservative, insofar as the 'worst' month for outage is selected to reflect the Outage Allowance for each WRZ, the exclusion of any 'residual outages' in other months would not underestimate outage.

4.50 Table 4-4 summarises our Outage Allowances by WRZ for 2015/16, 2016/17 and the values at WRMP14 based on AR13 data, as well as the baseline for the revised draft WRMP19, i.e. AR17+. Changes to the Outage Allowance between reporting years are explained as part of the Annual Review reporting process, but it can be seen that the latest Outage Allowance shows a significant increase from that of WRMP14. This is as a result of the assessment of the historical outage record undertaken as part of the AR16. As part of the review we noted that our Outage Allowance is biased downwards by data gaps within the earlier records from which it is calculated; an important element in the calculation of the frequency of events. On reviewing the results it shows that using the more recent record gives a better reflection of recent events and the level of actual outage.

4.51 Following detailed discussions with the Environment Agency, and after reviewing our approach and datasets against those of other water companies, we concluded that our Outage Allowance would be more representative of the current day if we were to reduce the length of historic data used in the assessment from 15 years (2001/02 to 2015/16) to nine years (2007/08 to 2015/16). We agreed this adjustment with the Environment Agency in 2016 and so now are also considering outages from 2016/17 as well as 2017/18. Although shortening the historical outage record has resulted in increased confidence in the calculated Outage Allowance, to avoid the calculated value being overly skewed to very recent outages, particular attention was given to reservoir and raw water tunnel outages. This relates to a number of London reservoir outages that occurred recently following the failure of a raw water tunnel connected to a storage reservoir. Several other tunnels were of similar design, and so these were relined, resulting in outages during construction works. This resulted in the reservoir Outage Allowance being skewed towards very recent outages, when there had been no other such outages over the previous 30 years. To reflect this historical position and mitigate an overly skewed Outage Allowance, the outage record was lengthened from 10 to 30 years. The programme of raw water tunnel relining is coming to an end and will be completed in the next few years. We have, accordingly, removed some of the reservoir and raw water tunnel outages found in the historical record, and will remove all of these outages when the programme is finished to reflect the reduction in risk as a result of asset investment.

Table 4-4: Outage Allowances by WRZ

WRZ	Outage (Ml/d)*			
	WRMP14	AR16	AR17	AR17+**
London	46.27	81.72	84.55	99.76
SWOX	14.88	16.73	17.50	17.23
Kennet Valley	1.85	2.80	2.59	2.49
Henley	1.05	0.44	0.40	0.36
SWA	12.53	10.75	9.99	9.46
Guildford	0.81	1.25	1.33	1.40
Total	77.39	113.69	116.36	130.7

**Note figures are consistent for DYAA and DYCP*

*** Note A17+ figures have been used in the revised draft WRMP19. These are AR17 figures updated with the best available outage information at the time of producing the revised draft WRMP19.*

4.52 The change in Outage Allowance between WRMP14 (77.39 Ml/d) and revised draft WRMP19 (130.7 Ml/d) is largely driven by changes in the London WRZ and the methodology noted above. This resulted in an increase in Outage Allowance from 46.27 Ml/d in WRMP14 to 81.72 Ml/d in AR16. In the draft WRMP19, the Outage Allowance was very similar at 84.55

Ml/d, increasing to 99.76 Ml/d in London for the revised draft WRMP19 as shown in Table 4-4. As part of a continual data improvement process, our AR18 Outage Allowance has decreased to around 93 Ml/d in London. This accounts for outages in strategic schemes, resulting for example from raw water quality and asset condition issues, while ensuring that where previous investment has improved asset performance, so addressing the outage root cause, these outages are removed from the historical record (see para 4.50). In future, it is likely that resolution of water quality constraints through installation of new or modified treatment processes will also result in the associated outages being removed from the historical record.

4.53 The Outage Allowance used in the baseline forecast is considered to remain constant across the 80 year planning period. Considering future Outage Allowance and the final preferred programme, none of the options have any implicit bias towards greater or smaller outages and so it is not practical to estimate with confidence the Outage Allowance for new schemes. As a result, we consider it is appropriate to use the base year Outage Allowance throughout the planning period, recognising that this generally implies an effective change in Outage Allowance as a proportion of WRZ supply capability.

4.54 The Outage Allowance is currently considered to be same for both the DYAA and DYCP condition. The Outage Allowance for each WRZ is calculated based on the analysis of actual outage data record. Historically, we have not recorded outages against peak DOs, with one of the key reasons being that a peak DO is not needed for the majority of the time, only at times of peak demand, so our WTWs do not need to be available to deliver peak DO at all times. As such, simply altering the 'outage against average DO' model to measure outage against peak DO at times of peak demand would not necessarily give an accurate reflection of peak period outage. To ensure that our outage modelling provides an appropriate assessment of peak supply impact, specifically in those WRZs where DYCP is the supply demand driver, we will be reviewing and updating our methodology, as necessary. We aim to build on our outage reporting approaches to include recording and analysis of WTW capability to meet peak demands when required, and include an assessment of 'peak period outage' for WRMP24.

4.55 To ensure future outage risk is reduced to a minimum, we are developing plans and programmes for returning water sources to optimum availability and maintaining that availability into the future. This includes identifying the issues causing the outages, the impact on DO, the actions being undertaken to address the outage, and the outcome of our actions. In the revised draft WRMP19 we consider the significance of more than 90 days outages on Outage Allowance and the supply demand balance and the consequences for our preferred programme. This analysis is presented as an EBSD ‘what if’ scenario as part of Section 10: Programme appraisal and scenario testing.

Bulk supplies

4.56 Efficient and effective use of water is vital in the south east of England and bulk supplies form a part of that need. Bulk supplies are transfers of either raw or treated water into or out of the company’s supply area.

4.57 We have a number of bulk supply agreements with neighbouring water companies. These can be for temporary support in an emergency situation, or as a permanently available supply. It is the latter which are of importance to the WRMP. Inset appointments[10] granted to other companies means that we have formal arrangements to supply water in certain areas, which have to be accounted for in the supply demand balance.

4.58 Most of the bulk supply agreements are long-standing and are in perpetuity and terminable only by mutual consent. Variation is only possible through renegotiation. The supply of water is 'on demand', and up to the quantities specified in the agreements. A summary of the bulk supply arrangements and volumes which are consistent for AR17, AR17+ and AR18 is shown in Table 4-5.

4.59 We consulted all our neighbouring companies prior to the production of our draft WRMP19 and have continued these discussions between the draft and revised draft WRMP19 in association with our response to the public consultation on our draft plan. Volumes for the bulk supplies will be agreed in the final plan for each year of the planning period under a dry year scenario.

4.60 While there are some minor bulk supply import/exports in the Thames Valley, London is the only WRZ where bulk supplies are a significant factor in the supply/demand balance. Where we have external imports or transfers between WRZs, the associated water quality is considered in our Drinking Water Safety Plans covering groundwater as well as surface water sources.

[10] Inset appointments are also known as New Appointments or Variations, or 'NAVs'. NAVs occur when one company replaces another as the statutory water and / or sewerage company for a specific geographic area.

Table 4-5: Bulk transfers (imports and exports) arrangements and volumes from base year 2016/17 and over the 80 year planning horizon

WRZ	Imports	Exports	DYAA Total (Ml/d)	DYCP Total (Ml/d)
London*	None	-2 Ml/d raw water to Affinity Water Central (Wraysbury to Sunnymeads) from 2016/17 -0.2 Ml/d treated water to Affinity Water Central at Hampstead Lane from 2016/17 -11.8 Ml/d treated water to Affinity Water Central at Fortis Green 2016/17 to 2018/19**. The bulk supply is set to increase over the planning period; From 2018/19 to -12.6 Ml/d From 2036/37 to -13.9 Ml/d From 2039/40 to -14.0 Ml/d	-14.0 (From 2016/17) to -16.2 (From 2039/40)	N/A
SWOX* **	2.08 Ml/d from SWA (5 Ml/d on peak) 2016/17 onwards NB: internal transfer	None	+2.08 (From 2016/17)	+5 (From 2016/17)
SWA	None	-2.08 Ml/d to SWOX (-5 Ml/d on peak) from 2016/17 -NB- internal transfer	-2.08 (From 2016/17)	-5 (From 2016/17)
Kennet Valley	None	None	0 (From 2016/17)	0 (From 2016/17)
Guildford	None	-2.27 Ml/d treated water to Affinity Water Central (Ladymead) from 2016/17 The peak bulk supply is set to increase over the planning period; in 2030/31 to -3.38 in 2031/32 to -4.7 Ml/d in 2032/33 -4.9 Ml/d in 2033/34 -5.0 Ml/d	-2.27 (From 2016/17) to -5.0 (From 2033/34)	-2.27 (From 2016/17) to -5.0 (From 2033/34)
Henley	None	None	0 (From 2016/17)	0 (From 2016/17)

**There is also a renegotiation of the export from London WRZ to Essex and Suffolk Water (Northumbrian Water South) 91 Ml/d on average (118.2 Ml/d on peak) and an import from Severn Trent Water to SWOX WRZ 0.1 Ml/d on average and peak, both from 2016/17 onwards. These are included within the WARMS2 modelling and taken into account in the calculation of DO and hence not included in the WRMP19 tables as a bulk supply.*

*** Affinity Water did not provided a confirmed revised profile through the 80 year planning horizon for use within our revised draft WRMP19, so we have carried forward the profile used within the draft WRMP19. Between draft and revised draft WRMP19 Affinity Water sent across to us by email two possible profiles for the Fortis Green export one for their preferred and one for their alternative plans. Values stated were higher than those included within the draft WRMP19 however Affinity did not confirm that these were the final figures and stated that these were expected to change again between draft and revised draft. To account for the impact of a revised profile Affinity's alternative plan (confirmed to be the* *plan Affinity are publishing as their revised draft WRMP19) profile will be included as an EBSD 'what-if' scenario within Section 10: Programme appraisal and scenario testing as part of programme appraisal.*

****There is an additional export from SWOX WRZ to Wessex Water 0.01 Ml/d on average (-0.06 Ml/d on peak) which is lost in rounding error and therefore not included in the revised draft WRMP19 tables.*

4.61 Accounting for both the bulk supply volumes presented in Table 4-5 and the bulk transfers included within the DO calculation (the export to Essex and Suffolk and the import from Severn Trent Water) we are a net exporter of water.

Transfers to Essex and Suffolk Water

4.62 The largest bulk supply export agreement covers the raw water transfer of up to 91 Ml/d average and 118.2 Ml/d peak, to Northumbrian Water's Essex and Suffolk area from our Lee Valley reservoirs. This export is included within the WARMS2 modelling and is taken into account in the calculation of DO and hence is not included in Table 4-5 as a bulk supply.

4.63 As highlighted at WRMP14 there was an option to improve supplies in the London area with agreement to reduce the quantity to be transferred to Essex and Suffolk during a dry year. A first Trading Agreement was reached with Essex and Suffolk at AR15 that benefitted London's resources by 17 Ml/d. Since then a further opportunity arose to reduce the amount transferred, increase the benefit to London by 6 Ml/d at AR17. The reduction in the bulk supply with Essex and Suffolk ceases in 2035 (31 March 2035) where it then reverts to the original agreement.

Transfers to Affinity Water Central

4.64 There are three existing treated water bulk supply exports to Affinity Water Central:

1) from a supply point in the London Borough of Haringey, London WRZ (initially 11.8 Ml/d), known as Fortis Green;
2) from a supply point in the London Borough of Haringey, London WRZ known as Hampstead Lane (0.2 Ml/d); and
3) from a groundwater source in the Guildford WRZ via Ladymead WTW (2.27 Ml/d average 5.0 Ml/d peak).

4.65 The Fortis Green agreement allows for 27 Ml/d, although historically the amount agreed for water resources planning purpose has been 10 Ml/d. This has now increased to 11.8 Ml/d and will increase to 14.0 Ml/d by 2039 in agreement with Affinity Water (Affinity). Affinity has confirmed that they have identified that they will need access to the full existing entitlement, 27Ml/d, of treated water bulk supply during peak conditions at various points throughout the planning period.

4.66 The assumptions relating to the Affinity bulk supply transfer at Fortis Green are based upon information provided by Affinity in correspondence on the draft WRMP19. The information relates to calculated usage over the planning period for both the DYAA and DYCP scenarios. The DYAA usage, however, has not been adjusted by Affinity to take account of the DYCP usage. DYAA is the critical condition for us in London, and thus Affinity's demand under dry year conditions needs to be reflected in our DYAA forecasts, rather than peak. Affinity's DYCP use is variable throughout the planning period as it is naturally dependent on weather conditions but is also determined by the development of water supply options identified in their WRMP. To provide a consistent view on usage we have used the DYAA data provided by Affinity and added the annualised DYCP usage to increase the DYAA value. The DYAA usage then reflects the effect on the DYAA utilisation from DYCP. The amendment to the DYAA profile is based on a 56 day critical period that Affinity supplied for the period 1 April to 30 September. A summary of the subsequently adjusted DYAA profile is given in Table 4-5.

4.67 Additionally, there is a raw water supply from two of our West London reservoirs to an Affinity Water Central treatment works, known as Wraysbury-Sunnymeads, of 2 Ml/d. This forms part of an agreement that permits Affinity Water Central to use our reservoir storage in the event of a serious pollution incident impacting their run-of-river source on the River Thames. The overall agreement is only for the duration of the pollution event but there is a provision for up to 10 Ml/d as a sweetening flow in the connecting pipeline, which can be accounted for as a raw water bulk supply.

4.68 As previously reported in WRMP14, it has been agreed with Affinity that the bulk supply be reduced from 10 Ml/d to 2 Ml/d. The updated agreement now reflects the reduced requirement.

Inset appointments

4.69 Our supply area has a number of Inset Appointments[11] that supply customers in various WRZs. The exports to inset appointments have been uplifted from actual to dry year using the AA and CP uplift factors specific to each WRZ, and these are shown in Table 4-6 and Table 4-7 respectively. These figures are consistent for both AR17 and AR17+ with a marginal increase in the figures for AR18. The Inset Appointment exports are accounted for in the baseline supply demand balance and growth is accounted for within the demand forecasts.

Table 4-6: DYAA exports to Inset Appointments in 2016/17

WRZs for annual average exports to inset appointees	Ml/d
London	2.30
SWOX	0.98
Kennet Valley	0.17
Henley	0.00
SWA	0.26
Guildford	0.00
Total	3.71

[11] An inset appointment (or NAV) is when one company replaces another as the statutory water and / or sewerage company for a specific geographic area.

Table 4-7: DYCP exports to Inset Appointments in 2016/17

WRZs for critical period exports to inset appointees	Ml/d
London	--
SWOX	1.18
Kennet Valley	0.20
Henley	0.00
SWA	0.32
Guildford	0.00
Total	4.00

4.70 AR18 inset appointments in SWA, Henley and Guildford are consistent with AR17 and AR17+ figures. However, AR18 figures in London since AR17 and AR17+ have increased by +0.53 Ml/d DYAA, SWOX by +0.29 Ml/d DYAA and +0.35 Ml/d DYCP and Kennet Valley by +0.04 Ml/d DYAA and +0.05 Ml/d DYCP.

Summary

4.71 The average and peak WAFU for the last reporting year 2016/17 in each WRZ using AR17+ figures are shown in Table 4-8 and Table 4-9 respectively.

Table 4-8: DYAA WAFU 2016/17

WRZ (Units Ml/d)	DO	–	Climate change impact*	–	Constraints	–	Outage	+/–	Bulk supplies and insets	=	WAFU
London	2302.00	–	19.70	–	0.00	–	99.76	–	16.30	=	2166.22
SWOX	329.17	–	1.12	–	0.28	–	17.23	+	1.10	=	311.63
Kennet Valley	143.87	–	1.26	–	0.00	–	2.49	–	0.17	=	139.95
Henley	25.65	–	0.00	–	0.00	–	0.36	N/A	0.00	=	25.29
SWA	185.05	–	0.36	–	2.0	–	9.46	–	2.34	=	170.89
Guildford	65.82	–	0.04	–	0.00	–	1.40	–	2.27	=	62.11
Total	3051.56		22.48		2.28		130.70		19.98		2876.09

** The method for assessing the impact of climate change on supply over the planning period is explained in Para 4.112 to 4.121 and in more detail in Appendix U: Climate change.*

Table 4-9: DYCP WAFU 2016/17

WRZ (Units Ml/d)	DO	–	Climate change impact*	–	Constraints	–	Outage	+/–	Bulk supplies and insets	=	WAFU
London**	N/A		N/A		N/A		N/A		N/A		N/A
SWOX	385.38	–	1.28	–	1.19	–	17.23	+	3.82	=	369.50
Kennet Valley	155.40	–	0.94	–	0.00	–	2.45	–	0.20	=	151.77
Henley	25.90	–	0.00	–	0.00	–	0.36	N/A	0.00	=	25.54
SWA	214.40	–	0.24	–	2.0	–	9.46	–	5.32	=	197.38
Guildford	71.70	–	0.04	–	0.00	–	1.40	–	2.27	=	67.99
Total	852.78		2.50		3.19		30.9		3.97		812.18

** The method for assessing the impact of climate change on supply over the planning period is explained in Para 4.112 to 4.121 and in more detail in Appendix U: Climate change.*

***The DO for our London WRZ is assessed for DYAA only due to both London's reservoirs and ring main providing a buffer during peak periods.*

4.72 The modelling of the Target Headroom, and resultant supply demand balance for 2016/17, have been re-run with A17+ figures and therefore differs from those values in the published AR17 and AR18 tables due to the nature of the risk analysis models which uses Monte Carlo sampling techniques. Specifically when inclusion of the AR17+ DO, inset appointments, Outage Allowance and demand forecasts is made and the models re-run, the climate change component changes marginally and thus so does the WAFU.

C. Baseline supply forecast

General

4.73 The baseline supply forecast is built from the base year values discussed above. Activity to the end of 2019/20 is as discussed in Section 2: Water resources programme 2015-2020. Beyond 2020, the following assumptions are made in the baseline plan:

- DO reduces with the cessation of the trading agreements with RWE Npower (from 2020/21) and Essex and Suffolk Water (from 2035/36);
- No increase in DO through new resource developments (these are accounted for within the final plan supply forecast rather than within the baseline supply forecast);
- No change in constraints;
- Process losses, as a percentage of DO, change in proportion to the movement in DO;
- Outage Allowance is flat over the planning period;
- Treated imports and exports are largely unchanged

4.74 The only changes to WAFU are from updates to DO due to:

- The impact of climate change on supplies;
- The inclusion of impacts that reflect changes in upstream licensing that increase river flows and water available for abstraction;
- The impact on DO that will reflect trading agreements that are assumed to expire in line with the current arrangements;
- The impact of sustainability reductions following guidance from the Environment agency in March 2018 (WINEP 3.

Sustainability reductions

Background

4.75 Water companies are required to include an allowance for sustainability reductions in their draft plans. Sustainability reductions are reductions in abstraction that are required to provide environmental improvements, typically through increased flows in rivers which are identified as suffering from low flows due to the effects of abstraction.

4.76 Water companies work closely with the Environment Agency to identify where abstraction may be having an adverse environmental impact and then putting plans in place to address this impact, if necessary. The mechanism by which this is achieved is through the WINEP, which is how the Environment Agency identifies and prioritises its requirements for water companies to undertake measures to improve the environment. The process by which the requirement for sustainability reductions is identified is described in Section 2: Water resources programme 2015-2020. It also explains the sustainability reductions to be delivered before 2020.

4.77 The WINEP classifies sustainability reductions in three ways:

- **Certain**: those for which a full investigation and an options appraisal is complete, the Environment Agency is certain of the need for the sustainability reductions and the water company is in agreement in principle that they should be delivered. These cases will also have been demonstrated to be cost beneficial and affordable (where applicable).
- **Indicative**: those where the investigations have reached a stage where there is sufficient information to include the need for sustainability reductions but the requirement for their delivery has not been agreed between the water company and the Environment Agency. This can include cases where an options appraisal has been completed and the scheme is cost beneficial but is not yet confirmed as affordable, it also includes cases where a change is required to meet a statutory driver either a) before completion of an investigation or b) following completion of an investigation but before completion of an options appraisal. In these cases the cost benefit assessment will be a factor in determining the need for their final delivery but the Environment Agency requires water companies to make allowance for them in their WRMPs. Indicative sustainability reductions are included in the baseline supply demand balance.

- **Unconfirmed**: These are sites where there is a possible but non-quantified change to a licence but the investigations have not reached a stage where there is evidence to justify a sustainability reduction being considered as confirmed or likely.

4.78 A further category was also specified by the Environment Agency in the guidance on sustainability change categories prior to the draft WRMP19. This further category is 'Direction of Travel' and covers situations where the Environment Agency has not identified sustainability changes but has identified the need for investigation though no implementation action is required in AMP7.

4.79 Certain and indicative sustainability reductions are included within the baseline supply demand balance as an adjustment to DO. Unconfirmed sustainability reductions can only be assessed in the WRMP through the running of scenarios, to determine what impact on the WRMP they would have were they to become certain. However, even if the impact is potentially significant, the Water Resources Planning Guidelines (WRPG)[12] do not permit any allowance for them to be included in the preferred plan and thus they do not trigger future investment.

4.80 It is assumed that the WINEP is a key initiative by which our WAFU will be reduced or Headroom increased. However, it should be noted that from our experience to date, the Catchment Abstraction Management Strategies (CAMS) process and the requirements of the Water Framework Directive (WFD) have the potential to result in not only sustainability reductions, but also a very serious limiting of future resource options due to the Environment Agency's view on the catchment's potential to support further abstraction without adverse impact on the environment or groundwater bodies.

Overall policy

4.81 Our policy on sustainability reductions can be summarised as follows:

- The proposed reduction should be justifiable in terms of the three elements of sustainability (economic, environmental and social) and, where relevant, the cost-benefit case should be proven;
- Viable twin-track demand and supply options to replace the loss of supply capability should be in place and operational before the licence reduction takes place;
- The investment needed to replace the loss to supply capability caused by the sustainability reduction should be funded within price limits;
- Under no circumstances would we proceed with the implementation of a sustainability reduction programme without an alternate supply option available, this is to ensure that the security of public water supplies can be maintained.

4.82 It is limiting that the WRPG do not allow a company to take adequate account of the potential impact of future sustainability reductions, where these have not been confirmed by the Environment Agency through the WINEP. We consider the potential loss of supply to be a significant risk to the supply demand balance in view of the likely impact of the WFD and River Basin Management Plans (RBMP) on the future of abstraction licence volumes,

[12] Environment Agency and Natural Resources Wales produced in collaboration with Defra, the Welsh Government, and Ofwat, Water Resources Planning Guideline: July 2018

particularly through the potential reduction required to ensure no deterioration of status. The WRPG approach may not ensure the identification of 'best value' investment schemes and we have therefore included scenarios as part of Section 10: Programme appraisal and scenario testing to ensure that this risk is considered.

4.83 The WFD deadline of achieving 'good ecological status' in all water bodies by 2027 is fast approaching. Some of the measures that may have to be taken to comply with the WFD will take a long-time to fulfil and we do not wish to be in a situation where we are forced into short-term, unsustainable options when there was the opportunity to take a longer term view. Whilst it is likely that the end date of 2027 will be extended, this has not yet been confirmed and we cannot be confident that this will be the case.

4.84 We explore this further through our programme appraisal analysis (Section 10: Programme appraisal and scenario testing) and show how our plan would change against different futures associated with varying levels of sustainability reductions after 2025.

4.85 The Environment Agency released the first summary of requirements (WINEP1) on 31 March 2017 followed by a further release (WINEP2) in 29 September 2017. This provided an indication of the potential sustainability reductions and investigations within our supply area. A further release of the WINEP was provided on 29 March 2018 (WINEP3) which confirmed the requirement as to what should be included within our WRMP – see Table 4-10 for WINEP3 sustainability reductions and Table 4-11 for the impact of these reductions on DO. The Environment Agency WINEP3 contained significant changes when compared with WINEP1 and WINEP2. It changed the status of a number of the schemes such that only Bexley and Hawridge are now 'indicative' schemes meaning they should be included in the baseline WRMP. There are no sustainability reductions specified in WINEP3 as 'unconfirmed'. In addition to the WINEP3 scenario we have developed scenarios to assess the potential impact of sustainability reductions that may be required to achieve WFD deterioration objectives and reductions in chalk stream abstractions which adversely impact on vulnerable chalk streams. These scenarios are included in the WRMP (Section 10: Programme appraisal and scenario testing).

4.86 As detailed in Section 10: Programme appraisal and scenario testing, four additional sustainability reduction scenarios have been run as EBSD 'what if' analysis:

1) **WFD No Deterioration lower scenario**, which is our estimate of a more likely sustainability reductions associated with No Deterioration investigations
2) **WFD No Deterioration higher loss scenario** which is our estimate of the full loss of unused licence at all sources being investigated under No Deterioration
3) **Chalk streams scenario 1** which is our estimate of a medium potential loss scenario from the licences that have adverse impacts on vulnerable chalk streams in the medium to long term
4) **Chalk streams scenario 2** which is our estimate of high potential loss of licences that have adverse impacts on vulnerable chalk streams in the medium to long term.

Table 4-10: Sustainability reductions in the Water Industry National Environment 3 (WINEP3) Programme 2 – 29 March 2018 (Ml/d)

WRZ	Certain			Indicative			Unconfirmed		
	Source	Reduction		Source	Reduction		Source	Reduction	
		DYAA	DYCP		DYAA	DYCP		DYAA	DYCP
London	None			Bexley	8.97	4.18	None		
SWOX	None			None			None		
SWA	None			Hawridge	9.09	9.09	None		
Kennet Valley	None			None			None		
Guildford	None			None			None		
Henley									
Total					18.06	13.27			

Table 4-11: Sustainability reductions impact on DO, including WINEP 3 and AMP6 reductions

		Loss of DO (Ml/d)		
WRZ	**Source**	**DYAA**	**DYCP**	**Year**
London**	Bexley***	9.0	--	2024/25
SWOX	Axford*	5.0	6.0	2017/18
	Ogbourne*	4.0	4.7	2017/18
	Childrey Warren	3.7	3.7	2019/20
SWA	Hawridge***	6.8	6.9	2024/25
	Pann Mill	0.0	7.3	2019/20

Note:

** The impact on SWOX shown in the table of the Axford and Ogbourne source DO reductions are from the results modelled in WARMS2.*

***The DO for our London WRZ is assessed for DYAA only due to both London's reservoirs and ring main providing a buffer during peak periods.*

**** WINEP3 (all other reductions in the table are AMP6 reductions).*

4.87 Sustainability reductions as included in WINEP3 and in the revised draft WRMP19 are as described in the following sections.

Certain reductions

4.88 There are no certain reductions included in WINEP3. The known reductions to be implemented in AMP6 are Axford, Ogbourne, Pann Mill and Childrey Warren which are included in baseline DO.

Indicative reductions

4.89 There are indicative reductions included in WINEP3 for Bexley and Hawridge which are included in baseline DO.

Unconfirmed reductions (for scenario planning)

4.90 There are no unconfirmed reductions received in WINEP3. However we are examining a number of scenarios related to WFD No Deterioration and vulnerable chalk streams reductions. The timings of investigations and subsequent options appraisals relating to WINEP3 reductions in abstractions have been agreed with the Environment Agency as part of the ongoing WINEP programme.

4.91 Sustainability reductions are further detailed by WRZ below.

London WRZ

4.92 An investigation has been undertaken into the impact of the abstraction from the Lower River Lee intakes on the Lower Lee. The investigation was completed at the end of April 2018 and concluded that the abstraction has a limited adverse impact on the River Lee and that an options appraisal is required. This is underway and it has confirmed at an early stage that it will not be cost beneficial to make a reduction in baseline DO by way of an abstraction licence reduction. The options appraisal is due to be completed at the end of 2018.

London WRZ: Bexley

4.93 Bexley sustainability reduction has been included in the baseline DO with a potential implementation year of 2024/25 (8.97 Ml/d average).

4.94 An investigation is currently being undertaken into the impact of the water abstraction source at Bexley on the River Cray. The investigation is due to conclude at the end of December 2018. The investigation is currently showing that the abstraction has an adverse impact on the River Cray and that an options appraisal will be required. The options appraisal is also due for completion at the end of December 2018.

4.95 The Bexley licence has a time limited variation to the annual volume. The current annual volume is equivalent to a daily average of 31.7 Ml/d. This condition is time limited and will revert to an annual total equivalent to 22.73 Ml/d from 31 March 2020. It will be necessary to renew this licence variation but it is anticipated that it will again be time limited and that if the investigation demonstrates that the Bexley abstraction has an adverse impact on the River Cray it may not be renewed further in the future. It is assumed that the licence variation will not be renewed beyond 1 April 2025 with the result that a sustainability reduction of 8.97 Ml/d will be required from 1 April 2025.

London WRZ: Sundridge and Westerham

4.96 An investigation has been undertaken into the impact of our abstractions in the Upper Darent from Westerham and Sundridge. It concluded at the end of March 2018 and found that the abstraction does not have a significant adverse impact on the River Darent. However, it is also recommended that an options appraisal should be required by the end of 2018 to determine if any river restoration measures could have a beneficial impact on the drought resilience of the upper Darent.

SWA WRZ: Hawridge

4.97 Hawridge sustainability reduction has been included in the baseline DO with an implementation year of 2024/25 (9.09 Ml/d average and 9.09 Ml/d peak).

4.98 An investigation is currently being undertaken into the impact of the water abstraction source at Hawridge on the River Chess. The investigation is due to conclude at the end of September 2018. The investigation findings to date have suggested that the abstraction has an adverse impact on the River Chess and so an options appraisal would be required. If the investigation concludes with this finding confirmed, the options appraisal would be completed by the end of December 2018.

Summary

4.99 We have included a total of 15.8 Ml/d sustainability reductions in our revised draft WRMP19 baseline DO, comprising 9 Ml/d for Bexley and 6.8 Ml/d for Hawridge. These sources are both the subject of ongoing options appraisal and this will include cost benefit analysis. This may result in the implementation of alternative solutions to mitigate the impact of abstraction such as river restoration.

4.100 We have sought further guidance for the revised draft WRMP19 from the Environment Agency on the potential location and magnitude of any sustainability reductions that might arise as a result of the WFD or as a result of investigations undertaken in AMP6; these, if any, are expected to be identified in future WINEP updates. The WINEP includes the requirement for investigations at a number of sources into the potential for increased abstraction to cause deterioration in the water body status. These investigations will be undertaken in AMP7 and are due to be completed at the end of 2022.

4.101 We have estimated reductions in DO to be used as the basis for scenarios to demonstrate the impact of potential sustainability reductions that could be required for WFD No Deterioration and for reductions in abstractions that adversely affect vulnerable chalk streams. These scenarios are only indicative, and future investigations and options appraisals will inform the requirement for actual reductions in the future.

4.102 In summary, we have developed four scenarios to explore the implications of potential sustainability reductions, but reliable estimates of future sustainability reductions are required to enable robust long-term planning. Given the potential magnitude of these reductions, as indicated by the Environment Agency, a major resource development is likely to be required if the potential identified sustainability reductions are to be made. The timing of that water resource being available will dictate the time at which any sustainability reduction can be accommodated where they are found to be cost beneficial.

4.103 We remain reliant upon the Environment Agency to clarify the position on future sustainability reductions. The decisions on long-term sustainability reductions are pivotal to efficient long-term planning and without these decisions being made customer Levels of Service could be put at risk or bills could end up being higher than they need to be.

4.104 The results of this scenario testing are discussed in the programme appraisal analysis in Section 10: Programme appraisal and scenario testing.

No Deterioration

4.105 In addition to the WINEP3 scenario we have developed scenarios to assess the potential impact of sustainability reductions that may be required to achieve WFD deterioration objectives.

4.106 The Environment Agency has an obligation to ensure no deterioration of any water bodies under the WFD, for any category (e.g. water quality and ecology) including the status for river flow and groundwater. Therefore the WINEP also includes a requirement to investigate the impact of existing water abstraction sources that have not been used up to full licensed quantities. Such investigations, which could reduce DO significantly, have the potential to result in some licences requiring sustainability reductions to prevent water body deterioration. The WINEP has not specified any volumes for assessment in our WRMP and so this remains a source of considerable uncertainty for our plan. As the WINEP did not include any additional information on scope or methodology for this assessment, we have included two scenarios to assess the risk arising from no deterioration obligations. The first is a lower loss scenario and the second is a full unused licence loss scenario estimated with the current best knowledge of abstraction impacts. These scenarios are summarised in Table 4-12.

Table 4-12: No deterioration, potential uncertain sustainability reductions*

	No deterioration low loss sustainability reduction (Ml/d)	No deterioration higher loss sustainability reduction (Ml/d)
London	20.00	75.86
Guildford	0	2.87
Henley	0	0
Kennet	6.70	9.89
SWOX	5.00	17.08
SWA	0	0
Total	31.70	105.71

**Accounted for as EBSD 'what-if' scenarios within Section 10: Programme appraisal and scenario testing.*

Vulnerable chalk streams

4.107 In addition to the WINEP3 scenario and scenarios to assess the potential impact of sustainability reductions that may be required to achieve WFD deterioration objectives, we have developed other scenarios to assess the potential impact of reductions in chalk stream abstractions which adversely impact on vulnerable chalk streams and water courses.

4.108 We have made a commitment to cease abstraction from vulnerable chalk streams and water courses. As part of this commitment two different abstraction reduction scenarios have been assessed in the revised draft WRMP19.

4.109 The first scenario includes abstraction reductions at a number of sources that have previously been investigated in the Environment Agency's Restoring Sustainable Abstraction Programme and found to have an adverse impact on the environment, but it was not cost beneficial to make a full licence reduction. The sources included in this scenario are Pann Mill, Waddon and North Orpington which equate to a reduction in DO of 26 Ml/d. There are also two licence changes that could be implemented without impacting available water resources, but would have significant capital costs. The first of these is Farmoor where abstraction could be transferred to an intake downstream of the Oxford Watercourses, during periods of low river flows. This option would be associated with implementation of the South East Strategic Reservoir Option and would require a new pipeline to transfer the water from the South East Strategic Reservoir to Farmoor reservoir. The second option is a partial transfer from the abstraction source at New Gauge to existing intakes in the lower Lee system. This option would be associated with upgrading and reconfiguring the raw water network in the Lee Valley area. In line with our commitment to cease abstraction from vulnerable chalk streams this scenario has been included in the preferred plan.

4.110 The second chalk streams scenario includes additional licence reductions, which have a total DO impact of 58 Ml/d. This scenario includes the licence reductions from the first scenario as well as additional reductions at Eynsford, Horton Kirby, Lullingstone, Epsom, Marlborough and Clatford. All of these sources are either currently being reviewed or will be investigated in AMP7 and therefore we need to complete further work to confirm if further abstraction reductions are required to protect vulnerable chalk streams and also to assess the responses to abstraction reductions, such as increased risk of groundwater flooding. We will continue to investigate if further changes to abstractions are required at these sources during the rest of AMP6 and during AMP7.

4.111 The two scenarios are shown in Table 4-13.

Table 4-13: Vulnerable chalk stream reductions

WRZ	Chalk Stream medium loss sustainability reduction (Ml/d)	No deterioration higher loss sustainability reduction (Ml/d)
London	15.97	44.43
Guildford	0	0
Henley	0	0
Kennet	0	0
SWOX	0	3.72
SWA	9.80	9.80
Total	25.77	57.95

Impact of climate change on supply

4.112 Climate change is an important factor in long-term water resource planning. The WRPG requires that the WRMP includes the impact of climate change on DO calculated for the mid-2080s using the Medium emissions scenario as a minimum, and we have specified how this impact is scaled over the planning period.

4.113 Updated climate change scenarios were launched by the UK Climate Impacts Programme (UKCIP) in June 2009, known as the UK Climate Projections 2009 (UKCP09). They provide a large amount of information on how the UK climate may change over the next 100 years in response to different levels of greenhouse gas emissions.

4.114 The projections are ‘probabilistic’ in the sense that they encapsulate a wide range of possible changes in climate based on observations, climate models and expert opinion.

4.115 The methodology of the climate change impact assessment and how the UKCP09 data has been used is explained in Appendix U: Climate change.

4.116 The central (or ‘best estimate’) impact of climate change on DO for the 2080s under the Medium Emissions scenario has been determined together with the uncertainty around the data[13]. Between the draft and revised draft WRMP19, we have investigated the climate change impacts of a High Emissions UKCP09 scenario for the 2080s within the London WRZ. On average, there is little change in the impact of a High Emissions 2080s scenario compared with a Medium Emissions 2080s scenario. Within the sample of 20 climate change scenarios from the High Emissions 10,000 member ensemble, the weighted average climate change impact is about 12 Ml/d lower (i.e. less severe) with the impact of the very dry end of the sample quite significantly more severe and the impact of the very wet end of the sample significantly less severe.

4.117 The ‘best estimate’ value for the 2080s (2085/86) under the Medium Emissions scenario for AR17 and AR17+, the figures used for the revised draft WRMP19, are shown in Table 4-14, this is applied directly as a change in DO. A negative value indicates a reduction.

4.118 The climate change analysis has not been updated between producing the draft WRMP19 AR17 figures and the revised draft WRMP19 AR17+ figures. However, the baseline DOs have been updated to align them with AR17+ figures which has resulted in a marginal change in the climate change impact when determining the ‘best estimate’ or mean impact value using Monte Carlo techniques within the Target Headroom model. For AR18 the change to the baseline DO in London and SWOX and re-running Monte Carlo within the Target Headroom model has marginally changed ‘best estimate’ or mean climate change impact value again.

[13] HR Wallingford report (November 2017) ‘Trajectory of climate change impacts and scaling’ states that ‘The range of uncertainty related to system performance [on the London WRZ] within a UKCP09 climate ensemble is significantly larger than that between climate ensembles for different time horizons or emissions scenarios’ and the full range of uncertainty within the medium emissions scenario has been captured within headroom (Appendix V: Risk and Uncertainty)

Table 4-14: UKCP09 climate change impact on DO by the 2080s (2085/86)

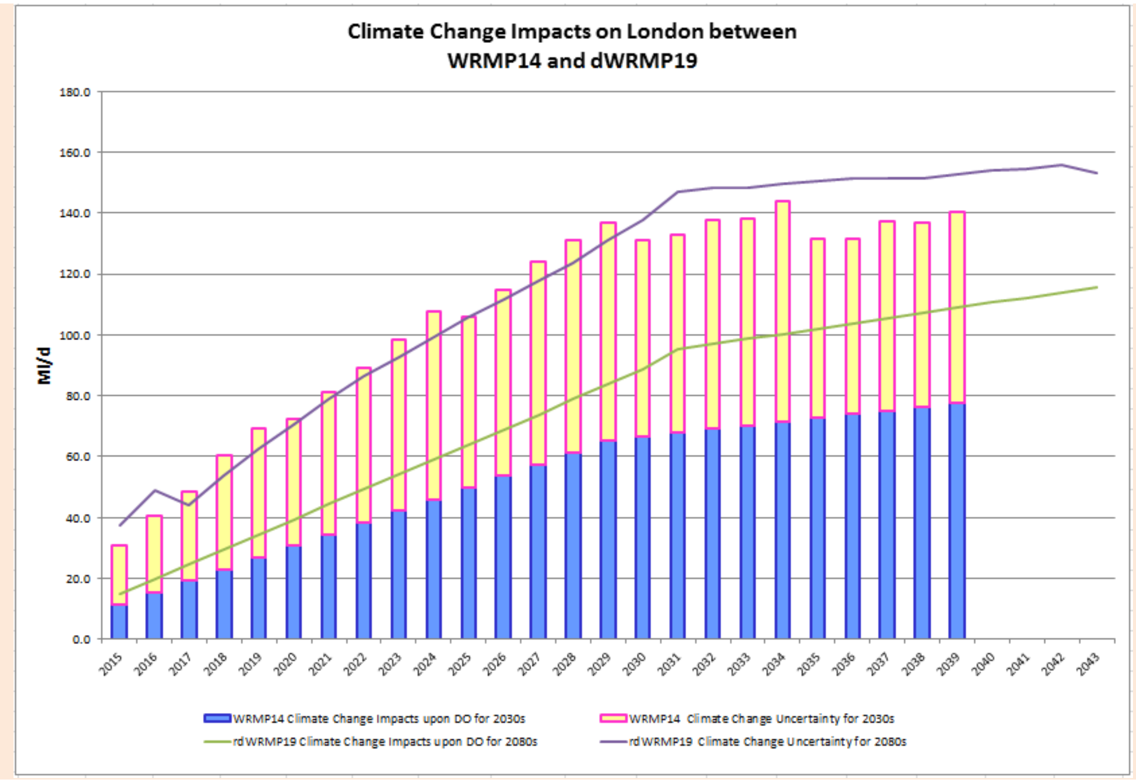
WRZ	UKCP09 climate change impact (Ml/d)			
	DYAA AR17	DYAA AR17+	DYCP AR17	DYCP AR17+
London	-184.9	-187.2	N/A	N/A
SWOX	-10.6	-10.6	-12.1	-12.1
Kennet Valley	-4.0	-12.0	-11.5	-9.0
Henley	0.0	0.0	0.0	0.0
SWA	-1.8	-3.5	-1.2	-2.3
Guildford	0.0	-0.4	0.0	-0.4

**The DO for our London WRZ is assessed for DYAA only due to both London's reservoirs and ring main providing a buffer during peak periods.*

4.119 The climate change impact has been compared with that from WRMP14, which was based on UKCP09 impacts for the 2030s under the Medium Emissions scenario, and it can be seen from Figure 4-5 that both the central estimate and uncertainty around climate change impacts for London have increased. The uncertainty around the central estimate of climate change impact is accounted for within Headroom the detail of which is dealt with in Section 5: Allowing for risk and uncertainty and Appendix V: Risk and uncertainty.

4.120 A correction has been made to the climate change scaling factors inthe Target Headroom model between the draft and revised draft WRMP19 which explains the step in revised draft climate change uncertainty for the 2080s in Figure 4-5. For AR17 the Target Headroom model was updated to reflect the updated climate change methodology used to assess climate change impacts for the draft WRMP19. This update was a step change from using climate change UKCP09 medium emissions impacts for the 2030s (in 2035/36) to using the 2080s (in 2085/86). The AR18 review has identified and corrected one omission from the Target Headroom model update namely ensuring that the model is using 2080s as opposed to 2030s scaling factors to scale the climate change impacts through the planning horizon. The impact of this correction is a reduction in the climate change component of Target Headroom uncertainty from 25.2 Ml/d AR17 (29.2 Ml/d AR17+) to 19.07 Ml/d for AR18.

Figure 4-5: Comparison of climate change impacts on London for WRMP14 vs. revised draft WRMP19



4.121 Updated climate change scenarios, UKCP18, were due to be launched by the UKCIP at a high level in May/June 2018. This has now been pushed back to November 2018 by the Met Office so will be launched too late to be taken into account in the revised draft WRMP19 and will instead be considered within the climate change analysis for WRMP24.

Summary

4.122 Table 4-15 shows AR17+ WAFU changes over the planning period for the baseline scenario under DYAA conditions for London and DYCP conditions for the zones in the Thames Valley. The results show a steady decline in WAFU due to the impacts of climate change and include some step changes due to licence changes and changes in the bulk supply assumptions.

Table 4-15: WAFU over the planning period – baseline

WRZ	WAFU (Ml/d)						
	2016/17	**2019/20**	**2024/25**	**2029/30**	**2034/35**	**2039/40**	**2044/45**
London	2166.22	2154.68	2096.03	2071.41	2054.75	2021.83	2013.32
SWOX	369.50	354.82	353.30	351.70	350.62	350.07	349.52
Kennet Valley	151.77	151.06	149.88	148.69	147.89	147.49	147.08
Henley	25.54	25.54	25.54	25.54	25.54	25.54	25.54
SWA	197.38	189.89	182.69	182.39	182.18	182.08	181.97
Guildford	67.99	67.96	67.90	67.85	65.12	65.10	64.97
Total	**2978.39**	**2943.95**	**2875.34**	**2847.58**	**2826.10**	**2792.09**	**2782.40**

WRZ	WAFU (Ml/d)					
	2049/50	**2059/60**	**2069/70**	**2079/80**	**2089/90**	**2099/00**
London	2004.81	1987.80	1970.78	1953.77	1936.76	1919.74
SWOX	348.96	347.86	346.76	345.65	344.55	343.45
Kennet Valley	146.67	145.85	145.04	144.22	143.41	142.59
Henley	25.54	25.54	25.54	25.54	25.54	25.54
SWA	181.87	181.66	181.45	181.24	181.03	180.82
Guildford	64.96	64.92	64.88	64.95	64.92	64.88
Total	**2772.81**	**2753.63**	**2734.45**	**2715.38**	**2696.20**	**2677.02**

D. Drought and risk

Background to stochastic modelling

4.123 In our Water Resources Management Plan 2014 (WRMP14), we discussed whether the risk to supplies from climate change is underestimated using traditional approaches (see Section 5: Allowing for risk and uncertainty and Appendix U: Climate change.

4.124 These approaches primarily use analysis of historic, recorded data for rainfall, evaporation, flow and groundwater levels to calculate DO and the climate impacts on them. There are some limitations to this, particularly with respect to understanding the resilience of the current or future system to different types of droughts that might occur under climate change. The historic record does not contain sufficient representation of extended severe droughts which are likely to become a real and more frequent occurrence under climate change.

4.125 Analysis of the Future Flows[14] dataset confirmed that prolonged periods of drought, more severe than those seen in the historical record, are predicted to occur. This confirms that there is a risk to supplies and that this should be accounted for in long-term planning.

4.126 Further climate change evidence for WRMP19 is the MaRIUS project data. We commissioned CEH to complete the Severn Thames Transfer Study (CEH, June 2018) using simulations from the NERC-funded project MaRIUS. The results showed that the number of droughts of moderate severity or greater in the Thames catchment is projected to increase into the future.

Stochastic modelling for the revised draft WRMP19

4.127 For the revised draft WRMP19, we have noted the Environment Agency's updated guidance, including Section 3.4 of the 2018 WRPG on drought risk assessment and the UKWIR WRMP19 Methods report on Risk Based Planning[15]. Water companies are encouraged to consider resilience of the supply system to more extreme drought events than might be present in the historical record.

4.128 Sensitivity testing of WRMP14 showed vulnerability of the preferred plan to severe droughts not present in the historic record 1920-2010. We know of a prolonged period of drought in the late 19th century (1890-1910) and Kew Gardens records show intense drought in the mid-18th century.

4.129 We commissioned Atkins, HR Wallingford and the University of Manchester to take this work forward for the draft WRMP19 which has been carried forward to the revised draft WRMP19. The first phase was to conduct a project scoping exercise that defined how the project would be taken forward and objectives of the work including how the outputs were to be used. The outcome was reported in August 2015[16] and followed up with details of the process to be adopted in delivering a stochastically based approach to our water resources planning[17].

4.130 The 'core' of the method is a statistically based weather generator, which is used to generate spatially and temporally coherent artificial drought data that models current climate. The weather and flow generator has been developed based on the rainfall and potential evapotranspiration (PET) in the 20th century and specifically for the known droughts in that period. It uses a multi-site analysis process to evaluate the influences of random variability, regional climatic factors (such as the North Atlantic Oscillation and Mean Sea Surface Temperature) and observable drought anomalies to produce an emulation of the 20th century climate. The model can be run multiple times in order to produce 'what if' analyses of drought conditions that could have occurred within the 20th century.

[14] Centre for Ecology and Hydrology Natural Environment Research Council, Future Flows and Groundwater Levels: British projections for the 21st century, 2012
[15] UKWIR, WRMP19 Methods report on Risk Based Planning, 2016
[16] Atkins, Thames Water Stochastic Drought Generation, Scoping Report, August 2015
[17] Atkins, Thames Water Stochastic Drought Generation, Hydrological Modelling and Weather Generation Review, Technical Note, November 2015

4.131 The historic PET record that was used for re-sampling and generation was limited to the period 1920–1959 and 1973–1997 inclusive. This was because there is a clear inconsistency within the PET record for the north western half of the catchment, where PET for the period 1950 to 1972 is not consistent with the rest of the record. A further explanation of this difference is provided in Appendix I: Deployable Output.

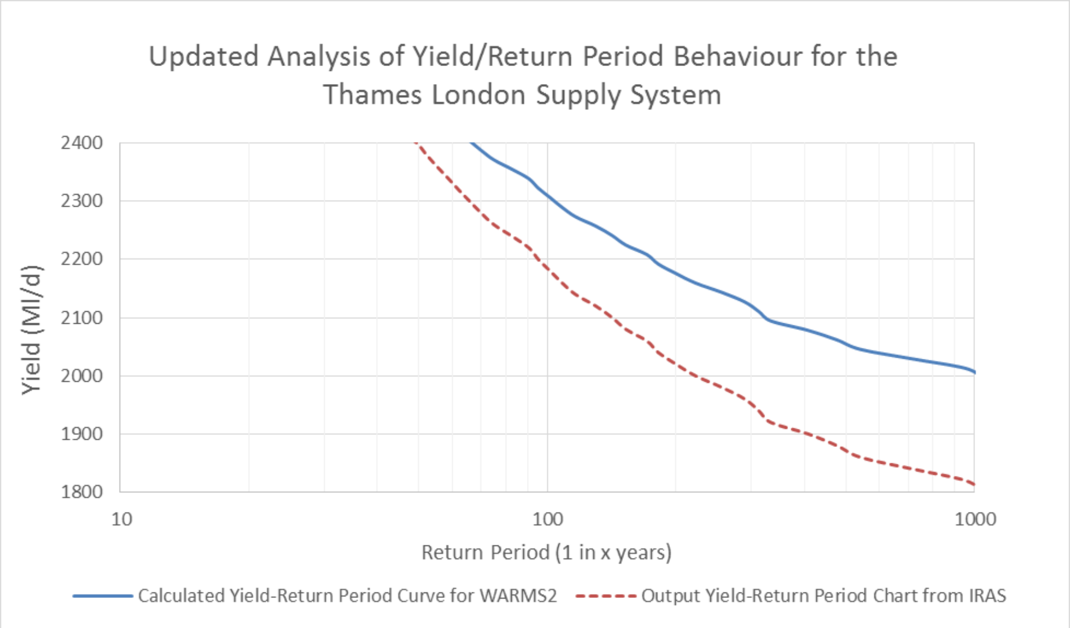
4.132 The rainfall and PET are then run through a Catchmod based rainfall/runoff model to generate multiple 100 year time series of River Thames and River Severn river flows. The River Thames flows are then run through the (IRAS) model, which is a highly simplified, but much faster, version of our WARMS2 water resources model. This carries out a mass-balance analysis of our reservoirs, which can produce yield, resilience and DO metrics in a similar way to WARMS2. The main point of using IRAS is not to replace WARMS2, but to allow the full stochastically generated weather and flow dataset to be analysed within reasonable timescales. The IRAS outputs are then used to rank both individual droughts and each 100 year time series according to water resource severity. This allows specific 100 year sequences, with known relative risk profiles, to be selected for full testing of resilience and key water resource options within the WARMS2 model.

4.133 A full weather data set equivalent to 200 'what if' iterations has been run and the IRAS behavioural analysis tool has been used to analyse the relative return period of all droughts contained within this data set according to system yield. This has allowed a number of 'drought libraries' with known return period events in them to be extracted and run using a more detailed analysis in the WARMS2 behavioural analysis model. Each drought within each 'drought library' is therefore temporally and spatially coherent, and generates time-series that can be run through the existing rainfall-runoff and behavioural models (WARMS2), or used to examine the probability of meteorological conditions associated with events that have been tested in the draft Drought Plan 2017.

4.134 Analysis of the results of this work for London, presented in Figure 4-6, illustrates that a 1:200 year event reduces DO by approximately 130-150 Ml/d (140 Ml/d being the central estimate) and a 1:500 year event reduces it by around 250 Ml/d. Details of this analysis were published by Atkins in July 2018[18]. This report also shows that the current return period of the historic 20th century drought events in the Thames catchment is 1:100 years. Details of the stochastic analysis are presented in Appendix I: Deployable Output.

[18] Atkins, Thames Water Stochastic Resource Modelling Stage 2 and 3 Report, July 2018.

Figure 4-6: London supply system yield/return period



Source: Figure 5.4 Analysis of WARMS2 Yield/Return Period Curve after Catchmod Re-Calibration, Thames Water Stochastic Resource Modelling Stage 2 and 3 report, July 2018page 37.

4.135 Additional modelling between the draft and revised draft WRMP19 of 1 in 200 droughts in WARMS2 and a comparison of DOs generated to those from IRAS has justified the appropriateness of using IRAS as a screening tool for WARMS2; further details of this analysis is provided in Appendix I.

4.136 We also commissioned Atkins to analyse more severe droughts for the other WRZs; SWOX, Kennet Valley, Henley, SWA and Guildford. These zones were assessed using a simpler EVA methodology. Atkins completed the EVA analysis based on the primary system stress metric for sources that were identified as potentially at risk during a severe drought. For the Kennet and Guildford surface water abstractions, the assessment looked at the annual summer minimum flow. For the Kennet and SWA groundwater sources the assessment used the annual summer minimum water levels in the indicator observation boreholes, which are used for assessing the DO of the sources. For SWOX the assessment calculated the Farmoor reservoir storage minima for the DO demand conditions run in WARMS2. From this assessment an estimated return period for the worst historic drought was calculated from the EVA curve fit, as well as an estimated indicator level for a 1:200 year drought. This was then converted into a DO impact for each source. The full methodology for each WRZ is detailed in Appendix I.

4.137 The following text is taken from the 'Thames Water Table 10 Extreme Value Analysis' (November 2017) report[19], although the report itself contains a lot more detail:

[19] Atkins, Thames Water Table 10 Extreme Value Analysis, November2017

'This report contains an evaluation of the potential risks faced by Thames Water in WRZs outside of London during severe (1 in 200) and extreme (1 in 500) droughts, and is written to act as a support to Thames Water's Appendix A: Table 10 of the WRMP19 submission. The form of assessment is relatively simple and follows the EVA principles outlined in the UKWIR 'WRMP19 Methods: Risk Based Planning' guidance. In order to provide inputs to Appendix A: Table 10, the impact of the two drought severities has been calculated in relation to the 'baseline' DO, which has been calculated separately by Thames Water and in all cases is equal to the calculated DO for the overall worst historic drought on record for each WRZ.'

4.138 For the Guildford, Kennet and SWA WRZs the primary analysis was carried out for the summer Dry Year Critical Period (DYCP) as this generates the greatest stress in the supply/demand balance, however Dry Year Annual Average (DYAA) conditions were also assessed to allow completion of Appendix A: Table 10. For SWOX only the DYAA was analysed as the WRZ incorporates the Farmoor storage reservoir. For the Henley WRZ there are no sources vulnerable to drought DO impacts, so no analysis was required for Appendix A: Table 10.

4.139 Analysis of the results indicates that there is a reduction in DO for a 1:200 year event for SWOX, Kennet Valley and SWA, but that Henley and Guildford are resilient[20]. The impact on DYAA DO of a 1:200 year drought is summarised in Table 4-16 and for DYCP DO in Table 4-17.

4.140 The stochastic analysis has not been updated between the draft and revised draft WRMP19 however the baseline DOs have been updated to align them with AR17+ figures.

Table 4-16: Risk to DYAA DO of increased drought severity

WRZ	AR17+ DYAA DO (Ml/d)	Critical year (Ml/d)	DO of 1:200 drought (Ml/d)	Impact on DO of 1:200 drought (Ml/d)
London	2302.00	1921	2162.00	140.00
SWOX	329.17	1976	323.29	5.88
Kennet Valley	143.87	1976	141.07	2.80
Henley	25.65	1976	25.65	0.00
SWA	185.05	1976	183.19	1.86
Guildford	65.82	1992	65.82	0.00

[20] Atkins, Thames Water Table 10 Extreme Value Analysis, November2017

Table 4-17: Risk to DYCP DO of increased drought severity

WRZ	AR17+ DYCP DO (Ml/d)	Critical year (Ml/d)	DO of 1:200 drought (Ml/d)	Impact on DO of 1:200 drought (Ml/d)
London*	N/A	N/A	N/A	N/A
SWOX	385.38	1976	378.51	6.87
Kennet Valley	155.40	1976	152.04	3.36
Henley	25.9	1976	25.9	0.00
SWA	214.40	1976	211.14	3.26
Guildford	71.70	1992	71.70	0.00

4.141 We have assessed the impact of more severe droughts in the revised draft WRMP19 and Drought Plan. We have assessed the impacts of a 1:200 year drought for our revised draft WRMP19 and included the assessment results in Appendix A: Table 10. This demonstrates that we can manage a 1:200 year drought but would require the use of Drought Permits for an extended period. We have assessed the potential impact of 1:300 and 1:500 droughts in our Drought Plan and this also shows that it is possible to maintain supplies through these droughts with the use of Drought Permits over an extended period and with Drought Orders to ban non-essential use. This means that we do not plan for reaching Level 4 and our Levels of Service reflect this. However the environmental and economic impact of this prolonged use of Drought Permits and DOs would be severe, particularly on the environment, and in our view it is not acceptable to plan on this basis. Therefore we plan to develop in increased resource base so that we are resilient to 1:200 year drought without the requirement for prolonged use of drought permits. Section 11: Preferred plan describes how the preferred plan will increase the company's level of drought resilience from 1 in 100 to 1 in 200 by 2030.

4.142 It should be noted that the resilience described in our Drought Plan is only for the duration of the current plan, up to 2024/25, after which we will develop our next edition of the plan. Therefore the plan does not include the impacts of future growth in population or climate change and so without new resource development or improved supply demand balance we are not likely to be resilient to more severe droughts for the period of our next Drought Plan.

4.143 For the London WRZ, 'drought severity' has been calculated using the WARMS2 model that quantifies the combined duration and intensity of a drought, as stated according to the amount of stress it places on the London water resource system. All drought severities (return periods) have been defined according to the relative London system yield as calculated in IRAS, with the return period of each drought calculated based on a simple ranked return period analysis. The 'severity' of each drought therefore takes into account all of the meteorological drought attributes (timing, duration and intensity) and expresses them in terms of the impact that they have on the London system yield. This represents the best practice for drought analysis as described in the UKWIR 2016 'WRMP19 Risk Based Methods'

Guidance[21] and the Environment Agency 2017 'Drought Vulnerability Framework' Guidance (Environment Agency, 2017[22]).

4.144 Between the draft and revised draft WRMP19, the Environment Agency issued the 2017 guidance on the production of DVS. The essence of a DVS is a chart with an x-axis of drought length, a y-axis of rainfall, and a z-axis (represented using colours) showing a system drought performance metric. The concept is that a water resource system should be tested against droughts of various durations and intensities, in order to identify tipping points where system performance quickly degrades and to highlight areas of relative vulnerabilities of water resource systems. These DVSs were initially to be produced for inclusion in revised draft WRMP19, although the Environment Agency later withdrew this requirement, suggesting that DVSs should be included as part of the Annual Review process.

4.145 We have decided to include DVSs for the London WRZ, our most vulnerable and complex WRZ, within the revised draft WRMP19 as these are useful illustrations of the impact that droughts, across a range of varying intensities and durations as well as severities, have on the supply system. We have followed a slightly different methodology than initial EA guidance suggested regarding the production of DVSs, where it was suggested that DVSs should present days of emergency restrictions at a level of demand equal to distribution input (DI) plus Target Headroom. We have instead decided to present yield-based metrics on our DVSs in order to align with Appendix A: Table 10. This has also allowed us to produce a more meaningful system metric for our planning, particularly relating to WRMP responses regarding the consideration of contrasting extreme and severe drought profiles and our drought resilience across a range of 'types' of droughts. In addition, data was also readily available for the production of a DVS using a yield-based metric, where further modelling would have been necessary to produce a DVS using days of emergency restrictions. A final point is that 2017 Environment Agency guidance on the production of DVSs was withdrawn so the production of a yield-based DVS, presented here, is going beyond the requirements within the current Environment Agency guidelines for the revised draft WRMP19.

4.146 DVSs for the London WRZ are presented in Figure 4-7 and Figure 4-8 under worst historic (1 in 100 year) company drought resilience using a yield-based metric to align with Appendix A: Table 10. These surfaces present the resilience / sensitivity to droughts of different durations, intensities and severities and the range of drought 'types' of varying duration and intensity which the drought severities presented in Appendix A: Table 10 (1 in 100, 1 in 200 and 1 in 500) account for. The DVSs also include points relating to the historical record to indicate how the worst historical events relate to more extreme events.

[21] UKWIR, WRMP19 Methods report on Risk Based Planning, 2016
[22] Using the Drought Vulnerability Framework in Water Resources Management Plans, 2017, Environment Agency

Figure 4-7: DVS for London WRZ with Supply Demand Balance (SDB) as the metric and historic droughts, characterised by percentage long term average (LTA) rainfall and duration, shown with a 'calendar' year end point under worst historic (1 in 100 year) drought company resilience

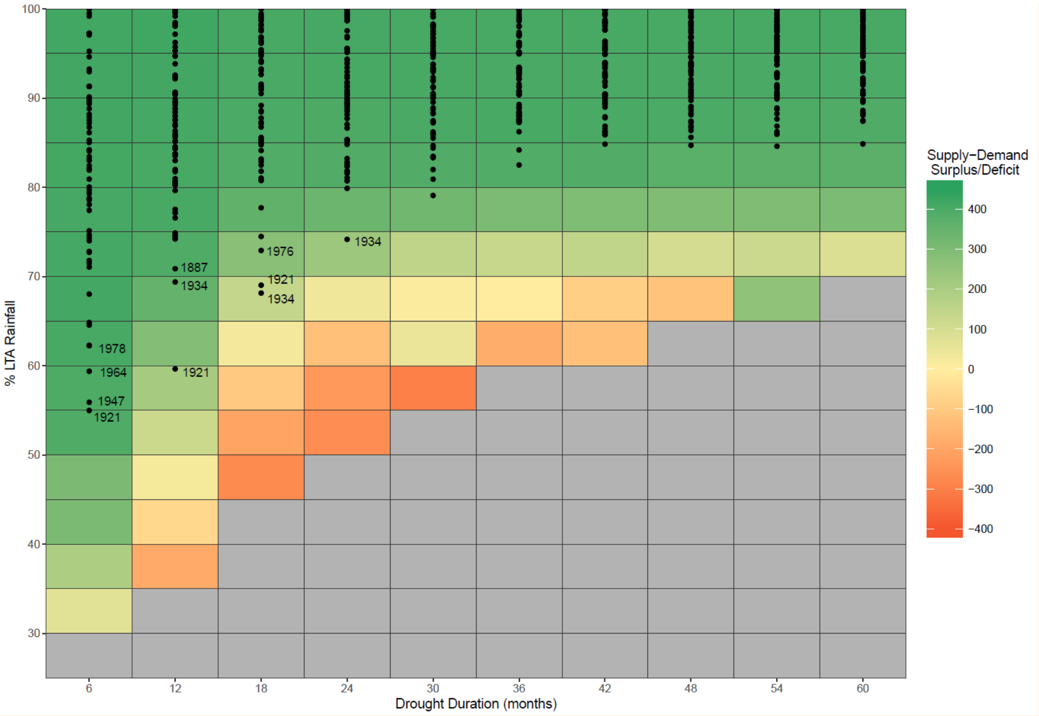
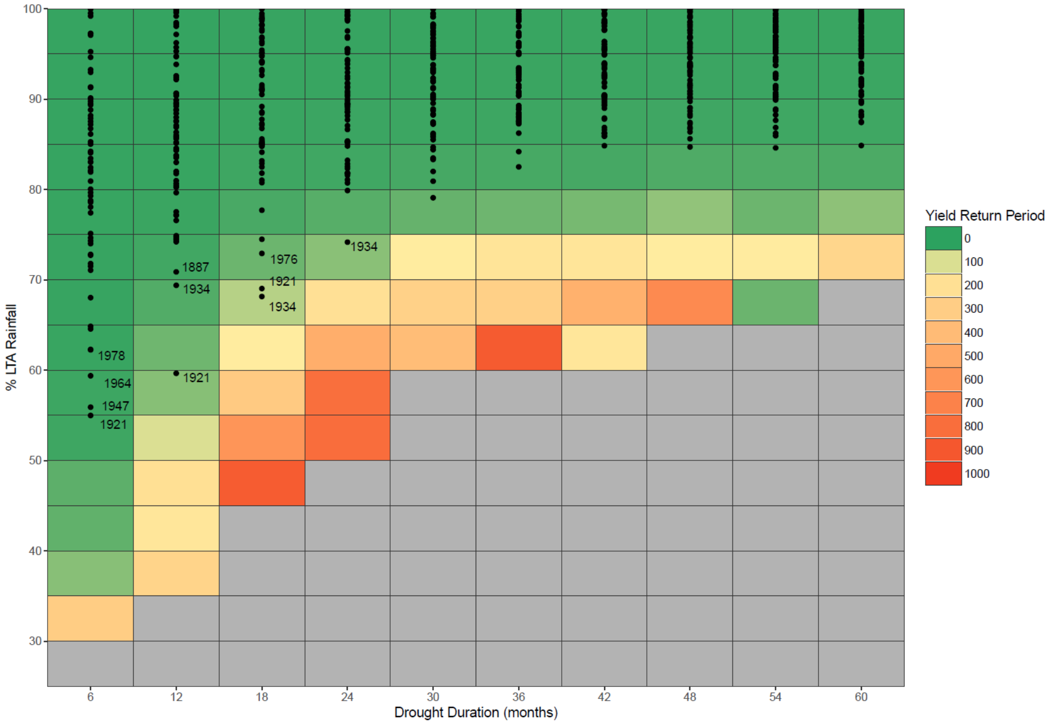


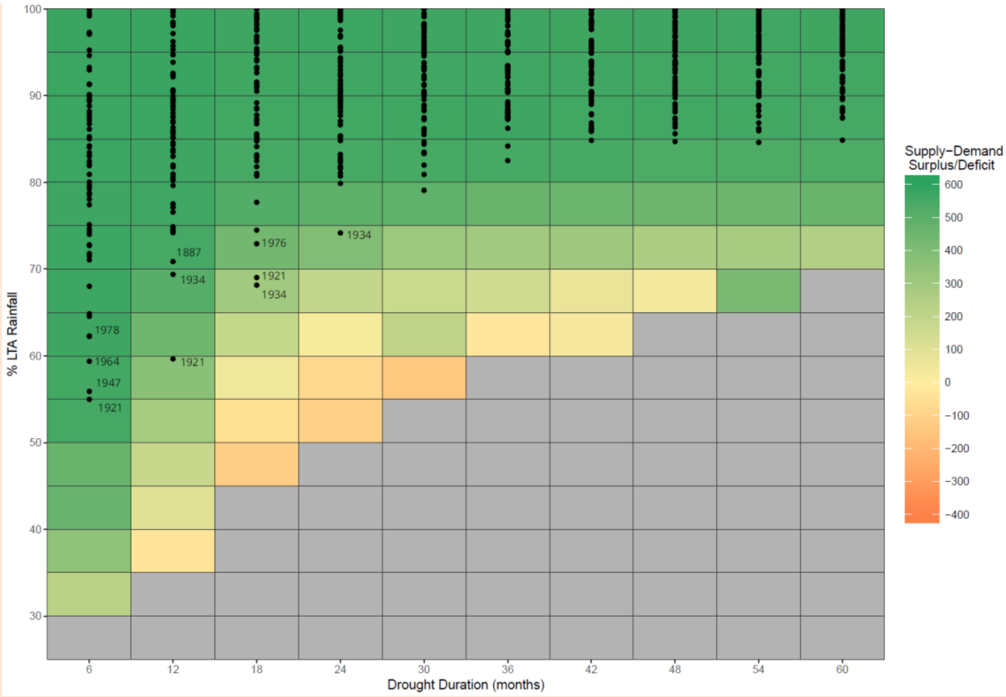
Figure 4-8: DVS for London WRZ with return period of average yield as the metric and historic droughts, characterised by percentage long term average (LTA) rainfall and duration, shown with a 'calendar' year end point



4.147 The DVSs presented here in Figure 4-7 and Figure 4-8 are for the base year of the revised draft WRMP19 to align with Appendix A: Table 10 for the London WRZ under worst historic (1 in 100 year) company drought resilience.

4.148 The DVS presented in Figure 4-9 is an illustration of how company resilience will improve in 2030 following the step up in company drought resilience from resilience to a worst historic (1 in 100 year) to a 1 in 200 year drought. This aligns with the 2030 drought resilience scenario presented in Appendix A: Table 10 for the London WRZ. See Section 11: Preferred plan for the suite of demand and supply options selected in 2030 which result in this increased 1 in 200 resilience see Section 11: Preferred plan.

Figure 4-9: DVS for London WRZ with Supply Demand Balance (SDB) as the metric and historic droughts, characterised by percentage long term average (LTA) rainfall and duration, shown with a 'calendar' year end point under 1 in 200 drought company resilience.



4.149 The key point from Figure 4-7, as expected, is that the London WRZ is most vulnerable to droughts of 18-24 months. This is where cells change colour relatively quickly from green (surplus) to orange (deficit) as percentage long term average (percentage LTA) rainfall decreases, and also where historical events plot closest to the green-yellow-orange tipping point. For events longer than 24 months, while severe impacts do occur, they are well beyond events that have historically occurred, and are well outside the scope of consideration within planning (e.g. the 30 month, 55-60% LTA cell shows a very severe impact, but this has a yield return period of over 1000 years).

4.150 When Figure 4-8 with return period of average yield as a metric is viewed in conjunction with the DVS with SDB as the metric Figure 4-7, the worst historic critical drought event experienced in the London WRZ, the 1921 drought, is shown to have a 1 in 100 years yield impact (Figure 4-8) and is not shown to result in a deficit (Figure 4-7). This demonstrates that for the base year of the WRMP19 the London WRZ the baseline DO is resilient to a worst historic 1 in 100 drought event and this level of resilience is maintained for the first 10 years of the plan.

4.151 The 'severity' of each drought under which the preferred programme has been tested takes into account all of the meteorological drought attributes (timing, duration and intensity) and expresses them in terms of the impact that they have on the London system yield. For the critical 1 in 100 drought event Figure 4-8 demonstrates that this covers a range of percentage long term average rainfall deficits and durations.

4.152 When considering the impact of more severe droughts under worst historic (1 in 100 year) company drought resilience, the droughts which do result in a deficit in Figure 4-7 and which have a return period of greater than 1 in 100 in Figure 4-8, for the first 10 years of the WRMP the Drought Plan shows that:

- 1 in 200 year droughts in Figure 4-8 can be managed but would require the use of Drought Permits for extended periods of time, i.e. greater than 12 months
- It is possible to maintain supplies through 1 in 300 and 1 in 500 droughts in Figure 4-8 with the use of Drought Permits over an extended period and with Drought Orders to ban non-essential use.

4.153 This means that we are robust against Level 4 severe drought restrictions and our Levels of Service reflect this. However, as noted above, the environmental and economic impact of this prolonged, extended use of DPs and DOs would be severe, particularly on the environment, and in our view it is not acceptable to plan on this basis.

4.154 Therefore we plan to develop an increased resource base so that we are resilient to the 1 in 200 year droughts identified in Figure 4-8 from 2030 onwards without the requirement for prolonged use of drought permits. Figure 4-9 presents a DVS for 2030 and the step change to 1 in 200 drought resilience in the London WRZ.

4.155 For the Thames Valley WRZs, the drought resilience has been assessed as detailed within the Drought Plan. Where potential vulnerabilities to drought were identified for sources then these were estimated using similar methods to those detailed in the EA draft 'Drought Vulnerability Framework' with the estimates based on groundwater levels, minimum river levels or reservoir storage as appropriate. As for the London WRZ, the drought severity risks therefore inherently account for both duration and intensity of droughts.

4.156 The impact on DO of a 1:500 year drought on all WRZs is presented in Appendix I: Deployable Output and is included as a 'what-if' scenario as part of programme appraisal in Section 10: Programme appraisal and scenario testing. An additional scenario exploring the timing of delivering 1 in 200 drought resilience is also included within Section 10: Programme appraisal and scenario testing.

E. Water Resources in the South East Group

Purpose

4.157 We have been working with five other water companies (Portsmouth Water, South East Water, Southern Water, Affinity Water and Sutton & East Surrey Water), the Environment Agency, Ofwat, Natural England, CCWater and consultant partners to identify potential opportunities for sharing of resources in the South East of England[23].

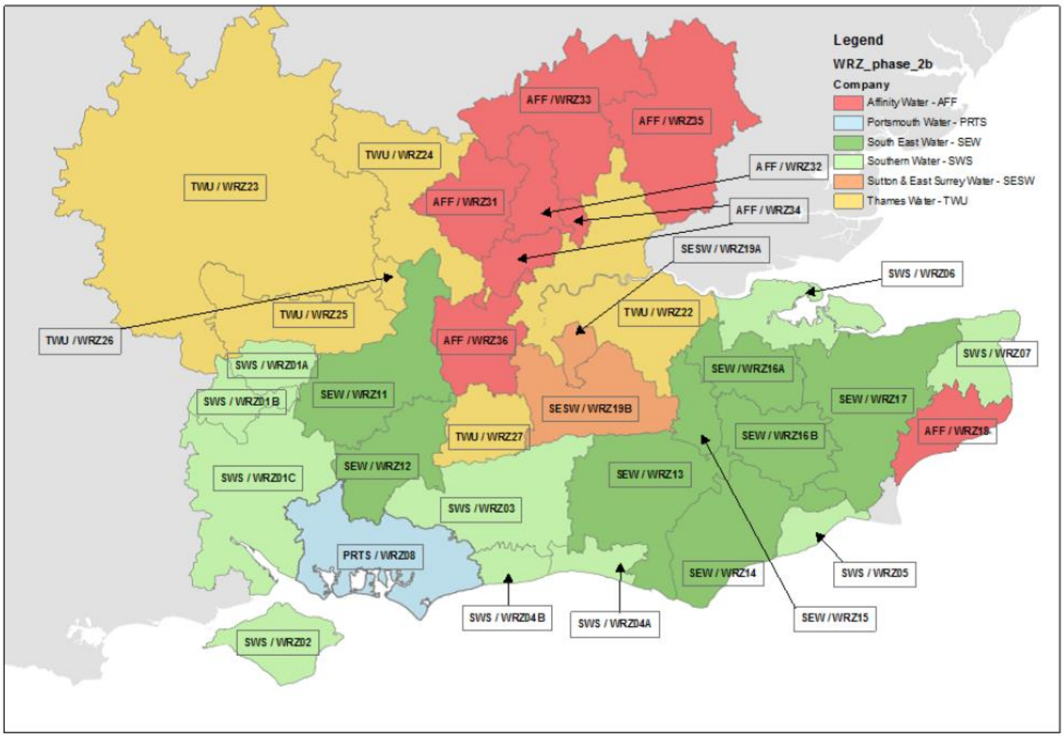
4.158 The overall aims of the WRSE group are:

'to identify and investigate a range of regionally based scenarios which when collated will form a range of potential regional strategies; and

to work together to understand the investments required for those strategies[24]*.'*

4.159 The outcomes of this project have been designed to inform the participating water companies (supply areas shown in Figure 4-10), of potential resource sharing options for consideration in their own water resource management plans and to provide a regional framework for the requirement for strategic resource development for the south east of England. The group addresses all aspects of water resources planning and attempts to identify areas of common ground, which can then be adopted by the water companies for planning should they chose to do so.

Figure 4-10: Water companies participating in WRSE and their respective WRZs



23 WRSE, Collaborative Agreement, April 2016
24 Water Resources in the South East of England, Memorandum of Understanding, January 2016

Background

4.160 The WRSE work is focussed around the strategic application of a water resource planning options selection model, with the objective function of balancing supply and demand across the region at least cost. The model has been constructed to satisfy the requirements and principles of the WRPG. It contains water resources planning options for all participating companies, including; various types of new resources, existing supply enhancements, demand management options (leakage reduction, household metering, household and non-household water efficiency) and raw and treated water transfers between resource zones and water companies. An 80 year planning horizon to 2080 was chosen and several scenarios considered exploring the uncertainty inherent in forecasting future water resource development requirements. These included:

- A range of medium and high DI forecasts
- A variety of different drought severities representing historical twentieth century droughts, 1 in 200 year severe drought events and 1 in 500 year extreme drought events
- Reductions in water availability linked to the effects of climate change
- Application of the WINEP sustainability reductions
- Application of drought permit options and drought order water use restriction savings
- Reductions in raw water availability linked to water quality issues and other extreme weather events in addition to drought

4.161 A total of 12 scenarios were run through the WRSE model using different combinations of the above factors to enable the model to select a broad range of options to test the resilience of potential investment portfolios to a wide range of future uncertainties. This facilitates identification of options that can be considered ‘no regrets’ best value options, as opposed to strictly least cost options, which are consistently selected under a wide range of different futures. Four of the investment scenarios were selected for more detailed resilience testing using an advanced decision making approach, Infogap, to quantify robustness given minimum performance requirements. Infogap Decision Theory (IGDT)[25] characterises the uncertainty of future system stresses by establishing a series of progressive incremental deviations between the best estimate of a parameter (such as an expression of supply or demand) and its future value.

4.162 The WRSE work is jointly funded by the water companies and the Environment Agency and they commissioned CH2M to apply the modelling consultancy package. Other parallel work packages undertaken by other consultants for the WRSE Group are:

- Independent project management (Atkins)
- Construction and application of a water resources system simulation of the South East area (Atkins and the University of Manchester)
- Cumulative and in combination environmental impact assessment of the water resource options selected within the WRSE water companies’ WRMPs (Ricardo)

[25] WRMP19 Methods - Decision Making Process: Guidance UK Water Industry Research 2016 Report Ref. No. 16/WR/02/10

4.163 In WRMP24 we expect to produce a regional WRMP for the south east region in combination with other WRSE companies.

Strategic transfer options to other companies

4.164 The strategic Thames Water options explored within the WRSE analysis include:

- Bulk transfer of raw water by pipeline from Oxfordshire to Southern Water's network in Hampshire. A number of different volumes were available for transfer of up to 100 Ml/d
- Bulk transfer of 100 Ml/d of raw water from Oxfordshire using the River Thames as the conveyance mechanism to Affinity Water's existing abstraction points on the Lower Thames
- Bulk transfer of up to 50 Ml/d of raw water from Oxfordshire using the River Thames as a conveyance mechanism to South East Water from a new abstraction location on the River Thames at Reading to its existing abstraction point at Bray, Berkshire
- Bulk transfer by pipeline from our treated water network in SE London to Southern Water's network in Kent. A number of different volumes were available for transfer, of up to 50 Ml/d
- Bulk transfer by pipeline from our treated water network in South London to Sutton and East Surrey Water. A number of different volumes were available for transfer, of up to 30 Ml/d
- Bulk transfer of treated water by pipeline from London and Guildford to Affinity Water. These options capture the existing treated water bulk supply agreements between Thames Water and Affinity Water where the total amount of available water is not yet taken

WRSE modelling

4.165 All companies provided their baseline supply and demand data and draft option costs for all water supply/demand options for modelling purposes in September 2017. Details of all our options can be found in Section 7: Appraisal of water resource options, Section 8: Demand management options appraisal and in Appendix P: Options list tables.

4.166 The project was divided into three phases:

- **Phase 1**: April 2014 to March 2015: Scoping, preparation, formalisation of modelling work
- **Phase 2a:** April 2015 to August 2017: Main period of technical assessment and development using WRMP14 data. Application of InfoGap stress testing of selected investment portfolios
- **Phase 3:** September 2017 to January 2018: Final strategic modelling runs using data that companies used for the draft WRMP19 plans

4.167 The intention of the Phase 3 modelling was to allow water companies to assess consistency of the WRSE results with their own draft WRMPs, to understand the causes of any significant differences and to support companies in the submission of their draft plans. Our draft

WRMP19 was therefore consistent with the plans of our neighbouring WRSE companies and where transfers had been agreed between us these were included in the results discussed in Section 10: Programme appraisal and scenario testing, where the results of the Phase 3 modelling were discussed.

4.168 Between the draft and the revised draft WRMP19 we have increased our commitment to our work with the WRSE group, and our revised draft WRMP19 reflects the principles and commitments set out in the WRSE report 'From Source to Tap: The south east strategy for water', published in April 2018.

4.169 In this revised draft plan we include the requirements of our neighbours for both raw and treated water transfers totalling in excess of 100 Ml/d, a reduction from our draft WRMP19 position and being primarily a large raw water need from Affinity Water. The final report from the WRSE group is expected to be published in Autumn 2018, which will outline potential solutions available to meet the south east regional deficit.

4.170 A note from WRSE states:

"Following the close of the consultation period, further regional modelling has been undertaken, exploring more scenarios to assess the feedback from customers. In addition, the scenarios being explored include a range of regional targets to assess the effect of meeting the recommendations from the National Infrastructure Commission (NIC) and Defra on leakage and per capita consumption in terms of option selection.

This work is currently ongoing. Preliminary outputs have been produced and these are being subject to close examination, as per all previous phases, to ensure robust confidence can be placed in the results. When the review period is completed, the finding of the revised modelling work can be used to update the revised WRMP, if necessary."

4.171 WRSE will play an important role in improving the resilience of the South East region. Recent discussions between the CEO's of the six companies and regulators have confirmed this role, moving the WRSE into the strategic development of the regional plan for WRMP24. We have committed to our involvement within this group, and included funding within our plan to assist and drive development.

Section 5

Allowing for risk and uncertainty

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Section 5.

Allowing for risk and uncertainty

- In this section we describe how we have assessed risk and uncertainty relating to our supply demand balance to calculate an allowance called Target Headroom.
- The components of Target Headroom are explained and baseline values are presented for each water resource zone (WRZ) for both average and peak scenarios.
- The methodology for both baseline and final plan Target Headroom is described. However outcomes, including Target Headroom over the planning period and component graphs, are presented for baseline only; final plan Target Headroom outcomes are presented in Section 10: Programme appraisal and scenario testing.

In response to feedback as part of the public consultation on the draft Plan and new information, the following changes to Section 5 have been made:

- **Leakage Uncertainty:** Final Plan Headroom has been reviewed following the adoption of new and more stretching leakage targets. It now includes uncertainties around the benefits of new enhanced leakage schemes within the D4 component 'Uncertainty of demand management measures', while still excluding uncertainties around more standard activities or "base" leakage. Uncertainties in "base" leakage are not included in Baseline Headroom which is unchanged from, and is consistent with, the draft WRMP19.
- **PCC uncertainty:** Calculated by using factors generated by the household demand forecasting model produced by Artesia Consulting used as inputs to the demand uncertainty model; these factors have been updated between draft and revised draft.
- **Demand Uncertainty:** Expert judgement has been used to refine the uncertainty around the deterministic demand forecast. This was included via an internal workshop which reviewed and validated demand uncertainty triangular distributions.
- **Climate Change 'Best Estimate':** Updating the baseline deployable outputs (DOs) for the revised draft WRMP19 has marginally impacted the central or 'best estimate' impact of climate change on DO. The climate change analysis using the UKCP09 Medium Emissions 2080s scenario has not been updated between the draft and revised draft WRMP19. However the baseline DOs have been updated (as described in Section 4: Current and Future Water Supply) to align them with AR17+ figures. In addition, as a medium emissions scenario is used to derive the baseline DO 'best estimate' impact, a sensitivity analysis has been carried out to determine the impact of a high emissions scenario. A climate change impacts assessment of a High Emissions UKCP09 scenario for the 2080s in the London WRZ showed only a marginal difference from the Medium Emissions 2080s impacts used for the baseline supply forecast.
- **Climate Change Uncertainty:** A correction has been made to the scaling factor used to determine the climate change uncertainty component of Target Headroom through the 80

year planning horizon. This correction was made between the draft and revised draft WRMP19 and explains the step in revised draft climate change uncertainty for the 2080s. The details of the correction made to the climate change scaling factors within the Target Headroom are as follows:

- For AR17 the Target Headroom model was updated to reflect the updated climate change methodology used to assess climate change impacts for the draft WRMP19. This update was a step change from using climate change UKCP09 medium emissions impacts for the 2030s time slice (2035/36) to using the 2080s time slice (2085/86).
- The AR18 review identified and corrected one omission to the Target Headroom model update, namely ensuring that the model is using 2080s as opposed to 2030s scaling factors to scale the climate change impacts through the planning horizon. The impact of this correction is a reduction in the climate change component of Target Headroom uncertainty from 25.2 Ml/d AR17 (29.2 Ml/d AR17+) to 19.07 Ml/d for AR18.

- **Baseline Target Headroom:** The correction made to climate change scaling factors within the Target Headroom model between the draft and revised draft WRMP19 resulting in a reduction in the climate change component of Target Headroom uncertainty is driving a reduction in overall headroom.
- **Final Plan Target Headroom:** Updated to reflect 5% of overall scheme yield for each year of the 80 year planning horizon.

A. Introduction

5.1 Uncertainties are inevitable in the planning process and how uncertainty is handled is important in the formulation of a supply demand programme. In water resources planning, uncertainty is handled through the calculation of 'Target Headroom', defined as:

> *'The minimum buffer that water companies are required to maintain between supply and demand in order to account for current and future uncertainties in supply and demand.'*[1]

5.2 Thus, Target Headroom is the minimum buffer that a prudent company should allow between supply and demand to cater for uncertainties in the overall supply demand balance and to meet its agreed level of service.

5.3 We use a statistical technique called Monte Carlo analysis to examine the uncertainty in specific elements of our supply and demand forecast.

5.4 In this process we examine the possible range of values (termed distribution) that elements of our forecast could take. We examine the uncertainty around both the supply and demand side forecasts and bring these values together to understand the range of uncertainty in our plan.

[1] UKWIR, WRMP19 - Risk Based Planning Methods Guidance, 2016

We then choose a single allowance (Target Headroom) to allow for a proportion of this uncertainty.

5.5 This allows for the fact that we have more time to adapt to risks further into the future as they begin to become evident. Therefore we are able to accommodate more risk in our future plans. Our allowance for uncertainty is not fixed over time. We take less risk in the short term (5%) over the current AMP period and more risk in the long term (29%)[2]. The level of risk is fixed at 29% from 2044 as Target Headroom starts to decrease with an increase in the level of risk from this point onwards.

5.6 The remainder of this section is structured as follows:

- Introduction
- How the supply side uncertainty components are included in headroom
- How the uncertainty components of demand forecasting are included in headroom
- The baseline Target Headroom is presented for each WRZ

B. Methodology and approach

5.7 Target Headroom is the minimum buffer that a prudent company should allow between supply and demand to cater for uncertainties in the overall supply demand balance and meet its agreed level of service.

Methodology

5.8 We use the 'improved methodology' in our assessment for all WRZs. This Target Headroom concept, which utilises UKWIR methods from 2002[3,4] to address uncertainty, is a best practice method which links to Risk Composition 3. This is the risk composition we are following for our revised draft WRMP19 set out in Section 4: Current and Future Water Supply as described within the UKWIR (2016) guidance[5] and as referred to in the Water Resource Planning Guideline. We adopt this improved method to ensure we have an accurate estimate of uncertainty in our plan, given the importance of our plan to customer supply security and the number of customers we serve. The improved method uses a risk-based technique, full details of which are available in Appendix V: Risk and uncertainty. We are also addressing the vulnerability of our system to more extreme drought events through sensitivity analysis of the current Thames Water resource system and water resource options to different drought types than those in the historical record, as well as providing the basis for a more varied and robust assessment of climate change impacts through the modelling of stochastic weather patterns.

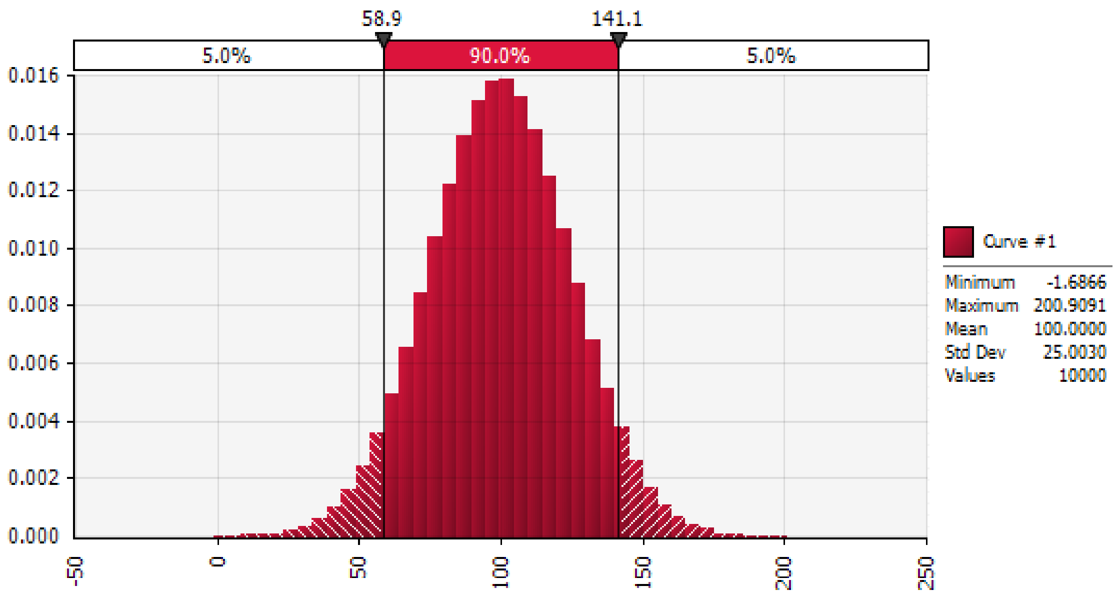
[2] We make the choice about the level of risk we are prepared to accept as a business. The choice we believe is the best balance between the risks of supply failure and investing in assets before they are needed. Section G of this document and of Appendix V: Risk and uncertainty provides an explanation of our decision making process surrounding setting the level of Target Headroom risk.

[3] UKWIR (2002) An Improved Methodology for Assessing Headroom
[4] UKWIR (2002) Uncertainty and Risk in Supply/Demand Forecasting
[5] UKWIR, WRMP19 - Risk Based Planning Methods Guidance, 2016

This is explained in Appendix I: Deployable output and will be tested using various scenarios and development programmes.

5.9 The calculation of Target Headroom uses Monte Carlo simulation, a computerised mathematical technique that allows us to account for risk in quantitative analysis and decision making. Effectively it enables any chosen uncertain parameter, which up to this point would have had a deterministic (or specific chosen or calculated value), to be replaced with a range of potential values, defined by a statistical distribution. An example of a probability distribution is shown in Figure 5-1; it shows a probability density function (pdf). A pdf tells you the probability (value on the y-axis) that a random sample from the probability distribution will equal the corresponding value on the x-axis. The data in Figure 5-1 is purely illustrative, but you could suppose the x-axis represents the volume of water produced by a single borehole in Ml/yr. The bar along the top (from left to right) shows there is a 5% chance that the borehole produces less than 58.9 Ml/yr, a 90% chance it produces between 58.9 and 141.1 Ml/yr and a 5% chance it produces more than 141.1 Ml/yr.

Figure 5-1: An example distribution used in headroom modelling



5.10 Once it has been decided which parameters are particularly uncertain and would better be defined by a probability distribution, models are used to run calculations thousands of times, taking a random sample from within the defined probability distributions.

5.11 This enables a probabilistic output to be produced (i.e. how likely is it that supply would be less than demand) and enables us to take an informed view on the level of risk we should allow for in our future planning. Should we take no risk and thus plan for sufficient headroom that even in an extreme case we will achieve our levels of service? Or is it more reasonable, particularly when looking decades into the future that we take more risk, confident that all the risk will not materialise, or that there will be time for us to act before the risk is realised?

5.12 Once calculated and a risk profile agreed, Target Headroom is added to the forecast of demand and compared with the water available for use (WAFU) to establish the available headroom or the gap in the baseline supply demand balance.

Approach

5.13 There are two stages at which Target Headroom is calculated. We assess uncertainty on both the supply side and the demand-side in separate models, and then draw them together using a Monte Carlo process to produce a combined uncertainty.

5.14 The initial assessment of headroom for the baseline supply demand balance does not include two of the headroom categories: S9 "Uncertain output from new resource developments"; and "Uncertain outcome from demand management measures". The uncertainty associated with new resource developments and demand management measures is incorporated along with baseline uncertainty through the programme appraisal in the development of the preferred plan. This is described in Section 10: Programme appraisal.

5.15 The total volume of Target Headroom for a given WRZ in a given year may then be disaggregated into its component parts.

5.16 Below we discuss how we have accounted for the various supply side and demand side uncertainties acting on our plan.

C. Supply side uncertainty

Components of supply side uncertainty

5.17 The headroom components identified in the methodology that are supply-related are as follows:

- S1 - Vulnerable surface water licences
- S2 - Vulnerable groundwater licences
- S3 - Time-limited licences
- S4 - Bulk imports/exports
- S5 - Gradual pollution of sources (causing a reduction in abstraction)
- S6 - Accuracy of supply side data
- S8 - Uncertainty of impact of climate change on source yields
- S9 - Uncertain output from new resource developments

5.18 S1, S2 and S3 components are not included in the analysis following guidance from the Environment Agency, as set out on page 26 of the 2017 Water Resources Planning Guidelines (WRPG)[6]. With regard to S1 and S2 the guidance states 'You should not include any allowance for uncertainty related to sustainability changes to permanent licences'. With

[6] Environment Agency and Natural Resources Wales and also produced in collaboration with Defra, the Welsh Government, and Ofwat, Final Water Resources Planning Guideline, July 2018

regard to S3 the guidance states 'You may include an allowance for uncertainty related to non-replacement of time-limited licences on current terms' however, following a review of our time-limited licences we have made a presumption of renewal with the exception of Bexley within our London WRZ where a risk of non-renewal has been identified and this has been included as an unconfirmed sustainability reduction (Section 4: Current and future water supply) and addressed through scenario testing during programme appraisal (Section 10: Programme appraisal).

5.19 Bulk imports/exports (S4): Our bulk supply imports and exports are subject to contractual agreements and as such we consider that the uncertainty around them is minimal. We do not include this component in our headroom assessment.

5.20 Gradual pollution (S5): With regard to gradual pollution we have reviewed the risk of our groundwater sources to gradual pollution and confirmed that there are no issues to include at this stage. This is due to the installation (or programmed installation) of suitable treatment processes for nitrates and cryptosporidium. In addition, we are working with the Environment Agency to develop suitable Catchment Management Plans that mitigate recognised issues. We also have a specific risk of bromate pollution in London which we deal with separately; this is discussed below under new resource development (S9).

5.21 Accuracy of supply side data (S6): Data inaccuracy and scarcity of information may render estimates of DO unreliable and this uncertainty needs to be included in headroom uncertainty. The impact of data inaccuracy affects all sources but depends on the factors that are constraining DO. The following issues have been assessed for impact on each of the resource zones:

- Pump or infrastructure capacity
- Abstraction licence limits
- Aquifer characteristics for groundwater
- Climate and catchment characteristics affecting surface waters

5.22 These issues are discussed in detail in Appendix V: Risk and uncertainty.

5.23 As part of the methodology for our Drought Plan we are required to introduce Temporary Use Ban (TUB) restrictions upon customers earlier than has historically been the case, based on the Lower Thames Control Diagram (LTCD). This is to allow time for the process of securing "regulatory permissions" such as Drought Orders and Drought Permits. As a result of imposing Level 3 restrictions (temporary use or hosepipe bans) in London at an earlier stage in a drought event, and earlier than in the defined methodology for determining DO, there will be a potential DO benefit.

5.24 However, the timing of the introduction of restrictions is subjective and the benefit will not necessarily always be there. By imposing restrictions upon customers earlier than in the methodology for determining the DO, a potential bias in favour of an increased DO is being introduced. To address this potential bias in the DO calculation and the supply demand balance, the "risk" can be included within the Target Headroom modelling with a negative skew, i.e. a reduction. The details are explained in Appendix V: Risk and uncertainty.

5.25 Climate change (S8): The uncertainty around climate change is discussed in the climate change sub-section below, with further detail contained in Appendix V: Risk and uncertainty.

5.26 New resource developments (S9): The uncertainty around new schemes has been assessed as part of the development of the final planning programme. Since no new resources are considered as part of the baseline this component has no impact on baseline Target Headroom. The risk around each scheme relates to changes in the DO of the scheme. Uncertainty is also estimated around the cost to deliver a new resource, but this does not contribute to Target Headroom and is discussed further in Appendix V: Risk and Uncertainty. A brief discussion of the process is provided in paragraphs 5.54 to 5.57 and the application of final plan Target Headroom is discussed in Section 10: Programme appraisal.

5.27 Northern New River Wells (NNRW): An additional uncertainty has been included within the Target Headroom modelling which relates to the risk to the NNRW sources from bromate pollution. The source of the bromate pollution is a former bromine chemicals factory at Sandridge, now redeveloped as a housing estate. The presence of bromate in the water pumped from the NNRW has meant that abstraction from these wells has had to be reduced in recent years to meet water quality standards. This is because current treatment facilities in north London cannot deal with the concentration of bromate in the water, which is also exacerbated by the ozonation process at two works. The combined licensed output from the sources average 100.5 Ml/d with an average Source Deployable Output (SDO) of 98.8 Ml/d.

5.28 In 2005, a scavenging remediation scheme was implemented in conjunction with Affinity Water from one of their groundwater sources. This was done to assist remediation of the bromate plume in the chalk aquifer and also to manage the concentration of bromate reaching the NNRW sources. There is however a risk that the NNRW would not be able to deliver its output should there be a problem, for whatever reason, with the scavenging remediation scheme. As this is not an outage issue but represents a real risk to our resources and with no recognized way within the methodology of including the risk, it has been included as a risk to our resources within Target Headroom. The impact of the reduced output from the NNRW was evaluated by inputting this data into the Water Resources Management System (WARMS2) and comparing it with the value of DO before the change; here the AR17 baseline London DO of 2,305 Ml/d, derived using the optimised LTCD, is used as the base run. The results from which is a reduction in DO of 12 Ml/d and for modelling expedience this is applied as the most likely impact in a triangular distribution within the Target Headroom analysis under the S9 functionality.

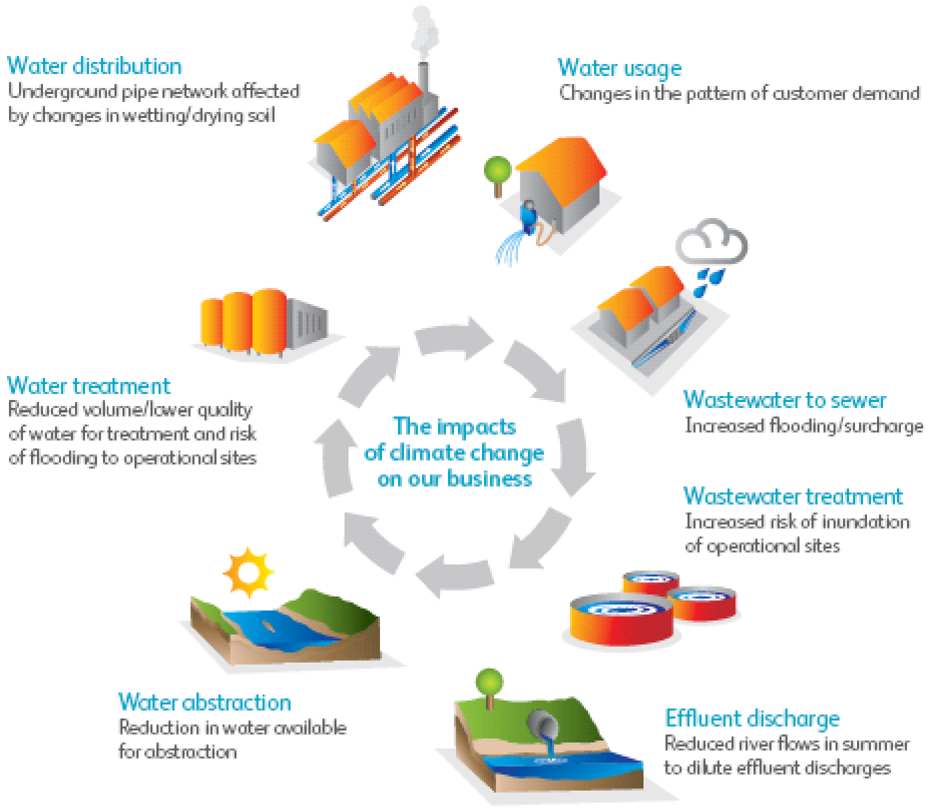
5.29 North London Artificial Recharge Scheme (NLARS): One of our strategic water resource schemes is the NLARS. This scheme abstracts water from a number of boreholes in the Lee Valley and discharges to the raw water system including from some boreholes to the New River and in some cases directly to reservoir. The nature of the scheme is to abstract water from the confined aquifer where output will decrease over time. Improved information on borehole performance, together with better information about the aquifer state of storage allowed an updated view of NLARS output at AR16; named NLARS Scenario 3. There remains a risk around what the scheme may actually be capable of during a drought thus two further scenarios of the output from NLARS have been evaluated (named 1 and 2) to aid the evaluation of the risk around NLARS. The impact of the modified output from NLARS for the two alternative scenarios was evaluated by inputting this data into WARMS2 and comparing with the value of DO before the change; here the AR17 baseline London DO of 2,305 Ml/d derived using the optimised LTCD is used as the base run. The risk is now in the range 15 Ml/d to 17 Ml/d and for modelling expedience these values are applied as the most likely and maximum impact in a triangular distribution within the Target Headroom analysis under the S9 functionality.

Climate change

5.30 Climate change is expected to lead to variations in patterns and frequencies of droughts, and other extreme weather events. The UK Climate Projections 2009 (UKCP09) reports that by the 2080s with medium emissions, "The biggest changes in precipitation in summer, are possibly down to about –50% by the 2080s, are seen in parts of the far south of England"[7].

5.31 The impacts of climate change will be felt throughout our business, as shown in Figure 5-2. The potential impact on water usage and abstraction is of concern. Reduced or extreme variation in annual rainfall rates may mean that the yields from river or groundwater sources could be reduced and household water use could increase through increased garden watering and increased frequency of bathing and showering.

Figure 5-2: The impacts of climate change on our business



5.32 UKCP09 provides a large amount of information on how the UK climate may change over the next 100 years in response to different levels of greenhouse gas emissions. To understand the impact of the new scenarios on our assessments of supply and demand, HR Wallingford was engaged to develop a methodology to make the most use of the UKCP09 output data as

[7] UK Climate Projections Online UKCP09 data

practically possible. An outline of our climate change impact assessment is presented here and a detailed account of the methodology and how it has been applied is given in Appendix U: Climate change.

5.33 The updated climate change scenarios were launched by UK Climate Impacts Programme in June 2009 and provide 10,000 equally possible outcomes of future temperature and rainfall. The new projections are 'probabilistic' in that they encompass a wide range of possible changes in climate based upon the strength of evidence from observations, climate change models and expert opinion.

Basic vulnerability assessment

5.34 The first stage of the analysis by HR Wallingford was to undertake a basic vulnerability assessment (BVA) of all our WRZs (HR Wallingford 2017)[8]. This is the first phase of analysis in a tiered approach to climate change analysis as outlined in the Environment Agency/UKWIR (2013) report[9]. Guildford and Henley WRZs have been identified as low vulnerability, Kennet and the Slough, Wycombe and Aylesbury (SWA) WRZs as medium vulnerability with the Swindon and Oxfordshire (SWOX) and London WRZs classified as high vulnerability, which required further "intermediate assessment". Note the magnitude-sensitivity for SWOX was classified initially as medium vulnerability. However, given the interactions between London and SWOX, and SWOX's vulnerability to short, intense droughts, it has been upgraded to high vulnerability.

Intermediate assessment

5.35 The intermediate assessment involves the identification of current system vulnerability through the analysis of the causes and mechanisms of historic droughts.

5.36 The Water Resources Management Plan 2014 (WRMP14) approach to assessing climate change impacts was based around using climatological drought indicators to identify a sub-sample of 20 climate change scenarios. When a similar approach was applied for the 2080s, the detailed analysis presented in the HR Wallingford report suggests that the resulting sub-sample may not be as adequate for identifying an appropriate sub-sample to take forward to the DO assessment.

5.37 In order to identify a more robust sample of climate change scenarios, simplified London and SWOX water supply system models were used to simulate the full 10,000 member UKCP09 ensemble for the 2080s, Medium Emission scenario. This allows the impacts of each climate change scenario on water supply system performance to be calculated using a system-based metric, as opposed to relying on the drought indicator methods which were shown to be less reliable for the 2080s. The climate change impacts simulated using the simplified water supply system model are considered to much better reflect what their relative impacts would be when used in WARMS2 and therefore provide a better basis for identifying a sub-sample to take forward into the draft Water Resources Management Plan 2019 (draft WRMP19) and carried forward to the revised draft WRMP19.

[8] HR Wallingford, Thames Water climate change assessment and impacts on supply, March 2017
[9] Environment Agency/UKWIR, Climate change approaches in water resources planning – Overview of new methods, 2013

5.38 WARMS2 currently applies the Teddington flow factors to the Teddington and Days Weir natural inflows. It also uses a number of rainfall run-off models to simulate flows in various sub-catchments of the Thames. Thus when climate change factors of rainfall, evaporation and flows are input to the model, perturbed flows are generated and then used to calculate the flows of the various gauged and ungauged catchments throughout the model. It should be noted that in WARMS2, the greater proportion of flows are generated by rainfall-runoff models for gauged locations, where climate change impacts are simulated with the use of climate factors, and not through the use of flow factors. The simplified water supply system model demonstrates that by using only a single set of flow factors, as opposed to location specific hydrometric factors, the impacts of climate change on DO may be under-estimated by ~50 Ml/day for London. This is because WARMS2 is more detailed and generates and accumulates flows from various points throughout the Thames catchment rather than from a limited number of locations.

5.39 The output from the HR Wallingford study is a sub-sample of 20 UKCP09 climate change scenarios that are considered to provide the most appropriate representation as to the range and likelihood of the projected climate change impacts in the London WRZ. The sub-sample has also been shown to be valid for the SWOX WRZ and is therefore considered to represent the most robust sample of scenarios to use.

Emissions scenarios

5.40 The UKCP09 projections are available for three emissions scenarios; low medium and high, where for WRMP14 we used the medium emissions scenario to quantify the impact of climate change on our water resources. The Environment Agency's 2017 WRPG Supplementary Guidance[10], states that when using the Spatially Coherent Projections (SCPs) that a medium emission should be used as a minimum. This is also relevant when using the UKCP09 probabilistic scenarios that we used for the draft WRMP19 and carried forward to the revised draft, thus to be consistent with previous analysis at WRMP14 and be compliant with the guidance, the medium emission scenario has been used to assess climate change impacts for the 2080s.

5.41 Between the draft and revised draft WRMP19, we have investigated the climate change impacts of a High Emissions UKCP09 scenario for the 2080s within the London WRZ. On average, there is little change in the impact of a High Emissions 2080s scenario compared to a Medium Emissions 2080s scenario. Within the sample of 20 climate change scenarios from the High Emissions 10,000 member ensemble, the weighted average climate change impact is about 12Ml/d lower (i.e. less severe) with the impact of the very dry end of the sample quite significantly more severe and the impact of the very wet end of the sample significantly less severe.

5.42 It should also be noted that we understand that the UKCP18 data will include a medium emission scenario but not a high scenario. Updated climate change scenarios, UKCP18, were due to be launched by the UKCIP at a high level in May/June 2018. This has now been pushed back to November 2018 by the Met Office so will be launched too late for

[10] Environment Agency, Estimating the impacts of climate change on water supply, April 2017

consideration in the revised draft WRMP19 and will instead be considered within the climate change analysis for WRMP24.

Assessment of climate change on groundwater

5.43 We have undertaken the analysis of our groundwater source drought performance based on the UKCP09 data for the 2080s. Five scenarios from the 20 were selected to assess the groundwater system sensitivity to each of the potential futures. The scenarios were selected, based on their percentiles, to focus on drier potential futures, but also to consider wetter scenarios. The percentiles used are 99, 95, 90, 50 and 10. The rainfall and temperature climate change factors for each of the five scenarios were used to generate recharge scenarios for input into Environment Agency regional groundwater models covering the major aquifers of London and the Thames Valley. These models were then used to undertake hydrogeological analysis of the climate change impacts on the aquifers, specifically the impact on groundwater levels.

5.44 The groundwater level changes derived from this regional analysis of five scenarios for each of the groundwater sources were then used to assess the impact on groundwater SDOs. The SDO for the remainder of the twenty climate change scenarios was derived by interpolation. This interpolation was based on a relationship between SDO and modelled baseflow change in the River Thames at Teddington for each of the five successive pairs of discretely defined SDOs. This data based on the UKCP09 data for the 2080s is used to assess the central or "best estimate" impact of climate change on DO.

Climate change impacts on deployable output

5.45 The amended groundwater SDOs together with the rainfall, potential evapotranspiration (PET) and flow factors were input to the WARMS2 to assess the impact on the DO for London and SWOX from the 20 climate change scenarios. The results of the groundwater analysis also provided the basis for the impact assessments for the other non-conjunctive use WRZs. The flow factors derived from the HR Wallingford work for the 2080s is the basis for the impact assessment on the Fobney DO in the Kennet Valley WRZ and Shalford DO in the Guildford WRZ, which are both river abstraction sources.

5.46 The methodologies developed have then allowed us to derive uncertainties around these possible outcomes such that Target Headroom can be calculated for London and the other WRZs. The uncertainty around the "best estimate" value is included in Target Headroom. We sought advice and peer review from notable experts in climate change including Professor Nigel Arnell (Director of the Walker Institute and Professor of Climate Science), Professor Jim Hall (Director of the Environmental Change Institute and Professor of Climate and Environmental Risk, University of Oxford) and Dr Steven Wade (Head of the Met Office's Scientific Consultancy). It was decided that consideration of a discrete distribution of the climate change impacts was most appropriate as it takes into account the full variability of the calculated impacts. A discrete distribution was built into the Target Headroom models to be able to determine the uncertainty around the "best estimate" of the impact on DO.

5.47 Using the sub-sample of 20 climate change scenarios to assess the impact on the London DO gives a range of change by 2080s from −485 Ml/d (dry scenario) to +204 Ml/d (very wet scenario) with a 'best estimate' of the impact of −187.15 Ml/d. This indicates that the more extreme changes could be highly significant for supply/demand long term planning. The 'best estimate' of the climate change impact has been calculated by modelling a discrete probability distribution function (pdf) using the variation in DO data and probability weightings. The Target Headroom model applies Monte Carlo techniques to determine the statistics from the discrete distribution and the mean impact value of -187.15 Ml/d has been calculated as the 'best estimate' by 2085.

Climate change uncertainty in Target Headroom

5.48 The Environment Agency specifies that the 'best estimate' of the modelled climate projection is applied as a reduction in DO and the uncertainty around this projection is handled in headroom. The impact of the 'best estimate' scenario for each of the WRZs average DO is shown in Table 5-1 and for peak DO in Table 5-2.

5.49 In our current forecast the impact of climate change is greatest in London. This is also the zone where we have most customers.

Table 5-1: Climate change impact on DYAA[11] DO

WRZ	Reduction in DYAA DO due to climate change (Ml/d)						
	2016/17	2019/20	2024/25	2029/30	2034/35	2039/40	2044/45
London	19.70	34.48	59.10	83.73	100.38	108.89	117.40
SWOX	1.12	1.96	3.35	4.75	5.69	6.18	6.66
Kennet Valley	1.26	2.21	3.79	5.37	6.44	6.99	7.54
Henley	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SWA	0.36	0.64	1.09	1.55	1.85	2.01	2.17
Guildford	0.04	0.07	0.13	0.18	0.21	0.23	0.36

WRZ	Reduction in DYAA DO due to climate change (Ml/d)					
	2049/50	2059/60	2069/70	2079/80	2089/90	2099/00
London	125.90	142.92	159.93	176.94	193.96	210.97
SWOX	7.14	8.11	9.07	10.04	11.00	11.97
Kennet Valley	8.08	9.17	10.27	11.36	12.45	13.54
Henley	0.00	0.00	0.00	0.00	0.00	0.00
SWA	2.32	2.64	2.95	3.27	3.58	3.90
Guildford	0.37	0.41	0.45	0.38	0.41	0.45

[11] DYAA – Dry Year Annual Average

Table 5-2: Climate change impact on DYCP[12] DO

WRZ	Reduction in DYCP DO due to climate change (Ml/d)						
	2016/17	2019/20	2024/25	2029/30	2034/35	2039/40	2044/45
London	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SWOX	1.28	2.24	3.83	5.43	6.51	7.06	7.62
Kennet Valley	0.94	1.65	2.83	4.02	4.82	5.22	5.63
Henley	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SWA	0.24	0.43	0.73	1.03	1.24	1.34	1.45
Guildford	0.04	0.07	0.13	0.18	0.21	0.23	0.36

WRZ	Reduction in DYCP DO due to climate change (Ml/d)					
	2049/50	2059/60	2069/70	2079/80	2089/90	2099/00
London	N/A	N/A	N/A	N/A	N/A	N/A
SWOX	8.17	9.27	10.37	11.48	12.58	13.69
Kennet Valley	6.04	6.86	7.67	8.49	9.30	10.12
Henley	0.00	0.00	0.00	0.00	0.00	0.00
SWA	1.55	1.76	1.97	2.18	2.39	2.60
Guildford	0.37	0.41	0.45	0.38	0.41	0.45

5.50 The difference around this “best estimate” value is used to create discrete distributions for both groundwater and surface water climate change impacts for each year of the planning period within each WRZ. The uncertainty around the “best estimate” value is derived from the Target Headroom model and the results shown in Table 5-3 and Table 5-4.

5.51 A correction has been made to climate change scaling factors within the Target Headroom model between the draft and revised draft WRMP19 which explains the step in revised draft climate change uncertainty for the 2080s in Table 5-3. For AR17 the Target Headroom model was updated to reflect the updated climate change methodology used to assess climate change impacts for the draft WRMP19. This update was a step change from using climate change UKCP09 medium emissions impacts for the 2030s time slice (2035/36) to using the 2080s time slice (2085/86). The AR18 review has identified and corrected one omission to the Target Headroom model update namely ensuring that the model is using 2080s as opposed to 2030s scaling factors to scale the climate change impacts through the planning horizon. The impact of this correction is a reduction in the climate change component of Target Headroom uncertainty from 25.2 Ml/d AR17 (29.2 Ml/d AR17+) to 19.07 Ml/d for AR18.

[12] DYCP - Dry Year Critical Peak

Table 5-3: Uncertainty around climate change in Target Headroom for DYAA

WRZ	Climate change uncertainty for DYAA Target Headroom (Ml/d)						
	2016/17	2019/20	2024/25	2029/30	2034/35	2039/40	2044/45
London	29.2	28.1	40.3	47.4	49.1	43.9	37.6
SWOX	2.30	2.14	2.98	3.27	3.38	3.05	2.71
Kennet Valley	0.61	0.49	0.82	1.11	1.21	1.13	1.06
Henley	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SWA	0.36	0.36	0.53	0.65	0.71	0.65	0.62
Guildford	0.00	0.00	0.00	0.00	0.00	0.00	0.00

WRZ	Climate change uncertainty for DYAA Target Headroom (Ml/d)					
	2049/50	2059/60	2069/70	2079/80	2089/90	2099/00
London	37.6	37.6	37.6	37.6	37.6	37.6
SWOX	2.71	2.71	2.71	2.71	2.71	2.71
Kennet Valley	1.06	1.06	1.06	1.06	1.06	1.06
Henley	0.00	0.00	0.00	0.00	0.00	0.00
SWA	0.62	0.62	0.62	0.62	0.62	0.62
Guildford	0.00	0.00	0.00	0.00	0.00	0.00

Table 5-4: Uncertainty around climate change in Target Headroom for DYCP

WRZ	Climate change uncertainty for DYCP Target Headroom (Ml/d)						
	2016/17	2019/20	2024/25	2029/30	2034/35	2039/40	2044/45
London	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SWOX	2.92	2.70	3.75	4.28	4.36	4.12	3.59
Kennet Valley	0.74	0.60	0.97	1.12	1.22	1.14	0.95
Henley	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SWA	0.38	0.38	0.56	0.71	0.76	0.70	0.68
Guildford	0.00	0.00	0.00	0.00	0.00	0.00	0.00

WRZ	Climate change uncertainty for DYCP Target Headroom (Ml/d)					
	2049/50	2059/60	2069/70	2079/80	2089/90	2099/00
London	N/A	N/A	N/A	N/A	N/A	N/A
SWOX	3.59	3.59	3.59	3.59	3.59	3.59
Kennet Valley	0.95	0.95	0.95	0.95	0.95	0.95
Henley	0.00	0.00	0.00	0.00	0.00	0.00
SWA	0.68	0.68	0.68	0.68	0.68	0.68
Guildford	0.00	0.00	0.00	0.00	0.00	0.00

5.52 Therefore it can be seen that the total impact of climate change on the supply demand balance for the DYAA conditions is as presented in Table 5-5 and for the DYCP conditions in Table 5-6.

Table 5-5: Total impact of climate change for DYAA

WRZ	Climate change impact for DYAA Target Headroom (Ml/d)						
	2016/17	2019/20	2024/25	2029/30	2034/35	2039/40	2044/45
London	48.90	62.58	99.40	131.13	149.48	152.79	155.00
SWOX	3.42	4.10	6.33	8.02	9.07	9.23	9.37
Kennet Valley	1.87	2.70	4.61	6.48	7.65	8.12	8.60
Henley	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SWA	0.72	1.00	1.62	2.20	2.56	2.66	2.79
Guildford	0.04	0.07	0.13	0.18	0.21	0.23	0.36

WRZ	Climate change impact for DYAA Target Headroom (Ml/d)					
	2049/50	2059/60	2069/70	2079/80	2089/90	2099/00
London	163.50	180.52	197.53	214.54	231.56	248.57
SWOX	9.85	10.82	11.78	12.75	13.71	14.68
Kennet Valley	9.14	10.23	11.33	12.42	13.51	14.60
Henley	0.00	0.00	0.00	0.00	0.00	0.00
SWA	2.94	3.26	3.57	3.89	4.20	4.52
Guildford	0.37	0.41	0.45	0.38	0.41	0.45

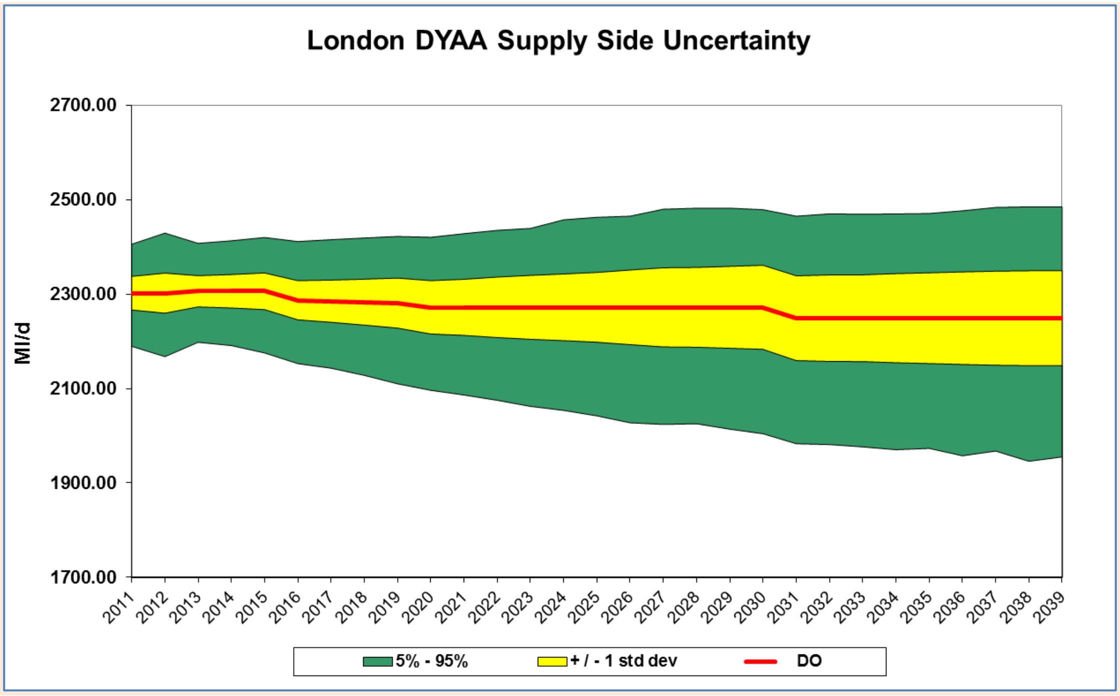
Table 5-6: Total impact of climate change for DYCP

WRZ	Climate change impact for DYCP Target Headroom (Ml/d)						
	2016/17	2019/20	2024/25	2029/30	2034/35	2039/40	2044/45
London	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SWOX	4.20	4.94	7.58	9.71	10.87	11.18	11.21
Kennet Valley	1.68	2.25	3.80	5.14	6.04	6.36	6.58
Henley	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SWA	0.62	0.81	1.29	1.74	2.00	2.04	2.13
Guildford	0.04	0.07	0.13	0.18	0.21	0.23	0.36

WRZ	Climate change impact for DYCP Target Headroom (Ml/d)					
	2049/50	2059/60	2069/70	2079/80	2089/90	2099/00
London	N/A	N/A	N/A	N/A	N/A	N/A
SWOX	11.76	12.86	13.96	15.07	16.17	17.28
Kennet Valley	6.99	7.81	8.62	9.44	10.25	11.07
Henley	0.00	0.00	0.00	0.00	0.00	0.00
SWA	2.23	2.44	2.65	2.86	3.07	3.28
Guildford	0.37	0.41	0.45	0.38	0.41	0.45

5.53 The Target Headroom methodology shows climate change to be the most significant uncertainty on the supply side. In London the direct impact on average DO is around 19.7 Ml/d at the start of the planning period increasing to around 117.40 Ml/d by 2044 and climbing to 210.97 Ml/d by 2099. When the uncertainty on this is taken into account the combined impact is ~49 Ml/d at the start increasing to ~155 Ml/d by 2044 increasing to ~249 Ml/d by 2099. The range of potential uncertainty around DO is shown in Figure 5-3.

Figure 5-3: London DYAA supply side baseline headroom uncertainty



New resource development uncertainty

5.54 The volume of water delivered by new resources can often be uncertain. The uncertainty around existing resources is captured in the supply-side baseline uncertainty. But new resources included as a result of decisions made in this plan are not part of the baseline and must be included as part of a final plan re-assessment of Target Headroom. Section 10: Programme appraisal, presents a discussion of the application of final plan Target Headroom.

5.55 The inclusion of new resource schemes within the preferred programme will include elements of uncertainty over the actual DO produced by that scheme under the planning scenario delivered and also the cost of delivering the scheme. In essence the scope of the scheme, the assets constructed, are considered to be fixed and equal to that identified in Appendix R: Scheme dossiers. Note that cost uncertainty is not considered as part of the Target Headroom calculation and is discussed further in Section R: Scheme dossiers.

5.56 Between the draft and the revised draft WRMP19 we worked to replicate the approach to final plan Target Headroom followed for the draft WRMP19.

5.57 The draft approach involved assessing uncertainty around scheme yield (using the judgement of expert hydrologists and hydrogeologists supported by estimates and associated justification made by our engineering partner Mott MacDonald in Appendix R: Scheme dossiers) and characterising an uncertainty distribution, by percentile outputs in 5% increments, for each year of the 80 year planning horizon. The EBSD model then interpolated the value of the distribution between these points and sampled from the interpolated distribution. This analysis did not include uncertainty around scheme timing.

5.58 The results from this full appraisal for the revised draft WRMP19 were counterintuitive due to an underlying issue. This lead to an allowance of 5% of overall scheme yield being carried forward and added to baseline Target Headroom to calculate final plan Target Headroom.

Summary

5.59 We have used the 'improved methodology'[13] for calculating the impact of uncertainty on the supply side of our supply demand balance. The work shows that the impact of climate change is the most significant uncertainty on the supply side. We have undertaken considerable work to understand the impact.

D. Demand side uncertainty

Components of demand side uncertainty

5.60 The demand-related headroom components identified in the methodology are as follows:

- D1 – Uncertainty in base year data
- D2 – Demand forecast variation
- D3 – Uncertainty of climate change on demand
- D4 – Uncertainty of demand management measures

5.61 We have undertaken analysis of demand uncertainty using Monte Carlo simulation to understand the uncertainty around the deterministic demand forecast. We describe this briefly in the "Demand uncertainty overview" section below, before examining the individual components D1 to D4. For further detail see Appendix V: Risk and uncertainty.

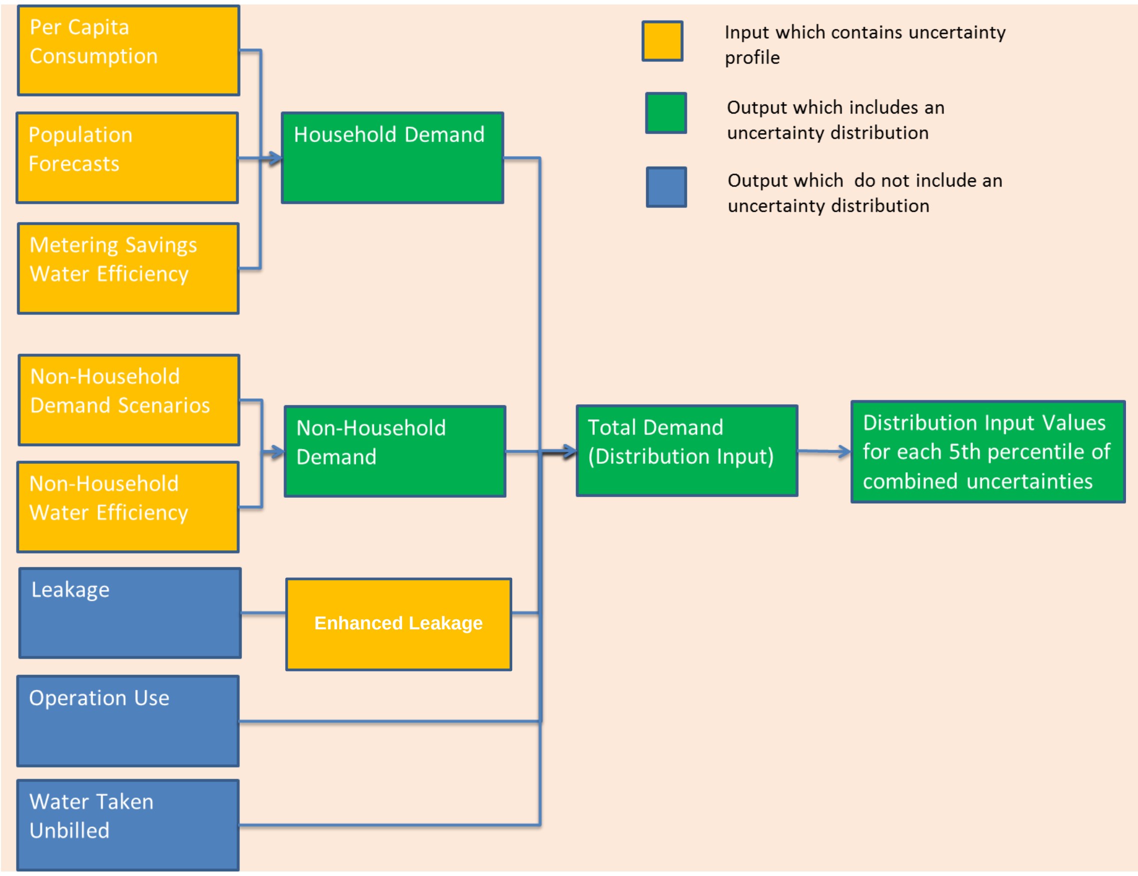
5.62 The approach we have used is consistent with the current UKWIR guidance[14] which is recommended by the Environment Agency's 2018 WRPG.

Demand uncertainty overview

5.63 Specialist software is used to calculate the uncertainty associated with the demand forecasts that are described in Section 3: Current and future demand for water. The demand forecasts produce a single value for demand for each year of the forecast period. Underpinning the demand forecast is a series of values which are considered the best estimate. Like any estimate, there is scope for uncertainty and analysis of these uncertainties is used to produce the demand uncertainty, that is then used in the calculation of Target Headroom. Monte Carlo simulation is used to understand how the uncertainties from input variables translate into uncertainty in the overall demand forecast. An overview of this is shown in Figure 5-4.

[13] UKWIR (2002) An Improved Methodology for Assessing Headroom
[14] UKWIR, WRMP 2019 Methods – Risk Based Planning, Appendix D7, (16/WR/02/11), 2016.

Figure 5-4: Overview of analysis of uncertainty in demand forecasts



5.64 Each demand component shown in orange is assigned a probability distribution according to the information available. Most of the uncertainty ranges around these components have been estimated based on studies where possible, and expert judgment or opinion where little information is available. Where judgment/opinion has been used output values have been examined to ensure that the uncertainty range is reasonable.

5.65 Traditionally, we have not considered uncertainties around leakage because the outturn value is, to a degree, within our management control to deliver. This does not mean there is no uncertainty. Weather, particularly cold winters, can cause metal pipes to contract and fracture, therefore increasing leakage. Furthermore, we have more than 30,000km of buried water network and, whilst we invest considerable effort in understanding and modelling how it deteriorates over time, it is not an exact science. For the revised draft WRMP we have adopted new and more stretching leakage targets and have now included uncertainties around the benefits of new enhanced leakage schemes (see component D4 below), while still excluding uncertainties around more standard activities or "base" leakage.

5.66 Uncertainty distributions for the following outputs are not included for demand components shown in blue in Figure 5-4:

- **Leakage** – For standard leakage management activities we consider the uncertainty in terms of the cost it will take for us to meet or out-perform our leakage target in each year through a mix of activities including finding and fixing leaks as they break out and replacing our old iron pipes with new plastic pipes. We do not include uncertainties in this “base” leakage in Headroom.

- **Operational use and demand from our properties** – This component reflects the water we use in operational activity such as flushing mains for water quality reasons or water used at out sites or offices for sanitation purposes. Similarly to leakage the outturn value for this component is, to a large degree, within our management control to deliver. Therefore the same logic applies around the inclusion of uncertainty in future forecasts. Note that these values are not actually forecast and are assumed to be constant at base year values over the planning period. As such the uncertainty around this output is part of the base year measurement uncertainty described in paragraphs 5.67 to 5.72. Additionally the total volume of this category is approximately 1% of total distribution input (DI) and therefore any reasonable uncertainty estimates around forecast values would be unlikely to have a material impact on the results of this analysis.
- **Water taken illegally or unbilled** – These values are not actually forecast and are assumed to be constant at base year values over the planning period. As such the uncertainty around this output is part of the base year measurement uncertainty described in paragraphs 5.67 to 5.72. Additionally the total volume of this category is approximately 1% of total DI and therefore any reasonable uncertainty estimates around forecast values would be unlikely to have a material impact on the results of this analysis.

D1 – Uncertainty in the base year data

5.67 The actual DI supplied in the base year is used as base data to support the forecast of demand for the 80 year planning period. DI is measured by meters, typically located at the outlet of a water treatment works. These meters are subject to a statutory verification programme, but there is still uncertainty about the results they record. This uncertainty is reflected in the calculation of the water balance as part of the annual performance report to Ofwat.

5.68 Here we have used the same uncertainty distribution for base year DI used as part of the water balance calculation. Base year DI is a random variable with a normal distribution where the mean is equal to the deterministic estimate of base year DI and the standard deviation is equal to 1.02%[15] of deterministic DI.

5.69 Uncertainty is also estimated around the uplift from the base year recorded value of DI to reflect the planning scenario in use[16]. This uplift reflects the weather and operational circumstance of the base year may have been more (or less) favourable than would be expected to be the case in a year typical of the planning scenario i.e. a dry year. For example, in London the recorded DI in the base year was 2,080.7 Ml/d. The weather in the base year was assessed to have suppressed demand below what it would have been in dry year

[15] This is based on a 95% confidence interval for reported DI being +/- 2% and 95% confidence interval for a normal distribution being +/- 1.96 standard deviations. The 2% divided by 1.96 equals a standard deviation of 1.02%.
[16] E.g. Dry Year Annual Average basis for London.

conditions. An uplift of 24.6 Ml/d is applied to convert DI to the value expected if conditions in the base year had been equal to dry year conditions.

5.70 There is uncertainty about the accuracy of the recording of conditions in the base year, the assessment of conditions in the dry year and the impact of those conditions on DI. Therefore we apply an uncertainty to the value of the uplift used. Because it is impossible to validate the accuracy of the uplift directly[17] we use expert judgement to set the uncertainty distribution used to reflect uncertainty around the uplift.

5.71 The value of the uplift in deterministic forecast is our best estimate and therefore we believe is also the most likely value. We do not have any reason to believe that the distribution is likely to be skewed and therefore we have used a normal distribution to characterise the uncertainty around the uplift. We chose to set standard deviation for the distribution at 5% of the value of the deterministic uplift value. This resulted in a distribution which best matched the expectation of a number of experts.

5.72 The impact of the uncertainty around base year estimates is then set the sum of both uncertainty distributions less the deterministic value of the base year DI in dry year conditions[18].

D2 – Demand forecast variation

5.73 The sources of demand forecast variation considered in the Demand Uncertainty Model are as shown in the list below. Each is discussed in a separate section which follows below:

- Household per capita consumption (PCC)
- Household population
- Non-household demand

Household PCC uncertainty

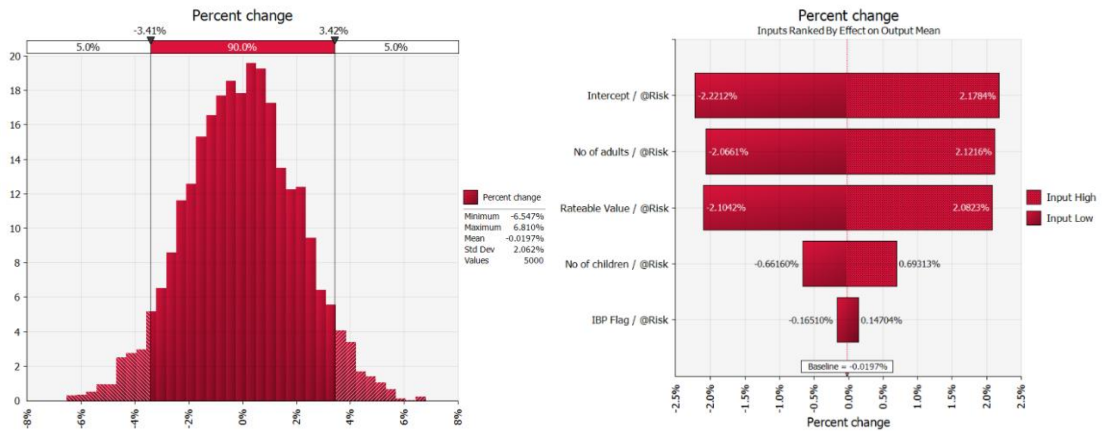
5.74 Household PCC is the average volume of water used by each person in a household. Typically it is reported in units of litres per head per day (l/h/d). PCC is a measure of customers' water use behaviour. In this section the PCC discussed is the baseline[19] value, meaning that it is the value prior to any demand management activity we might deliver to influence the value.

5.75 PCC uncertainty is calculated by using the household demand forecasting model produced by Artesia Consulting. The demand forecasting model uses a multiple linear regression approach, which produces standard errors around each of the input values that indicate uncertainties and can used to simulate confidence intervals around the central PCC forecast. The uncertainties related to the Artesia final model are illustrated in Figure 5-5, which shows

[17] There is no opportunity to actually replicate the base year circumstances (population, customer water use behaviour, etc.…) in dry year weather conditions.
[18] Because of the properties of normal distributions this results in a normal distribution with a mean of zero and a standard error of the square route of the sum of the squared standard errors of the original distributions. For example, standard error of the distribution of the impact of uncertainty around the base year estimate is equal to the square root of the sum of 1.02% of the measured DI squared and 5% of the deterministic uplift value squared.
[19] For example, progressive metering or water efficiency Smarter Home Visits.

that uncertainty in model coefficients alone translates to a PCC uncertainty range of +/- 3.4%[20]. It also shows that the number of adults and size of property are the key variables. This approach and the setup of the model are explained further in Section 3(C): Current and future demand for water (Household water use) and Appendix F: Household water demand modelling (Section 20 - uncertainties). This Section 20 discusses uncertainties where base year, model coefficients, property types and population uncertainties are combined to show impacts on water resource zone consumption in Ml/d.

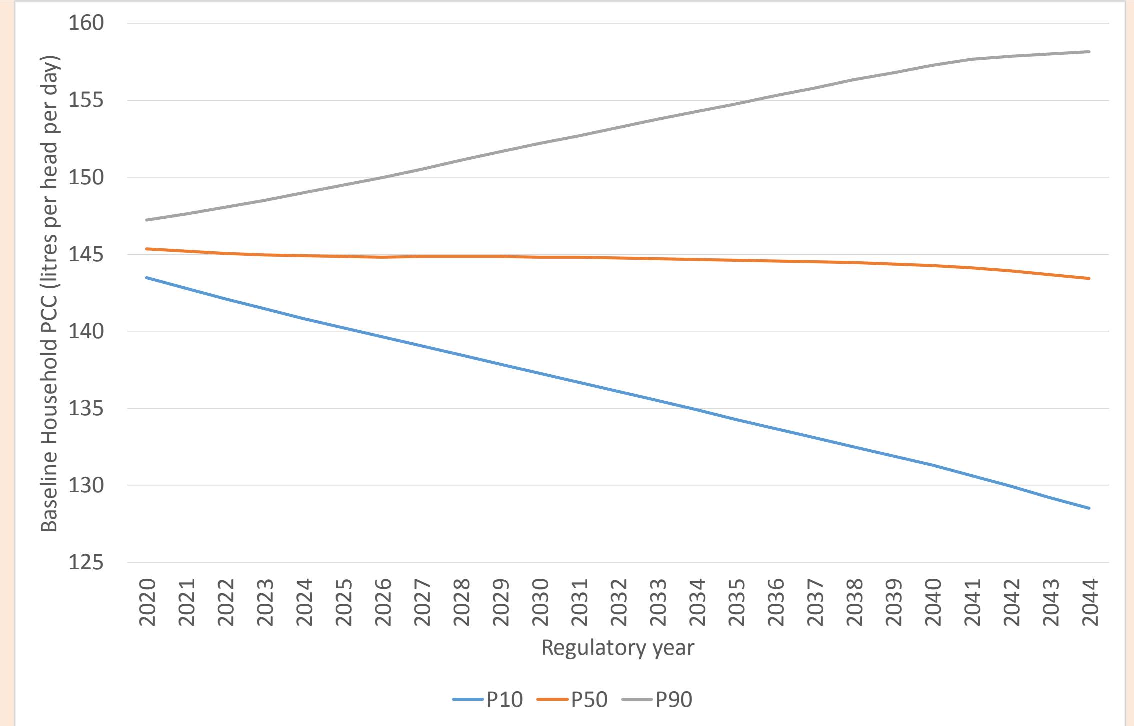
Figure 5-5: Illustration of PCC model coefficient uncertainty on PCC (percentage) and sensitivity to input variables



5.76 An 80% confidence interval for forecasts of household PCC produced by applying the household demand forecasting model are used as inputs to the demand uncertainty model. The limits of this confidence interval along with the expected value used in the deterministic demand forecast are used to characterise a PERT probability density function[21] for household PCC for each year of the planning problem. Figure 5-6 shows the expected value, and the 10th percentile and 90th percentile values which form the 80% confidence interval for household PCC.

[20] This illustrative calculation is based on a household of 3 adults, one child with a rateable value of £283,000.
[21] More detail on how a probability density function is characterised in Target Headroom analysis can be found in Appendix V: Risk and uncertainty.

Figure 5-6: Baseline household PCC results from demand forecasting model



Household population uncertainty

5.77 The household population we serve is a key factor in forecasting demand. Population is the result of a myriad of uncertain components including, birth rates, death rates and net migration. Each of these components is influenced by a range of underlying factors such as macro-economic growth. As such it is easy to see why there is uncertainty in the forecast of population.

5.78 Population uncertainty has been estimated using the methodology suggested in the UKWIR report on population, household property and occupancy forecasting project[22]. The method uses three separate sets of normal uncertainty distributions for population uncertainty which are chosen on the basis of the relative scale of the population being forecast:

- Region (i.e. population of the order of 5 million)
- County (i.e. population of the order of 500,000)
- Local Authority (i.e. population of order of 100,000) or smaller

5.79 The report uses data from a number of Office for National Statistics population forecasts compared to the actual outturn population to calibrate the distributions. The results show that generally the smaller the population grouping being forecast the larger the inaccuracy of the forecast in percentage terms tended to be. The apparent logic is that for smaller population groups there is more of a chance for local effects to have a larger impact and less chance to

[22] UKWIR, WRMP19 Methods – Population, Household Property and Occupancy Forecasting (15/WR/02/8), 2015

be offset by counteracting effects in other parts of the area. More detail on the approach is provided in Appendix V: Risk and uncertainty.

5.80 We have applied the method at a WRZ level, which results in the following allocation of uncertainty distribution sets:

- Region: London
- County: SWOX, SWA, Kennet Valley
- Local Authority: Guildford, Henley

5.81 Figure 5-7 shows the 90% confidence interval over a period of 30 years for each of the three geographic scale types. The confidence interval is expressed in relative terms to the 50th percentile population forecast. Note that the region and county level values are highly similar. Figure 5-8 shows 50%, 80%, 90% and 95% confidence intervals for the region geographic scale type over 30 years.

Figure 5-7: Comparison of 90% confidence intervals for UKWIR population uncertainty

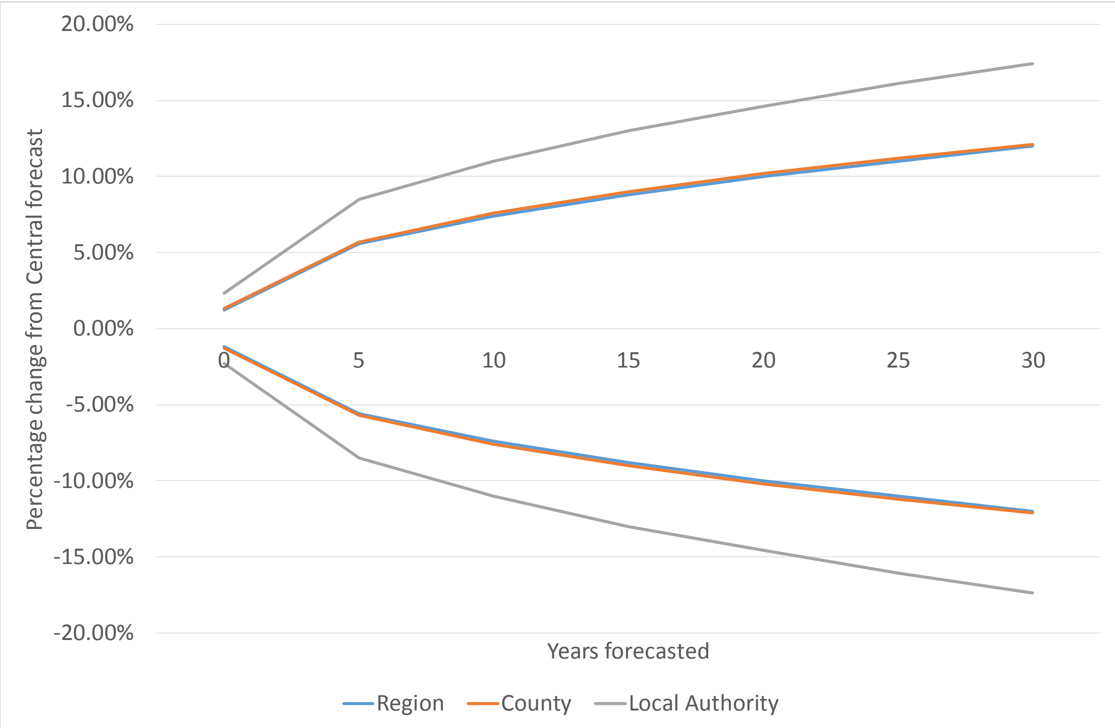
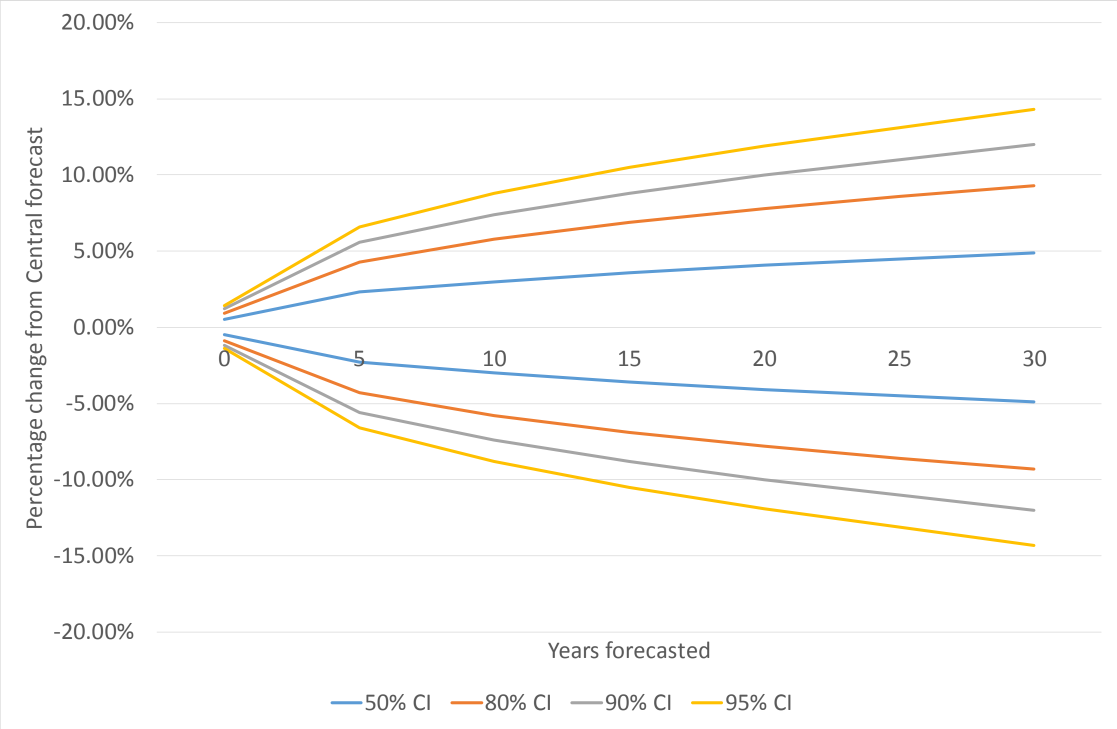


Figure 5-8: Confidence intervals for region level population forecasts



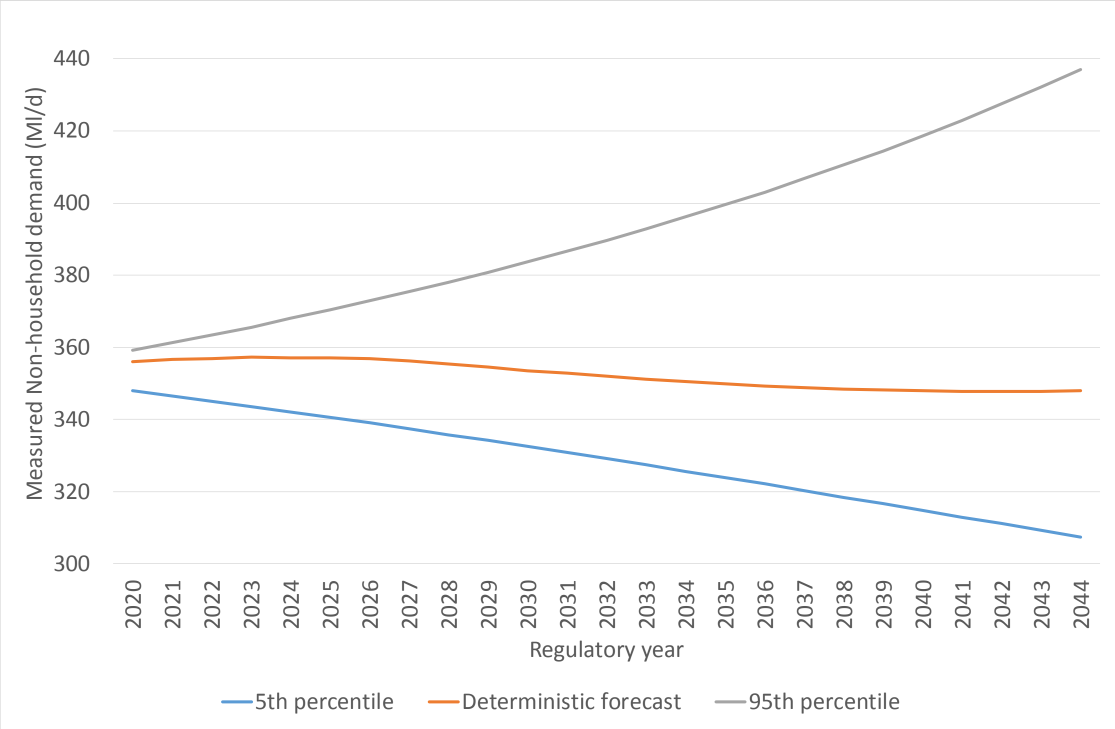
Non-household demand

5.82 Unmeasured non-household demand is a comparatively small component of total non-household demand, approximately 4% in London. We believe that measured and unmeasured non-household demand for water will tend to be well correlated as both are primarily driven by regional macro-economic factors. Therefore we have assumed that the uncertainty distribution for measured non-household demand can be applied proportionately to unmeasured non-household demand.

5.83 The deterministic forecast for non-household demand was produced by Servelec Technologies. As part of that work, using the same methodology and varying future macro-economic projections, they also produced lower and upper forecasts for measured non-household demand in each year. These estimates represent a 90% confidence interval for the value of non-household demand in each year.

5.84 We have fitted a PERT probability density function using the deterministic forecast as the 50th percentile value and the limits of the 90% confidence interval as 5th and 95th percentiles. More details on how distributions are fitted can be found in Appendix V: Risk and uncertainty. Figure 5-9 shows the values used to fit uncertainty distributions.

Figure 5-9: Measured non-household demand forecast uncertainty



D3 – Impact of climate change on demand

5.85 HR Wallingford carried out a study[23] to estimate the likely impacts of climate change upon household demand. Climate change effects are only considered for domestic water use. More information regarding the effects of climate change on demand can be found in Section 3: Current and future demand for water. The climate change ranges are summarised in Figure 5-10 for DYAA and Figure 5-11 for DYCP.

5.86 No allowance has been included for non-household demand based on the findings on the UKWIR report 13/CL/04/12 “Impact of climate change on water demand” which stated:

> *‘It was concluded that, except in the case of agriculture and horticulture in South East Water area, there is inadequate consistent evidence to justify making any allowance for climate change impacts on non-household demand.’*

5.87 The low, mid and upper scenarios presented in these figures are 10th percentile, 50th percentile and 90th percentile forecasts for the impact of climate change on demand. We have used these data points to fit a normal probability density function for each year in the planning period.

[23] HR Wallingford, EX6828 Thames Water Climate Change Impacts and Water Resource Planning. Thames Water Climate Change Impacts on Demand for the 2030s, 2012

Figure 5-10: The impacts of climate change for the DYAA scenario

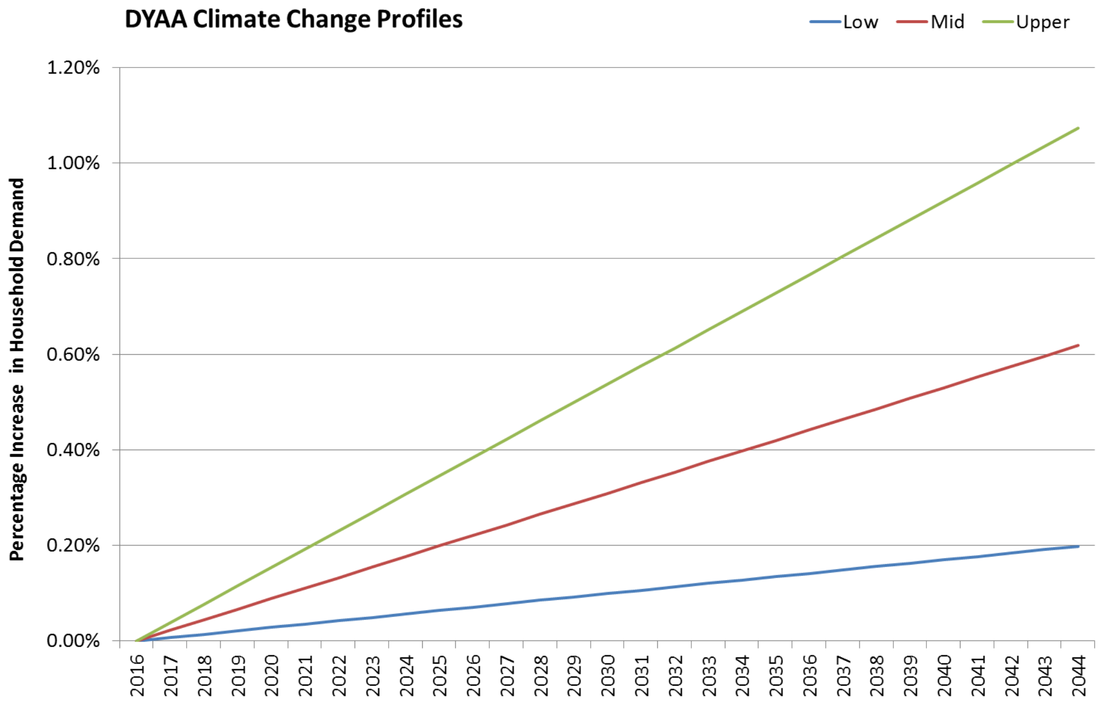
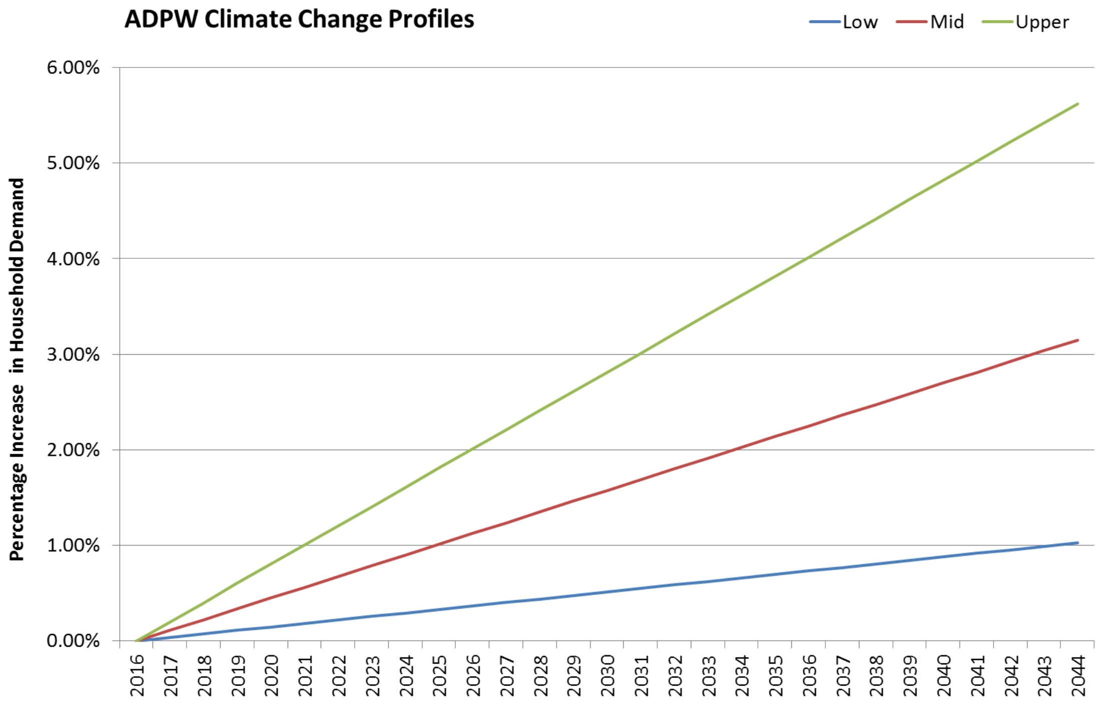


Figure 5-11: The impacts of climate change for the DYCP scenario



D4 – Uncertainty of demand management measures

5.88 These components are not part of the baseline Target Headroom calculation as the baseline position includes no demand management activity. These components are therefore only used as part of the assessment of Target Headroom of a candidate final plan as part of the programme appraisal. More detail can be found on the results of applying Target Headroom analysis on the final plan as part of programme appraisal in Section 10: Programme appraisal.

5.89 As stated in paragraph 5.66 uncertainty around "base" leakage is not considered as part of the assessment of Target Headroom. However, we have introduced uncertainties around new enhanced leakage activities in the revised draft plan. Uncertainty estimates for the material components of the demand management programme are produced separately:

- Metering savings from new meter installations.
- Water efficiency savings from smarter home visits for both household and non-household customers.
- The benefits of enhanced demand savings in Demand Management Areas (DMAs) due to Active Leakage Control (ALC) and other activities.
- The benefits of enhanced activities including mains replacement, further pressure management and customer supply line leakage.

Metering savings

5.90 The central estimate for progressive metering savings has been revised since WRMP14 based on the data collected from the delivery and subsequent monitoring of our progressive metering programme (PMP). Data from a sample of 9,567 households[24] were used in a report produced by expert statistical analysts from our Innovation team. The results of the analysis were controlled for the primary influencing factors:

- Housing type
- Occupancy
- Ethnicity

5.91 The analysis predicts household water use savings of 17.0% if the remaining unmeasured household population were to be metered. However, our experience in the delivery of our AMP6 PMP is showing that the percentage success rates when attempting to meter flats in London is in the low twenties. This is largely due to the complexity of plumbing in many converted flats precluding the ability of economically metering the supply to a single property. Adjusting the analysis to calculate savings for all unmeasured household properties but excluding 80% of flats results in an expected saving of 19.0%.

5.92 We have attempted to corroborate these results with data from other sources. We have been informed by Southern Water and Anglian Water that they have observed savings from their progressive metering programmes of 16.5% and 16.0% respectively. Note that the figure for Anglian Water includes a concurrent water efficiency programme.

[24] 8,567 households which have been measured and a control group of 1,000 properties from the unmeasured domestic water use study

5.93 Triangulation from these sources has led us to use a deterministic forecast of 17.0% for progressive metering savings in the revised draft WRMP19.

5.94 Our internal analysis also produced a 95% confidence interval for the estimate of meter savings, shown in the Table 5-7.

Table 5-7: Progressive metering saving uncertainty parameters

WRZ	Unit	Upper estimate	Most likely	Lower estimate
London	%	79	81	83.2
Thames Valley	%	79	81	83.2

5.95 We have used the same width of confidence interval produced by our internal analysis to estimate the uncertainty around the deterministic value of 17.0%. Because the confidence interval is largely symmetrical and actual results will be delivered by many hundreds of thousands of households over likely more than a decade. We have assumed a normal distribution with a mean of the deterministic value and a standard deviation of the width of the 95% confidence interval (4.2%) divided by 3.92[25]. We have increased the amount of water efficiency activity in our revised draft plan but still assumed they will perform at the same level, Therefore we have applied the same uncertainty distribution through the whole planning period.

Smarter homes visit uncertainty

5.96 The uncertainty for water efficiency savings is based on a study of the activity carried out in AMP6. The results of this study are presented in Table 5-8. The upper and lower estimates are used as a 95% confidence interval for the most likely saving. This has been used to fit a normal distribution in the same manner as described for metering saving uncertainty in the section above. We have increased the amount of activity in our revised plan but still have used the same assumptions for AMP7 and beyond.

Table 5-8: Water efficiency savings uncertainty parameters for households and non-household

WRZ	Unit	Lower estimate	Most likely	Upper estimate
London	l/prop/d	9.1	10.6	12.1
Thames Valley	l/prop/d	9.1	10.6	12.1

Demand Management Areas (DMA Enhanced)

5.97 As outlined in section 5.65 we have included greater leakage reduction in the revised draft WRMP19 and now include uncertainties around the benefits of these activities. DMA Enhanced activities are planned for London, SWOX and Guildford only. Previous internal assessments for PR14 have assumed uncertainty ranges of +/-10-20% on the benefits of

[25] Note the standard normal distribution has a 95% confidence interval bounded by the mean +/- 1.96 times the standard deviation.

leakage activities[26]. Ongoing research with Artesia Consulting on the uncertainties associated with ALC suggested very wide-ranging uncertainties in the benefits. An internal workshop with the operational leakage team was used to estimate the likelihood of underperformance and exceedance of planned benefits. This suggested a moderate likelihood of not meeting planned targets for additional activities and a small chance of exceeding targets. Therefore, a simple triangular distribution was used with the 'most likely' value of 100% of the planned benefits, a minimum of 70% and a maximum of 105%.

Mains replacement, pressure management and customer supply line leakage.

5.98 In addition, we have included enhanced levels of main replacement, pressure management and customer side leakage (CSL) activities with ambitious targets. Previous internal assessments for PR14 have assumed uncertainty ranges of +/-16% on the benefits of these leakage activities. For AMP6 internal models assumed uncertainties of -25%/+10% on the benefits of these activities. An internal workshop with the operational leakage team was used to estimate the likelihood of underperformance and exceedance of planned benefits. This suggested a moderate to low likelihood of not meeting planned targets for additional activities and a small chance of exceeding targets. Therefore, a simple triangular distribution was used with the 'most likely' value of 100% of the planned benefits, a minimum of 80% and a maximum of 105%.

E. Accounting for correlation in demand side uncertainty

5.99 Some of the sources of uncertainty considered in this analysis will be influenced by similar underlying causes and hence their distributions will be correlated. We have completed a pairwise assessment of each source of uncertainty using expert judgement, the results of which are shown in Appendix V: Risk and uncertainty.

5.100 As a result of this analysis we have used a positive 0.75 correlation factor between the results of uncertainty for metering savings and water efficiency savings. These factors are both heavily influenced by customer attitudes to water use. This means that the model will reflect that if metering savings are higher than expected then water efficiency savings will also tend to be higher than expected. This has the effect of widening the overall uncertainty distribution from which Target Headroom is produced. Thus, it will marginally increase the resulting final plan Target Headroom over and above what would result from assuming the distributions are independent. In addition, we have assumed a lower positive correlation of 0.5 between AMP7 water efficiency and enhanced leakage activities.

[26] These uncertainties were not included in Headroom and managed as business risk in PR14 and in dWRMP, based on lower levels of ambition.

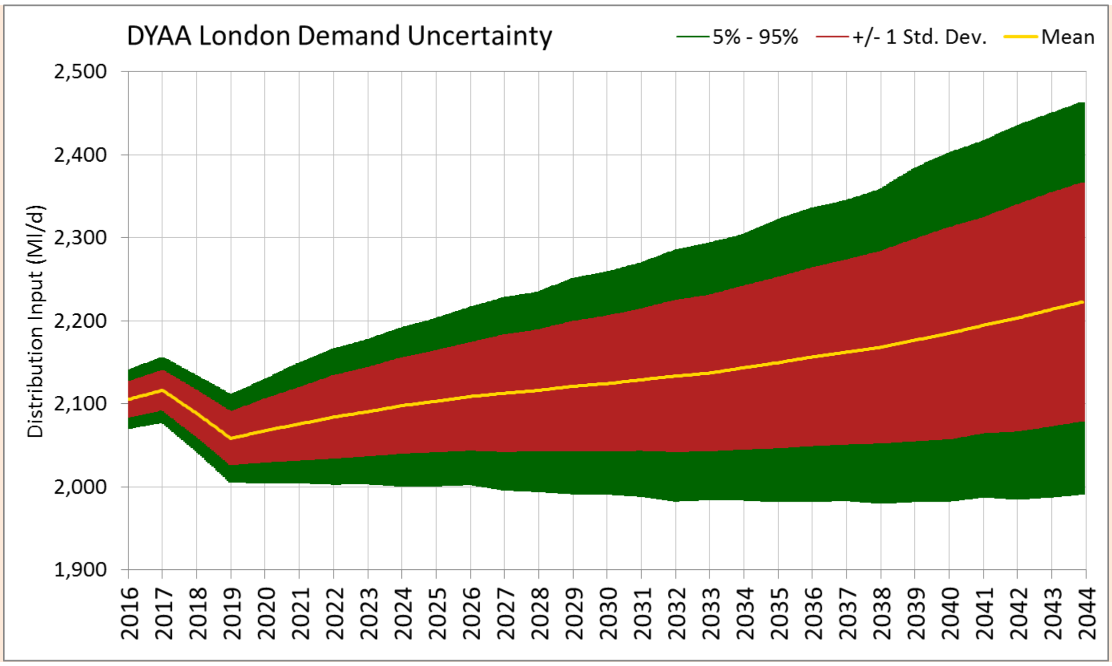
F. Sensitivity of demand side uncertainty

5.101 Climate change is the most important Headroom theme, but total demand side uncertainty is the second most important and a significant part of the plan. For Baseline Headroom both base uncertainty (D1) and population uncertainty (part of D2) are key components. Most uncertainty in future DI is due to uncertainty in population forecasts; over 40% of the variance in DI in 2044 is due to the population forecast alone. Introducing uncertainties for demand management measures (D4) for the final planning results increases the magnitude of uncertainty (by a maximum ca. 1% of DI) but population uncertainty remains the dominant factor. Further information on the contribution and impacts of demand uncertainty are included in Appendix V: Risk and uncertainty. In addition, further scenario testing and sensitivity analysis on population forecasts is completed in Section 10.

G. Model outputs

5.102 The output from the model, which is then used in the headroom model, is a table with a demand value for each 5th percentile. A graphical representation of the output can be seen in Figure 5-12.

Figure 5-12: Baseline demand forecast uncertainty spread - London WRZ



5.103 Results from the baseline model run are used as input into the headroom model to form an initial view of Target Headroom for the baseline forecasts.

H. Baseline Target Headroom and risk profile

5.104 Our baseline forecast has used a risk profile as shown in Table 5-9. A smaller allowance for uncertainty is made in the future as we consider the opportunity to review plans and adapt to changes. A profile has been adopted of 5% in AMP6, which then increases at 1% per annum until 2043/44. Thus the risk taken is increased from 5% to 29% by 2043/44 and is then held at this level over the remainder of the planning period till 2100. We have based our risk profile on a range of factors and made a judgement on what we consider is a reasonable balance of risk over the plan period[27]. Appendix V: Risk and uncertainty, Section G provides a detailed explanation of our decision making process surrounding setting the level of Target Headroom risk.

Table 5-9: Risk profile for Target Headroom assessment in WRMP14 and revised draft WRMP19

	Headroom Risk Profile (%)						
	2016/17	2019/20	2024/25	2029/30	2034/35	2039/40	2043/44
WRMP14	10	10	15	20	25	30	N/A
WRMP19	5	5	10	15	20	25	29

Note: Revised draft WRMP19 Risk is held at 29% from 2043/44

Baseline Target Headroom components

5.105 An example of the typical components of a Target Headroom profile is provided in Figure 5-13, illustrating the relative importance of each of the parameters.

5.106 Figure 5-13 shows baseline supply and demand Target Headroom components for the London WRZ. As described in Section C: Supply side uncertainty and Section D: Demand side uncertainty the following components are considered when calculating baseline Target Headroom

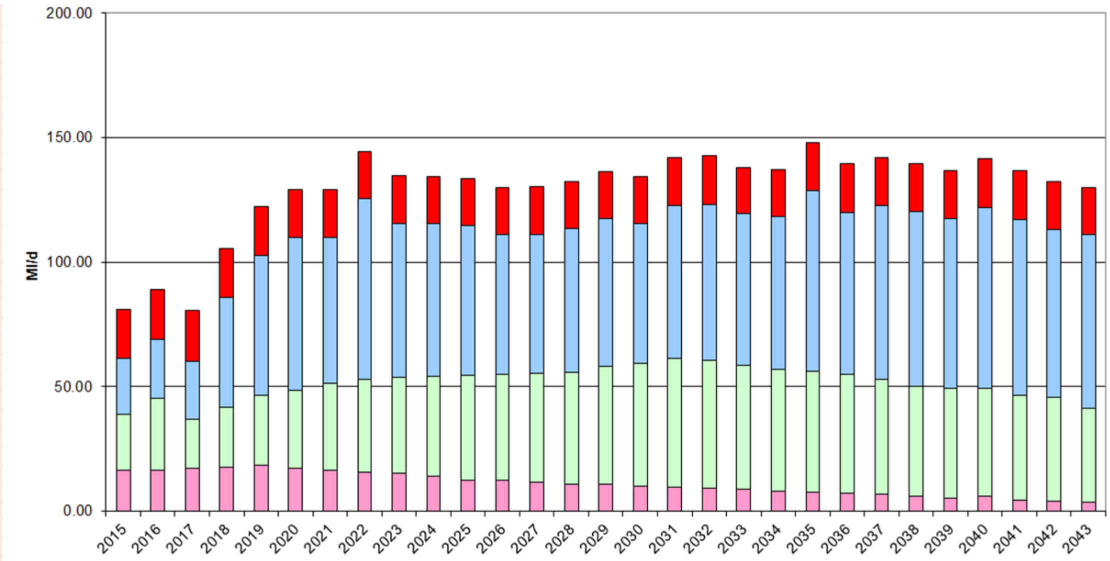
- S6 – Accuracy of supply side data
  - Additional supply side uncertainty in the London WRZ only around NLARS and bromates included as a separate component
- S8 – Uncertainty of impact of climate change on source yields
- D1 – Uncertainty in base year data
- D2 – Demand forecast variation
- D3 – Uncertainty of climate change on demand

5.107 Supply side climate change uncertainty (Supply component S8) and the demand forecast uncertainty (Sum of demand components D1-D3) are the most significant components of the

[27] Risk profile based on judgement (informed by the Environment Agency's 2018 WRPG to ensure an appropriate level of risk has been selected), the strength of customer research on reliability of supply, the future risks and their characteristics. We tested the plan in Section 10: Programme appraisal to changes in the supply demand balance which can also be used to test how the plan changes with different risk profiles.

headroom forecast for the London WRZ. Demand uncertainty (Sum of demand components D1-D3) is the largest uncertainty. Supply side climate change uncertainty (Supply component S8) is also a dominant component and continues to increase over the planning period; which is unsurprising given the relative importance of surface water supplies in this zone and the uncertainty around future river flows. The impact of supply side climate change uncertainty in other WRZs is less marked than in London with uncertainty around demand dominating. Further details of the component breakdown for each WRZ are given in Appendix V: Risk and uncertainty. The baseline DYAA Target Headroom is shown in Table 5-10 with the DYCP Target Headroom in Table 5-11. Note the Target Headroom is maintained at the same level in each WRZ from 2043/44 to 2100.

Figure 5-13: Baseline Target Headroom components for the London WRZ



5.108 It is noted that for final plan Target Headroom as described in Section C: Supply side uncertainty and Section D: Demand side uncertainty there are two additional components considered which are not considered in baseline Target Headroom or Figure 5-13:

- S9 Uncertain outputs from new resource developments
- D4 Uncertainty of demand management measures

5.109 The outcome from the final plan Target Headroom calculation, in terms of the magnitude of the uncertainty of these components compared to baseline components, is discussed in Section 10: Programme appraisal.

5.110 The correction made to climate change scaling factors within the Target Headroom model between the draft and revised draft WRMP19 resulting in a reduction in the climate change component of Target Headroom uncertainty is driving a reduction in overall headroom which is a key factor driving an overall reduction in Target Headroom from 86.70 Ml/d AR17 (88.81 Ml/d AR17+) to 79.24 Ml/d for AR18.

Table 5-10: Baseline Target Headroom by WRZ – DYAA

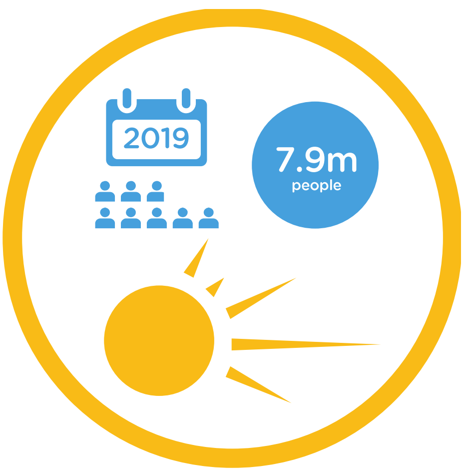
WRZ	Baseline Target Headroom – DYAA (Ml/d)						
	2016/17	2019/20	2024/25	2029/30	2034/35	2039/40	2043/44
Risk Profile →	5%	5%	10%	15%	20%	25%	29%
London	88.81	122.20	134.31	136.50	137.02	136.85	130.09
SWOX	9.00	11.82	13.89	14.12	12.52	12.26	11.77
Kennet Valley	4.02	4.41	5.17	5.35	5.63	4.36	4.06
Henley	0.33	0.59	0.73	0.63	0.51	0.52	0.46
SWA	3.13	5.42	5.16	4.64	4.55	4.20	3.92
Guildford	1.15	1.87	2.12	2.15	1.88	1.66	1.57

Table 5-11: Baseline Target Headroom by WRZ – DYCP

WRZ	Baseline Target Headroom – DYCP (Ml/d)						
	2016/17	2019/20	2024/25	2029/30	2034/35	2039/40	2043/44
Risk Profile →	5%	5%	10%	15%	20%	25%	29%
London	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SWOX	11.17	15.91	19.39	19.04	19.91	20.02	17.82
Kennet Valley	4.46	5.54	7.19	6.91	7.11	7.13	6.22
Henley	0.42	0.73	0.90	0.90	0.91	0.80	0.76
SWA	4.24	6.16	7.20	8.02	7.56	7.36	7.33
Guildford	1.55	2.57	3.27	3.45	3.31	3.17	2.74

Section 6

Baseline water supply demand position



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Section 6.

Baseline water supply demand position

- In this section we provide the baseline water supply demand position for each of our six water resource zones (WRZs).
- An immediate and increasing supply demand deficit is evident in the London zone. Within 10 years, deficits appear in the near term in the Swindon and Oxfordshire (SWOX) and Guildford zones. Beyond 2050, deficits appear in the Slough, Wycombe and Aylesbury (SWA) and Kennet Valley zones. Henley remains in surplus throughout the planning period.
- The forecast deficits are primarily caused by a combination of population growth and climate change impacts.

- Supply demand balances have been updated for all zones

A. Introduction

6.1 The baseline supply demand position is defined as:

> *"The resulting supply demand balance assuming no activity beyond the immediate AMP period other than that required to maintain leakage or that required by law."*

6.2 By comparing the profile of the unrestricted demand (Section 3: Current and future demand for water), against the available supply (Section 4: Current and future water supply), plus an allowance for uncertainty (Section 5: Allowing for risk and uncertainty), a baseline supply demand balance for each WRZ is created.

6.3 This highlights if there is a "planning problem" i.e. a forecast deficit in any zone before significant intervention from the company. We test this for both the dry year annual average (DYAA) and average day peak week (ADPW) conditions, where appropriate. It is possible that deficits exist under both conditions. In this situation, the condition showing the larger deficit takes precedence in terms of its resolution, although the plan must provide a solution to both.

6.4 This section, B to D, is structured as follows:

- Activity within the baseline scenario
- Summary baseline position
- What happens next?

B. Activity within the baseline scenario

6.5 It is assumed that water resource activity included in price limits for the period 2015-2020 is delivered as set out in Section 2: Water resources programme 2016-2020. Baseline activity beyond 2020 is restricted to the following components.

- Leakage levels are maintained at the target position for 2020 (646[1] Ml/d)
- Optant metering programme continues at the current level (~16,000/year)
- Water efficiency continues to be promoted to our customers (saving 0.85 Ml/d per year).

6.6 The demand forecast assumes that no progressive metering or resource development activity is undertaken, beyond AMP6. It also assumes no reductions to our abstraction licences (Sustainability Reductions).

C. Baseline supply demand position

6.7 The baseline water supply demand position by zone is shown in Table 6-1 and summary graphs within the following sub-sections. A full breakdown of the components of the forecast can be found in the Water Resource Management Plan (WRMP) tables (Appendix A: rdWRMP19 tables).

6.8 We explain in Section 4: Current and future water supply, Appendix A: rdWRMP19 tables (Table 10) and Appendix I: Deployable output, that the baseline assessment for supply is on the basis of historical droughts in the 20th Century and hence is resilient to a 1:125 drought to Level 4, without drought permits. To be resilient to the Environment Agency's suggested reference level of a 1:200 drought, the reported deficit in London that would need to be addressed would increase by ~150 Ml/d.

6.9 Overall, the baseline forecasts remain broadly in line with those predicted in our WRMP14. The London WRZ has seen a reduction in the size of the deficit it faces, principally due to changes to the Lower Thames Operating Agreement. Despite this, the scale of the supply demand balance resolution challenge is still considerable. Extending the planning horizon has also revealed a notable long-term deficit in the SWA WRZ. This is caused primarily by population growth projections for the long-term.

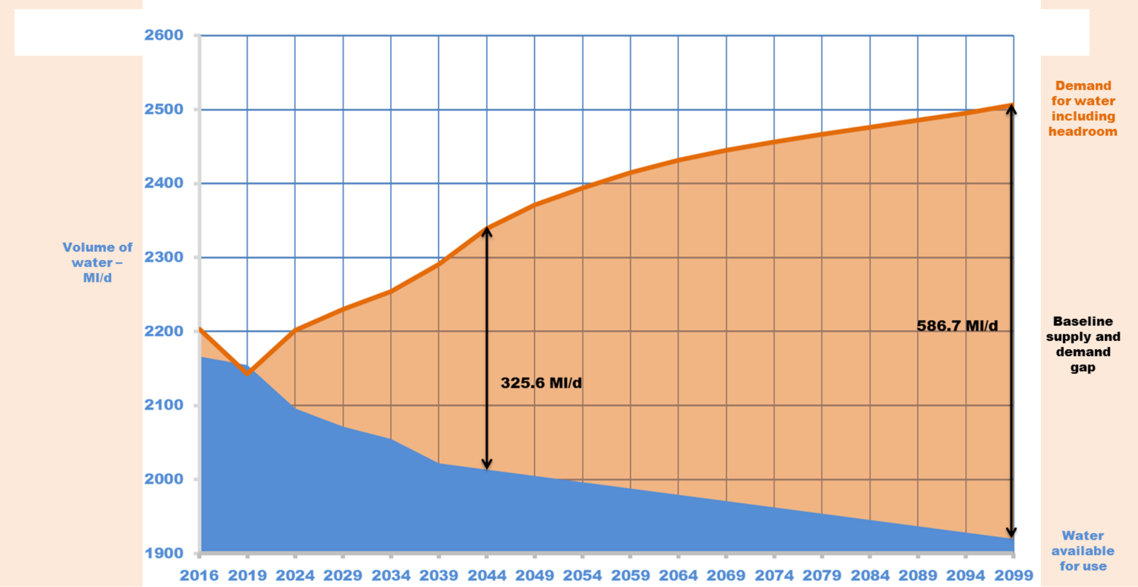
[1] AMP6 output in WRMP14 was 606 Ml/d. The extra 40 Ml/d is linked to a reporting methodology change, as explained in Section 2: Water resources programme 2016-2020.

Table 6-1: Baseline supply demand position by zone (compared with WRMP14)

WRZ	Item	Volume (Ml/d)					
		2019/20	2024/25	2029/30	2039/40	2074/75	2099/00
London (DYAA)	Demand	2020	2068	2093	2154	2326	2376
	Headroom	122	134	136	137	130	130
	Supply	2155	2096	2071	2022	1962	1920
	Balance	12	-106	-158	-269	-494	-587
	(WRMP14)	-133	-213	-292	-416		
SWOX (ADPW)	Demand	330	336	339	342	346	357
	Headroom	16	19	19	20	18	18
	Supply	355	353	352	350	346	343
	Balance	9	-2	-7	-12	-18	-31
	WRMP14	-1	-12	-21	-32		
SWA (ADPW)	Demand	170	172	174	178	186	195
	Headroom	6	7	8	7	7	7
	Supply	190	183	182	182	181	181
	Balance	14	4	1	-3	-12	-21
	(WRMP14)	8	5	1	-6		
Kennet Valley (ADPW)	Demand	122	125	126	128	130	136
	Headroom	6	7	7	7	6	6
	Supply	151	150	149	147	145	143
	Balance	23	18	16	13	8	1
	(WRMP14)	22	16	11	5		
Guildford (ADPW)	Demand	63	64	66	69	72	75
	Headroom	3	3	3	3	3	3
	Supply	68	68	68	65	65	65
	Balance	3	0	-2	-8	-10	-13
	(WRMP14)	0	-1	-2	-4		
Henley (ADPW)	Demand	19	19	19	19	20	20
	Headroom	1	1	1	1	1	1
	Supply	26	26	26	26	26	26
	Balance	6	5	5	5	5	5
	(WRMP14)	5	4	4	3		

London

Figure 6-1: Baseline London supply demand summary (Ml/d) – dry year



6.10 Figure 6-1 highlights a significant supply demand deficit under dry year annual average conditions in the period 2016-2100. Growth in demand due to population growth outstrips any water demand management activity. Climate change,changes to bulk supplies (the end of an agreement with Essex and Suffolk Water to reduce our bulk supply to them) and increased third party abstraction from the River Thames, have an adverse impact on the amount of water available to supply.

6.11 The planning problem is therefore:

- A DYAA deficit of 326 Ml/d in 2044-45 and 587 Ml/d in 2099-2100.

6.12 Without corrective action, these deficits will result in a supply for London which is not secure. This means there is a greater probability that demand restrictions will be required in dry years than our stated levels of service. Demand management and resource options to close this gap have been addressed through our economic analysis process. The result of this analysis is presented in the final plan in Section 11: Preferred programme.

SWOX

Figure 6-2: Baseline SWOX supply demand summary (Ml/d) – dry year

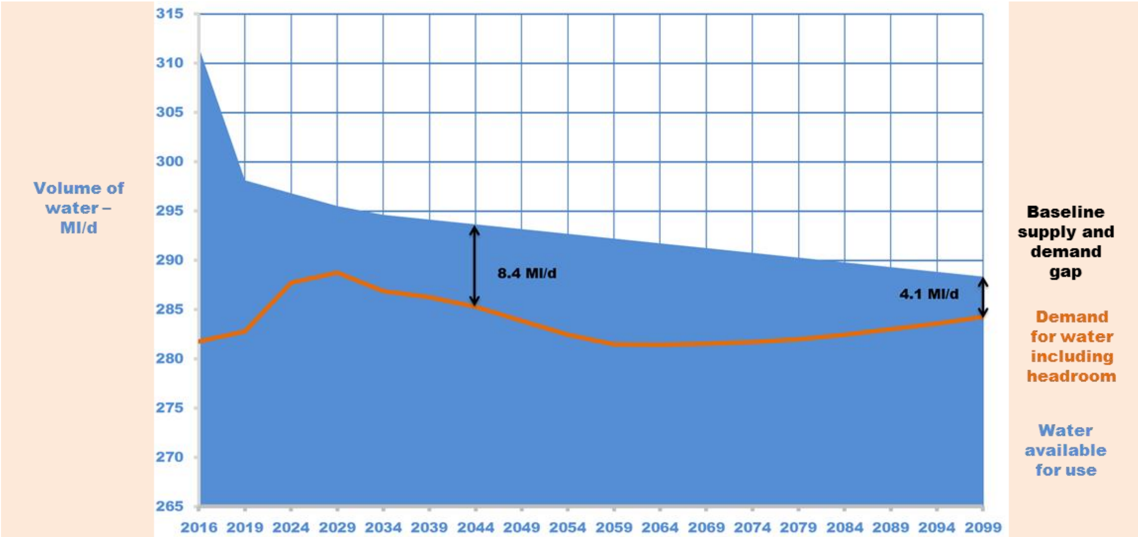
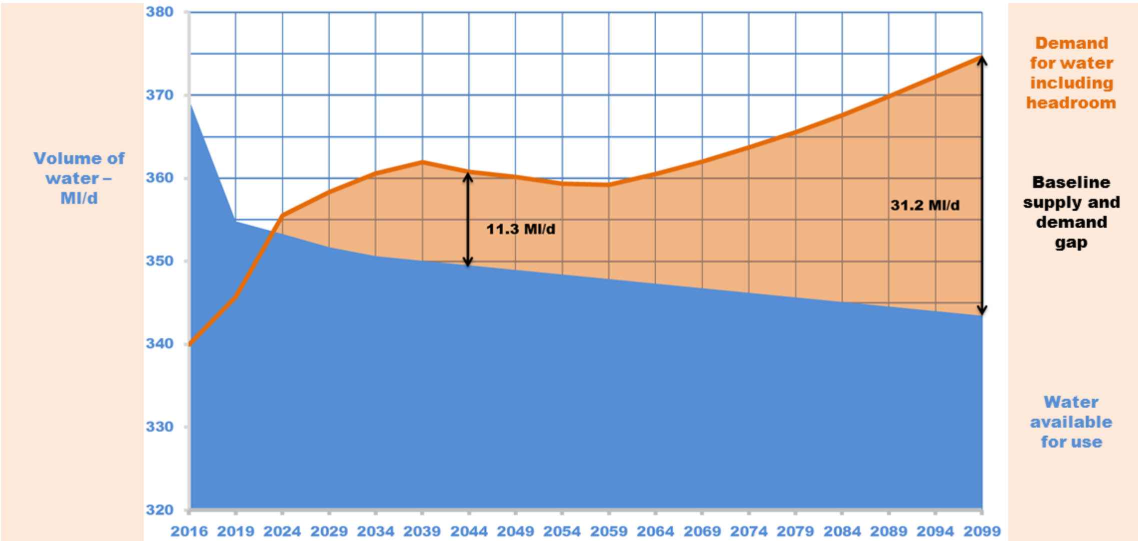


Figure 6-3: Baseline SWOX supply demand summary (Ml/d) – peak week



6.13 In the SWOX WRZ, a small surplus is forecast throughout the planning period under dry year annual average conditions (Figure 6-2). However, a supply demand deficit under peak week conditions is evident (Figure 6-3). The main investment driver is therefore peak conditions although, when developing a solution to the deficit, the dry year condition will also be resolved.

6.14 The planning problem is:

- An ADPW deficit in 2022-23, growing to 11 Ml/d by 2044-45 and 31 Ml/d 2099-2100.

6.15 Growth in demand due to population growth outstrips any water demand management activity. Also climate change affects the amount of water available to supply.

6.16 Without corrective action, these factors will result in a supply for SWOX which is not secure. This means there is a greater probability that demand restrictions will be required in dry years than stated in our levels of service. Demand management and resource options to close this gap have been addressed through our economic analysis process. The result of this analysis is presented in the final plan in Section 11: Preferred programme.

SWA

Figure 6-4: Baseline SWA supply demand summary (Ml/d) – dry year

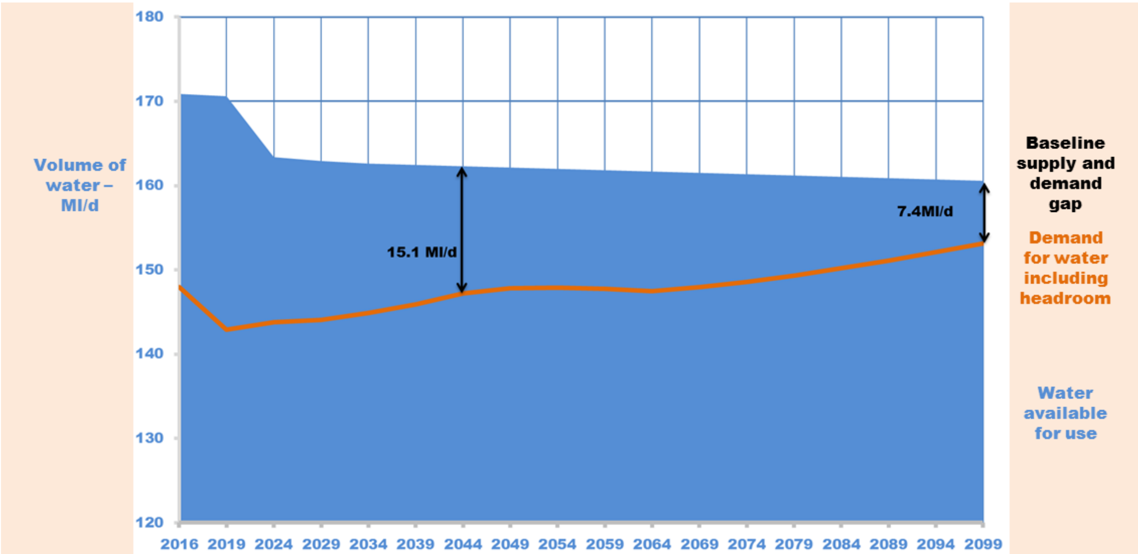
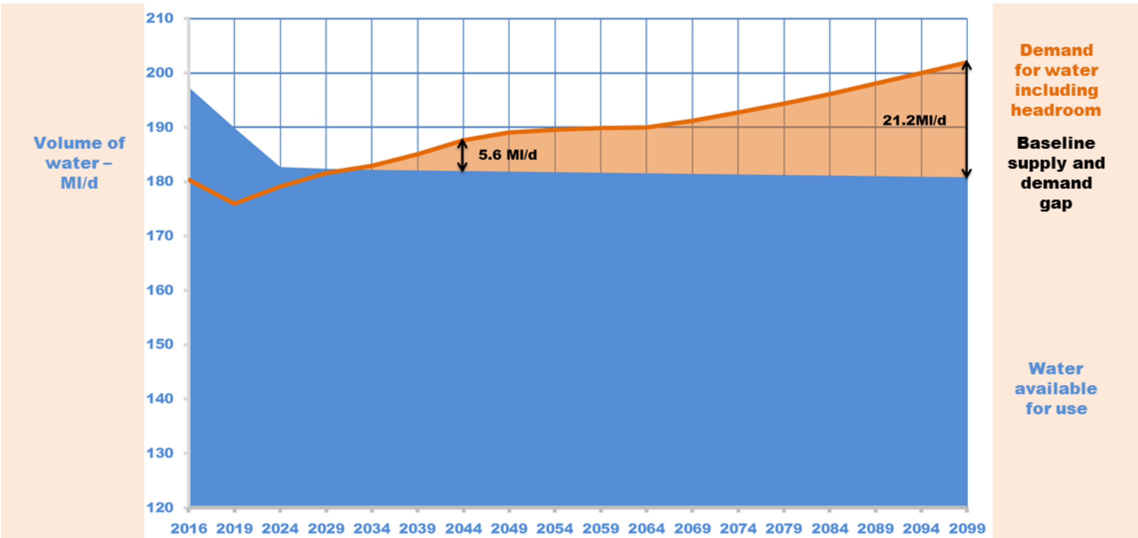


Figure 6-5: Baseline SWA supply demand summary (Ml/d) – peak week



6.17 In the SWA WRZ, a surplus is forecast throughout the planning period under dry year annual average conditions (Figure 6-4). However, a supply demand deficit under peak week conditions is evident (Figure 6-5). In the medium to long-term, these deficits are primarily driven by the forecast growth in housing and population. The investment driver is therefore peak conditions.

6.18 The planning problem is:

- An ADPW deficit in 2033-34, growing to 6 Ml/d by 2044-45 and 21 Ml/d 2099-2100.

6.19 Growth in demand due to population growth outstrips any water demand management activity. Also climate change affects the amount of water available to supply.

6.20 Without corrective action, these factors will result in a supply for SWA which is not secure. This means there is a greater probability that demand restrictions will be required in dry years than stated in our levels of service. Demand management and resource options to close this gap have been addressed through our economic analysis process. The result of this analysis is presented in the final plan in Section 11: Preferred programme.

Kennet Valley

Figure 6-6: Baseline Kennet Valley supply demand summary (Ml/d) – dry year

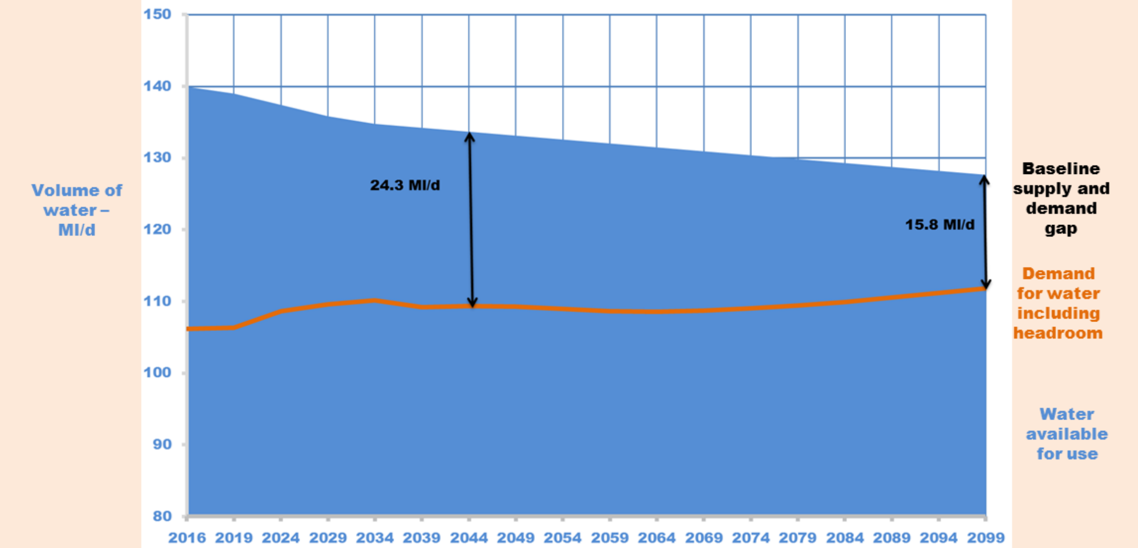
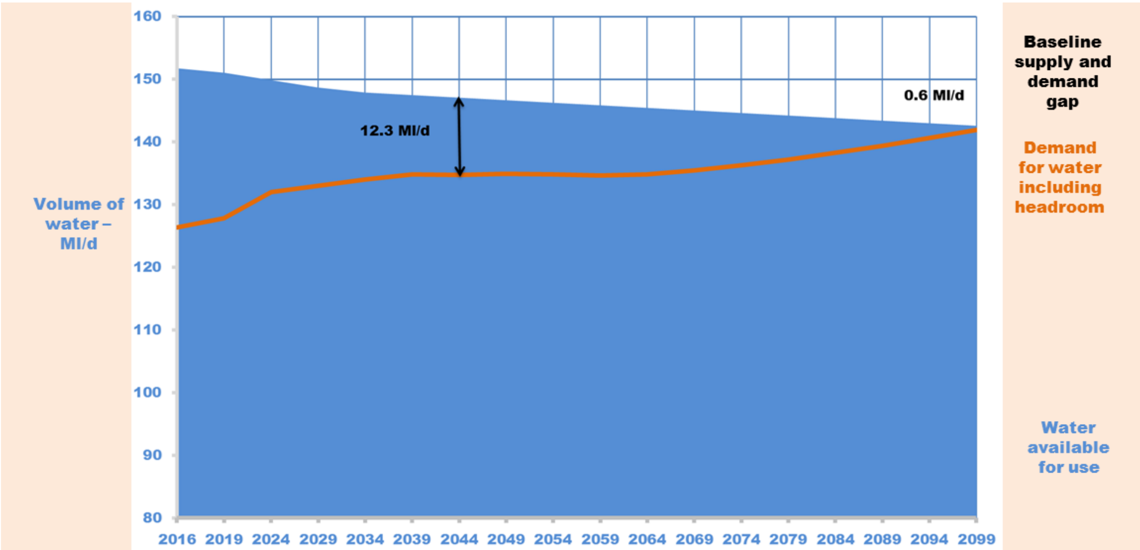


Figure 6-7: Baseline Kennet Valley supply demand summary (Ml/d) – peak week



6.21 No deficit exists in the Kennet Valley WRZ on average (Figure 6-6) or peak (Figure 6-7), based on the baseline supply demand balance throughout the planning period based on current forecasts. There is therefore no water planning problem to solve.

6.22 It may however, still be appropriate for interventions to be planned for in Henley, when catchment-wide and regional considerations are taken into account (see section D, below).

Guildford

Figure 6-8: Baseline Guildford supply demand summary (Ml/d) – dry year

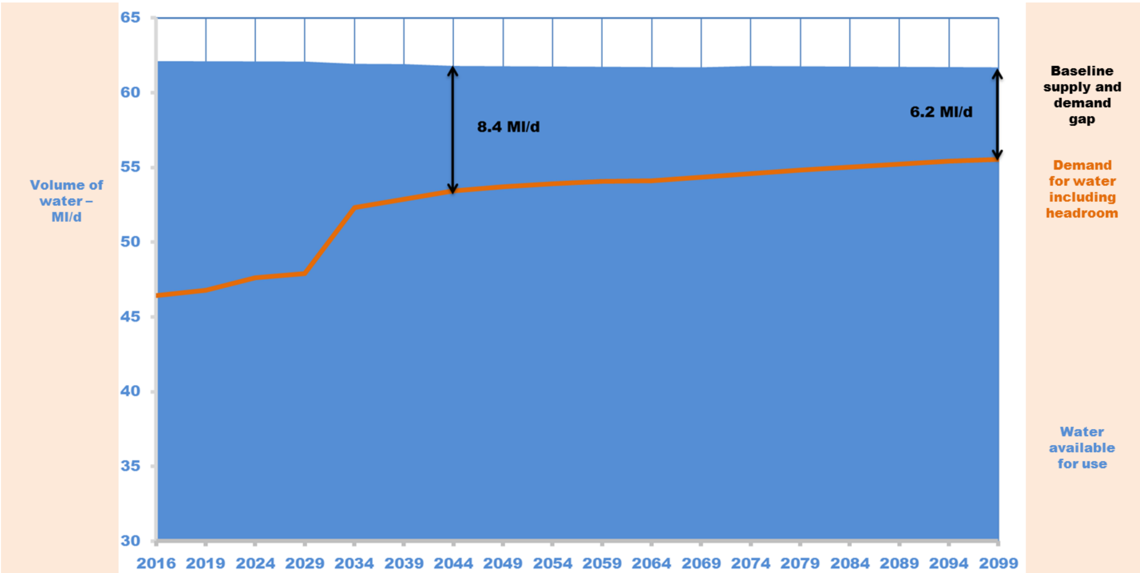
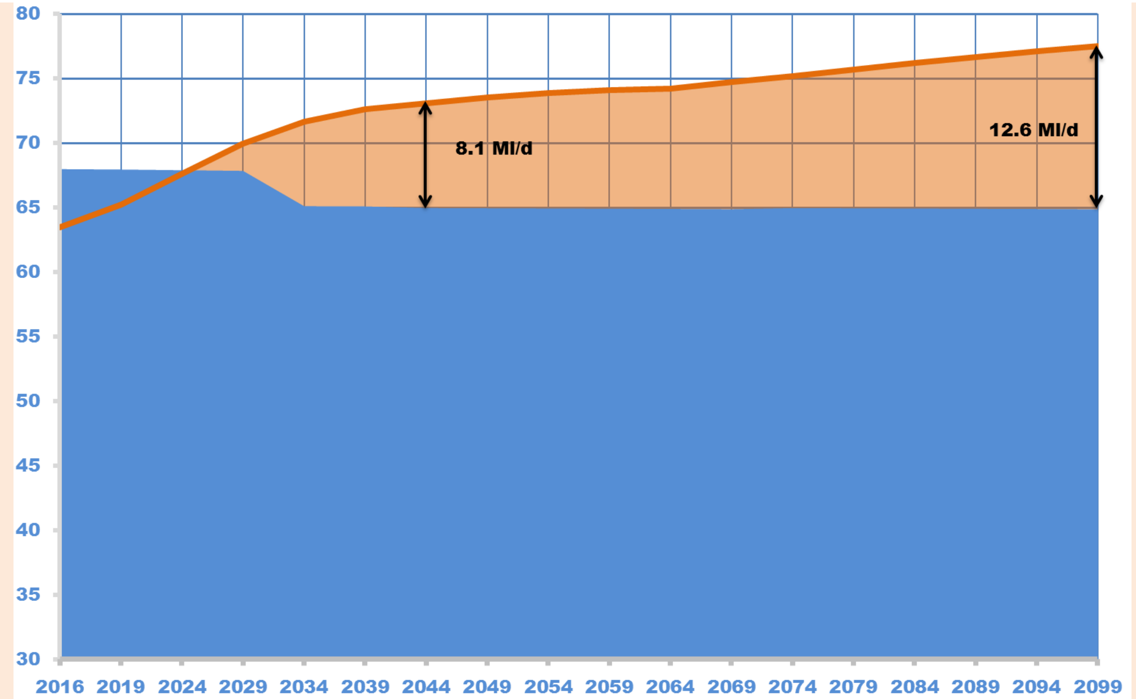


Figure 6-9: Baseline Guildford supply demand summary (Ml/d) – peak week



6.23 In a dry year, the Guildford WRZ is forecast to remain in surplus throughout the planning period (Figure 6-8). A supply demand deficit is however forecast under peak week conditions (Figure 6-9). The investment driver is therefore peak conditions, although when developing a solution to the deficit the dry year condition will also be resolved.

6.24 The planning problem is:

- An ADPW deficit in 2025-26, growing to 8 Ml/d by 2044-45 and 13 Ml/d 2099-2100.

6.25 Growth in demand due to population growth outstrips any water demand management activity. Additionally, the amount of water available to supply is reduced by increases in exports to neighbouring companies[2].

6.26 Without corrective action, this will result in a supply for Guildford which is not secure. This means there is a greater probability that demand restrictions will be required in dry years than stated in our levels of service. Demand management and resource options to close this gap have been addressed through our economic analysis process. The result of this analysis is presented in the final plan in Section 11: Preferred programme.

[2] Since submission of the draft WRMP19 in December 2017 Affinity Water has advised that it will not require an increase in the existing bulk supply. This amendment does not have a material impact on the draft plan and will be updated in the revised draft WRMP19.

Henley

Figure 6-10: Baseline Henley supply demand summary (Ml/d) – dry year

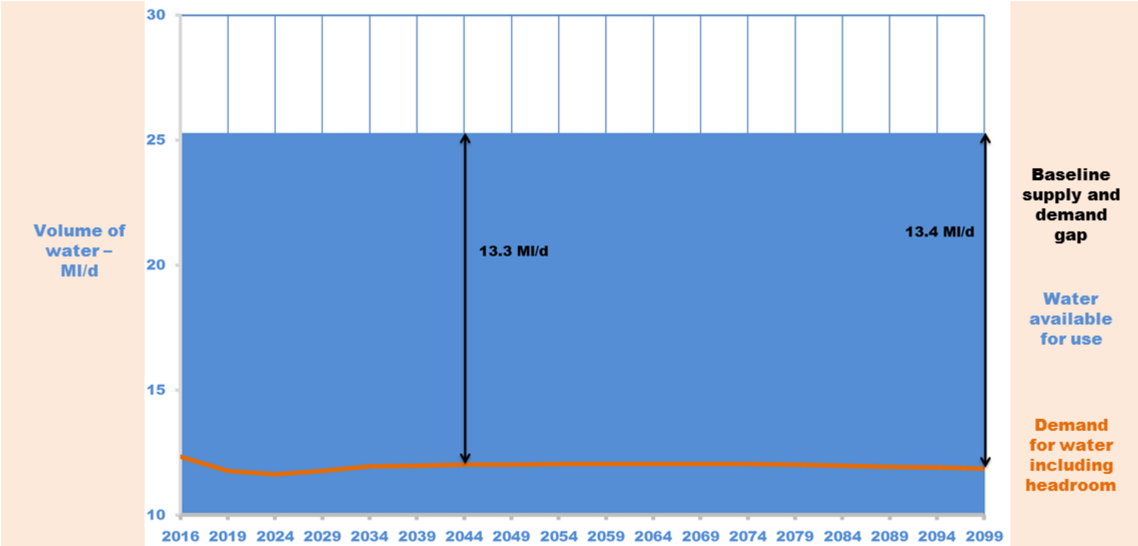
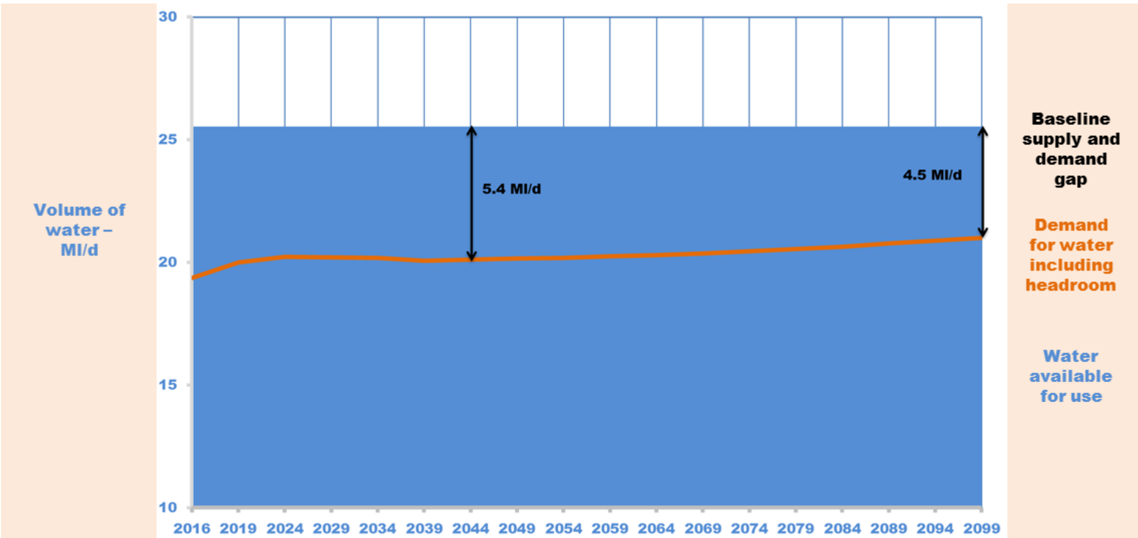


Figure 6-11: Baseline Henley supply demand summary (Ml/d) – peak week



6.27 No deficit exists in Henley WRZ on average (Figure 6-10) or peak (Figure 6-11), based on the baseline supply demand balance throughout the planning period based on current forecasts. There is therefore no water planning problem to solve.

6.28 It may however, still be appropriate for interventions to be planned for in Henley, when catchment-wide and regional considerations are taken into account (see section D, below).

D. What happens next?

6.29 Having understood the baseline water supply demand position, there are three possible paths to choose:

1) No further action. There is enough supply to meet demand, including target headroom, so no further action is required apart from continuation of existing baseline activity.

2) Remove the deficit. There is not enough supply to meet demand, including target headroom. Options to resolve the deficit should be investigated and the 'best' option(s) decided upon.

3) Wider considerations. There is enough supply to meet demand, including target headroom, however measures could be implemented to become more efficient, deliver environmental improvements, maintain a positive supply-demand balance, ensure equitable treatment of all our customers or to achieve company or stakeholder aspirations.

6.30 We have identified near-term deficits to resolve in London, SWOX and Guildford.

6.31 In SWA there are medium to long-term deficits. We consider that there may be wider benefits to be gained by addressing water supply demand issues in those zones earlier than needed by the baseline supply demand position. Intervention earlier than needed will ensure we make a positive contribution to sustainable development and we are flexible and robust to the range of future risks and uncertainties.

6.32 In Kennet Valley and Henley, despite the surplus throughout the planning period, we also consider that some intervention may be warranted to ensure equity across our supply area.

6.33 The potential options available to the company to address and resolve the deficits are considered in Section 7: Appraisal of water resource options and 8: Demand management options appraisal. The solutions (i.e. programmes of options) are compared with each other and tested for sensitivity in Section 10: Programme appraisal and a preferred 'best value' programme identified in Section 11: Preferred programme.

Section 7

Appraisal of resource options

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Section 7.

Appraisal of resource options

Section 7 describes:

- How we have identified our Feasible List and Constrained List of water resource options
- The associated system elements that are required to deliver the Constrained List resource options into supply
- The further option development that has been conducted on the Constrained List options to inform programme appraisal

We have made the following changes to points raised in the public consultation on the draft WRMP, and to include new information since the draft WRMP was published.

- We have updated the Feasible List (Section 0) to include further options that have been assessed as feasible and to remove options that are no longer considered feasible. The changes to resource options since the draft WRMP are detailed in an update note[1] published alongside this plan.
- We have updated the Constrained List (Section E) to take account of changes to the Feasible List. Key changes to the Constrained List include:
  - Teddington Direct River Abstraction resource element has been rejected due to environmental concerns associated with the impact of the option on river temperatures, described in detail in Appendix L: Water Reuse
  - Inclusion of Minworth, Netheridge and River Wye support elements for the Severn Thames Transfer
  - Inclusion of five new groundwater options providing an additional 12Ml/d, and removal of two small removal of constraints options for SWA that have been delivered in AMP6
  - Inclusion of a new option for Raw Water Purchase at Chingford extending (from 2035 up to 2060) the existing agreement to reduce the export to Essex & Suffolk Water
- We have updated the further investigations into Constrained List options to take account of work that has been untaken since the draft WRMP

[1] Mott MacDonald (September 2018) Thames Water WRMP19 Resource Options, Update note on changes to feasibility assessments and conceptual designs post draft WRMP19

A. Introduction

Purpose of section

7.1 Section 7 summarises the approach that has been followed for identifying water resource options and how screening has been applied to determine the Constrained List of options that has been taken forward into programme appraisal. The section then summarises the information that has been gathered on the Constrained List of options.

7.2 In conducting option screening we have balanced the need to have the widest choice of water resource options for assessment at programme appraisal against the need to have a manageable number of options.

Structure of this section

7.3 Following this introduction, Section 7 of the revised draft Water Resources Management Plan 2019 (revised draft WRMP19) summarises:

- the generic option type screening we have conducted (Section 7.B)
- the feasibility assessments we carried out to define the Feasible List of specific resource options (Section 7.0)
- the cross option studies we conducted to identify raw water system, treatment and network reinforcement requirements needed to deliver potable water to customers (Section 7.D)
- the fine screening exercise that combined consideration of the outputs of the feasibility reports and the cross option studies to produce a Constrained List of elements to be carried forward for further development (Section 7.E)
- the further development conducted with regard to elements on the Constrained List to inform programme appraisal (Section 7.F)
- Drought Permit options considered (Section 7.G)
- references to the sources of further information available in respect of the elements on the Constrained List (Section 7.H)

Phased approach to water resource option development

7.4 Following the principles of the Water Resource Planning Guideline[2] (WRPG) (04/2017) section 6, a phased approach to developing water resource options for the revised draft WRMP19 has been undertaken so that effort on reducing uncertainties is focused on the issues that could reasonably be expected to influence option screening decisions. An overview of the four-phase approach to reviewing and assessing resource options in the preparation of the revised draft WRMP19 is shown in Figure 7-1. The four phases comprise:

[2] Environment Agency and Natural Resources Wales and also produced in collaboration with Defra, the Welsh Government, and Ofwat, Final Water Resources Planning Guideline, July 2018

option review and screening; detailed investigations; programme appraisal; and scheme selection design and planning. These are described in more detail below.

7.5 **Phase 1 – Option review and screening:** The objective of Phase 1 was to review the water resource options carried forward from WRMP14 and to enable better targeting of Phase 2 option assessments by focusing on uncertainties and risks that were fundamentally material to option selection. The outputs from Phase 1 were fine screening reports for large[3] and small[4] water resource options.

7.6 **Phase 2 – Detailed investigations:** In Phase 2, targeted detailed investigations were undertaken to enable a clear explanation of how specific options have been identified and to reduce uncertainties concerning the identification of the best value options. The required investigations undertaken in Phase 1 were reported in a series of feasibility reports and cross-option studies listed in section 7.H.

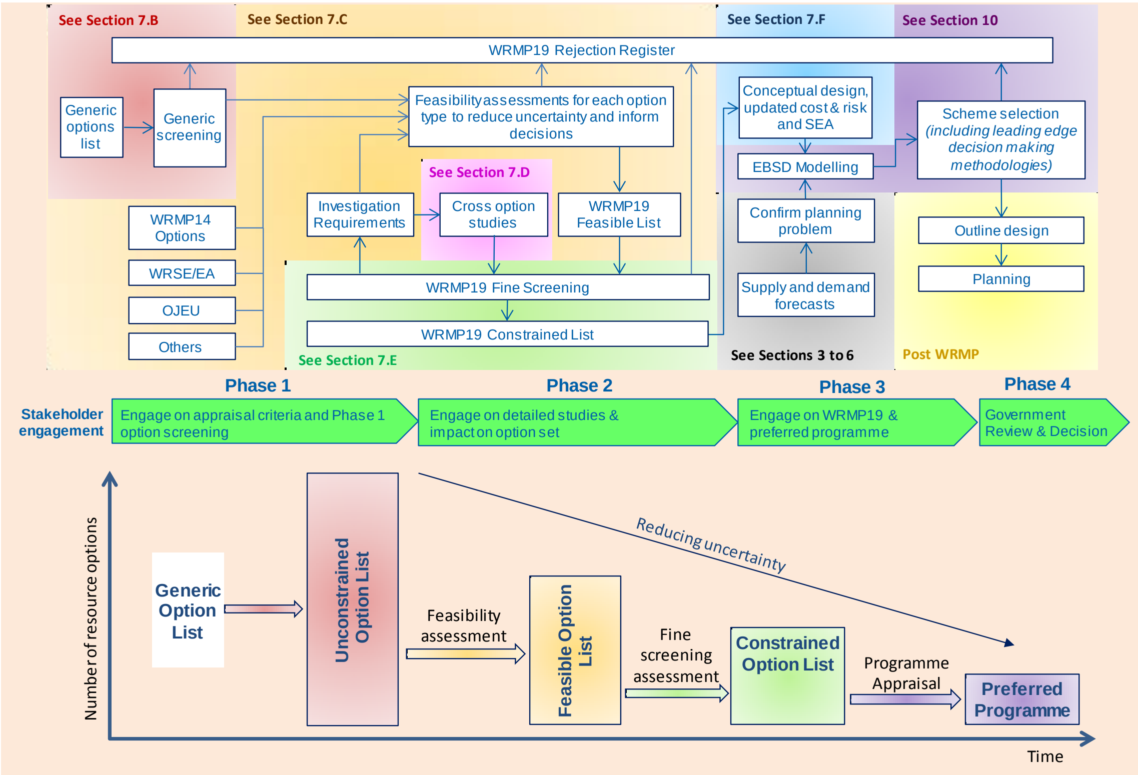
7.7 As these investigations have been completed, the fine screening process has been revisited to ensure that the new information thrown up has been accounted for in the assessment of options and in screening decisions. The resulting output of this updated fine screening exercise, reported in the Fine Screening Report[5], is the Constrained List of options that have then been carried forward for conceptual design and programme appraisal in Phase 3.

7.8 **Phase 3 – Programme appraisal:** In Phase 3, conceptual designs were prepared for options on the Constrained List, costs have been updated for all options, bottom-up risk assessments have been undertaken for options larger than 50 Ml/d and strategic environmental assessments of options have been carried out. Options on the Constrained List have then been subject to programme appraisal to determine the optimum best value programme of solutions to the water supply/demand deficit to ensure that supply balances demand, taking account of relevant future forecast water resource scenarios.

7.9 **Phase 4 – Scheme selection, outline design and planning:** Subject to confirmation of the preferred programme following consultation, Phase 4 will involve progressing the selected water resource options through to outline design for submission as applications for planning permission or a Development Consent Order.

[3] Phase 1 Large Option Screening Report, Mott MacDonald, (May 2015)
[4] Phase 1 Small Option Screening Report, Mott MacDonald, (November 2015)
[5] Fine Screening Report, Mott Macdonald, (September 2018)

Figure 7-1: A phased approach to reviewing and assessing water resource options



Stakeholder engagement

7.10 Throughout the water resource option development process we have worked closely with stakeholders. We held Technical Stakeholder meetings with representatives of interested stakeholder groups[6] and have held regular meetings to give briefings on the work that we have been doing, and to seek feedback and input to the process so that we could take interested parties' responses into account in developing the Constrained List of options. Technical Stakeholder Group meetings were held on the following dates, to discuss resource option development:

- September 2014 – review of WRMP14 options, any other options that should be considered and approach to option screening
- January 2015 – review of draft Phase 1 option screening report for large options
- March 2015 – review of updated Phase 1 option screening report for large options
- May 2015 – review of Severn Thames Transfer Water Quality and Ecology Study
- July 2015 – review of draft Phase 1a option screening report for small options
- November 2015 – overview and update on Phase 2 investigations into resource options
- December 2015 – stochastic drought generation

[6] Refer to Appendix S: Stakeholder engagement

- May 2016 – Update on Phase 2 investigation findings
- October 2016 – review of draft feasibility report and cross option study findings, together with updated Fine Screening Report
- February 2017 – initial response to comments from stakeholders on feasibility and fine screening reports
- April 2017 – presentation of updated Fine Screening Report
- June 2017 – presentation on environmental assessment of Constrained List
- January 2018 – presentation of the assessment of drought resilience

7.11 Documents shared with stakeholders, meeting minutes and presentations are all available on our website[7]. A log of stakeholder comments has also been kept, together with a record of how the comments have been considered and what the response was (including what, if any, changes have been required).

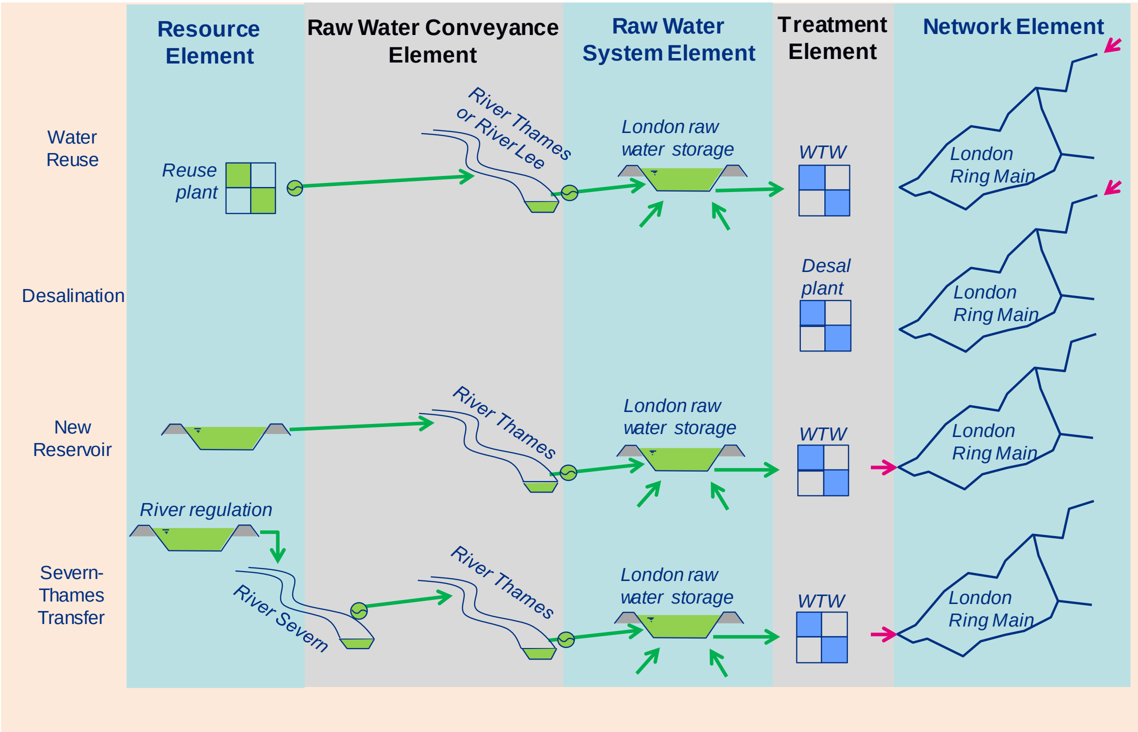
Taking a system approach

7.12 For new water resources to be put into supply, reinforcements are often required to other parts of the water supply system downstream of the resource, including to the raw water conveyance system, water treatment works and water distribution infrastructure. In many cases these water supply system reinforcements are common to a number of different water resource options. The supply system elements may also be implemented at a different time to water resource elements, for example if a zone is resource constrained and has sufficient treatment/network capacity in the short term but will require reinforcements in the medium-long term as demand increases. For these reasons separate supply system elements have been developed for new water resources, raw water conveyance, raw water system reinforcements, treatment reinforcements and treated water network reinforcements. The reinforcement elements have been combined with the resource and conveyance elements, where required, into options for the purpose of fine screening and programme appraisal.

7.13 Cross option studies have been carried out to identify the supply system reinforcement elements required and to establish the system operating philosophy. Figure 7-2 illustrates examples of how the different supply system elements combine to make up an overall water resources option.

[7] https://corporate.thameswater.co.uk/about-us/our-strategies-and-plans/water-resources/document-library

Figure 7-2: Separation of water resource options into supply system elements



B. Generic screening

7.14 The starting point for water resource option development is the generic list of resource option types (e.g. reservoirs, water transfers) referenced in the UKWIR Water Resources Planning Tools report[8]. The list has been reviewed to identify option types that have potential for providing feasible specific water resource options for the Thames Water supply area. A summary of the results of the generic screening exercise that we carried out is shown in Figure 7-3.

7.15 Water resource option types that have been rejected are marked with a cross in Figure 7-3. A summary of reasons for rejection can be found in Table 7-1, with further detail provided in the Rejection Register (see Appendix Q)

7.16 Resource option types that were assessed as having potential to provide specific options for the revised draft WRMP19 are marked with a tick in Figure 7-3. For these option types the figure also references the report that goes on to identify feasible specific options for our supply area.

[8] UKWIR (2012), Water Resources Planning Tools 2012, Economics of Balancing Supply and Demand Report (Ref 12/WR/27/6), pp 10-12.

Figure 7-3: Summary of generic water resource option type review

	Generic resource management options[†]	Generic screening	Specific option identification	Feasibility report	Feasible list	Fine screening	Constrained list
1	Direct river abstraction	✓	Direct River Abstraction Feasibility Report	✗			
2	New reservoir	✓	New Reservoirs Feasibility Report	✓		✓	
3	Groundwater sources	✓	Groundwater Feasibility Report	✓		✓	
4	Infiltration galleries	✓	Included in DRA/Desal as possible intake	n/a			
5	Aquifer storage and recovery	✓	Groundwater Feasibility Report	✓		✓	
6	Aquifer recharge	✓	Groundwater Feasibility Report	✓		✓	
7	Desalination	✓	Desalination Feasibility Report	✓		✓	
8a	Bulk transfers of raw water	✓	Raw Water Transfer Feasibility Report	✓		✓	
8b	Bulk inter/intra company transfers of treated water	✓	Inter-zonal Water Transfers Feasibility Report	✓		✓	
9	Tankering of water	✗					
10	Redevelopment of existing resources	✗					
11	Reuse of existing private supplies	✓	Third party options report	✗			
12	Water re-use	✓	Water Reuse Feasibility Report	✓		✓	
13	Imports (icebergs)	✗					
14	Rain cloud seeding	✗					
15	Tidal barrage	✗					
16	Rainwater harvesting	✗					
17	Abstraction licence trading	✓	Third party options report	✓		✓	
18	Water quality schemes that increase DO	✓	Catchment Management Feasibility Report	✗			
19	Catchment management schemes	✓	Catchment Management Feasibility Report	✗			
20	Conjunctive use operation of sources	✓	Built into DOs through WARMS	n/a			
21	Joint ("shared asset") resource	✓	Included in feasibility reports where applicable	n/a			
22	Asset transfers	✓	Third party options report	✗			
23	Options to trade other (infrastructure) assets	✓	Third party options report	✗			

† Taken from UKWIR 2012, Water Resources Planning Tools, EBSD Report, Ref 12/WR/27/6

Source: Taken from UKWIR 2012, Water Resources Planning Tools, EBSD Report, Ref 12/WR/27/6

7.17 We also have a number of drought permit options. These options require a drought permit or drought order to be issued by the Environment Agency or the Secretary of State and are subject to a significant level of uncertainty. Therefore they are not considered to provide any deployable output (DO) and are only available in the event of a drought arising from an exceptional shortage of rainfall. These options are covered in more detail in section 7.G.

Table 7-1: Summary of generic option rejection reasons

Scheme	Key elements	Screening decision	Comments
9 Tankering of water			
Tankering by sea	Tankering requires the development of new infrastructure, including pipelines and deep water facilities for loading / unloading. The logistical, environmental and planning constraints at the Thames Estuary are considerable as the estuary is relatively shallow and access would be restricted.	✗	A proposal by Albion Water for tankering from sources in Norway and the Netherlands has been considered. We concluded that while technically feasible at full utilisation (one tanker per day) it would be excessively costly; and at low utilisation (one tanker per week) the option remains uncompetitive with other options of a similar size. Tankering has therefore not been developed as a water resources option, but we are considering it as a potential emergency drought plan option to avoid level 4 restrictions.
13 Imports (icebergs)			
Icebergs	This option would require the development of a system for towing of icebergs over long distances e.g. from the Norwegian Sea to the	✗	Rejected on the basis that the techniques involved are not sufficiently advanced for commercial use and because of the high level of uncertainty around scheme yield. Also, as the Thames Estuary is designated under the Environment Agency Habitats Directive, an

Scheme	Key elements	Screening decision	Comments
	Thames Estuary.		Appropriate Assessment is likely to be required. As part of this, the company would be required to demonstrate that there are no feasible alternative options; which is not the case.
14 Rain cloud seeding			
Rain cloud seeding	This option would require the development of a system for wide commercial implementation.	✗	Rejected on the basis that the techniques involved are not sufficiently advanced for commercial use and because of the high level of uncertainty that the scheme would provide significant yield.
15 Tidal barrage			
The Thames Barrier	The option for the use of the Thames Barrier to impound fresh water.	✗	Rejected as this option would limit the navigation of the river Thames to both private and commercial traffic resulting in disproportionate social and economic costs. It would also limit the passage of aquatic life which would cause significant ecological damage. The option could also result in raising the groundwater levels in the surrounding areas which could increase the incidence of flooding and cause damage to services and historic buildings in London.
16 Rainwater harvesting			
Rainwater harvesting	Direct collection and storage of rainwater.	✗	Rejected on the basis of limited drought resilience.
10 Redevelopment of existing resources			
Redevelopment of existing resources (e.g. Staines Reservoir)	Changes to current system that could yield benefits to the supply /demand balance.	✗	Redevelopment of reservoir storage is not possible unless sufficient surplus resources are available to compensate for the temporary loss of storage and the consequent risks to security of supply that would therefore result whilst the reservoir is being redeveloped. The provision of the surplus resources would be likely to be required for several years to allow the redevelopment of existing sources.

C. Water resource feasibility assessment

Approach to feasibility assessment

7.18 For the water resource option types that have passed the generic screening, feasibility assessments have been conducted. A staged approach has been adopted for the feasibility assessment:

- **Stage 1:** a systematic search was conducted to identify potential new resources of each type, these collectively form the Unconstrained List of resource elements (see Appendix P) that were then screened against absolute constraints (pass/fail)
- **Stage 2:** the performance of each potential new resource was evaluated qualitatively against a number of criteria that enabled differentiation between options of that type
- **Stage 3:** the performance of the potential new resources was assessed in further detail (e.g. including costing)
- **Validation:** verification and review of the final list of specific resource elements was undertaken to determine the Feasible List

7.19 Further detail relating to the criteria used at each stage of the feasibility assessment can be found within each of the feasibility reports referred to in section 7.H.

7.20 New resource elements have been carried forward from the feasibility assessment into the Feasible List for further fine screening where they meet the following criteria:

- the resource is not compromised by any absolute or key constraints
- if there is mutual exclusivity between elements, only the best performing has been carried forward, provided that this assessment can reasonably be made based upon the information available at the feasibility assessment stage
- if the total estimated DO of resources for a given option type in a water resource zone (WRZ) exceeds the indicative deficit for the WRZ over the period of the planning horizon then only the best performing new resources have been carried forward to the Feasible List, provided that this assessment could reasonably be made based upon the information available at the feasibility assessment stage

Identifying third party options

7.21 We have sought to identify potential third party water resource options through three main approaches:

1) Request for proposals for water resources in the Official Journal of the European Union (OJEU)
2) Bilateral discussions with other water companies
3) Active engagement with regional water resource planning groups including the Water Resources in the South East Group (WRSE) and the Water Resources East Group (WRE)

Request for proposals for water resources

7.22 In preparation for WRMP14, on 1 June 2012 we published an OJEU notice to invite third party organisations to register interest in providing a bulk supply of raw or treated water. We regularly update the OJEU notice (17 February 2015, 25 January 2016 and 18 February 2017). A summary of the responses received related to new water resource options is set out in Table 7-2 together with an update on their revised draft WRMP19 status.

Table 7-2: Status of OJEU water resource options

Company	Nature of supply option	Volume (Ml/d)	Revised draft WRMP19 status
Tankering by sea			
Albion Water	Raw water tankering by sea from Norway	30 - 440	Assessment at WRMP14 found tankering by sea to be excessively costly to supply our geographic area. Albion engaged further with us during preparation of the revised draft WRMP19 through the stakeholder engagement process. However the assessment of the option remains that it is excessively costly as a water resource option. Tankering has therefore not been developed as a water resources option, but we are considering it as a potential emergency drought plan option to avoid level 4 restrictions
Iceland Ventures Limited	Raw water from Iceland via shipping tankers, bladders or pipeline	>400	
Scottish Water Horizons	Raw water tankering by sea from Loch Glass catchment, Scotland	5	
Raw water inter-company transfers			
United Utilities	Redeployment of Lake Vyrnwy for Severn-Thames Transfer	=<180	Proposals further developed for the revised draft WRMP19 and included in the Raw Water Transfers Feasibility Report[9].
Severn Trent	Combination of redeployment of resources, resource development and water reuse to support Severn-Thames Transfer	=<165	
Joint United Utilities/Severn Trent Option	Alternative method for making water from Lake Vyrnwy release available to Thames Water through joint approach from United Utilities and Severn Trent	12-30	Included in Programme Appraisal
Desalination			
Subsea Desalination	Redeployment of an existing mobile desalination plant to Beckton	20.5	Technical and commercial risks too high compared with a permanent solution tailored to our specific needs.
Raw Water Purchase			
RWE Npower	Temporary agreement in relation to Didcot power station abstraction licence.	17 Ml/d	Agreement reached over temporary transfer (10 years) of 17 Ml/d. Included in Programme Appraisal.

Source: Adapted from WRMP14, Table 7-10

[9] Raw Water Transfer Feasibility Report, Mott MacDonald, September 2018

Bilateral discussions with other water companies

7.23 We have engaged on a bilateral basis with other water companies to identify and develop potential new resource options in the form of:

- inter-company raw water transfers – these are assessed in the Raw Water Transfers Feasibility Report
- inter-company treated water transfers[10] – these are assessed in the Inter-Zonal Transfer Feasibility Report

7.24 Companies that are willing to offer water to supply us include: Wessex Water, South East Water, Severn Trent Water, Welsh Water, Essex and Suffolk Water, Canal and River Trust, RWE NPower and United Utilities.

7.25 We have also engaged with other companies concerning their future deficits and how we may be able to provide water to address these.

7.26 In addition, a further Phase 4 modelling exercise has been undertaken to examine changes in WRSE outputs in response to changes in company water resource options which have occurred between draft and revised draft plans.

Regional groups (WRSE)

Purpose

7.27 The overall aim of the WRSE group is:

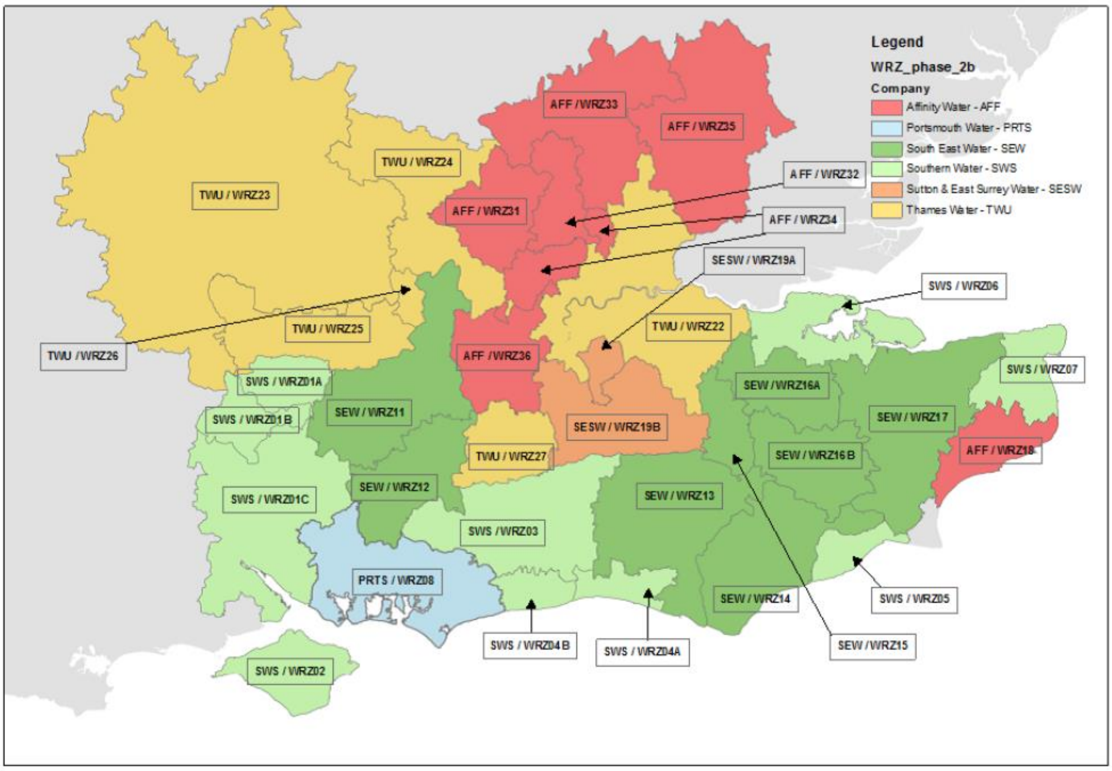
> *"to identify and investigate a range of regionally based scenarios which when collated will form a range of potential regional strategies; and*
>
> *to work together to understand the investments required for those strategies."*[11]

7.28 We have been working with five other water companies (Portsmouth Water, South East Water, Southern Water, Affinity Water and Sutton & East Surrey Water), the Environment Agency, Ofwat, Natural England, CCWater and consultant partners to identify potential opportunities for sharing of resources in South East England[12]. WRSE companies' supply areas are shown in Figure 7-4.

7.29 The outcomes of this engagement have been to inform the participating water companies of potential resource sharing options for consideration in their own WRMPs and to provide a regional framework for the requirement for strategic resource development for the south east of England. The group addresses all aspects of water resources planning and attempts to identify areas of common ground, which can then be exploited by the water companies for water resource planning should they chose to do so.

[10] Inter-zonal Water Transfers Feasibility Report, Mott MacDonald, February 2018
[11] Water Resources in the South East of England Memorandum of Understanding January 2016
[12] WRSE Collaborative Agreement April 2016

Figure 7-4: Water companies participating in WRSE and their respective WRZs



Background

7.30 The WRSE work is centred on the strategic application of a water resource planning options selection model, with the objective function of balancing supply and demand across the region at least cost. The model has been constructed to meet the requirements and principles of the WRPG. It contains water resource planning options for all participating companies, including:

- a range of types of new resources
- existing supply enhancements
- demand management options (leakage reduction, household metering, household and non-household water efficiency)
- raw and treated water transfers between resource zones and water companies

7.31 A 60 year planning horizon to 2080 has been chosen and several scenarios are examined to explore the uncertainty inherent in forecasting future water resource development requirements. These include:

- A variety of different drought severities representing historical 20th century droughts, 1 in 200 year severe drought events and 1 in 500 year extreme drought events
- Reductions in water availability linked to the effects of climate change
- Application of the Water Industry National Environment Programme (WINEP) sustainability reductions
- Application of supply side drought permit options and drought order water use restriction savings
- Reductions in raw water availability linked to water quality issues

7.32 A total of eight scenarios[13] were run through the WRSE model using different combinations of the above factors to enable the model to select a broad range of options in order to test the resilience of potential investment portfolios against a wide range of future uncertainties. This facilitated identification of options that could be considered 'no regrets' best value options, as opposed to strictly least cost options, which were consistently selected under a wide range of different futures. Four of the investment scenarios were selected for more detailed resilience testing using an advanced decision making approach, Info-Gap, to quantify robustness given minimum performance requirements. Info-Gap Decision Theory (IGDT)[14] characterises the uncertainty of future system stresses by establishing a series of progressive incremental deviations between the best future estimate of a parameter (such as an expression of supply or demand) and its change in value due to uncertainty.

7.33 The WRSE work is jointly funded by the water companies and the Environment Agency. CH2M was commissioned to apply the modelling consultancy package. Other parallel work packages undertaken by other consultants for the WRSE Group were:

- Independent project management (Atkins)
- Construction and application of a water resources system simulation model of the south east area (Atkins and the University of Manchester)
- Cumulative and in-combination environmental impact assessment of the water resource options selected within the WRSE water companies' draft WRMP19 plans, subsequently updated to reflect revised draft WRMP19 plans (Ricardo)

13 12 scenarios were examined in the Phase 2 modelling work
14 WRMP19 Methods - Decision Making Process: Guidance UK Water Industry Research 2016 Report Ref. No. 16/WR/02/10

Strategic transfer options to other companies

7.34 The strategic water resource options for Thames Water that are explored within the WRSE analysis include:

- Bulk transfer of raw water by pipeline from Oxfordshire to Southern Water's network in Hampshire. A number of different volumes were available for transfer of up to 100 Ml/d
- Bulk transfer of 100 Ml/d of raw water from Oxfordshire using the River Thames as the conveyance mechanism to Affinity Water's existing abstraction points on the Lower Thames
- Bulk transfer of up to 60 Ml/d of raw water from Oxfordshire using the River Thames as a conveyance mechanism to South East Water using a new abstraction location on the River Thames at Reading
- Bulk transfer by pipeline from our treated water network in south east London to Southern Water's network in Kent. A number of different volumes were available for transfer, of up to 50 Ml/d
- Bulk transfer by pipeline from our treated water network in south London to Sutton and East Surrey Water. A number of different volumes were available for transfer, of up to 30 Ml/d
- Bulk transfer of treated water by pipeline from London and Guildford to Affinity Water. These options capture the existing treated water bulk supply agreements between Thames Water and Affinity Water where the total amount of available water is not yet taken

WRSE modelling

7.35 All companies provided their baseline supply and demand data and draft option costs for all water supply/demand options for modelling purposes in September 2017.

7.36 The WRSE project was divided into three phases:

- **Phase 1:** April 2014 to March 2015 – scoping, preparation, formalisation of modelling work
- **Phase 2:** April 2015 to August 2017 – main period of technical assessment and development using WRMP14 data. Application of Info-Gap stress testing of selected investment portfolios
- **Phase 3:** September 2017 to January 2018 – final strategic modelling runs using data that companies used for their revised draft WRMP19 plans

7.37 The intention of the Phase 3 modelling was to allow water companies to assess the consistency of the WRSE results with their own draft WRMPs, to understand the causes of any significant differences and to support companies in the submission of their draft plans. The Thames Water revised draft WRMP19 was shown to be consistent with the plans of our neighbouring WRSE companies and where transfers have been agreed between us, these are included in revised draft WRMP19 Section 10: Programme appraisal.

Feasible List

7.38 The output from the Phase 2 feasibility reports was the Feasible List of water resource options. The specific options in the Feasible List are summarised in Table 7-3 below.

Table 7-3: Feasible List of resource options

Option type	Name		Deployable Output (Ml/d)
London WRZ			**DYAA**
Water Reuse	Beckton Reuse - 380 Ml/d		336
	Beckton Reuse - 300 Ml/d		268
	Beckton Reuse - 200 Ml/d		183
	Beckton Reuse - 150 Ml/d		138
	Beckton Reuse - 100 Ml/d		95
	Beckton Reuse - 50 Ml/d		49
	Mogden Reuse - 200 Ml/d		180
	Mogden Reuse - 150 Ml/d		137
	Mogden Reuse - 100 Ml/d		94
	Mogden Reuse - 50 Ml/d		49
	Deephams Reuse – 46.5 Ml/d		45
	Crossness Reuse - 190 Ml/d		174
	Crossness Reuse - 150 Ml/d		138
	Crossness Reuse - 100 Ml/d		95
	Crossness Reuse - 50 Ml/d		49
	Mogden South Sewer Reuse - 50 Ml/d		49
Desalination	Crossness Desalination (Unblended) - 65 Ml/d		60
	Crossness Desalination (Blended) - 300 Ml/d		284
	Crossness Desalination (Blended) - 200 Ml/d		189
	Crossness Desalination (Blended) - 100 Ml/d		95
	Beckton Desalination - 150 Ml/d		142
Raw water transfer	Severn Thames Transfer*, Deerhurst - Culham 300 Ml/d	+ Vyrnwy (60Ml/d) - 60 Ml/d	110
		+ Vyrnwy (60Ml/d) + Mythe - 75 Ml/d	122
		+ Vyrnwy (60 Ml/d) + Mythe + Shrewsbury (12 Ml/d) – 87 Ml/d	128
		+ Vyrnwy (60 Ml/d) + Mythe + Shrewsbury (12 Ml/d) + Netheridge – 122 Ml/d	146
		+ Vyrnwy (60 Ml/d) + Mythe + Shrewsbury (12 Ml/d) + Netheridge + Minworth – 237 Ml/d	204
		+ Vyrnwy (60 Ml/d) + Mythe + Shrewsbury (30 Ml/d) + Netheridge + Minworth – 255 Ml/d	213
		+ Vyrnwy (60 Ml/d) + Mythe + Shrewsbury (30 Ml/d) + Netheridge + Minworth + River Wye – 315.3 Ml/d	250
		+ Vyrnwy (148 Ml/d) + Mythe + Shrewsbury (30 Ml/d) + Netheridge + Minworth + River Wye – 403.3 Ml/d	294
		+ Vyrnwy (180 Ml/d) + Mythe + Netheridge + Minworth +	295

Option type	Name		Deployable Output (Ml/d)
		River Wye – 405.3 Ml/d	
	Severn Thames Transfer*, Deerhurst - Culham 400 Ml/d	+ Vyrnwy (60Ml/d) - 60 Ml/d	129
		+ Vyrnwy (60Ml/d) + Mythe - 75 Ml/d	141
		+ Vyrnwy (60 Ml/d) + Mythe + Shrewsbury (12 Ml/d) – 87 Ml/d	148
		+ Vyrnwy (60 Ml/d) + Mythe + Shrewsbury (12 Ml/d) + Netheridge – 122 Ml/d	168
		+ Vyrnwy (60 Ml/d) + Mythe + Shrewsbury (12 Ml/d) + Netheridge + Minworth – 237 Ml/d	233
		+ Vyrnwy (60 Ml/d) + Mythe + Shrewsbury (30 Ml/d) + Netheridge + Minworth – 255 Ml/d	243
		+ Vyrnwy (60 Ml/d) + Mythe + Shrewsbury (30 Ml/d) + Netheridge + Minworth + River Wye – 315.3 Ml/d	285
		+ Vyrnwy (148 Ml/d) + Mythe + Shrewsbury (30 Ml/d) + Netheridge + Minworth + River Wye – 403.3 Ml/d	335
		+ Vyrnwy (180 Ml/d) + Mythe + Netheridge + Minworth + River Wye – 405.3 Ml/d	336
	Severn Thames Transfer*, Deerhurst - Culham 500 Ml/d	+ Vyrnwy (60Ml/d) - 60 Ml/d	144
		+ Vyrnwy (60Ml/d) + Mythe - 75 Ml/d	156
		+ Vyrnwy (60 Ml/d) + Mythe + Shrewsbury (12 Ml/d) – 87 Ml/d	163
		+ Vyrnwy (60 Ml/d) + Mythe + Shrewsbury (12 Ml/d) + Netheridge – 122 Ml/d	183
		+ Vyrnwy (60 Ml/d) + Mythe + Shrewsbury (12 Ml/d) + Netheridge + Minworth – 237 Ml/d	248
		+ Vyrnwy (60 Ml/d) + Mythe + Shrewsbury (30 Ml/d) + Netheridge + Minworth – 255 Ml/d	258
		+ Vyrnwy (60 Ml/d) + Mythe + Shrewsbury (30 Ml/d) + Netheridge + Minworth + River Wye – 315.3 Ml/d	300
		+ Vyrnwy (148 Ml/d) + Mythe + Shrewsbury (30 Ml/d) + Netheridge + Minworth + River Wye – 403.3 Ml/d	350
		+ Vyrnwy (180 Ml/d) + Myth + Netheridge + Minworth + River Wye – 405.3 Ml/d	351
	Oxford Canal		11
New reservoir[#]	Abingdon Reservoir 150 Mm^3		275
	Abingdon Reservoir 125 Mm^3		234
	Abingdon Reservoir 100 Mm^3		190
	Abingdon Reservoir 75 Mm^3		142
	Abingdon Reservoir 50 Mm^3		91
	Abingdon Reservoir 30 Mm^3		49
	Abingdon Reservoir Phased 80+42 Mm^3 Phase 1		151
	Abingdon Reservoir Phased 80+42 Mm^3 Phase 2		83
	Abingdon Reservoir Phased 30+100 Mm^3 Phase 1		49
	Abingdon Reservoir Phased 30+100 Mm^3 Phase 2		199
	Chinnor Reservoir 50 Mm^3		91

Option type	Name		Deployable Output (Ml/d)
	Chinnor Reservoir 30 Mm^3		49
	Marsh Gibbon Reservoir 75 Mm^3		142
	Marsh Gibbon Reservoir 50 Mm^3		91
	Marsh Gibbon Reservoir 30 Mm^3		49
Direct river abstraction	River Lee Direct River Abstraction - 150 Ml/d		35
Raw water purchase	Didcot Raw Water Purchase		18
	Chingford Raw Water Purchase		20
Aquifer recharge	Kidbrooke Aquifer Recharge (SLARS1)[15]		7
	Merton Aquifer Recharge (SLARS3)		5
	Streatham Aquifer Recharge (SLARS2)		4
Aquifer storage and recovery	South East London (Addington) Aquifer Storage and Recovery		3
	Thames Valley Central Aquifer Storage and Recovery		3
	Horton Kirby Aquifer Storage and Recovery		5
Removal of constraints	Epsom		2
	New River Head		3
Groundwater	Addington		1
	London Confined Chalk (north)		2
	Southfleet/Greenhithe (new water treatment works (WTW))		8
	Honor Oak groundwater development		1
	Merton recommissioning		2
Swindon & Oxfordshire (SWOX) WRZ			**ADPW**
Raw water transfer	Severn Thames Transfer*, Deerhurst - Culham 300 Ml/d	+ Vyrnwy (60Ml/d) - 60 Ml/d	30
		+ Vyrnwy (60Ml/d) + Mythe - 75 Ml/d	42
		+ Vyrnwy (60 Ml/d) + Mythe + Shrewsbury (12 Ml/d) – 87 Ml/d	48
		+ Vyrnwy (60 Ml/d) + Mythe + Shrewsbury (12 Ml/d) + Netheridge – 122 Ml/d	66
		+ Vyrnwy (60 Ml/d) + Mythe + Shrewsbury (12 Ml/d) + Netheridge + Minworth – 237 Ml/d	124
		+ Vyrnwy (60 Ml/d) + Mythe + Shrewsbury (30 Ml/d) + Netheridge + Minworth – 255 Ml/d	133
		+ Vyrnwy (60 Ml/d) + Mythe + Shrewsbury (30 Ml/d) + Netheridge + Minworth + River Wye – 315.3 Ml/d	170
		+ Vyrnwy (148 Ml/d) + Mythe + Shrewsbury (30 Ml/d) + Netheridge + Minworth + River Wye – 403.3 Ml/d	214
		+ Vyrnwy (180 Ml/d) + Mythe + Netheridge + Minworth + River Wye – 405.3 Ml/d	215
	Severn Thames Transfer*,	+ Vyrnwy (60Ml/d) - 60 Ml/d	34
		+ Vyrnwy (60Ml/d) + Mythe - 75 Ml/d	46
		+ Vyrnwy (60 Ml/d) + Mythe + Shrewsbury (12 Ml/d) –	53

[15] SLARS – south London Artificial Recharge Scheme

Option type	Name		Deployable Output (Ml/d)
	Deerhurst - Culham 400 Ml/d	87 Ml/d	
		+ Vyrnwy (60 Ml/d) + Mythe + Shrewsbury (12 Ml/d) + Netheridge – 122 Ml/d	73
		+ Vyrnwy (60 Ml/d) + Mythe + Shrewsbury (12 Ml/d) + Netheridge + Minworth – 237 Ml/d	138
		+ Vyrnwy (60 Ml/d) + Mythe + Shrewsbury (30 Ml/d) + Netheridge + Minworth – 255 Ml/d	148
		+ Vyrnwy (60 Ml/d) + Mythe + Shrewsbury (30 Ml/d) + Netheridge + Minworth + River Wye – 315.3 Ml/d	190
		+ Vyrnwy (148 Ml/d) + Mythe + Shrewsbury (30 Ml/d) + Netheridge + Minworth + River Wye – 403.3 Ml/d	240
		+ Vyrnwy (180 Ml/d) + Mythe + Netheridge + Minworth + River Wye – 405.3 Ml/d	241
	Severn Thames Transfer*, Deerhurst - Culham 500 Ml/d	+ Vyrnwy (60Ml/d) - 60 Ml/d	34
		+ Vyrnwy (60Ml/d) + Mythe - 75 Ml/d	46
		+ Vyrnwy (60 Ml/d) + Mythe + Shrewsbury (12 Ml/d) – 87 Ml/d	53
		+ Vyrnwy (60 Ml/d) + Mythe + Shrewsbury (12 Ml/d) + Netheridge – 122 Ml/d	73
		+ Vyrnwy (60 Ml/d) + Mythe + Shrewsbury (12 Ml/d) + Netheridge + Minworth – 237 Ml/d	138
		+ Vyrnwy (60 Ml/d) + Mythe + Shrewsbury (30 Ml/d) + Netheridge + Minworth – 255 Ml/d	148
		+ Vyrnwy (60 Ml/d) + Mythe + Shrewsbury (30 Ml/d) + Netheridge + Minworth + River Wye – 315.3 Ml/d	190
		+ Vyrnwy (148 Ml/d) + Mythe + Shrewsbury (30 Ml/d) + Netheridge + Minworth + River Wye – 403.3 Ml/d	240
		+ Vyrnwy (180 Ml/d) + Myth + Netheridge + Minworth + River Wye – 405.3 Ml/d	241
	Oxford Canal		12
New reservoir#	Abingdon Reservoir 150 Mm^3		294
	Abingdon Reservoir 125 Mm^3		253
	Abingdon Reservoir 100 Mm^3		210
	Abingdon Reservoir 75 Mm^3		161
	Abingdon Reservoir 50 Mm^3		111
	Abingdon Reservoir 30 Mm^3		69
	Abingdon Reservoir Phased 80+42 Mm^3 Phase 1		170
	Abingdon Reservoir Phased 80+42 Mm^3 Phase 2		83
	Abingdon Reservoir Phased 30+100 Mm^3 Phase 1		69
	Abingdon Reservoir Phased 30+100 Mm^3 Phase 2		199
	Chinnor Reservoir 50 Mm^3		111
	Chinnor Reservoir 30 Mm^3		69
	Marsh Gibbon Reservoir 75 Mm^3		161
	Marsh Gibbon Reservoir 50 Mm^3		111
	Marsh Gibbon Reservoir 30 Mm^3		69

Option type	Name	Deployable Output (Ml/d)
Groundwater	Moulsford 1	3.5
Removal of constraints to DO	Ashton Keynes borehole pumps - Removal of Constraints to DO	1.5
	Britwell Removal of Constraints	1.3
Internal inter-zonal transfer	Henley to SWOX - 2.4 Ml/d	2.4
	Henley to SWOX - 5 Ml/d	5
	Kennet Valley to SWOX - 6.7 Ml/d	4.5
	Kennet Valley to SWOX - 2.3 Ml/d	2.3
Inter-company transfers	Wessex Water to SWOX	2.9
Slough, Wycombe & Aylesbury (SWA) WRZ		**ADPW**
Raw water transfer	Severn Thames Transfer*, Deerhurst – Culham: see SWOX WRZs for sizes and DO	
	Oxford Canal	12
New reservoir#	Abingdon Reservoir: see SWOX WRZs for sizes and DO	
	Chinnor Reservoir: see SWOX WRZs for sizes and DO	
	Marsh Gibbon Reservoir: see SWOX WRZs for sizes and DO	
Raw water purchase	Didcot Raw Water Purchase	18
Groundwater	Datchet	5.4
Internal inter-zonal transfer	Henley to SWA - 2.4 Ml/d	2.4
	Henley to SWA - 5 Ml/d	5
Guildford WRZ		**ADPW**
Groundwater	Dapdune Licence Disaggregation	2.2
Removal of constraints to DO	Dapdune Removal of constraints to DO	1
	Ladymead WTW Removal of Constraints to DO	4.6
Inter-company transfers	Southeast Water to Guildford	10
Henley WRZ		
No feasible options identified		
Kennet Valley WRZ		**ADPW**
Groundwater	Mortimer Disused Source (Recommission)	4.5
Removal of constraints to DO	East Woodhay borehole pumps Removal of Constraints to DO	2.1

Table Notes:

** Stochastic yields for the Severn Thames Transfer are based upon stochastic analysis and take account of estimated impacts of climate change and other abstractors. The DO benefit of unsupported volumes in the River Severn are included under the Dry Year Annual Average condition (for the London WRZ), but not under Average Day Peak Week conditions (for the SWOX and SWA WRZs). Further information can be found in the Raw Water Transfers Feasibility Report and Fine Screening Report. All support sources, except Mythe, River Wye and Netheridge have been assessed assuming 20% loss between discharge into River Severn and abstraction at Deerhurst.*

 # Abingdon Reservoir DOs used at programme appraisal are based upon the two zone DOs from WARMS2 analysis, reduced by 3% to account for stochastic analysis. For the London WRZ the DOs are capped at the two zone London DO, being the lower of the two zone London DO and the single zone London DO

Yields for London are for Dry Year Annual Average (DYAA) condition, whereas for the Thames Valley they are for Average Day Peak Week (ADPW) condition.

7.39 For those options that have not been carried forward to the Feasible List an explanation of the reasons for rejection is included in Appendix Q: Scheme rejection register.

D. System reinforcements

7.40 Cross-option studies have been conducted to identify the water treatment, raw water system and treated water transmission reinforcements required to deliver the new resources into distribution. In many cases the same system reinforcements are required for a number of different water resources and the timing of the need for the system reinforcements may also not coincide with the need for water resources. The system reinforcements have therefore been developed as separate system elements that can be combined with water resource elements when developing an overall programme. It should be noted that the exact configuration of system reinforcements required at a programme level will be refined and explained at the programme appraisal stage in revised draft WRMP19 Section 10. Demand management options that are selected will also have a significant impact on the requirement for additional system reinforcements.

Water treatment cross option study

7.41 We are continuing our review of the resilience of water treatment capability in the London WRZ. Demand management options that are selected will also have a significant impact on the requirement for additional water treatment. However, following preliminary findings, it has been concluded that when peak demands (after accounting for demand management measures) exceed existing treatment capacity then additional treatment capacity will be required, except where the new resource is provided through desalination which produces potable water. A cross-option study has been undertaken to investigate feasible options for additional treatment capacity. Two options have been identified in London, with sites at:

- **Kempton WTW** for additional resources from the west (e.g. Upper Thames Reservoir, Severn-Thames Transfer, Oxford Canal Transfer), including a new connection into the Thames Water Ring Main (TWRM)
- **Coppermills WTW** for additional resources from the east (e.g. Beckton and Deephams reuse) – this would entail redevelopment of the existing works as there is no further space on the existing site. Alternative sites to Coppermills in east London are also being investigated.

7.42 For the SWOX WRZ two sites have been identified for additional treatment:

- **Abingdon WTW** for resources from the Abingdon Reservoir
- **Radcot WTW** for resources from the Severn-Thames Transfer

7.43 For the SWA WRZ two options have also been identified for additional treatment of resources from either the Abingdon reservoir or the Severn-Thames Transfer

- **Abingdon WTW** for treated water transfer into the north of the SWA area
- **A new river abstraction from the River Thames** and treatment works in the vicinity of Medmenham supplying the south of SWA.

Network reinforcement cross option study

7.44 A cross-option study has been undertaken to identify supply network reinforcement requirements for London. The report identified six interventions that could be required, including two extensions to the TWRM, with the necessary reinforcements dependent on whether the additional water resource is treated in east or west London. The network reinforcement requirements identified are:

1) Replace pump infrastructure at New River Head
2) Replace pump infrastructure at Barrow Hill
3) TWRM extension - Hampton to Battersea
4) TWRM level controlled by new header tank and pumping station at Coppermills WTW
5) TWRM extension - Coppermills to Honor Oak
6) Resolve issues with supply to Surbiton during TWRM outage

7.45 The matrix in Table 7-4 shows which of these reinforcements would be required for different combinations of new treatment capacity, depending upon whether the additional water resource is available for treatment to the east or the west of the existing TWRM. It can be seen that initially no reinforcement may be required. The precise timing of the requirement for individual network reinforcements is optimised as part of programme appraisal but will also depend on the demand management options selected as part of the programme appraisal process.

Table 7-4: Network reinforcement requirements for additional water resources treated in east or west London

		East (Ml/d)								
		0	**100**	**200**	**300**	**400**	**500**	**600**	**700**	**800**
West (Ml/d)	**0**	-	-	5	4,5	4,5	4,5	4,5	1,4,5	1,4,5
	100	1	1	3,4,5	3,4,5	3,4,5	3,4,5	4,5	1,4,5	
	200	1,3	1,3	3,4	3,4,5	3,4,5	3,4,5	3,4,5		
	300	1,3	1,3	1,3,4	3,4,5	3,4,5	3,4,5			
	400	1,3	1,3	1,3,5	3,4,5	3,4,5				
	500	1,3,5,6	1,3,5,6	1,3,5	1,3,5					
	600	1,2,3,5,6	1,3,5,6	1,3,5,6						
	700	1,2,3,5,6	1,2,3,5,6							
	800	1,2,3,5,6								

7.46 Additional network reinforcement elements have been identified that are specific for individual options. These include:

- Tunnel from Beckton to Coppermills WTW for blending of water from Beckton and Crossness desalination options
- Tunnel from Crossness desalination plant site to Beckton to extend the Beckton-Coppermills tunnel to Crossness so that it can transfer resource from the proposed desalination plant at Crossness
- Pipeline from proposed Abingdon WTW to Long Crendon to supply SWA

7.47 Further work is being undertaken to identify local supply network reinforcements required to accommodate growth however these interventions are outside the scope of the WRMP and so are not included as specific reinforcement elements.

Raw water system cross option study

7.48 A cross-option study has been undertaken to identify supply reinforcements required to the raw water system (between the point of abstraction and the WTW inlet) for the different water resource options. This is of particular relevance for options that augment resources in the River Thames or the River Lee (including new reservoir options, raw water transfers, effluent reuse and some direct river abstraction options). The study used currently available models of the raw water system for the River Thames and River Lee abstractions.

7.49 The study identified ten interventions that may be required, the most significant including an extension to the Thames Lee Tunnel, a second Spine Tunnel and additional conveyance from Queen Mary Reservoir to Kempton WTW. The necessity for the reinforcements will be dependent on the water resource options selected and whether they enter the raw water system in east or west London. The identified raw water system reinforcements, divided between east and west London, are:

East London

1) King George V Reservoir intake capacity increase
2) Chingford South intake capacity increase
3) Thames Lee Tunnel extension from Lockwood pumping station to King George V Reservoir intake
4) Thames Lee Tunnel upgrade to remove existing constraints to maximise transfer capacity (not shown in Table 7-5)
5) Additional conveyance from King George V Reservoir to break tank
6) Second Spine Tunnel from break tank to Reservoir 5 upstream of Coppermills WTW

West London

7) Datchet intake capacity increase with transfer to Queen Mother and Wraysbury Reservoirs
8) Littleton intake capacity increase with transfer to Queen Mary Reservoir
9) Surbiton intake capacity increase with transfer to Walton inlet channel
10) Additional conveyance from Queen Mary Reservoir to Kempton WTW

7.50 The matrix in Table 7-5 shows which of these reinforcements are required depending upon the additional water resource added to the east and west London raw water systems. It can be seen that initially no reinforcement may be required. The precise timing of the requirement for individual reinforcements is optimised as part of programme appraisal.

Table 7-5: Raw water system reinforcement requirements for additional water resources in east or west London

Additional raw water resource in the west (Ml/d) \ Additional raw water resource in the east (Ml/d)	0	100	200	300	400	500	600	700	800
0	-	3	1,3,5	1-3,5,6	1-3, 5, 6	1-3, 5, 6	1-3, 5, 6	1-3, 5, 6	1-3, 5, 6
100	-	3	1,3,5	1-3,5,6	1-3, 5, 6	1-3, 5, 6	1-3, 5, 6	1-3, 5, 6	
200		3	1,3,5	1-3,5,6	1-3, 5,6	1-3, 5, 6	1-3, 5, 6		
300		3	1,3,5	1-3,5,6	1-3, 5, 6	1-3, 5, 6			
400	7	3,7		1,3,5,7		1-3,5-7		1-3, 5-7	
500	7/8,10	3,7/8,10		1,3,5,7/8,10		1-3,5-7/8,10			
600	7/8,10	3, 7/8,10		1,3,5,7/8,10					
700	7/8,10	3, 7/8,10							
800	7/8,10								

7.51 For the Deephams Reuse option two alternative conveyances have been considered, depending upon whether the Thames Lee Tunnel extension is developed. If the extension is developed then Deephams reuse would discharge into it, otherwise a separate pipeline conveyance element has been included from Deephams to King George V Reservoir intake.

E. Fine screening of water resource options

Approach to fine screening

7.52 The water resource elements that passed the validation stage of the feasibility assessments form the Feasible List. These elements have then been subjected to a further fine screening stage to produce the Constrained List of options for further development before Phase 3 programme appraisal. The fine screening process brought together all water resource types and compared them using a consistent set of criteria. Where options have been rejected an explanation is provided in the Fine Screening Report[16] and in the Rejection Register (Appendix Q: Scheme rejection register).

7.53 The fine screening process compared water resource options within each WRZ. It combined quantitative analysis of costs with qualitative analysis using six relevant factors or ‘dimensions’. These qualitative factors relate to the different stages in the project lifecycle as shown in Figure 7-5. These dimensions are defined in the Fine Screening Report.

[16] Fine Screening Report, Mot MacDonald, September 2018

Figure 7-5: Mapping of six fine screening dimensions to project lifecycle

Dimension	Option Development	Planning permission granted	Construction	Commissioning	Operation
Environment & Social			✓		✓
Cost			✓		✓
Promotability	✓				
Deliverability			✓		
Flexibility			✓		✓
Resilience					✓

(Time → Stage in project lifecycle)

7.54 All resource options on the Feasible List have been assessed against these dimensions to identify the potential benefits/opportunities and the dis-benefits/risks of each option. The assessment against each dimension is categorised and visualised in summary matrices (included in the appendices to the Fine Screening Report) using the categories shown in Table 7-6. For any one dimension more than one symbol was in some cases needed to capture the nature of the risks and benefits. For example, under the environmental and social dimension some options included material dis-benefits during the construction stage, but material benefits during the operational phase.

Table 7-6: Dimension category definitions

Symbol	Meaning	Definition
◉	Substantial benefit/opportunity	The option has substantial benefits/opportunities either individually or cumulatively.
◎	Material benefit/opportunity	The option has some material benefits/opportunities.
○	Neutral	The option does not have significant residual effects.
◑ (r)	Material dis-benefit/risk	The option has some material residual dis-benefits/risks, either individually or cumulatively
● (r)	Substantial dis-benefit/risk	The option has substantial residual dis-benefits/risks, either individually or cumulatively

Note: A superscript '(r)' next to the symbol would highlight that a dis-benefit/risk could potentially be reduced to 'neutral' by additional development of mitigation measures during detailed design.

Results of fine screening

7.55 To arrive at the Constrained List of options from the Feasible List, fine screening decisions have been made by evaluating water resource options across all six qualitative dimensions.

Rather than imposing rigid rules to make screening decisions, the focus has been on ensuring that there is a clear and robust reasoning for each screening decision which has then been recorded in Appendix Q: Scheme rejection register. The adoption of this approach has, nevertheless, shown that the reasons for rejecting options have tended to fall into three categories:

- Options were rejected if they presented substantial irreducible dis-benefits/risks unless these could be offset by a substantial benefit/opportunity
- Options would be rejected if they were clearly less favourable than other mutually exclusive options
- Options would be rejected if they were the least favourable of all options where there were more options than could reasonably be required over the planning horizon under future scenarios.

7.56 A summary of the fine screening results is presented in Table 7-7 showing those options that have passed from the Feasible List to the Constrained List and those that have been rejected. The reasons for screening decisions are recorded in Appendix Q: Scheme rejection register.

Table 7-7: Fine screening summary for specific options

Resource Option	Size Band (Ml/d)						
	0 to 25	25 to 75	75 to 125	125 to 175	175 to 225	225 to 275	275 to 325
London WRZ							
Reuse - Beckton							
Reuse - Mogden							
Reuse - Deephams							
Reuse - Crossness							
Reuse - Mogden South Sewer		*					
RWT - STT Deerhurst							
RWT - Oxford Canal							
New Reservoir - Abingdon							
New Reservoir - Chinnor							
New Reservoir - Marsh Gibbon							
DRA - Lower Lee							
Desalination - Beckton							
Desalination - Crossness (unblended)							
Desalination - Crossness (blended)							
AR/ASR - Kidbrooke (SLARS1)							
AR Merton (SLARS3)							
AR Streatham (SLARS2)							
ASR South East London (Addington)							
ASR Thames Valley/Thames Central							
ASR Horton Kirby							
GW - Addington							
GW - London confined Chalk (north)							
GW - Southfleet/Greenhithe (new WTW)							
GW - Merton recomissioning							
GW - Honor Oak							
New River Head removal of constraints							
Epsom removal of constraints							
Swindon and Oxfordshire (SWOX) WRZ							
RWT - STT Deerhurst							
RWT - Oxford Canal							
New Reservoir - Abingdon							
New Reservoir - Chinnor							
New Reservoir - Marsh Gibbon							
GW - Moulsford							
Ashton Keynes borehole pumps							

Resource Option	Size Band (Ml/d)						
	0 to 25	25 to 75	75 to 125	125 to 175	175 to 225	225 to 275	275 to 325
Britwell removal of constraints							
IZT - Kennet Valley to SWOX	Pass						
IZT - Henley to SWOX	Pass						
ICT - Wessex Water to SWOX	Pass						
Slough, Wycombe & Aylesbury (SWA) WRZ							
RWT - STT Deerhurst			Pass	Pass	Pass	Pass	Pass
RWT - Oxford Canal	Pass						
New Reservoir - Abingdon		Pass	Pass	Pass	Pass	Pass	Pass
New Reservoir - Chinnor		Screened out	Screened out				
New Reservoir - Marsh Gibbon		Screened out	Screened out	Screened out			
GW - Datchet	Pass						
IZT - Henley to SWA	Pass						
Henley WRZ							
No feasble options identified							
Guildford WRZ							
Dapdune licence disaggregation	Pass						
Dapdune removal of constraints	Pass						
Ladymead WTW	Pass						
ICT - South East Water to Guildford	Pass						
Kennet Valley (KV) WRZ							
GW - Mortimer recommissioning	Pass						
East Woodhay borehole pumps	Pass						

Key

Screened out at fine screening

Passes fine screening

* Mogden South Sewer option has passed fine screening but is not included on the Constrained List

Constrained List

7.57 For the purposes of programme appraisal, resource elements from the Constrained List and system elements have been combined to provide the best value 80 year programme to address future water supply requirements. A summary of the elements included on the Constrained List is provided in Table 7-8 for the London WRZ and in Table 7-9 for the Thames Valley WRZs. The tables indicate how the system elements combine with each resource element to provide an overall supply option. The location of the resource elements is mapped on Figure 7-6.

Table 7-8: Constrained List for London WRZs

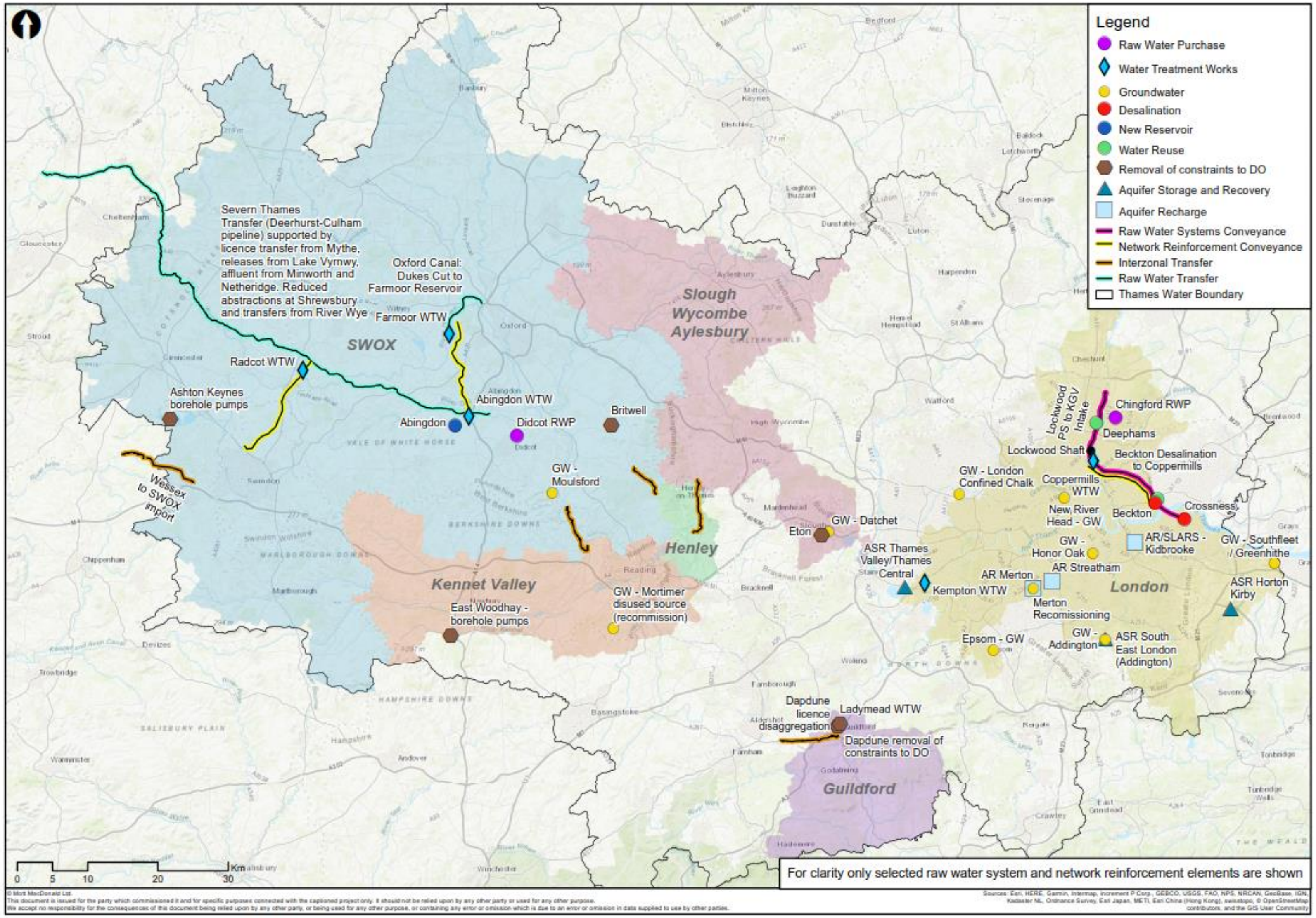
Option Type	Resource Element: Location	Resource Element: DO* (DYAA) Ml/d	Conveyance Element: Location	Conveyance Element: Nominal Capacity Ml/d	Raw Water System	Treatment Element: Location	Treatment Element: Nominal Capacity Ml/d	Network Element
Water reuse	**Deephams**	45	**Deephams to KGV**	60		**East London**	100	See network reinforcement matrix - Section 7.D
			Deephams to TLT extension		See raw water system matrix - Section 7.D			
	Beckton 100 Ml/d	95	**Beckton to Lockwood shaft**	800		**East London**	100	
	Beckton 150 Ml/d	138					150	
	Beckton 200 Ml/d	183					200	
	Beckton 300 Ml/d	268					300	
Raw Water Transfer	**Vyrnwy**	60/148/180*	**Deerhurst to Culham**	300/400/500	See raw water system matrix - Section 7.D	**Kempton**	300	See network reinforcement matrix - Section 7.D
	Mythe	15*					150	
	River Wye to Deerhurst	60*					100	
	Netheridge to River Severn	35*						
	Minworth to River Avon	115*						
	Redeployment of Shrewsbury abstractions	12/30*						
	Oxford Canal	11						
Desalination	**Beckton (blended)**	142	N/A		N/A	N/A		See matrix Section 7.D, plus **Beckton to Coppermills**
	Crossness 100 Ml/d	95			**Beckton-Crossness**			As above plus **Crossness to Beckton**
	Crossness 200 Ml/d	189						
	Crossness 300 Ml/d	284						
New Reservoir	**Abingdon 75Mm3**	142	N/A		See raw water system matrix - Section 7.D	**Kempton**	300	See network reinforcement matrix - Section 7.D
	Abingdon 100Mm3	190					150	
	Abingdon 125Mm3	234					150	
	Abingdon 150Mm3	275						
	Abingdon 30+ 100Mm3	49+199						
	Abingdon 80+ 42Mm3	151+83						
Aquifer Recharge	**AR/SLARS - Kidbrooke (SLARS1)**	7	N/A		N/A	N/A		N/A
	AR Merton (SLARS3)	5						
	AR Streatham (SLARS2)	4						
Aquifer Storage and Recovery	**ASR South East London (Addington)**	3	N/A		N/A	N/A		N/A
	ASR Thames Valley/Thames Central	3						
	ASR Horton Kirby	5						
Groundwater	**GW - Addington**	1	N/A		N/A	N/A		N/A
	GW - London Confined Chalk (north)	2						
	GW - Southfleet/Greenhithe (new WTW)	8						
	GW - Honor Oak	1						
	GW - Merton recommissioning	2						
	Epsom removal of constraints	2						
	New River Head	3						
Inter-company transfer	**Chingford raw water purchase**	20	N/A		N/A	N/A		N/A
	Didcot raw water purchase	18	N/A		N/A	N/A		N/A

* For the Severn Thames Transfer (STT) support elements the volumes shown represent the gross volumes released for the River Severn before allowance for losses. Actual deployable outputs depend upon the combination of support elements selected and the size of the transfer pipeline.

Table 7-9: Constrained List for Thames Valley WRZs

WRZ	Option Type	Resource Element: Location	Resource Element: DO Ml/d ADPW	Conveyance Element: Location	Conveyance Element: Nominal Capacity Ml/d	Raw Water System	Treatment Element: Location	Treatment Element: Nominal Capacity Ml/d	Network Element: Location	Network Element: Nominal Capacity Ml/d
Swindon & Oxfordshire (SWOX)	Raw Water Transfer	**Severn Thames Transfer** (See London WRZ for support elements)	See Table 7.3	**Deerhurst to Culham**	300 400 500	N/A	**Radcot WTW**	24 each phase	Transfers to service reservoir included in WTW elements	
		Oxford Canal	12	**Dukes Cut to Farmoor**	15					
	New Reservoir	**Abingdon 75Mm3** **Abingdon 100Mm3** **Abingdon 125Mm3** **Abingdon 150Mm3** **Abingdon 30+ 100Mm3** **Abingdon 80+ 42Mm3**	161 210 253 294 69+199 170+83	**Abingdon to Farmoor Reservoir** (if treatment capacity not required)	24	N/A	N/A		N/A	
							Abingdon SWOX WTW (if treatment capacity required)	24 each phase	Transfers to service reservoir included in WTW elements	
	Groundwater	**GW - Moulsford 1**	3.5	N/A		N/A	N/A		N/A	
	Removal of constraints to DO	**Ashton Keynes borehole pumps** **Britwell**	1.5 1.3	N/A		N/A	N/A		N/A	
	Inter-zonal transfers		2.4 5	**Henley to SWOX**	2.4 5	N/A	N/A		N/A	
		GW - Mortimer disused source	4.5 2.3	**Kennet Valley to SWOX**	6.7 2.3					
	Inter-company transfer		2.9	**Wessex Water to SWOX (Flaxlands)**	2.9	N/A	N/A		N/A	
Slough, Wycombe & Aylesbury (SWA)	Raw Water Transfer	**Severn Thames Transfer**[#] (See London WRZ for support elements)	See Table 7.3	**Deerhurst to Culham**	300/400/500	N/A	**Abingdon SWA WTW**	24 each phase	**Abingdon to north SWA**	**72 / 48**
						New intake 80 / 53	**Medmenham WTW**	24 each phase	Transfers to service reservoir included in WTW elements	
		Oxford Canal	12							
	New Reservoir[#]	**Abingdon 75Mm3** **Abingdon 100Mm3** **Abingdon 125Mm3** **Abingdon 150Mm3** **Abingdon 30+ 100Mm3** **Abingdon 80+ 42Mm3**	161 210 253 294 69+199 170+83	N/A		N/A	**Abingdon SWA WTW**	24 each phase	**Abingdon to north SWA**	**72 / 48**
						New intake 80 / 53	**Medmenham WTW**	24 each phase	Transfers to service reservoir included in WTW elements	
	Raw Water Purchase	**Didcot**	18	N/A		**New intake 80 / 53**	**Medmenham WTW**	24 each phase	Transfers to service reservoir included in WTW elements	
	Groundwater	**GW - Datchet**	5.4	N/A		N/A	N/A		N/A	
	Inter-zonal transfers		2.4/5	Henley to SWA	2.4 / 5	N/A	N/A		N/A	
Guildford	Groundwater	**Dapdune licence disaggregation**	7.8	N/A		N/A	N/A		N/A	
	Removal of constraints to DO	**Dapdune removal of constraints** **Ladymead WTW removal of constraints**		N/A		N/A	N/A		N/A	
	Inter-co. transfers		10	SouthEast Water to Guildford	10	N/A	N/A		N/A	
Kennet Valley	Groundwater	**GW - Mortimer disused source (recommission)**	4.5	N/A		N/A	N/A		N/A	
	Removal of constraints to DO	**East Woodhay borehole pumps**	2.1	N/A		N/A	N/A		N/A	

Figure 7-6: Map of Constrained List options



F. Further option development for the Constrained List

Conceptual design

7.58 For water resource elements on the Constrained List, Conceptual Design Reports (CDRs) have been prepared. The CDRs provide information on the location of the works, engineering and land requirements, dependencies with other elements, construction impacts, environmental and social mitigations, DO, programme assumptions and risks.

7.59 The information gathered from the CDRs was used as the basis for updating cost estimates, developing a risk register, and for conducting the Strategic Environmental Assessment of options (SEA).

Cost and risk

7.60 For all elements on the Constrained List a review of feasibility stage costs was conducted. Costs were updated to reflect conceptual designs, where these have changed from the feasibility stage. Unit rates were updated for material cost items where confidence in the feasibility stage estimates was low.

7.61 For all large resource elements on the Constrained List (i.e. resources with a capacity of more than 50 Ml/d) a risk register was developed and estimates of likelihood and consequence of risks occurring were assigned. Monte Carlo analysis was used to combine these estimates to provide a probability distribution for risk.

7.62 An allowance for optimism bias was applied to all elements at feasibility stage, and this was scaled back to reflect the level of confidence around solution delivery at conceptual design stage. For elements where a risk allowance was applied from the risk register, the scaling back of optimism bias was revisited following completion of the risk register so as to avoid double counting of risk between optimism bias and the bottom-up allowance of risk identified through the risk register.

Strategic environmental assessment

7.63 For all elements on the Constrained List a SEA was conducted. Further information on the Strategic Environmental Assessment appraisal can be found in revised draft WRMP19 Section 9: Environmental appraisal.

Further investigations into Constrained List options

7.64 The options on the Feasible List and Constrained List are assessed as being feasible based upon existing knowledge. At this stage of project development it is inevitable that uncertainties will exist and a number of investigations are ongoing to further reduce uncertainty. These include:

7.65 The major option on the Constrained List with the most significant uncertainties is the Severn Thames Transfer. In responding to the consultation on the Statement of Response a number of stakeholders requested that investigations into the feasibility of the Severn Thames Transfer should continue. A programme of investigations is proposed that includes investigations into losses that would occur in the River Severn associated with supporting resource options for the Severn Thames Transfer from Lake Vyrnwy, redeployment of the River Severn abstractions at Shrewsbury and Minworth STW discharges to the River Avon. Associated with these investigations are discussions through the River Severn Working Group on potential future abstraction arrangements. The EA has indicated that existing information/data does not allow a definitive estimate of losses to be agreed and that they would not agree to a put and take licensing arrangement based on currently available information. Instead they would apply the published abstraction licensing policy (currently no abstraction when River Severn flow is below 1800Ml/d and restricted abstraction when flow is between 1800Ml/d and 2400Ml/d) to any new licence at Deerhurst in order to protect the Severn Estuary Special Area of Conservation (SAC). The loss assumption has, accordingly, been increased from 10% to 20% for the revised draft WRMP. Further work and consultations are ongoing; however, the issues described above pose a significant risk that water released to the River Severn from 3rd party support options would not be available for transfer when required by Thames Water.

7.66 The Mogden South Sewer option was rejected at Fine Screening in the draft WRMP as being mutually exclusive with the Teddington DRA option. The Teddington DRA option has now been removed from the Feasible List due to environmental concerns raised by the Environment Agency and the Mogden South Sewer option has now been assessed as passing Fine Screening. Details of the concerns can be found in Appendix L: Water Reuse. However, it has not been possible to further develop the Mogden South Sewer option sufficiently to include it in the Constrained List for this revised draft WRMP, but initial review suggests that the option, if included, would not have impacted the preferred programme. Further work is needed to develop the option for inclusion in the Constrained List in future and to confirm this assessment.

G. Drought permits

7.67 We have identified a number of drought permit options that would be used to augment existing water supplies in the event of a severe drought. Drought permits are options that enable water companies to abstract more water than permitted by their abstraction licences. These options are only available in drought situations and require the water company to demonstrate that there has been an exceptional shortage of rainfall. They are initially issued for a six month period but may be extended for a further six months if the drought persists. These drought permit options are set out in more detail in our Drought Plan and its appendices[17].

7.68 The volumes associated with each drought permit are uncertain because the yields will be subject to the impact of the severe drought that would trigger their implementation. The

[17] Thames Water draft Drought Plan, 2017

Drought Plan provides an indication of the yield that would be expected from each option. An estimate of this yield has been produced and the associated resource benefit volumes used for modelling of scenarios by WRSE. The yields for each WRZ under the worst droughts from the historic record and the worst droughts from a 1:200 stochastic record are shown below in Table 7-10. The historic record is the period for which data is available and is used to calculate the deployable output for our water resources. The 1 in 200 year estimate has been derived from stochastic analysis to provide a longer period than the historic record which can then be used to examine the impact of more severe droughts than those that occur in the historic record.

Table 7-10: Yields for each WRZ under the worst droughts from the historic record and the worst droughts from a 1:200 stochastic record[18]

WRZ	Historic record	1:200
London	240 Ml/d	126 Ml/d
SWOX	81 Ml/d	42 Ml/d
Kennet Valley	61 Ml/d	9 Ml/d
SWA	14 Ml/d	11 Ml/d
Guildford	12 Ml/d	9 Ml/d
Henley	6 Ml/d	6 Ml/d

7.69 The drought permit options generally exist where we have water sources that are restricted or have been closed because of their potential to exacerbate low flows in rivers. Therefore the options, in most cases, would have some adverse environmental impact if implemented, although in most cases it would be temporary and reversible in that the ecology would recover after drought conditions ceased if permits are implemented for up to six months. In each case the environmental impact has been assessed and Environmental Assessment Reports produced and these have been used in the production of a Habitats Regulations Assessment and a SEA for the Drought Plan. The prolonged use of drought permits during severe drought events would be likely to cause significant environmental damage. This is discussed in our Drought Plan and Appendices.

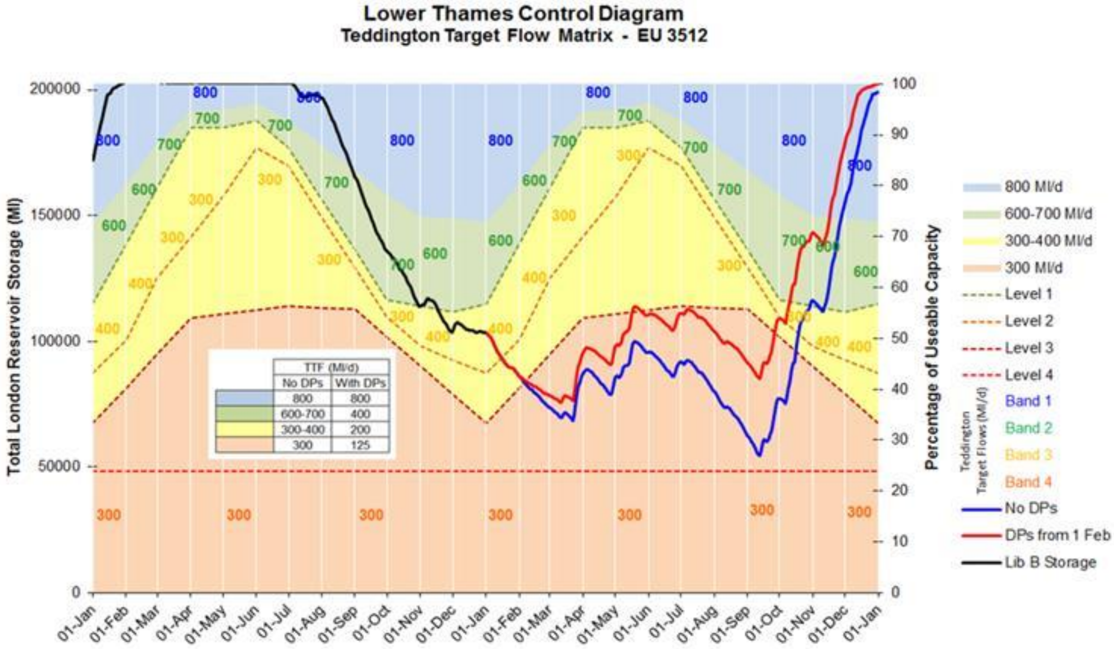
7.70 These drought permit options provide an important resource to ensure continuity of supply in the event of severe drought. The longer a drought permit option is used the greater the environmental impact is likely to be. It is also important to consider that the yield of these options would decrease through time as the drought severity intensifies and this is shown above in Table 7-10 for a 1:200 year drought. In addition there is a risk that drought permits may not be renewed for a further period of six months if the Environment Agency / Secretary of State consider the actual or potential environmental impact would be too great.

7.71 We have assessed the impact of more severe droughts for our Drought Plan using stochastically generated data to provide a much longer time series which gives a greater range of droughts for assessment. Figure 7-7 and Figure 7-8 show the impact of droughts of severity of 1:300 for London using the Lower Thames Control Diagram (LTCD) and demonstrate the importance of drought permits in preserving reservoir storage. A full

[18] These estimates are for yield, not the associated deployable output figure which would be lower.

explanation of the LTCD is provided in Appendix I sections D and F. In the first example we would need to implement drought permits from 1st February until the end of September. In the second example we would need drought permits from 1st March until the end of October. In each case drought permits would have been needed for longer than six months and so a reapplication would be necessary. The reapplication would be subject to significant uncertainty in yield, because of the impact of a more severe drought on water resource availability, and environmental impact and would be likely to be strongly opposed by regulators and stakeholders concerned with impact on the environment.

Figure 7-7: Impact of the Generated 'Severe' Drought Event 1 (modelled 1 in 300 Return Period) on Aggregated London Reservoir Storage – example 1[19]



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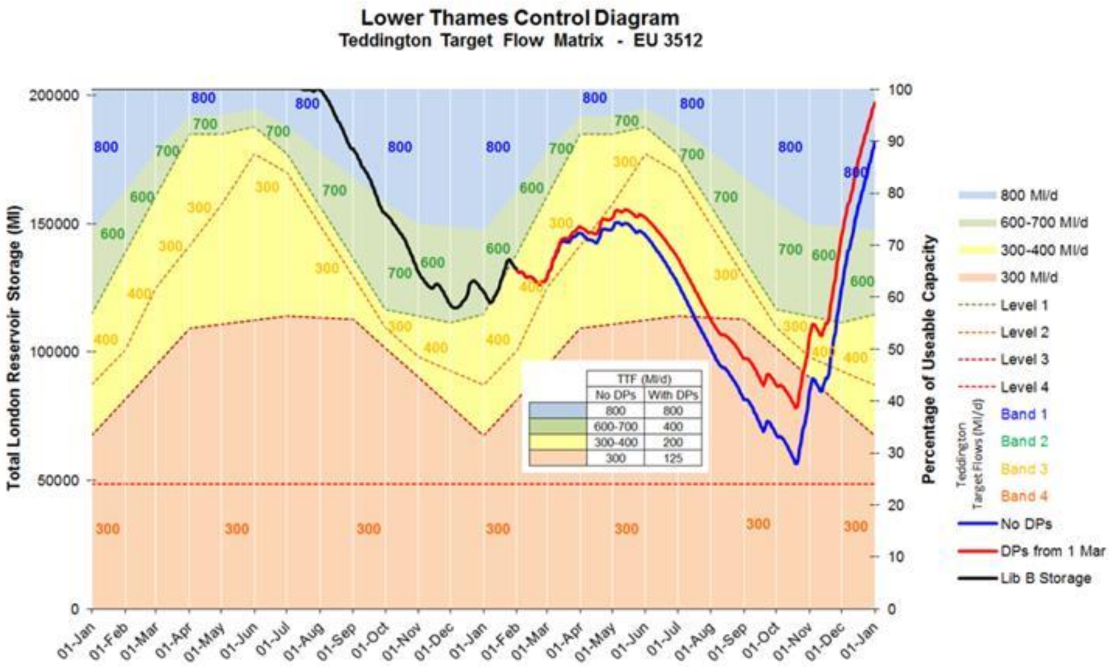
19 Thames Water draft Drought Plan, 2017

Figure 7-8: Impact of the Generated 'Severe' Drought Event 2 (modelled 1 in 300 Return Period) on Aggregated London Reservoir Storage – example 2



7.72 We do not consider the prolonged use of drought permits to be a sustainable use of water resources for a resilient 1:200 water supply system. That does not mean that we would only use drought permits with an expected drought frequency of 1 in 200 years; their use is likely to be significantly more frequent than this. Our aspiration is not to abstract from these sources apart from in very severe drought events. As a drought begins to unfold it is impossible to say at the time how severe the event will be. It is only with hindsight that it is possible to look back and state what the severity of the event was. Therefore during an emerging drought event that has the potential to be very severe, it is inevitable that drought permits will be requested, and if granted, implemented much more frequently than once in every 200 years. Figure 7-9 and Figure 7-10 below show two emerging drought events from the historical record; drought permits would have been requested from the EA given the pending severity of the event. Figure 7-11 and Figure 7-12 show how these two events subsequently unfolded; neither event was subsequently shown to be a 1 in 200 year event, the frequency was approximately 1 in 100 year. Under climate change scenarios, where drought events are forecast to become more extreme with less summer rainfall, it is inevitable that the frequency and occurrence of such events will increase and consequently that drought permits requests to the EA and subsequent implementation will be much more frequent than once every 200 years, indeed they will be significantly more frequent than once every 100 years.

7.73 We have undertaken analysis of the frequency of Level 3 and Level 4 events under 1 in 100 and 1 in 200 year droughts. This work is based on the analysis of stochastically generated records used to assess the likelihood of greater drought severity than experienced in the historic record and is presented in Appendix I.

7.74 To plan for a resilient water supply system that relies on the frequent use of drought permits is not appropriate due to their association with environmental damage. Therefore, these temporary supply options are not taken forward for inclusion in our programme appraisal. However, they do provide a short term unsustainable option which would need to be implemented in the event that a severe drought occurs. We believe that, in the long term, alternative options should be developed to provide resilience to more severe droughts such as those with a level of severity of 1:200. In this respect our approach is consistent with that adopted by other water companies.

7.75 Our revised draft WRMP19 ensures a reduction in the frequency of reliance on drought permits by increasing resource availability and becoming resilient to a 1 in 200 year drought event. The company will only rely on drought permits during severe drought events, i.e. events which, as they begin to unfold, suggest that they could be very severe in terms of the incidence of occurrence. The analysis presented in revised draft WRMP19 Appendix I, Table I-7, shows that the frequency of drought permit implementation improves to 1 in 40 years post 2030 when new resources are introduced to deliver 1 in 200 year level 4 resilience.

Figure 7-9: Emerging drought event (1921/22)

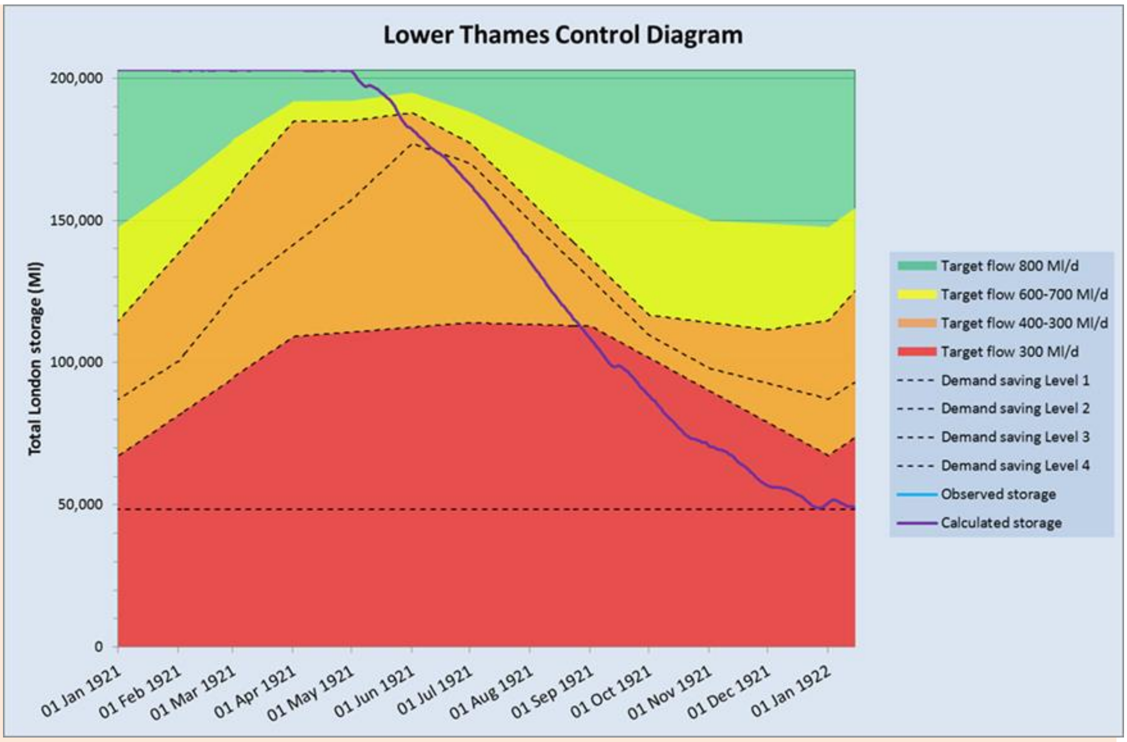


Figure 7-10: Emerging drought event (1976)

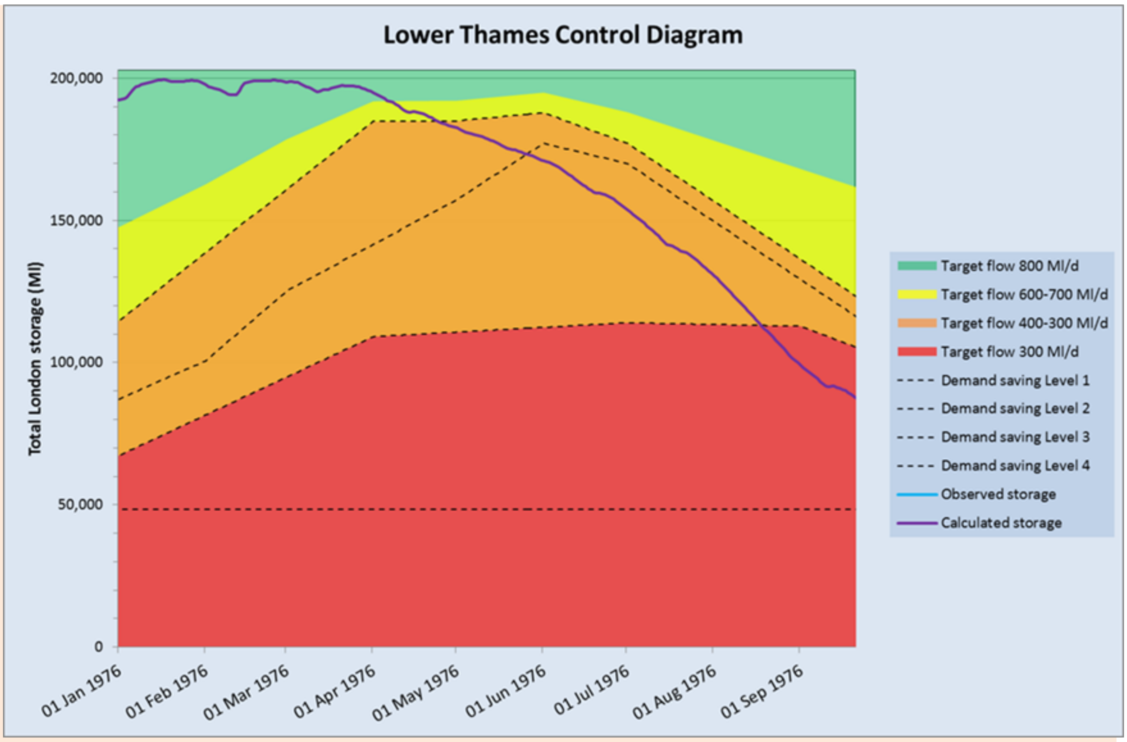


Figure 7-11: How the drought subsequently unfolded (1921/22)

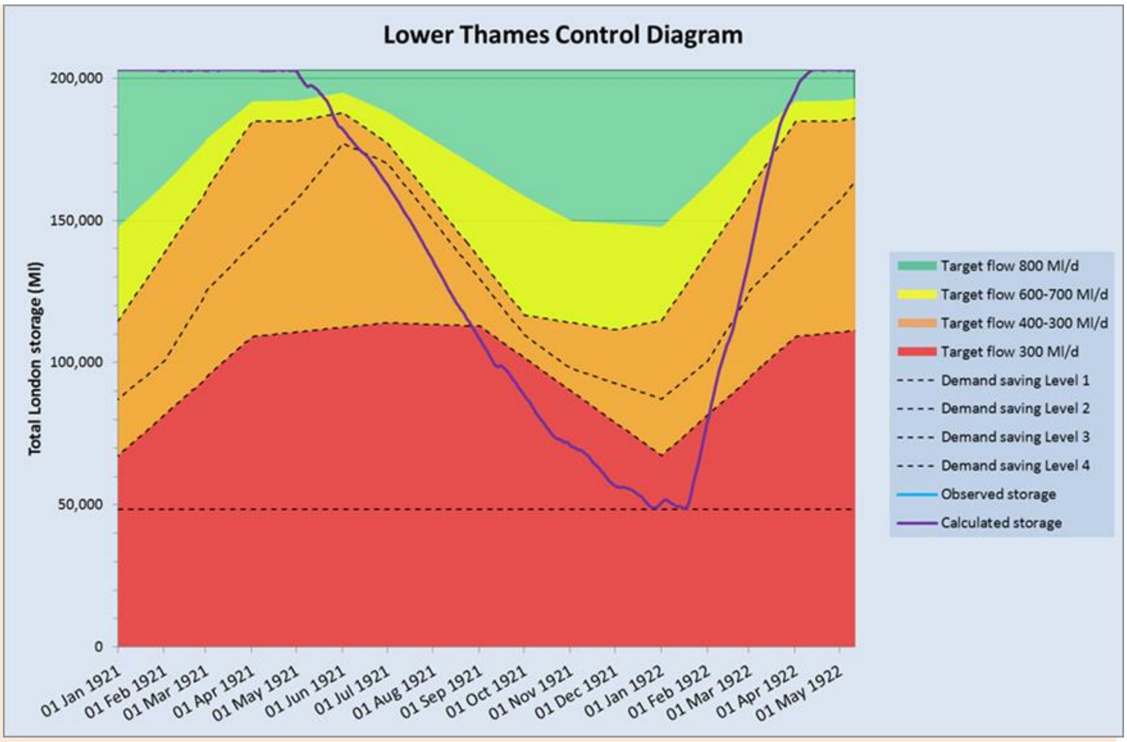
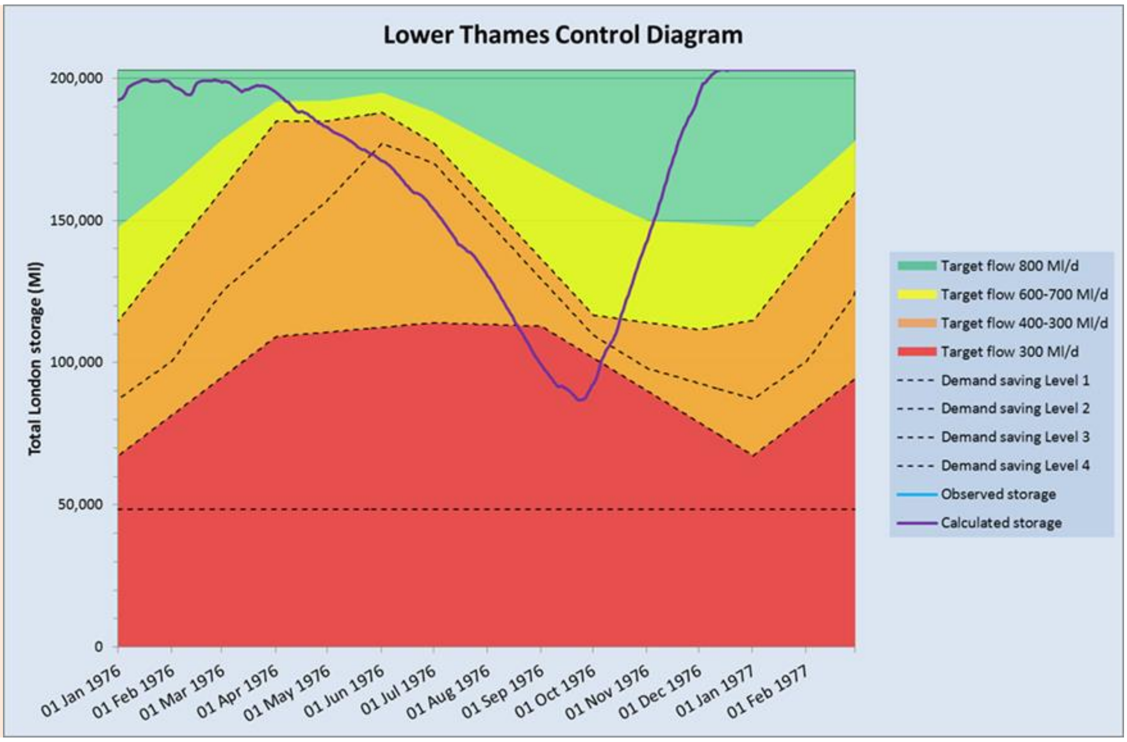


Figure 7-12: How the drought subsequently unfolded (1976)



H. Sources of further information

7.76 The following information is available on the Constrained List options.

- Fine screening report, Mott MacDonald, September 2018
- Feasibility reports
  - Raw Water Transfer Feasibility report, Mott MacDonald, September 2018
  - Groundwater Feasibility report, Mott MacDonald, September 2018
  - New Reservoirs Feasibility report, Mott MacDonald, July 2017
  - Water Reuse Feasibility report, Mott MacDonald, September 2018
  - Desalination Feasibility report, Mott MacDonald, February 2018
  - Direct River Abstraction Feasibility report, Mott MacDonald, September 2018
  - Catchment Management Feasibility report, Mott MacDonald, March 2018
  - Inter-Zonal Transfer Feasibility report, Mott MacDonald, February 2018
- Risk methodology, Mott MacDonald, March 2018
- Cost and Carbon and Whole Life Cost Methodology reports, Mott MacDonald, March 2018
- Network Reinforcement Cross Option study, Mott MacDonald, January 2018
- Raw Water System Cross Option study, Mott MacDonald, January 2018

- Water Treatment Cross Option study, Mott MacDonald, January 2018
- Discharge Design Standards Cross Option study, Mott MacDonald, February 2018
- Operating Philosophy, Mott MacDonald, February 2018
- Stochastic Resource Modelling, Stage 2 & 3 Report, Atkins, July 2018
- Conceptual Design Reports – these are available in CWC by appointment
- Constrained List Scheme Dossiers, Appendix R

7.77 Please contact consultations@thameswater.co.uk for access to any of these documents

Section 8

Appraisal of demand options

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Section 8.

Appraisal of demand options

Section 8 outlines the demand management options appraisal process. This process has led to the development of a range of demand management programmes for assessment as part of the preparation of our preferred plan.

This section includes the details of:

- The three stages of demand management options appraisal; screening, evaluation and optimisation to develop a range of deliverable demand management programmes.
- The costs, benefits and delivery constraints of each feasible demand management option.
- The process of demand management optimisation using our Integrated Demand Management (IDM) model to produce a range of demand management programmes.
- The implications of the costs, benefits and delivery constraints of each feasible option on the optimisation process.

In response to the public consultation on the draft WRMP19, the following changes have been made to Section 8:

- Update to the Screening process (Section B) to clarify the feasible demand management options specifically in relation to activities categorised under the Water Efficiency, Metering and Non-Potable options.
- Update to the detail provided for each demand management feasible option, specifically in relation to Metering, DMA Enhancement, Water Efficiency and Non-Potable Solutions (Section 8.D to 8.F).
- Introduction of a Delivery Constraints and Confidence of Delivery section for the demand management feasible options (Sections 8.H and 8.I).
- Introduction of a 'Long Term Demand Management' section to detail the development of the 15-80 year profile of demand management and maintenance of demand management benefits (Section 8.J).

A. Options appraisal process

8.1 Section 8 details the identification and appraisal of water demand management options considered in our plan. The purpose of water demand management is to reduce the volume of demand and thereby reduce the size of the supply demand deficit identified in Section 6: Baseline supply demand position, as part of a best value investment programme. The purpose of demand management options appraisal is to identify and compare demand management interventions and thereby to produce demand management programmes that can best achieve water demand reduction over the plan period. These demand management programmes are then optimised alongside the supply options (Section 7: Appraisal of water resource options) for inclusion as appropriate in our preferred plan (Section 11: Preferred programme).

Overview

8.2 We have conducted our demand management options appraisal in three stages to produce a range of demand management programmes. They are the screening, evaluation and optimisation of demand management options.

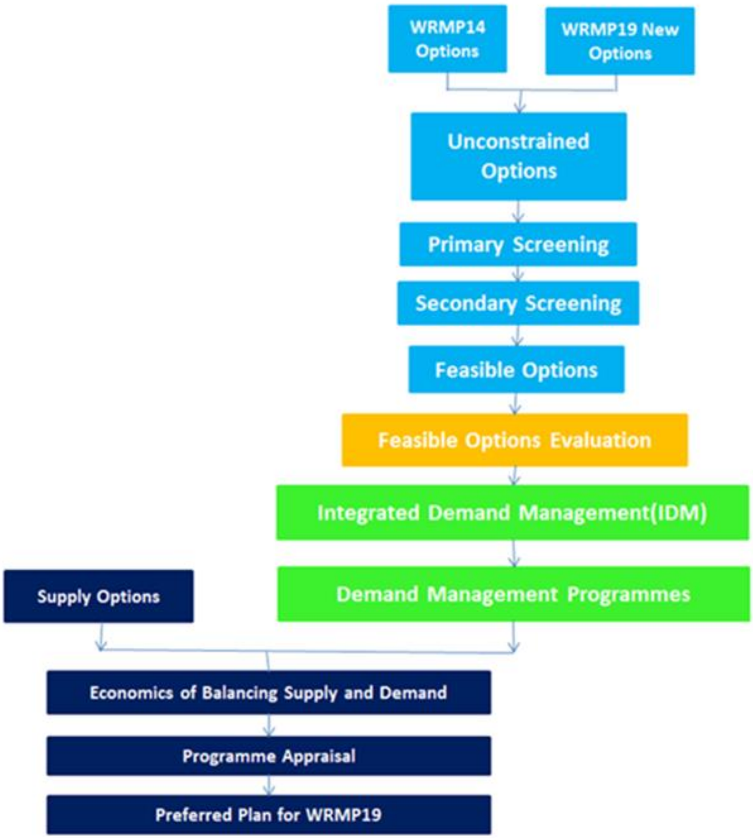
8.3 The **Screening** of options involved the identification of a list of generic demand management options. These options underwent primary and secondary screening against technological, financial, environmental, risk and resilience and legal constraint criteria. The output of this process was a list of feasible demand management options that were then evaluated in the evaluation stage of demand management options appraisal. Section 8.B sets out the principles and approach we used to screen 135 generic demand management options to produce 47 feasible options for evaluation.

8.4 The **Evaluation** of the 47 feasible demand management options classified the options by whether they could reduce either leakage or usage (including usage and wastage) or both. To quantify the value of these options, we assessed the cost and reduction in demand that could be achieved by implementing each option individually. Section 8.C provides an overview of the evaluation process, Section 8.G describes the optimisation process itself, and Sections 8.D to 8.G outline the detail for each demand management option.

8.5 The **Optimisation** of options involved the comparative assessment of feasible options using the IDM model. The purpose of optimisation was to develop a range of deliverable, cost efficient demand management programmes. In this exercise we looked at the overlapping costs and benefits of options that could be promoted in combination in addition to assessing each option individually. This enabled us to look at the optimised combination of options for each District Metered Area (DMA) and to assess their deliverability constraints.

8.6 Figure 8-1 illustrates the demand management options appraisal process and its connection with the next stage of the preparation of the plan, Economics of Balancing Supply and Demand (EBSD) Plus and Programme Appraisal (Section 10: Programme appraisal).

Figure 8-1: Demand management options appraisal overview



8.7 Section 8.G outlines the procedure used for conducting this optimisation. Sections 8.D to 8.F detail the information we used to determine the costs and benefits of each feasible water demand management option, the reason for any significant changes to options since the publication of the Water Resources Management Plan 2014 (WRMP14), the delivery constraints of each option and the impact these had on demand management optimisation.

8.8 The output of the demand management options appraisal process was a range of water demand management programmes. A demand management programme consists of an optimised mix of demand management options or interventions to achieve a certain level of demand reduction in each Asset Management Planning (AMP) period. Section 8.K and J summarise the optimised combinations of options making up the demand management programmes and the relative usage and leakage savings achieved by each programme.

8.9 The demand management programmes produced as a result of the demand management options optimisation process were considered in the next stage of the preparation of the revised draft WRMP19; this is where the demand programmes were assessed with the water resource options in the EBSD Plus model, through our Programme Appraisal process to produce our preferred or 'best value' plan.

B. Screening

8.10 The purpose of options screening was to develop a list of feasible demand management options. Feasible demand management options are those options considered to have a reasonable prospect of implementation and of achieving a water demand saving. The number of feasible options must be both sufficient and manageable to allow real choices to be made when undertaking their optimisation (Section 8.G).

8.11 There are two predominant stages in the Demand Options Screening Process; first, create an unconstrained list of options; second, undertake primary and secondary screening to create a list of feasible options.

8.12 The full Demand Management Options Screening process is presented in the report, 'Thames Water WRMP19 Demand Management Options Screening Report', March 2017[1]. This report was reviewed by external stakeholders at our technical stakeholder forum on 19th June 2017.

Unconstrained options list

8.13 The purpose of this stage is to create a list of all possible water demand management options that may be technically feasible but not necessarily free of environmental or planning constraints. This Unconstrained Options list is developed from the Generic List of Options outlined by United Kingdom Water Industry Research (UKWIR) in its Water Resources Planning Tools 2012 Report[2]. All water companies are encouraged to use this generic list as the starting point in identifying potential water Supply and Demand Management Options in their areas.

8.14 The generic water Demand Management Options identified by UKWIR are grouped into five categories: Leakage, Metering, Water Efficiency, Tariffs and Non-Potable (termed 'Water Recycling' in the UKWIR document). Using these five categories as a base, we developed each Generic Option to derive multiple potential sub-options and specific options.

8.15 In drawing-up the list of sub-options and specific options, we utilised two sources of WRMP14 Demand Management Options to evaluate or re-evaluate, and identified new options for our revised draft WRMP19:

- WRMP14 Accepted Options: these options passed the screening process in WRMP14 to make the Feasible Options list
- WRMP14 Rejected Options: these options did not pass the screening process in WRMP14 and were recorded on the Rejection Register. The issue giving rise to non-compliance is noted in the table in the Rejection Register
- Revised Draft WRMP19 New Options: these options were not considered in WRMP14

8.16 The sub-options and specific options identified under each Generic Option category forms the Unconstrained Options List (Appendix P: Options List Tables).

[1] Thames Water (2017), 'Thames Water WRMP19 Demand Management Options Screening Report', March 2017
[2] UKWIR (2012), Water Resources Planning Tools 2012, Economics of Balancing Supply and Demand Report

8.17 For the revised draft WRMP19, we have developed an unconstrained list of 135 water Demand Management Options under the Generic Option categories Leakage, Metering, Water Efficiency, Incentives and Non-Potable Water Supply. Of the 135 options, 26 have been sourced from WRMP14 Accepted Options, 65 from the WRMP14 Rejected Options and 44 are new options for the revised draft WRMP19.

Primary and secondary screening

8.18 Each option in the unconstrained options list is then subjected to Primary Screening and Secondary Screening.

Primary screening

8.19 Primary Screening assesses option feasibility at a high level for acceptance within technological, financial, environmental, risk and resilience and legal constraints.

8.20 In Primary Screening, each option in the Unconstrained Options List is assessed against the following criteria:

- Technical: Is the option currently technically feasible?[3]
- Cost: Does the option avoid excessive cost, using available outline cost information?
- Environmental: From an initial environmental assessment, are the likely significant effects of the option on the environment considered acceptable?
- Risk: Does the option give rise to an acceptable risk of it being implemented? Is there an acceptable risk that the option will not provide a net water resource benefit or not provide sufficient future resilience?
- Legal: Does the option comply with current legal requirements?[4]

8.21 This assessment is conducted at a high level by our own economists, engineers and environmental experts who specialise in each of these areas.

8.22 To pass through the Primary Screening exercise each Demand Management Option must score 'yes' to all five questions. If an option is rejected it will not continue to Secondary Screening and will be listed on the WRMP19 Rejection Register (Appendix Q: Scheme rejection register). Options that pass Primary Screening continue to Secondary Screening.

8.23 For the revised draft WRMP19, 44 of the 135 Demand Management Options in the Unconstrained Options list have been screened out by Primary Screening, leaving 91 potential options.

Secondary screening

8.24 Secondary Screening further refines the 91 options in the list that has emerged from the primary screening exercise by reference to qualitative criteria. Each option that passed through the Primary Screening process is assessed against the following criteria applied for

[3] This screening question is new to the revised draft WRMP19
[4] This screening question is new to the revised draft WRMP19

the purposes of Secondary Screening, to produce the final feasible list of water demand management options.

- Does the option avoid excessive cost?
- Is the option likely to be acceptable in terms of planning and environmental constraints?
- Is the option likely to help meet Water Framework Directive objectives and prevent deterioration of water body status?
- Does the option have an acceptable risk of social impact or inequality?
- Does the option align with company policy objectives?
- Does the option provide flexibility/adaptability to climate change uncertainty?
- Does the option provide conjunctive use benefits or other benefits to water resource management?
- Is the option practical and efficient to implement and maintain? (new to the revised draft WRMP19)
- Is the option lead time sufficiently flexible to planning or other uncertainties to ensure security of supply is maintained?
- Are all other risks and uncertainties acceptable?
- Can costs and benefits of the demand option be modelled for comparison with alternatives at DMA level?

8.25 This assessment is carried out by internal Thames Water economists, engineers and environmental experts who specialise in each of the Generic Demand Management Options areas. To pass Secondary Screening each option must score 'yes' to all eleven questions. If an option is rejected it will be listed on the revised draft WRMP19 Rejection Register (Appendix Q: Scheme rejection register).

8.26 Options that pass through the Secondary Screening exercise make up the List of Demand Management Feasible Options. For the revised draft WRMP19, of the 91 Demand Management Options remaining after Primary Screening, 44 options were screened out by Secondary Screening, leaving 47 feasible options.

Feasible demand management options

8.27 The Feasible List of Demand Management Options must provide a sufficient but manageable number of options to allow real choices to be made between options when undertaking optimisation in IDM.

8.28 The outcome of Primary and Secondary screening is the drawing up of the Feasible Demand Management Options list. There are 47 Feasible Demand Management Options for the WRMP19. These are grouped into 7 categories: Metering, DMA Enhancement, Mains Replacement, Pressure Management, Water Efficiency, Incentives and Tariffs and Non-Potable water. These are amalgamated by type and summarised in Figure 8-2 i.e. the feasible option mains rehabilitation is made up of four individual options:

1) replace 25% of mains in a DMA
2) replace 50% of mains in a DMA
3) replace 75% of mains in a DMA
4) replace 100% of mains in a DMA

8.29 The list of options broken down individually is provided in the report, 'Thames Water WRMP19 Demand Management Options Screening Report', March 2017[5].

Figure 8-2: Feasible demand management options

Leakage and Usage Benefit	Leakage Benefit	Usage Benefit		
Metering	**Leakage**	**Water Efficiency**	**Incentives and Tariffs**	**Non-Potable Water**
Metering houses only	Mains Replacement	Smarter Home Visit	Incentives Programme	Rainwater harvesting
Metering blocks of flats (bulks) only		Smarter Business Visit	Innovative Tariffs	Stormwater harvesting
Metering houses and bulks	Pressure Management	Wastage Fix ('leaky loos')		Greywater harvesting
Metering houses, bulks and individual flats	DMA Enhancement	Housing Association Fix		
Customer Side Leakage (CSL) repair		Intensive area based promotional campaigns		
Metering houses, bulks and individual flats + CSL repair + Smarter Home Visit				
Metering houses, bulks and individual flats + CSL repair + Housing Association Fix				
Metering houses + CSL repair + Smarter Home Visit				

Note: green indicates new options for the revised draft WRMP19

8.30 The feasible options list was presented to external stakeholders at the Technical Stakeholder Forum on 19th June 2017 and published in the Thames Water WRMP19 Demand Management Options Screening Report and the Feasibility Paper[6].

[5] Thames Water (2017), 'Thames Water WRMP19 Demand Management Options Screening Report', March 2017
[6] Thames Water (2017), 'Thames Water WRMP19 Demand Management Options Feasibility Paper', June 2017

C. Evaluation

8.31 In Section 8.B we explained the screening process to derive the feasible demand management options. Section 8.C provides an overview of the approach we employed to individually evaluate these feasible options and Sections 8.D to 8.F provide the detail behind the evaluation of each option.

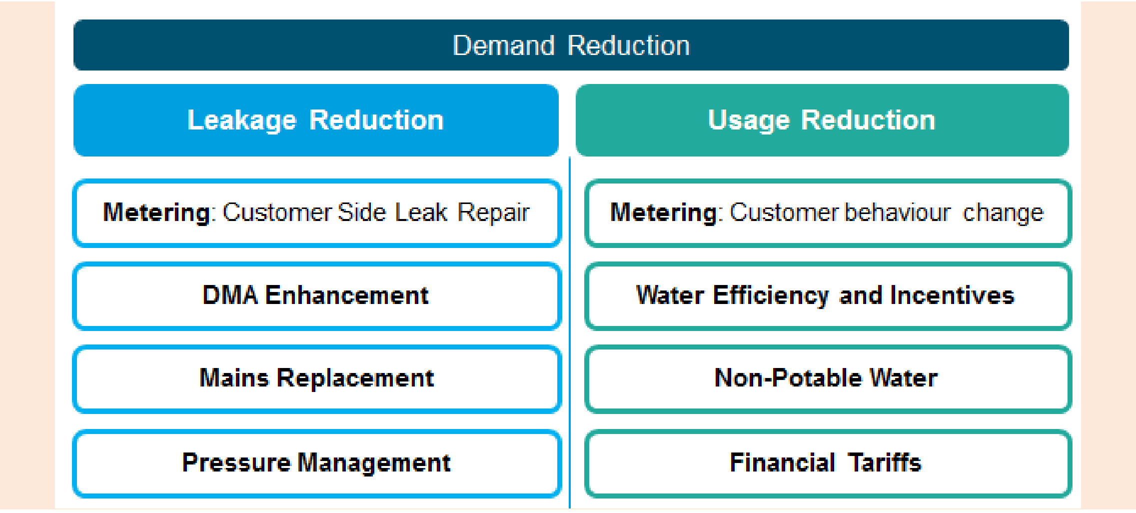
Leakage and usage reduction

8.32 The screening process identified seven overarching demand management feasible options:

1) Metering
2) DMA Enhancement
3) Mains Rehabilitation
4) Pressure Management
5) Water Efficiency and Incentives
6) Non-Potable Sources
7) Tariffs

8.33 These options can be grouped as targeting either a reduction in leakage or a reduction in customer usage. As the exception, metering can achieve both a reduction in leakage (customer side leakage (CSL)) and customer usage to reduce overall demand (Figure 8-3).

Figure 8-3: Demand management options categorised by leakage and usage reduction



8.34 An additional leakage reduction option, 'AMP6 Leakage Savings Carry Over' has been introduced to the revised draft WRMP for year 1 of AMP7. That is, since the leakage in April 2020 is expected to be 21 Ml/d lower than the leakage in April 2019, this leakage reduction is applicable to year 1 of AMP7 at no additional cost to the programme. Section 8.E illustrates the details behind this benefit.

8.35 To quantify the value of the 47 feasible options for water demand management, we evaluate the cost and reduction in demand that could be achieved by implementing these options. For example, to achieve a reduction in customer usage and leakage from metering, there is a cost to install the meter, maintain meter reading infrastructure, fix any CSL and replace the meter when it reaches the end of its operational life.

8.36 Figure 8-4 provides an overview for each demand management feasible option that includes the direct and indirect benefits of the option and the work required and constraints associated with implementing the option. It also shows the average cost benefit of each option relative to one another. This relative value estimate does not consider cost benefit over time (i.e. that options may become more expensive in the future) or take account of the constraints on availability and delivery (Section 8.H). However, it does highlight the demand management feasible options that are the cheapest and the most expensive.

8.37 The data lying behind this overview is presented in Sections 8.D to 8.F. These sections outline the source of data for our costs and benefits and the reason for any significant changes since WRMP14. The delivery constraint of each intervention and the impact this has on demand management optimisation is presented in Section 8.H. This detail underpins the discussion of the optimisation phase of demand management and is critical to the development of our demand management programmes (Section 8.J).

Figure 8-4: Overview of demand management option costs, benefits and constraints

Feasible Option	Direct Benefits		Indirect benefits	Work Required	Constraints	Relative Cost Benefit*
	Leakage Reduction	Usage Reduction				
Metering	Increased ability to find customer supply leakage (CSL)	Reduced usage due to behaviour change due to metered bill	Enhanced detection of network leaks with sufficient meter coverage (DMA Enhancement)	Household meter installation and replacement Bulk meter installation and replacement Meter reading costs CSL repair costs	Ability to fit a meter on a property Physical maximum meter installs per year	**Medium**
Mains Rehabilitation	Direct Leakage Reduction Reduced mains deterioration Increased ability to find leaks Reduced number of mains bursts	n/a	Aligned to customer preference Minimise customer supply interruptions from emergency bursts	Street works permits Size and length of main to rehabilitate Number of network monitoring meters, chambers and customer connections to be replaced	Efficient number of kilometres that can be replaced in one year Access to congested roads	**High**
Pressure Management	Direct Leakage Reduction Reduced burst frequency	n/a	Aligned to customer preference Reduced customer supply interruptions Increased mains asset life	Number and size of pressure reducing valves and chambers Number of tall building boosters Number of critical pressure points (ongoing maintenance)	Accurate level of pressure management reduction and therefore pressure management schemes available	**Medium**
DMA Enhancement	Increased ability to find leaks Direct Leakage Reduction	n/a	Detection of illegal customer usage Increase accuracy of DMA Water Balances Accurate allocation of customer use	Number of network monitoring meters and chambers Number and cost of leak detection hours Leak repair costs and street works	Maximum number of DMA Enhancement/ Plus schemes identified	**Medium**
Water Efficiency	n/a	Reduced usage Reduced wastage Reduced business usage	Aligned to customer Wider awareness through media campaigns Long term behaviour change	Free water saving devices Plumber assisted audit	Customer uptake rate Smarter Home Visit to newly metered customers dependent on the number of new meters	**Low**
Non-Potable Supplies	n/a	Reduced customer usage from the potable network	Increased customer awareness Promotion of innovative solutions for the	Construction and implementation of non-potable supplies on new developments	Maximum number of schemes currently available	**Very High**
Incentives	n/a	Reduced usage	Increased customer awareness	Media campaign to advertise incentives Administrative costs	Uptake rate of the incentives programme	**Low**
Financial Tariffs	n/a	Reduced usage	Increased customer awareness	Administrative costs to implement and track the programme	Minimum meter penetration required	**Very Low**

Note: High = high cost to benefit received in comparison with other demand management options

Geographical scale

8.38 Demand Management options can be implemented anywhere, on any property or any pipe in the network. This is in contrast to water resource options which have fixed geographical locations and can be categorised at Water Resource Zone (WRZ) level.

8.39 To accurately assess demand management options, we must examine them at a smaller scale than WRZ level. The basic geographical unit for which costs and benefits are calculated and compared for each demand management intervention is the District Metered Area (DMA).

District Metered Area (DMA)

8.40 A DMA is a discrete area of the water distribution network that can be isolated by closing valves so that the quantities of water entering and leaving the area can be metered. The volume of water into and out of the DMA is measured by a district meter. The purpose of a DMA is to divide each WRZ into manageable sections to detect and determine the location of burst mains, calculate the level of leakage in each DMA and compare DMAs so that activities can be targeted to where they will have the greatest impact in reducing leakage.

8.41 There are 1,640 DMAs in our supply area, typically covering approximately 2,500 properties each.

D. Options to reduce leakage and usage - metering

8.42 Section 8.D details the source of data for the costs and benefits of metering and the reason for any significant changes since WRMP14. The constraints and confidence in delivery are outlined in Section 8.H and Section 8.I. This information is used in the optimisation phase (Section 8.G) of demand management appraisal to calculate the total benefit expected from metering in each demand management programme (Section 8.J).

8.43 Metering is the only feasible demand option that delivers both a leakage and usage (usage and wastage) reduction.

Overview

8.44 Our supply area was designated as being in an area of serious water stress[7] and, in 2012, legal powers were granted to us to compulsory meter properties across our area by the Secretary of State. In the Water Resources Management Plan 2014 (WRMP14), this led to our Progressive Metering Programme (PMP) being initiated within the London WRZ.

8.45 The Water Services Regulation Authority (Ofwat), Department for Environment, Food and Rural Affairs (Defra), the Greater London Authority (GLA) and the Consumer Council for Water (CCWater) have all stated support for metering as the fairest way for customers to pay.

[7] Environment Agency and Natural Resources Wales, 2013, 'Water stressed areas – final classification', July 2013

Metering also has broad customer support, recognising that it is fair to pay according to how much water is used.

8.46 Our programme of progressive metering is underway in London with over 243,564 smart meters installed by the end of 2017/18 (Section 2: Water resources programme 2016-2020). The data from these meters is being used to educate customers on their water consumption, inform our Water Efficiency Smarter Home Visit (SHV) programme and build up our database on water consumption and customer side leaks.

8.47 This section provides an overview of our metering delivery programme used in the optimisation phase of demand management option appraisal. It sets out details of the infrastructure used, the types of benefits that can be achieved by metering (usage, wastage and CSL reduction) and the costs of metering. The delivery constraints and confidence in delivery are detailed in Section 8.H and Appendix N: Metering provides further information and a more detailed analysis of our approach to metering.

Programme type

8.48 The total demand reduction obtained from metering is dependent on the type of metering programme undertaken and whether it results in a usage reduction, leakage reduction or both.

8.49 In the revised draft WRMP19, our enhanced metering programme includes three delivery programmes: household metering, bulk metering and replacement metering. In the draft WRMP replacement metering was sometimes referred to as rehabilitation metering.

8.50 The fourth delivery programme, optant metering is included in our baseline water demand forecast detailed in Section 3.

Household metering (Progressive Metering Programme, PMP)

8.51 Household metering refers to any household property where a meter can be installed. It applies to compulsorily metered properties (referred to as ‘progressive metering’ in WRMP14) and includes detached, semi-detached or terraced properties as well as metering individual dwellings in small or large blocks of flats.

8.52 Household metering provides both a usage benefit from reduced customer consumption and wastage fixes, and a leakage benefit from the increased ability to detect and repair CSL.

Bulk metering

8.53 Bulk metering refers to the installation of bulk meters on the supply pipes of a block of flats. A small block of flats refers to properties with up to 12 dwellings. These properties are typically converted houses or terraces which have been developed into multiple dwellings. A large block of flats is defined as a property with greater than 12 dwellings, and is typically purpose built rather than converted.

8.54 There is a leakage benefit associated with bulk metering due to the increased ability to detect CSL on the shared supply pipe with smart metering data. There is no additional usage benefit claimed against the options as bulk customers are not billed individually based on their water use.

Replacement metering (proactive)

8.55 Proactive replacement metering refers to the programme to replace old 'dumb' meters with new 'smart' Automatic Meter Reading (AMR) or Advanced Metering Infrastructure (AMI) meters (Section 8.D - Technology).

8.56 There is a leakage benefit associated with this due to the increased ability to detect CSLs with smart metering data. That is, with the broader roll out of the 'fixed network' (see Section 8.D, Infrastructure – fixed network) the benefits of replacement meters will now be more easily available. There is no additional usage benefit assigned to the metering intervention as replacement meter customers are already paying on a metered tariff. However, these properties will still be targeted by our Water Efficiency options and therefore will achieve a reduction in usage.

8.57 In comparison, in WRMP14, the rollout of our enhanced metering programme occurred across two delivery models: progressive metering and bulk metering. The benefits from replacement metering were not included in our WRMP14 because, at this time we were replacing 'end of life' and faulty dumb meters with new dumb meters. This meant we could not get any additional benefit of a CSL reduction by changing a dumb meter for a smart meter. The work in WRMP14 was covered under our maintenance work and was due to the minimal coverage of the fixed network at the time, restricting smart meter roll out.

Optant metering

8.58 Optants are meters that have been installed at the request of the customer. Customers who request a meter are typically lower water users or single occupancy dwellings who wish to minimise their bill. The volume of Optant customers is difficult to predict and reliably model. Consequently, Optant meters are not optimised as part of the demand management programme but have been included as a fixed number removed from our baseline water demand forecast. This ensures Optant meters do not bias the optimised meter number or volume of savings that can be achieved from metering in the demand management appraisal process. Section 3 details the source of data and volume of optant meters used in the revised draft WRMP19.

Technology

Infrastructure – fixed network

8.59 In addition to the type of metering programme undertaken, the type of meter installed influences the total demand reduction achieved. There are three types of meters currently installed on our network:

- **Advanced Metering Infrastructure (AMI):** using our fixed network meter system, meters are read electronically rather than by a meter reading. Electronic readings are passed from the meter through to utility offices for billing and network management purposes. With these systems it is possible to collect more frequent data on water consumption and alarm conditions (i.e. high CSLs).
- **Automatic Meter Reading (AMR):** a meter with a short range radio installed at each property. The meter reader, equipped with a meter reading device, is required to

walk by the meter in order to take a meter reading but does not require physical access to the meter. This process can also be undertaken in certain circumstances by vehicle, known as drive-by reading. The data is captured electronically.

- **Dumb meter:** a conventional meter is installed with a register dial. Meter reading is undertaken by a meter reader gaining physical access to the meter and visually recording the meter reading. The meter reading can either be recorded in a book or keyed into an electronic meter reading data capture device. Some data capture devices have bar-code readers to record/check the meter serial number.

8.60 In our plan we refer to both AMR and AMI meters as smart meters with the intention that AMI meters become the predominant smart meter in our network.

8.61 In WRMP14 we made the decision to use AMI smart metering technology and phase out dumb meters. This is because smart metering data supports customer usage reduction, water efficiency programmes and achieves a greater leakage reduction; smart meters provide real time information which allows continuous flow to be easily and quickly identified. In comparison, dumb meters will only highlight significant changes in overall consumption. Smart meters also provide greater insight into asset performance, improving the speed and effectiveness of decision making and enabling investments to be made more informatively.

8.62 To enable AMI smart metering, we are currently in the process of commissioning a 'fixed network'. This means we are working with existing telecommunication companies to use their masts as part of our smart metering roll out. These masts will communicate with our AMI smart meters and send the real time meter readings to a database. As a result, customers will be able to view their water consumption in real time.

8.63 In AMP6, we have worked with telecommunications partners to commission 106 masts in London with plans for a further 180 London masts and the rollout of masts in Thames Valley to be commissioned in AMP7. As the fixed network is rolled out, our smart meters are installed with Local Communication Equipment. These are initially set up as AMR with the capability to be switched to AMI as the fixed network communication masts become available.

Monitoring – Smart Metering Operations Centre (SMOC)

8.64 Following the commissioning of a fixed network in London, we have established a Smart Metering Operations Centre (SMOC), to monitor the performance data from smart meters installed in AMP6. This team has been established to recognise potential leaks at a customer's property, identify disproportionate consumption to assist in our DMA enhancement programme (Section 8.E) and identify where a meter has gone missing resulting in a drop in communications. In response, the SMOC team will proactively dispatch technicians to investigate meters that are not performing as expected, and refer cases of suspected leakage onto our customer side leakage repair team to facilitate a timely repair.

8.65 In contrast, with traditional or 'dumb' meters, meter issues and suspected leakage would not have been dealt with proactively but rather in response to biannual meter readings.

Quantity

8.66 To determine the number of meters that can be installed across our area we model the number of meters that can be installed externally and internally and then apply a 'survey to fit ratio'[8] to different property types to account for the fact that not all properties can be metered.

External and internal installations

8.67 Meters can be fitted either externally or internally at a property. This means;

- **External**: a meter is fitted in the pavement in the boundary box which houses the outside stop tap. This has the benefit that the meter will record leakage on the customer's supply pipe aiding quicker leakage repair and the meters are easier to install and read.
- **Internal**: a meter is fitted at the first stop tap inside the property. This location is used if the property does not have an individual supply.

8.68 To determine the number of external and internal meters in a DMA, the internal-external split is applied per property type. The data providing this information is obtained from the number of internal and external installations carried out throughout AMP6.

8.69 In WRMP14, we planned to install 441,000 smart domestic water meters by the end of AMP6. So far, we have installed 243,564 meters which is below our target. This was due to start-up challenges and the number of internal installations required being above that originally envisaged. In WRMP14, it was assumed that almost all our meter installations would be external. However, due to the property distribution in London, it was found that up to 20% of properties required an internal installation.

8.70 To ensure we can provide a realistic and achievable programme for the revised draft WRMP19, we have used the internal and external data split from the last two years of our PMP, 2015/16 and 2016/17 (Appendix N: Metering for details). This data is the most accurate and current information of internal and external meter installations and allows for a higher proportion of internal installations (see Appendix N: Metering for details). We have also updated our survey to fit ratios to more accurately reflect the likelihood of needing to install an internal meter.

Survey to fit ratios

8.71 It is not possible to fit a meter at all properties. This can be for a variety of reasons both technical and economic. Technical reasons include modifications to internal plumbing which prevent fitting a meter (e.g. a fitted kitchen); or there may be more than one supply serving the property, or a single supply serves more than one property. Sometimes fitting a meter would be technically feasible but prohibitively expensive.

8.72 To accurately model the potential number of meters that could be installed in a DMA, a survey to fit ratio is applied to each property type to identify the number of properties that can have a meter fitted. The survey to fit ratios applicable to the revised draft WRMP19 are based on

[8] The ratio applied to different property types to identify the number of properties that can have a meter fitted – see subheading 'Survey to fit ratios' for full description.

access rates achieved during the PMP[9]. Compared with WRMP14, the average survey to fit ratio across all properties has remained consistent but with slight changes in the distribution, due to ratios having been updated in the latest three boroughs to be progressively metered. These are considered to be the most accurate representation of the survey to fit potential into the future and in subsequent AMPs (see Appendix N: Metering for details).

Demand reduction

8.73 There are two demand reduction benefits associated with metering. They are a reduction in customer usage (including usage and wastage), and repair of Customer Side Leakage (CSL). The total demand reduction obtained from metering is dependent on the type of metering undertaken and whether it results in a usage reduction, a leakage reduction or both.

Usage reduction

8.74 The reduction in customer usage as a result of metering is applied to household metering. This means that we have observed customers changing their behaviour in response to being charged specifically for the volume of water they use.

8.75 In the revised draft WRMP19, we have used the results of the metered consumption model (MCM) and the Domestic Water Use Study (DWUS) to estimate the usage savings achieved through household metering[10]. This study estimated an average 17-19% reduction in overall usage if 20% of unmeasured flats and all unmeasured houses were metered. We have used the 17% figure to represent the change in customer behaviour resulting from being billed on a metered tariff. It does not include any savings achieved from a CSL fix or the customer taking part in any Water Efficiency interventions (Section 8.F).

8.76 The average usage reduction of 17% per property is based on a comparison between two models; the MCM, which models the usages of 8,567 metered properties, and DWUS which models usages of 1,000 unmeasured properties.

[9] Based on survey to fit ratios and approach of three London boroughs during 2016
[10] Cocks R, February 2017, '*Using Household Consumption Models to Estimate the Impact of Metering'*, Thames Water.

The metered consumption model (MCM) – measured usage

8.77 The metered consumption model used for this study is based on 8,567 properties, across all property types and demographics. These properties had a dumb meter which had been fitted for up to 27 years (i.e. since 1990). We also had occupancy data, or data regarding the number of people living in each property, which is critical to accurately understand any change in usage (see subsection 'why do we need to know occupancy')[11]. The metered properties included in the MCM are:

- **New Domestics:** We have installed a meter on every new house since 1990 and charged customers on a metered tariff. These are considered to most closely represent the likely behaviour of households receiving meters under the PMP
- **Free Meter:** An old initiative where properties received a free meter and customers were charged on a metered tariff
- **Optants:** Households who have opted to have a meter fitted on their properties

Domestic water use study (DWUS) – unmeasured usage

8.78 Our DWUS dataset consists of approximately 1000 properties whose consumption is metered but they are not charged on a metered bill (i.e. they are charged as unmetered customers). This means they behave as unmetered customers. Similar to the MCM, the property type and property occupancy is known for all properties included in DWUS. The DWUS dataset is also used in our regulatory reporting to extrapolate to the unmeasured household population.

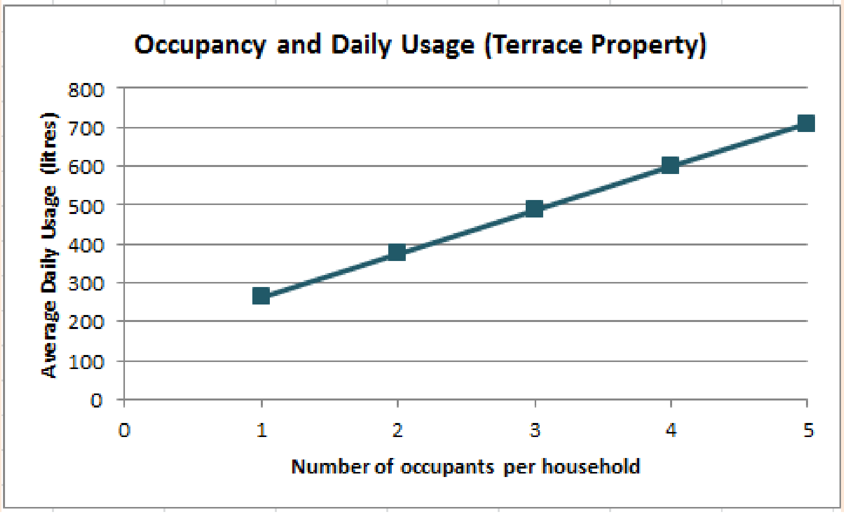
8.79 By comparing the water use for each property type between MCM and DWUS, (i.e. by comparing property metered usage with property unmetered usage), we can estimate the average usage saving made by a household when it becomes metered. Comparison and analysis between the MCM and DWUS shows that, on average, a 17% reduction occurs in customer usage when a property is metered due to behaviour changes reducing wastage (i.e. fixing small household leaks).

Why do we need to know occupancy?

8.80 Household water usage is determined by two components; personal usage and property usage. Personal usage is related to the number of occupants in a household. That is, personal usage of a household increases with the number of people living in the property. Property usage is unrelated to occupancy as it relates to base usage such as garden water usage or property wastage. This means household water usage is not only related to the number of occupants (Figure 8-5), so when modelling usage we need to understand both components.

[11] Understanding the number of people living in a property is critical to obtaining an accurate understanding of change in usage. See, '*Using Household Consumption Models to Estimate the Impact of Metering*', February 2017.

Figure 8-5: Example of the impact of occupancy on household use[12]



8.81 If we do not include occupancy we do not necessarily have an accurate or reliable comparison. That is, if we use metered properties with a high proportion of high occupancy properties, we are likely to severely underestimate the savings achieved from metering as it would appear that metered properties still use a large volume of water. Conversely, if we use metered properties with a high proportion of single or two people occupancies we are likely to severely overestimate the savings achieved by metering, as in comparison to the DWUS panel single occupancy households would use a much smaller volume of water.

8.82 Therefore, it is critical to know occupancy to ensure it is factored in to the metered consumption model to provide statistically robust results that can realistically be extrapolated to our wider area.

How has our data changed since WRMP14?

8.83 In WRMP14, it was assumed the usage savings achieved through household meter installation was 12% per property. This was based on a similar study to the revised draft WRMP19, where measured properties from the billing system were compared with data from our unmeasured consumption monitor (DWUS panel). However, in comparison with the measured data used for the revised draft WRMP19, the measured data for WRMP14 did not include occupancy. This means the risk to either overestimate or underestimate savings was inherent in this dataset.

8.84 For WRMP14, although it was known that occupancy was critical to ensure a robust and accurate assessment, we did not have occupancy data on our metered customers at this time. In transferring to a metered tariff our customers are not obliged to tell us the occupancy of their households and we do not keep these records on our billing system. Therefore, although the risk of conducting this study without occupancy was known, the data on our billing system was deemed the most accurate data available and the best we had at the time to estimate the impact of metering. It also aligned with previous studies available at the time

[12] Thames Water (2017), 'R modelling of metered households using SHV data' spreadsheet, October 2017

which indicated a saving of 10-15% from the national water metering trials conducted in the 1990s. However, this resulted in a much lower estimate of usage reduction in comparison with the subsequent study conducted for the revised draft WRMP when occupancy was known.

Benchmarking our savings

8.85 To understand how our savings compare with the water industry in the UK, we have benchmarked our 17% average usage saving against studies by Southern Water, Affinity Water and South East Water. In a report by Southampton University in February 2015, Southern Water present a 16.5%[13] reduction in usage studying over 500,000 customers from their universal metering programme. This reduction is also based on the reduction of usage from the impact of paying for the volume of water used. Similarly, studies by Affinity Water have shown a 16%[14] reduction in usage based on a 70,000 meter installation programme in Kent, South East Water has metered 90% of households during AMP6 and quotes savings of 16-18%, and Anglian Water quotes up to 15% savings.

8.86 This added to confidence that our average 17% usage saving from installing a meter was within expected bounds seen by the industry.

One year journey

8.87 To minimise the billing impact on customers, we currently implement a 'one year journey' from the time a customer has a meter installed to the time they begin paying on a metered tariff. Within this one year window, customers receive comparative bills which show the cost of water on an unmeasured and measured tariff. This incentivises customers to save water prior to being put on a metered tariff at the end of their one year journey.

8.88 This information is included in the optimisation stage of modelling so that the savings expected from household metering do not occur at the same time as a meter install but rather one year after the meter install.

Leakage reduction

8.89 When a customer has a meter fitted it will identify if there is a continuous flow of water on the property. Continuous flow is where the flow rate does not drop below a minimum consistently for a number of days. Continuous flow on an external meter indicates the customer either has a CSL on their supply pipe or wastage within their property (i.e. a leaking tap, toilet or internal small pipe leak). Continuous flow on an internal meter indicates the customer has wastage within their property.

8.90 When a property is identified as having continuous flow, it is labelled as a point of interest (POI) and our leakage teams will visit the property and prove whether there is a CSL or wastage. For the revised draft WRMP19, it is assumed that a POI is applicable when a property has continuous flow greater than 10l/hr.

[13] The UMP programme: Effects of metering, water efficiency visits and billing University of Southampton, Universits' di Bolzano in collaboration with Southern Water
[14] https://www.affinitywater.co.uk/water-saving-programme-faq.aspx

Customer side leakage

8.91 CSL reduction covers the losses within the customer's pipework on their property. It is estimated that over a quarter of our total leakage is due to CSLs. In WRMP14, CSL was considered to be part of the mains rehabilitation intervention. However, due to inefficiencies with detecting and repairing CSLs through the mains rehabilitation process together with the additional detection benefits realised through the installation of smart meters, CSL repair is considered under the metering intervention in the revised draft WRMP19.

8.92 In the revised draft WRMP19 we are also targeting smaller CSLs in comparison with our approach in WRMP14. That is, the minimum leakage level we plan to target is 10l/hr, compared with a level of 25l/hr targeted at WRMP14. This will allow us to detect and resolve the smaller leaks that may have been running unnoticed for a long period of time in addition to the larger leaks that are often easier to detect.

8.93 To model the volume of CSL, we calculate the number of properties where we expect CSL to occur throughout our area. This is based on the likely number of POIs to be raised for external and internal meters, the percentage of these POIs that can be attributed to CSL repairs and the average saving achieved from repair of a CSL for each property type. Appendix N: Metering details the numbers to calculate the POI, percentage attributed to CSL and the savings achieved per repair.

8.94 This data is based on real data collected from our PMP customers who have had a CSL detected and repaired in the last three years (Appendix N: Metering for details). The leakage deterioration rate is applied to CSL savings to account for deterioration.

Cost

Meter installation

8.95 Meter installation costs are made up of the cost to survey, install and read a meter. The cost to survey and install depends on the size and position of the meter regarding whether it is in the pavement, the soft verge or within the property. The cost of a bulk meter installation includes the cost of the meter and also the meter chamber, an extra cost against the standard rate.

8.96 The cost to install a meter internally is more expensive than an external install due to the additional time and resources required for the customer appointment facilitation. The cost to install an AMI meter both internally and externally is more expensive than for an AMR or a dumb meter due to the additional cost of the AMI meter itself.

8.97 The cost to read an AMR or dumb meter is based on the time and resource required to drive or walk by the meter respectively to collect the reading. The cost to read an AMI meter is not included on a per meter basis. This is because the cost of an AMI meter reading depends on the fixed network infrastructure and therefore does not fluctuate depending on the number of meters, unlike for AMR and dumb meters. The cost of fixed network is discussed below.

8.98 The metering costs used in the revised draft WRMP19 are based on actual costs from AMP6. These are higher than the costs used in WRMP14, due to substantial underestimates in the WRMP14 figures where overheads (i.e. running depots, travel) were not factored into the total costs. The supplier under WRMP14 also underquoted and then could not deliver the service required. We have rectified this situation by engaging a new supplier early in AMP6 to ensure we could deliver our metering programme. However, as a result there has been an increase in the costs we planned for in WRMP14.

Meter replacement

8.99 The cost to replace a dumb meter with a smart meter is based on the cost of the smart meter alone and the overheads to conduct the replacement. A replacement meter does not require the additional cost to survey or install a new boundary box. Consequently, it is cheaper to replace a dumb meter than install a new meter at a property.

Asset life and cost effectiveness of metering programme type

8.100 The asset life of a meter has been assumed to be 15 years. For AMI and AMR meters, this is the point where the manufacturer expects the battery life to cease and therefore stop the transmission of data. This assumption has also been applied to dumb meters for the purpose of the proactive replacement meter programme.

8.101 The cost effectiveness of each metering programme type has been detailed in Appendix N: Metering in relation to the comparative cost benefit of each type.

CSL repair

8.102 The CSL repair cost is based on the average CSL repair cost achieved in the first three years of AMP6.

Fixed network

8.103 The cost of the fixed network is included as one fixed cost. This is because there is a certain cost to commission and maintain further masts in both London and Thames Valley that is independent of the number of meters installed. The meters covered by the fixed network includes, all smart meters rolled out under the progressive, bulk, replacement and optant programmes.

8.104 The cost of the fixed network includes the cost to commission new masts and operate and store data each year of each AMP. That is, commissioning refers to the commissioning of the masts in London and Thames Valley. Operation refers to the ongoing maintenance costs of these masts and Head End Services (data storage) refers to the IT infrastructure to manage the real time data.

8.105 The cost of the fixed network is forecast to be much greater in AMP7 than in AMP8, AMP9 and beyond. This is due to the commissioning costs being incurred in AMP7 and the greater overhead services to complete a planned upgrade in 2020/21, the first year of AMP7. As more meters are added to the fixed network the cost per meter declines such that the average cost per meter per year is expected to be maintained beyond AMP9.

Smart Metering Operations Centre (SMOC)

8.106 The cost of the SMOC team is based on the number of meters installed each AMP. That is, once the number of household, bulk and replacement meters has been modelled, and the optant meter number confirmed, the SMOC cost is calculated based on the unit rate per meter to enable the SMOC team to monitor and follow up any issues for existing smart meter data and maintain this performance.

E. Options to reduce leakage

8.107 Leakage management consists of two predominant components:

- **Maintain:** the level of activity required to manage our existing level of leakage. This includes activity that either repairs or offsets (e.g. through maintenance of our pressure management schemes) the leakage resulting from the deterioration of our water mains. It also includes activity required to repair burst water mains and ongoing active leaks. We manage this activity in the Water Infrastructure or maintenance part of our business
- **Enhanced:** the level of activity required to go beyond this and reduce leakage further. Further reductions in leakage arise from our enhanced leakage programme which is covered by the activities in the revised draft WRMP19

8.108 Customers and stakeholders have clearly indicated they wish to see leakage reduced (Appendix T: Our customer priorities and preferences). Our ambition is to strike the right balance between our desire to reduce leakage further and the financial impact of leakage reduction on customers' bills. We also need to consider the need to maintain a robust and efficient water distribution network and the need to manage traffic congestion and household disruption that occur as a result of leakage reduction activity on our network.

8.109 Section 8.E details the source of data for the costs and benefits of options that reduce leakage: DMA Enhancement, Pressure Management, Mains Rehabilitation and AMP6 Leakage Reduction Carry Over. The constraints and confidence in delivery are outlined in Section 8.H and Section 8.I. This information is used in the optimisation phase (Section 8.G) of demand management appraisal to calculate the total leakage reduction expected from each demand management programme (Section 8.K).

8.110 Trunk mains leakage reduction has not been included in this section as it is an activity that contributes to the maintenance of our current leakage position. However, trunk mains leakage and the full details of our leakage interventions are contained in Appendix M: Leakage.

DMA enhancement

8.111 DMA Enhancement comprises two demand management interventions, DMA Enhancement and DMA Enhancement Plus (Figure 8-6).

8.112 DMA Enhancement replaces the demand management option, enhanced Active Leakage Control (ALC) that was included in WRMP14. ALC in WRMP14 referred to enhanced levels of 'find and fix' activity on top of the leakage activity being undertaken to maintain current levels of leakage. We have continued to pursue ways to improve our find and fix activity throughout AMP6, but, due to the condition of our network and volume of work we have undertaken in AMP6 (revised draft WRMP19 Section 2.0: Water Resources Programme 2016-2020), further conventional find and fix work is limited for the revised draft WRMP19.

8.113 Consequently, if we are to detect and repair enhanced levels of leakage on our network into AMP7, we need a more innovative solution. DMA Enhancement and DMA Enhancement Plus are the innovative solutions to achieve this objective and have been included in the revised draft WRMP19 to replace the traditional 'enhanced ALC' option.

DMA enhancement

8.114 DMA Enhancement is defined as improving the accuracy of leakage detection by better accounting for demand in a DMA, and then targeting particular areas with more intensive leak detection techniques.

8.115 To do this, the data that defines a DMA is checked; water supplied, water consumed and leakage. This includes looking at the number of assets, properties and expected customer water use in a DMA which can uncover anomalies in any of these areas. Corrections and improvements to these anomalies are then used to increase the data quality available regarding water supplied, water consumed and leakage in a DMA. The interaction between these components either reduces leakage directly or helps to narrow the search for leaks in a DMA.

8.116 Once the DMA has proven to be reporting leakage accurately, a range of leakage detection techniques (traditional and advanced) can be used in the DMA to find the leakage.

DMA enhancement plus

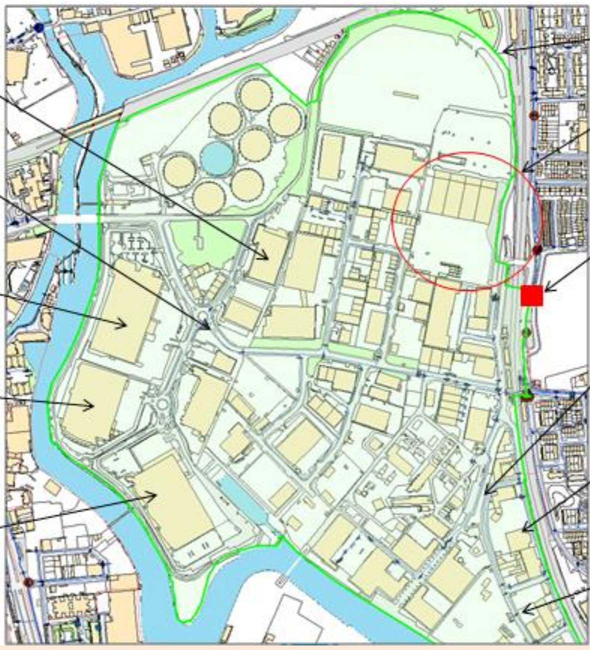
8.117 DMA Enhancement Plus combines DMA Enhancement with network reconfiguration activity. There are two parts of DMA enhancement plus; splitting large DMAs to create smaller DMAs and investigating historically 'unavailable' DMAs to make them available for leakage detection again.

8.118 DMA splitting is required because some DMAs are particularly large (> 5,000 properties or > 6 District Meters). This makes traditional 'find and fix' activity more difficult to yield leakage control results. In comparison, a small DMA has <=2,500 properties or <= 4 District Meters which makes it easier to know the water supplied, water consumed and leakage in that DMA and therefore yield much larger leakage control results. DMA splitting will involve the installation of new District Meters, valves and washouts and the provision of enabling activities including traffic management and network investigations. This work will enable more accurate targeting and efficient repair of leaks within a DMA, where before it has not been possible to find the leakage.

8.119 There are a number of DMAs that have historically been 'unavailable' for leakage detection due to inherent network configuration issues. For example, a DMA may have a broken district meter that it has not been possible to repair for a number of years because the meter is located beneath a main road on a major bus route lane. This means that the exact volume of water going into the DMA is not known for this time. To access and repair the meter requires substantial traffic management and a rerouting of the bus route. Permission to access this area may only be granted once every five years to minimise disruption to the community. Moving the meter to another location may also require additional network reconfiguration in the DMA. Consequently, the purpose of DMA Enhancement plus is to investigate and resolve these longer term issues to ensure all DMAs are available for leakage detection and repair.

8.120 Figure 8-6 provides an overview of activities undertaken in DMA Enhancement and DMA Enhancement Plus.

Figure 8-6: Typical activities included under DMA Enhancement



Leakage reduction and cost

8.121 The costs and benefits of DMA Enhancement and DMA Enhancement Plus have been derived from our DMA Enhancement trial. The DMA Enhancement trial was set up in July 2016 to test the approach, identify the tasks involved and develop the necessary processes to enable DMA Enhancement and DMA Enhancement Plus. The costs and benefits derived from this trial have been used to inform the costs and benefits applied to DMA Enhancement and DMA Enhancement Plus in the IDM model.

8.122 The leakage reduction resulting from DMA Enhancement has been derived by taking the leakage benefit delivered from DMAs currently in the trial and extrapolating it to other potential DMAs across the company.

8.123 The cost of DMA Enhancement and DMA Enhancement Plus was derived from a bottom up costing of the activities involved and the cost of each activity.

8.124 In addition to the enhanced find and fix activity, DMA Enhancement and DMA Enhancement Plus will also be a primary contributor to our ongoing programme of Smart District Metered Areas (Section 8.J.)

Mains rehabilitation

8.125 Mains rehabilitation is a long term sustainable option that involves the rehabilitation of water mains and communication pipes to achieve two objectives; maintain our existing level of leakage by preventing leakage recurrence and achieve further leakage reduction.

8.126 The objective to maintain our existing level of leakage (i.e. to prevent leakage increasing from our current level) is part of the asset health part of the business covered by the PR19 plan. To maintain our existing level of leakage we undertake activity to reduce:

- Bursts, visible leaks and active leaks on our network
- Deterioration of our network
- The number of interruptions to supply and therefore, complaints of no water or low pressure
- Interruptions to traffic and local amenities due to emergency and planned repairs

8.127 The objective to reduce leakage further is part of revised draft WRMP19. To reduce our existing level of leakage we undertake mains replacement activity.

Leakage reduction

8.128 To calculate the level of leakage reduction expected from mains replacement activity, we have considered mains replacement across four activities:

- Rehabilitate 25% of mains in a DMA
- Rehabilitate 50% of mains in a DMA
- Rehabilitate 75% of mains in a DMA
- Rehabilitate 100% of mains in a DMA

8.129 This means that during the optimisation phase, we input data into the IDM model (Section 8.G) so it can choose whether to rehabilitate all the mains in a DMA or only a portion of the mains in the DMA. For example, one DMA may provide a cost beneficial solution with 25% of mains rehabilitation and the remainder of the DMA is managed with other demand management interventions. An adjacent DMA may have limited demand management interventions available (for example, pressure management and DMA enhancement are not available and the DMA is already fully metered) and therefore the most cost beneficial solution would be to conduct 75% or 100% mains rehabilitation in that DMA.

8.130 Consideration of mains rehabilitation at a partial DMA level means we can fully optimise the demand management solutions in each DMA. This is an improvement on WRMP14 where we only considered 100% mains rehabilitation for each DMA, meaning that if a DMA was selected to receive mains rehabilitation, it could not also include any other demand management solution.

Asset Investment Manager (AIM) distribution mains model

8.131 The level of leakage reduction that can be achieved in each DMA is obtained from the output of our AIM Distribution Mains Model. This means that we use the AIM Distribution Mains Model to model the level of leakage reduction achieved from mains replacement at a pipe level. This pipe level is then grouped together by DMA and the output of the AIM model is used as an input into the IDM model to model the level of leakage reduction at a DMA or partial DMA level.

8.132 The AIM Distribution Mains Model looks at pipe condition as well as performance to ensure mains rehabilitation is targeted to deliver sustainable benefits. This means mains rehabilitation targeting is being done at street and 'superstring' level. Superstrings are pipes connected to each other of the same age, material and diameter. By analysing the performance of each pipe, those pipes within a DMA that are performing poorly can be targeted.

8.133 The output file from the AIM Distribution Mains Model is used as the input file for the mains rehabilitation component of the WRMP model optimisation (Section 8.G).

Cost

8.134 Data from our Engineering Estimating System (EES) is used to develop the cost models for mains rehabilitation. The output of the EES cost model is used as an input file for the mains rehabilitation component of the WRMP model optimisation (Section 8.G).

8.135 The cost of mains rehabilitation is modelled at DMA level and is based on:

- The size and length of main to be replaced
- The techniques required to replace the main (i.e. open cut, slip lining)
- For London, based on costed schemes by borough/cost zone models.
- For Thames Valley, based on inner city and outer city cost models.

8.136 The total cost of mains rehabilitation is made up of two predominant components, unit costs and uplifts.

Unit costs

8.137 The unit cost of replacing a pipe in a DMA is broken down by borough and zone according to the techniques required to replace the main. That is, there are different unit costs for the following activities in each borough or zone:

- Open cut installation
- Insertion
- Directional drilling
- Pipe bursting
- Communications pipe to customers
- Communications pipe to businesses

8.138 In doing this we have assumed that the proportion of open cut installation in each borough is based on the density of communication pipes. That is, a high density of communication pipes means open cut must be used, based on previous experience.

8.139 The rates per meter applied by zone are £400 to £800. The rate applied depends on whether the work will be undertaken in North London, South London, the Thames Valley city centre or the Thames Valley rural area. Both North and South London are made up of a mix of inner and outer London.

Uplifts

8.140 The complete cost to us (for both WRMP and Asset Health) includes going into some DMAs to rehabilitate short lengths of main. However, the cost per metre of replacing these shorter lengths is comparatively more expensive than replacing many streets of pipe in the one project. This is due to several fixed costs associated with mains rehabilitation such as setting up the site, organising traffic management, conducting health and safety assessments and establishing on site facilities (i.e. comfort facilities). To ensure we accurately model the costs and benefits of replacing different lengths of pipe we have included the costs to replace both longer and shorter lengths of pipe. Including shorter lengths of pipe has a minimal impact on the WRMP programme as our interventions are designed to rehabilitate a certain percentage of the DMA and consequently avoid the shorter lengths of mains rehabilitation.

8.141 In comparison with our estimates in WRMP14, the cost per meter of mains rehabilitation has increased. This is due to three factors:

- availability of cheaper areas for rehabilitation has reduced as we have targeting these cheaper areas in previous AMPs and therefore the costs are greater to work in the remaining areas
- the costs applied from councils for access and traffic management have increased
- a review of communications pipe density and short length uplift used in WRMP14 based on work completed in AMP6 resulted in updated cost models being used in the revised draft WRMP19

8.142 In addition, we have undertaken some improvement work in the revised draft WRMP19 to update our cost models so they more accurately reflect the zoning profiles in London and include actual costs of work over the previous AMP. These have been updated to revise the cost profile differentials between inner and outer London and cross check these profiles with our work to ensure they are realistic. Although this work has significantly improved the accuracy of our data it does reflect an increase in average cost from WRMP14 to the revised draft WRMP19.

Pressure management

8.143 Pressure Management refers to the reduction of excess pressure within the water mains network to reduce leakage in a discrete area. Pressure Management also minimises pressure fluctuations in the network, thereby reducing burst frequency and increasing the asset life of infrastructure in a pressure-managed network.

8.144 Pressure Management is achieved through the installation of Pressure Reducing Values (PRVs) in a discrete area termed a Pressure Managed Area (PMA). That is, a discrete area is established within a DMA by closing existing or installing new valves so that the area receives water via one or two PRVs. Each PRV in a PMA is set to deliver water at a certain pressure. The pressure being delivered by each PRV is monitored by the Critical Pressure Point (CPP) located at the highest point in the PMA. The CPP regularly feeds back to the

PRV through telemetry systems so that any change in pressure is rectified and the pressure throughout the PMA is minimised and remains constant.

Leakage reduction

8.145 The volume of leakage reduction achieved from a PMA has been modelled using data from Water Net. Water Net is a data management system that holds data for our existing PMAs whereby the average pressure reduction and resulting leakage reduction has been recorded for the life of the PMA. Water Net is our system for forecasting, calculating, reporting and monitoring leakage savings and PMA maintenance.

8.146 The total volume of pressure management available on our network in the plan period has been examined and verified internally and working in conjunction with our alliance partners. This is based on experience with AMP6 activity and includes the following assumptions:

- Greater than 5% of the DMA must have pressures higher than 35m head before a DMA was eligible for pressure management.
- The size of the PRV required and therefore the cost of the scheme is equal to the size of the largest two metered inlets (i.e. District Meters).
- The number of PRVs required is assumed to be 1 PRV per District Meter.
- The number of CPPs required is one per scheme.

8.147 DMAs with a current pressure below 30m were not considered as there are minimal leakage savings that can be achieved by dropping pressure 1-3m head. DMAs are also required to have an average minimum pressure of 25m head before they are considered for pressure management. This ensures we can continue to meet our service levels (i.e. 10m pressure and 9l/s flow at the property boundary) without an infeasible number of tall building boosters being installed. Although the legal position of water companies is unclear in this area, we have historically installed tall building boosters in PMAs to maintain supplies to tall buildings (anything above four stories) and avoid customer complaints.

8.148 DMAs with current pressure above 40m head were not considered to be reduced to 25m head due to:

- Network restrictions: areas with significantly higher pressures usually require the maintenance of the level of service.
- New developments in high pressure DMAs have often been found to have undersized pipes. When developers identify a high pressure area, a smaller bore of pipe is often considered to be a more cost-efficient development solution. Although this is the developer responsibility at construction stage, present and future customers in the supply area will be unaware of this and a significant reduction in pressure by us will cause additional costs to these customers
- Customer complaints: when pressure is reduced by more than 10% customer complaints increase to high volumes. Customers in particularly high pressure areas are used to that pressure and may be required to alter their own internal systems (i.e. pressure to attic bathrooms) to accommodate lower pressures (even if we still comply with the minimum level of service).

8.149 The total number of PMA schemes available and the leakage reduction expected from each scheme has been used as an input file for the pressure management component of the WRMP model optimisation (Section 8.G).

Cost

8.150 The cost to implement PMAs is based on our EES Cost Models. The output of the EES cost model is used as an input file for the pressure management component of the WRMP model optimisation (Section 8.H). This includes the cost of:

- Butterfly Valve – strategic valves only;
- Data Controller - PRV configuration;
- PRVs - configuration 1 (On bypass);
- PRV - configuration 2 (Inline);
- Tall building boosters; including the assumption that there is a 12% conversion rate from survey to install for Tall Building Boosters. i.e. 12 out of 100 surveys result in a tall building booster installation.
- Ongoing maintenance Opex.

8.151 In the revised draft WRMP19, we have also included a cost to maintain the benefits from pressure management beyond 20 years by maintaining the infrastructure. This is an improvement on WRMP14 where we assumed a pressure management scheme would provide no further benefit to leakage reduction at the end of its asset life of 20 years.

AMP6 Leakage reduction carry over

8.152 In the revised draft WRMP19, an additional leakage reduction option, ‘AMP6 Leakage Savings Carry Over’ has been introduced in year 1 of AMP7. That is, leakage in April 2020 is expected to be 21 Ml/d lower than the leakage in April 2019. This leakage reduction is applicable to year 1 of AMP7 at no additional cost to the programme.

8.153 Section 8.0 explains the source of the 21Ml/d AMP6 Leakage Carry Over.

F. Options to reduce usage

8.154 Section 8.F details the source of data for the costs and benefits of options that reduce usage; Water Efficiency, Non-potable water usage and Innovative Tariffs. The constraints and confidence in delivery are outlined in Section 8.H and Section 8.I. This information is used in the optimisation phase (Section 8.G) of demand management appraisal to calculate the total usage reduction expected from each demand management programme (Section 8.K).

Water efficiency

8.155 Water efficiency is a core component of the sustainable management of water resources. Water efficiency has received strong support from our customers as a priority only second to leakage reduction. The UK Government has also set out its aspiration to achieve a reduction in water use and support for measures to promote the efficient use of water[15].

8.156 We agree with our stakeholders, customers and the Government, that water efficiency is critical to the sustainable management of water resources. To date we have considered 56 different options to promote the efficient use of water as part of the Demand Management Options Screening Process[16]. These options have been broken down into Baseline Options (Section 3) and Feasible Options. Baseline options are the activity that we undertake to promote the efficient use of water and ensure we deliver our statutory duty to promote water efficiency and develop and maintain an efficient and economical system of water supply. The options that form part of our baseline are discussed further in Section 3 and Appendix O: Water efficiency.

8.157 Feasible Options are options that promote the efficient use of water above the baseline activities and promote a level of water efficiency activity greater than the baseline activity to deliver a larger reduction in customer usage. The feasible water efficiency options are optimised in IDM to be included in the demand management programmes.

8.158 The Water Efficiency feasible options are categorised into five areas:

- Smarter Home Visits (SHVs)
- Smarter Business Visits (SBVs)
- Wastage Fix (‘Leaky Loos’)
- Housing Association Fix
- Incentives

8.159 There is a sixth area, Intensive Area Based Media Campaigns that has not been included in the IDM optimisation but that has been included in our overall preferred plan. This has been included in our revised draft WRMP19 to facilitate more widespread campaigns across our whole supply area.

Smarter home visit

8.160 A SHV comprises a free in-home visit by one of our qualified staff to install water saving devices and provide personalised water savings advice to households. It includes an App which our in-home advisors use to produce a tailored water savings report for every customer that helps our customers quantify their potential water, energy and money savings. SHVs are the most intensive and face-to face communication we have with our customers about water use across our entire customer base.

[15] Water For Life, Defra, December 2011
[16] Thames Water (2017), ‘Thames Water WRMP19 Demand Management Options Screening Report’, March 2017.

8.161 SHVs are offered to both measured and unmeasured customers, with a focus that complements our rollout of smart water meters. A SHV can be applied to five different property types:

- newly metered properties
- existing metered properties
- unmeasured properties
- replacement metered properties
- bulk metered properties

8.162 Two of these categories, replacement metered properties and bulk metered properties are new for the revised draft WRMP19, representing innovation in future water efficiency opportunities.

8.163 The usage reduction achieved by implementing an SHV in each of these categories is based on data collected from over 100,000 SHVs conducted since 2015.

Newly metered (PMP smart metered) properties

8.164 The benefit used in IDM for conducting a SHV on a newly metered property is 37 litres per property per day. This saving represents a further 6% saving in addition to the 17% saving achieved by installing a smart meter (Section 8.D).

8.165 This figure is based on the water savings seen from our PMP customers who have received a SHV in AMP6. The analysis was carried out on 112,428 properties that received an SHV between September 2016 and November 2017. We commenced our IDM modelling in January 2018 so this was the most up to data dataset at that point in time.

8.166 We have used data since September 2016 to coincide with our new water efficiency saving devices which are more effective than those used prior to this date and therefore more likely to give an indication of future water savings. The five months prior to September 2016 (from April 2016 when we conducted our first smart metered SHV) have not been used as this early sample is not considered representative of the programme.

Uncertainty analysis – PMP and newly metered SHVs

8.167 Although this figure of 37 litres per property per day accurately quantifies the water savings achieved from a newly metered SHV, it may underrepresent the full benefit of undertaking a Smarter Home Visit. That is, more recent data for the period between June and November 2017 indicated that a Smarter Home Visit could achieve up to an average of 52 litres per property per day.

8.168 The higher figure was not used in IDM to ensure we were conservative in the prediction of future benefit. Also, there were some properties in the 112,428 property sample that were not yet paying on a metered tariff. This means there was a risk that these customers had not yet made all the changes we would expect from households once they pay for a metered bill. In the latter instances the SHV could have expedited the process rather than adding such a significant degree of additional benefit. Consequently, the figure of 37 litres per property per day was considered to be a more reliable and conservative figure to accurately represent the savings achieved from a newly metered Smarter Home Visit in the longer term.

8.169 To ensure we understood the impact of the Smarter Home Visit and benefit from paying on a metered tariff on an overall demand management programme, we undertook an uncertainty analysis around the usage benefit from PMP and the usage benefit from a newly metered SHV. This means we optimised the IDM model with both a 17% reduction and a 15% reduction in usage (i.e. to account for any potential double counting with the newly metered SHV) to account for any crossover between the metering and water efficiency interventions.

8.170 This uncertainty analysis between the two optimisations showed that the demand management programme with a 15% reduction applied to metering has a total usage saving 3Ml/d lower than the demand management programme with a 17% reduction applied. Due to the size of the overall programmes developed in the revised draft WRMP, a 3Ml/d difference was considered immaterial.

8.171 To improve our understanding of the impact of PMP usage and SHV usage reductions we will continue to monitor our customers on the PMP and update this data throughout AMP7.

Existing metered (dumb) properties

8.172 The benefit obtained by conducting a SHV on an existing metered property is 11 litres per household per day.

8.173 This figure is based on the analysis carried out on 7,836 properties which had received a SHV since 2015 and who were already paying on a metered tariff (on a dumb meter). The savings achieved by existing metered households are significantly lower than that of a newly metered household as there were a high proportion of optants in the existing metered sample. Customers who opt to have a meter installed tend to use less water prior to the meter installation in comparison to the average property.

Unmeasured properties

8.174 The benefit obtained by conducting an SHV on an unmeasured property is 25 litres per household per day.

8.175 This figure is based on analysis in comparison with DWUS data to determine water savings of unmeasured households having smarter home visits. Since unmeasured customers have been proven to use more water and therefore have the potential to achieve more savings, the final figure of 25 litres per property per day is considered the more conservative position.

Bulk metered (smart metered) properties - dwellings

8.176 Conducting a smarter home visit on a dwelling in a bulk metered property is a new demand management option for the revised draft WRMP19. This involves targeting dwellings within Small Blocks of Flats and Large Blocks of flats for a smarter home visit.

8.177 The benefit obtained by conducting an SHV on a dwelling in a bulk metered property is 15 litres per household per day.

8.178 Since this is a new option, this saving is based on expert judgement that the benefit will be close to that expected for an existing metered SHV. The additional 4 litres per property per day has been added due to the ability for Thames Water to use the bulk smart meter data to identify additional wastage savings on shared assets of a block of flats.

8.179 Although, these dwellings are considered unmeasured customers, on account that the bulk meter has been installed for CSL detection purposes and each customer remains on an unmeasured bill tariff, the savings assumed for this option have been based on the savings for an existing metered SHV to be conservative.

Replacement metered (smart metered) properties

8.180 Conducting a smarter home visit on a property with a dumb meter replaced to a smart meter is a new demand management option for the revised draft WRMP19.

8.181 The benefit obtained by conducting an SHV on a replacement metered property is 15 litres per household per day.

8.182 Since this is a new option, this saving is based on expert judgement that the benefit will be close to that expected for an existing metered SHV. The additional 4 litres per property per day has been added due to the ability for the customer to benefit from new smart data and associated longer term water efficiency engagement, using smart meter data.

Smarter business visit

8.183 The SBV initiative is similar to an SHV in that a qualified representative attends the business to assess where they can make improvements to their discretionary water usage by installing water saving devices, fixing internal leaks (wastage), converting toilets to dual-flush and installing urinal controls.

8.184 Although, following the introduction of non-household market competition in April 2017, we are no longer a retailer to business customers, businesses in our supply area make up a significant proportion of our demand. Consequently, we will still carry out water saving activities to business customers within our supply area to ensure the long term security of supply.

8.185 The benefit obtained by conducting an SBV on a business property is, on average, 1,316 litres per property per day. This information is based on the pilot study conducted throughout AMP6 where over 350 SBVs were conducted between April 2017 and November 2017. We commenced our IDM modelling in January 2018 so this was the most up to data dataset at that point in time. We will continue to monitor the savings achieved throughout AMP6 and into AMP7.

8.186 Figure 8-7 illustrates our leaflet to promote the activities carried out under our SBV.

Figure 8-7: Smarter Business Visits leaflet

Wastage fix ("leaky loos")

8.187 This is a water efficiency option specifically for free internal leak fixes (i.e. leaky loos and leaking taps). Following a collaborative UK water sector research project, and a parallel Thames Water initiative, it was found that 'Leaky loos' are one of the most common causes of high water use, but often go unnoticed or just left leaking. Our smart meter data and research shows that leaky loos can lose between 100 and 2,500 litres per day, often more than doubling a metered water bill. Consequently, we have devised our wastage fix programme to specifically target this usage.

8.188 The benefit obtained by conducting a wastage fix is, on average, 212 litres per household per day.

8.189 The wastage savings applied under the wastage fix option are predominantly due to the repair of 'leaky loos'. This saving was proven in the Fixed Network Trial whereby 12% of toilets were found to be severely leaking, 67% moderate and 21% minimal. On average, this equated to a saving of 405 l/day per repair. Factoring in the properties where there were no obvious savings, this equated to an average of 212 l/day saved per 'leaky loo' repair which is the average saving applied in the IDM model.

Housing association fix

8.190 We are working with local authorities, housing associations and other types of housing organisations to promote water efficiency advice to their residents This includes water efficiency retrofitting schemes, access to our specialist 'TAP app' water and energy saving calculator and app, and providing content for resident communications.

8.191 The benefit obtained by conducting a Housing Association Fix is 20 litres per property per day. This has been updated from our draft WRMP which was 15 litres per property per day. This updated assumption is based on updated data that shows our housing association visits were matching our weighted average (of metered and unmetered) smarter home visit savings.

8.192 This is based on our analysis of Housing Association Fix data from AMP6 which measure benefits from the installation of water saving devices and repair of wastage issues in Housing Association Properties.

Water efficiency costs

8.193 The cost of Water Efficiency options can range between £20 and £400 per visit/fix dependent on the activity required. This is based on the actual average cost to conduct Water Efficiency visits and wastage fixes since 2016.

Intensive area based media campaigns

8.194 Intensive area based media campaigns includes both large-scale baseline awareness raising and intensive marketing campaigns targeting specific locations throughout our supply area. Such full-time awareness raising and campaign work would help increase the public understanding of water resources, water efficiency and assist the take-up of specific water saving initiatives.

8.195 Intensive area based promotional campaigns are critical to ensuring a long term behavioural change and facilitate ongoing communications regarding all water efficiency activity streams.

8.196 We are currently trialling an intensive area campaign in Oxford. In Spring 2017 we set the scene about water resources and explained that there was the same amount of water for a growing demand. Our campaign, based around the message ‘more people, less water to go around’ included local advertising channels, comprising posters, press, digital advertising, radio, plus targeted door drops.

8.197 For autumn 2017 we have continued on from the Spring campaign to show there is no substitute for water to help customers really value water (Figure 8-8). This provides a solid base to encourage people to be water smart and demonstrate the collective benefit of communities taking simple actions.

Figure 8-8: Intensive media campaign poster for Oxford

8.198 The pre and post-campaign market research to date has shown very positive reactions to the campaign and proven that it has helped raise awareness of the water issues that we face.

We will continue to collect data about the impact of these campaigns to determine the quantitative impact on water saving. This information, together with the cost is included in the revised draft WRMP19 to facilitate more widespread campaigns across our whole supply area.

Water efficiency benefits over time

8.199 The life of water efficiency devices supplied by an SHV, SBV or Housing Association Fix has been assumed to be seven years. This deviates significantly from the assumption made in WRMP14 that water efficiency devices had a half-life of seven years based on the Waterwise evidence for large scale water efficiency in homes. This change has been made in response to a greater dataset available for the revised draft WRMP19 which has shown that water efficiency devices require rehabilitation much sooner than originally anticipated. Therefore, to ensure an accurate representation of Water Efficiency benefits, the life of water efficiency devices has been reduced to a total of seven years for the revised draft WRMP19.

8.200 The life of water efficiency behavioural change has also been reduced in comparison with WRMP14. That is, in WRMP14, it was assumed there was a half-life of 10 years for behavioural changes in response to water efficiency. This has been revised to a total life of seven years. This means that the repeat frequency for SHVs, Housing Association Fixes and Wastage Fixes has been assumed to be seven years for the revised draft WRMP19.

Water efficiency uptake rate

8.201 The uptake rates for each water efficiency activity are based on the Water Efficiency Programme Uptake throughout AMP6. Table 8-1 summarises the rates applied to each water efficiency option in the IDM model.

Table 8-1: Water efficiency uptake rates

Water Efficiency Activity	Uptake Rate
SHV - newly metered properties	33%
SHV - current metered properties	23%
SHV - unmeasured properties	20%
SHV - bulk metered properties	20%
SHV - replacement metered properties	33%
SBV - non household properties	13%
Wastage Fix - measured and unmeasured properties	5%
Housing Association Fix - Housing Association Properties	20%

8.202 For an SHV, the higher uptake by newly metered properties is because these newly metered customers are offered an SHV as part of the meter installation. Customers are more likely to take up an SHV offer when they have the convenience of a meter installation and SHV in the one appointment. This is based on data collected for all SHVs between January and July 2017.

8.203 Throughout AMP6 SBVs have been taken up at a rate of 13% across non-household properties based on data collected from January 2016 to January 2017. However, we have been targeting twelve specific cohorts of business within their area of supply meaning this assumption cannot be entered into the IDM model and applied to all non-household properties. Instead, the model assumes 13% of businesses within each cohort within each DMA receive a SBV. This does slightly limit the potential volume of SBVs in the longer term. However, with the introduction of the Non household retail market this is considered a realistic and achievable application of the potential SBV volume for the revised draft WRMP19.

8.204 For a Wastage Fix, the percentage uptake is based on the assumption that 1 in 20 properties across our supply area had a 'leaky loo'. This is based on the results of investigations during the installation of a new meter, the findings during SHVs between January 2016 and July 2017 and the evidence obtained from the Fixed Network Trial.

8.205 For a Housing Association Fix, the uptake rate has been based on access rates to housing association properties from January 2016 to July 2017.

8.206 With the exception of SHV – bulk metered properties and SHV – replacement metered properties, all uptake rates are based on uptake rates from properties in water efficiency activity since January 2016. The uptake rate of SHV – bulk metered properties has been assumed to be that of SHV – unmeasured properties based on the dwellings of a bulk metered property being unmeasured for billing purposes. The uptake rate of SHV – replacement metered properties has been assumed to be that of a SHV – newly metered property as replacement metered properties will receive the same communications when they are fitted with their smart meter as properties in the PMP programme.

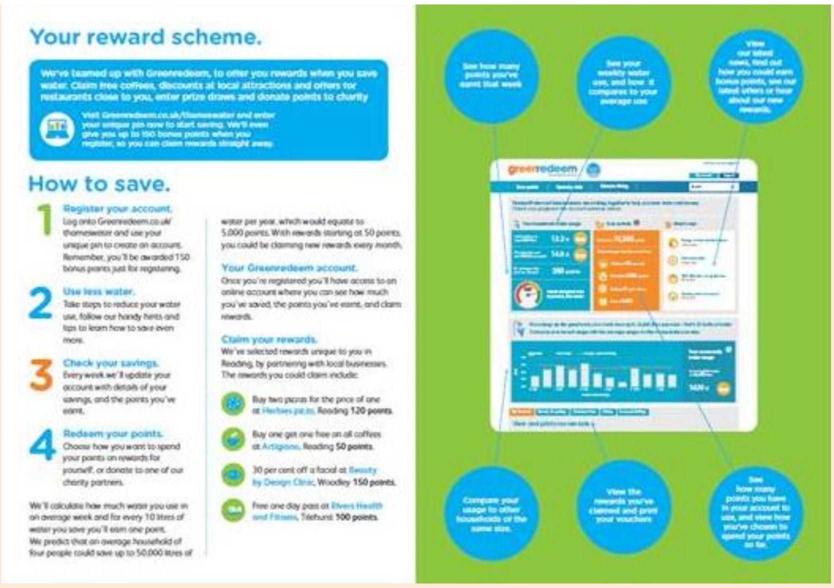
Incentives

8.207 The Incentives Programme is a scheme whereby customers are incentivised through non-financial offers (vouchers, prize draws, community rewards) to be more efficient with their water consumption. It works by incentivising customers to use less water through the awarding of points that can be exchanged for money-off vouchers, charity donations, prize draw entries and days out. We provide water reduction targets for customers based on their current usage and award points that may differ depending on whether they reach their water saving target, whether they sustain the reduction in water usage and or whether they exceed their target.

8.208 The incentives programme works in a similar way to financial tariffs with the main difference being that the incentive scheme does not directly affect customers' bills. We will not need to obtain a high level of meter penetration prior to implementing the scheme as there are no negative impacts on customers' bills. The scheme aims to influence customers' behaviours through offering positive rewards as opposed to the imposition of negative dis-benefits.

8.209 The costs and benefits for the incentives scheme have been based on the results of our trial scheme launched in Reading in Autumn 2016 (Figure 8-9). The Reading incentives programme was developed in partnership with Greenredeem, a recycling reward specialist with more than 5 years' experience in managing incentives. The trial involves offering this scheme up to 3,000 homes which are part of the smart metered fixed area network in Reading (Appendix O: Water Efficiency).

Figure 8-9: Greenredeem leaflet to customers as part of the incentives trial



8.210 The results achieved from these homes and the costs to roll out the programme have been used to inform the optimisation of Incentives Programme in IDM for the revised draft WRMP19. Current results show that customers are saving up to 2% of household water through this scheme. Of those homes that were offered the scheme, 24% of properties signed up. However, due to the small sample size (3,000 properties) of this trial and considering the rollout of this scheme across our entire area, we have reduced the uptake rate used in IDM to 1.2% of applicable households (i.e. households with a smart meter) to ensure we don't overestimate the savings.

Non-potable water

8.211 Non-potable water is water that is not of drinking water quality, but that can be used for other purposes such as toilet flushing, laundry and garden watering to reduce the total demand on potable supply. We have engaged Arup consulting to undertake an assessment of the non-potable water opportunities that are available within our area. The full details are in Appendix L: Water reuse.

8.212 There are three main components that have been considered in the non-potable schemes:

- rainwater harvesting
- stormwater harvesting
- greywater recycling

Rainwater harvesting

8.213 Rainwater harvesting refers to the collection of rainwater from property roof surfaces or freestanding collection vessels for reuse on site. Application of rainwater harvesting provides a substantial benefit for both water supply and wastewater in that it reduces the demand on the potable water system, decreases the volume of storm water that enters the sewer system and minimises storm water runoff polluting freshwater bodies.

8.214 Rainwater from roof surfaces is the least polluted source of non-potable water and requires minimal treatment prior to reuse. In most circumstances only physical treatment systems such as filtration are required. However, to guarantee the health of building occupants, and minimise the risks from cross contamination, the rainwater harvesting options that we assessed also include chlorine dosing for disinfection.

Stormwater harvesting

8.215 Stormwater harvesting refers to the collection of storm water from pedestrianised and road surfaces for reuse on site. It also refers to the collection of water from other urbanised environments such as parks, gardens and playing fields.

8.216 Stormwater has a higher pollutant load than rainwater and requires both physical and chemical treatment. To manage the risk to public health, we have assessed these options using greywater reuse systems.

Greywater recycling

8.217 Greywater refers to the relatively clean waste from baths, bathroom sinks and showers that can be collected in a central system and then treated for reuse in households and offices.

8.218 Greywater recycling systems can be installed at individual building level within a development or as a network between buildings. Greywater is treated using both physical and chemical treatment on site to a standard that can be reused for non-potable purposes.

Non-potable water and future innovation

8.219 The schemes that have been considered in the revised draft WRMP19 demand management programmes are made up of a combination of all three non-potable components. Due to the high cost of non-potable water options, the IDM optimisations did not select non-potable water for inclusion in the demand management programmes.

8.220 However, due to the support within the water industry to explore non-potable water opportunities and Thames Water’s direction to drive future innovation in demand reduction management, an allocation of 0.52 Ml/d per AMP has been included in the London demand management programmes for non-potable water. This will support our direction to explore emerging technologies and practices to achieve long term, sustainable reductions in demand management.

8.221 The outcome of our AMP7 programme for non-potable water will be monitored and quantified to inform our plan in WRMP24.

Innovative tariffs

8.222 The imposition of tariff or pricing controls can be an effective strategy for water demand management if the water rate structures contain strong incentives to conserve water. This view is supported by behavioural economic theory that indicates that consumers may respond to economic incentives by assuming behaviours that maximise their economic self- interest. Tariff charging can be implemented by reforming water rates, introducing surcharges or establishing penalties to deter high water or wasteful water usage practices, and encourage consumers to conserve water. However, tariff strategy with respect to water management has not been adopted in the UK mainly because it requires a high level of metering which may have significant financial impact on low income households of above average size.

8.223 We had previously planned to undertake variable tariffs trials in AMP6 with the aim of introducing them early in AMP7. Due to our AMP6 relatively low level of meter penetration and views expressed by customers during customer focus groups, we will not consider the introduction of Innovative Tariffs until the 2030's when it is expected we will have at least 65% meter penetration.

8.224 To understand and quantify customers' response to alternative tariffs and different communication approaches, as well as helping to understand the logistics, systems and technology requirements and costs of implementing tariffs, we have undertaken two studies:

- a desk based review of tariffs which have been trialled and adopted internationally[17]
- an assessment of innovative charging options for Thames Water[18]

8.225 Based on these studies, for the revised draft WRMP19, we have assumed a 5% reduction of measured household consumption with the introduction of tariffs in 2035. This has been introduced when meter penetration is planned to be much greater than 65% to ensure fairness to our customers.

G. Optimisation

8.226 In Sections 8.B and 8.C we explained the screening and evaluation process used to determine the feasible demand management options. In Section 8.D to Section 8.F, we detailed the costs and benefits associated with each feasible demand management option to assess the value of each option independently of one another.

8.227 Section 8.G. describes the final step in the demand management options appraisal process, optimisation of the feasible options to produce a range of demand management programmes.

Purpose of optimisation

8.228 The purpose of evaluating the feasible demand management options (Figure 8-4) is to provide cost and benefit data to appraise them with the supply options and develop our preferred water resources management plan. However, if we attempt to evaluate each

[17] RPS Literature Review, October 2017
[18] Review of Innovative Tariff Options, Nera, April 2015

demand management option against the supply options individually, we cannot deliver a deliverable or reliable programme. This is because on average demand management is cheaper than the supply options but, individually, the demand management options do not supply as much water to meet the supply demand deficits in AMP7. Therefore, the demand management options are developed into demand management programmes so they can be more accurately appraised against the supply options.

8.229 A demand management programme consists of a suite of demand management options to achieve a certain level of demand reduction in each AMP period. There is a wide range of demand management option interventions that could be put together in a large variety of potential programmes. For example, if we wanted to create the most cost effective demand management programme, it follows that we would predominantly make this up of the lower 'cost to benefit achieved' options (i.e. water efficiency and pressure management) rather than pursuing more expensive cost benefit options (i.e. mains rehabilitation).

8.230 However, simply selecting for the cheapest demand management options does not take account of the limitations to deliverability and availability. It also doesn't consider the additional benefits of combined options (i.e. following the installation of a meter with a water efficiency smarter home visit), the changing cost of schemes as they become more difficult to implement or the geographical scale of demand management. Consequently, not only must we develop demand management programmes but we must develop *optimised* demand management programmes (Section 8.G).

8.231 Section 8.H details the limitation on deliverability and constraints employed in the modelling process for each demand management option.

Integrated demand management (IDM) model

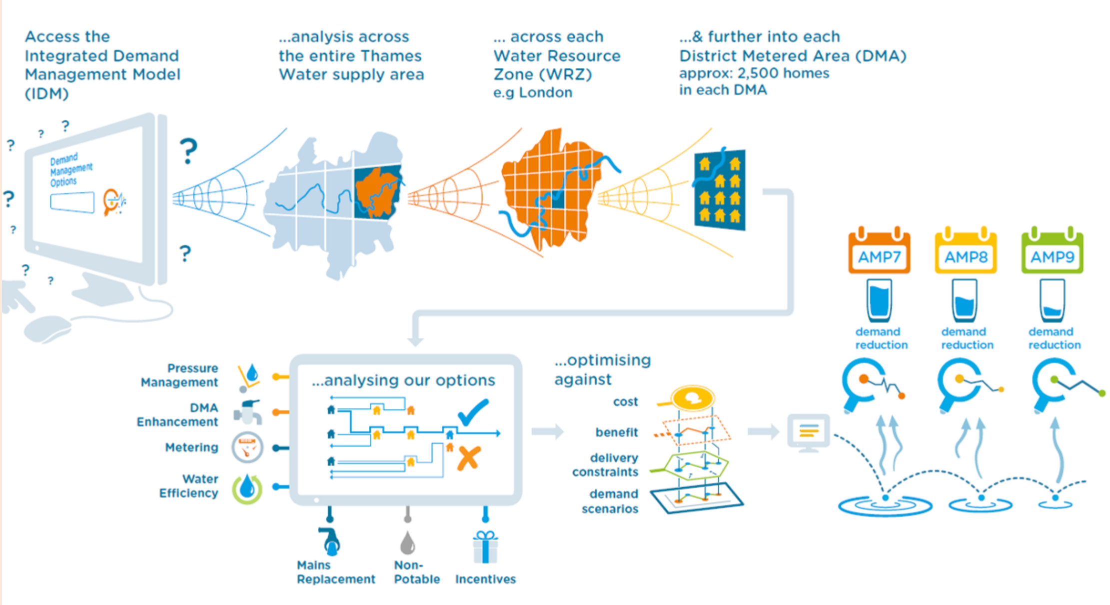
8.232 IDM is the optimisation modelling process we use to develop cost efficient demand management programmes. We do this using an optimisation tool called the IDM model. This involves appraising the overlapping costs and benefits of options that can be promoted in combination, in addition to evaluating each option individually. It also involves looking at the optimised combination of interventions for each DMA and assessing the deliverability constraints.

8.233 For example, considered independently, there is a fixed cost to install and read a meter at a customer's property. The benefit achieved is a reduction in usage and CSL. However, when metering is promoted in conjunction with a Water Efficiency Smarter Home Visit (SHV), whereby the customer receives free water efficiency devices and a plumber assisted audit, the benefit achieved is greater, for a minimal additional cost.

8.234 Furthermore, traditionally it has been the case that only one demand management activity could be allocated to each DMA. However, using IDM, more than one demand management option can be allocated to a DMA to provide an optimal water saving solution. In this way, the IDM model can produce a range of optimised demand management interventions in any DMA and in as many DMAs as is required.

8.235 The IDM model process encompasses three phases: data input, optimisation and programme outputs (Figure 8-10).

Figure 8-10: IDM process



Data input

8.236 All data inputs are made at the beginning of the process represented by the IDM model computer screen in Figure 8-10.

- **DMA inputs:** The IDM model is based on a GIS representation of our water network. This information is derived from our below ground asset register. This provides a list of DMAs and the physical attributes of the network within those DMAs. Background data relating to the number and distribution of properties, plus leakage, water usage and wastage in the DMA, forms the base data in the model. This information is sourced from our company asset register, Netbase, used in the daily running of the business
- **Feasible options:** The costs, benefits, availability and delivery constraints of the feasible demand management options are inputs into the model. Section 8.C provides an overview of these parameters and Sections 8.D to 8.F provide specific details of the data used in the model and the source of this data
- **Scenarios:** The IDM model produces an optimised set of demand management interventions to achieve a specified target. By specifying a range of different demand management requirements, a range of different demand management interventions can be generated for comparison with water resource options as potential solutions to remove the supply demand deficit

8.237 The specific scenarios input into IDM to derive our range of demand management programmes are detailed in Table 8-2 in Section 8.K.

Optimisation

8.238 Once all the data have been input to IDM and the deliverability constraints set (Section 8.H), IDM can be set to optimise. IDM will search for a minimum whole life cost demand management programme over the 15 year planning period specified. IDM conducts this optimisation at DMA level. This process is illustrated in Figure 8-10. The optimisation is conducted by reference to multiple parameters including cost, demand benefits and programme delivery constraints to produce demand management programme outputs.

8.239 Appendix N: Metering includes the detail behind this optimisation in IDM.

Programme outputs

8.240 The output of IDM is a range of optimised demand management programmes. Each programme represents the most cost efficient combination of demand management interventions for the demand scenario specified. The demand management programme can be broken down into the demand reduction it delivers per AMP.

8.241 Sections 8.K and 8.J summarise the demand management programmes that have been produced for the revised draft WRMP19.

Accounting for mains deterioration: changes between the draft and revised draft WRMP

8.242 For the revised draft WRMP, the IDM model optimised the demand management options to achieve a reduction in leakage. This leakage reduction is over and above that required to manage leakage deterioration (i.e. leakage that occurs as the infrastructure deteriorates), which is part of the capital maintenance part of the business.

8.243 In comparison, for the draft WRMP19, the IDM model optimised the demand management options to achieve both a reduction in leakage and to manage leakage deterioration. This meant that for the draft WRMP19, IDM identified the level of mains rehabilitation required to manage leakage deterioration, and, the level of mains rehabilitation required to reduce leakage further.

8.244 The reason for the change in the approach is due to the degree of modelling done in both the IDM model, and, a separate model, known as the AIM Distribution Mains Model (AIM)[19]. The purpose of the AIM model is to determine the level of mains rehabilitation required to manage leakage deterioration (i.e. the leakage to manage as part of the capital maintenance part of the business).

8.245 Both the IDM and AIM model utilise the same leakage costs and benefits. However, the AIM has pipes as the relevant assets in its base data whereas IDM has DMAs as its main base scale. In addition, the AIM model optimises to also reduce bursts, interruptions to supply, low pressure and the level of unwanted calls. This allows the distribution mains model to provide for mains rehabilitation on individual pipes, groups of connected pipes or at a whole DMA level to achieve these benefits.

8.246 In the draft WRMP19, the volume of mains replacement activity that is required to manage leakage deterioration (as determined by the AIM model), was included in the IDM model to ensure the most cost beneficial mains infrastructure was not targeted in both the IDM and

[19] The change in the degree of modelling was due to the decision to move from a 9% leakage reduction to 15% leakage reduction. This resulted in a substantially larger range and degree of demand management programmes for the revised draft WRMP19.

Distribution Mains Model. This would happen because the two models could potentially select the same pipes or DMAs to replace (i.e. the most cost/beneficial) therefore underestimating the total cost and length of mains rehabilitation required. To prevent this occurring, we included the leakage deterioration requirement in the IDM model, and at the demand management programme output stage (Section 8.H), we removed the mains rehabilitation required to manage leakage deterioration so only the enhanced programme was presented (note: the mains rehabilitation to manage leakage deterioration will be held within the Asset Health section of the overall price review).

8.247 For the revised draft WRMP19, a wider range of scenarios was modelled in IDM to reflect the business commitment to achieve more ambitious leakage reductions in future planning periods. In modelling these higher demand reduction scenarios, it was proven that modelling both deterioration and enhanced mains rehabilitation was not feasible in later AMPs.

8.248 Consequently, for the revised draft WRMP19, IDM was updated to consider the enhanced component of mains rehabilitation only. To eliminate the issue of IDM targeting the same, most cost beneficial DMAs as the AIM Model, the most cost beneficial DMAs were not input into the IDM model. This meant that the DMAs available for IDM to optimise in the enhanced programme did not include the most cost beneficial DMAs that had already been selected by the AIM model to manage deterioration.

H. Delivery and modelling constraints

8.249 Section 8.H specifies the modelling constraints used in IDM to reflect the practical delivery of the demand management programmes.

8.250 That is, in the absence of any constraints on the model, IDM will select the most cost beneficial demand management options first and leave the more expensive options for later AMPs. This is because we ask IDM to find the most cost beneficial demand management programme over the modelling period (15 years). This means it will ‘use up’ the cheaper options before selecting the more expensive options. For example, without constraints, IDM will select to meter the majority of properties and undertake water efficiency activity in the first AMP. It will then leave the more expensive options such as mains replacement and non-potable water sources to later AMPs. Not only does this pose a risk to the reliability of the overall programme (i.e. it relies heavily on a reduction in customer usage and does not include a significant reduction in leakage in earlier AMPs) and relegates some innovative solutions such as non-potable water to much further in the future, it also poses a risk to the deliverability of the programme.

8.251 To minimise the risk of delivery failure, we have constrained some areas of work in each AMP. These constraints have been determined following discussion with our delivery teams. For example, to ensure the continued quality roll out of the metering programme across all water resource zones including excellent communications with each of our customers, we have constrained the level of metering that can be undertaken in each AMP in IDM. In this way, we have ensured that the final demand management programmes reflect a practical level of delivery for each individual demand management option that is included in the programme.

8.252 The constraints used in IDM and the explanation for each constraint, are detailed in the following subsections; Demand Reduction, Metering, Options to reduce leakage and Options to reduce usage.

Demand reduction

8.253 To produce a range of demand management programmes, we specified the level of demand reduction required in each AMP in IDM. For example, in one scenario we would specify that IDM must optimise to achieve a 50Ml/d demand reduction in AMP7, 40Ml/d demand reduction in AMP8 and 10Ml/d demand reduction in AMP9 to give a total demand reduction of 100Ml/d over 15 years. By comparison, a different scenario would request 100Ml/d demand reduction in AMP7, 80Ml/d in AMP8 and 40Ml/d in AMP9 to give a total demand reduction of 220Ml/d over 15 years.

8.254 The minimum level of demand reduction specified for each WRZ was:

- London: 80 Ml/d demand reduction in AMP7 and no further demand reduction in AMP8 and 9. This was based on the minimum level of demand management required to meet the AMP7 supply demand deficit in combination with small supply options.
- SWOX: 2.3 ML/d demand reduction in AMP7 and no further demand reduction in AMP8 and 9. This was based on the minimum level of demand management required to meet the AMP7 supply demand deficit.
- Guildford: 2.1 Ml/d demand reduction by the end of AMP8 and no further reduction in AMP9. This was based on the minimum level of demand management required to meet the AMP8 supply demand deficit.
- SWA: 1 Ml/d demand reduction by the end of AMP9 based on the minimum level of demand management required to meet the AMP9 supply demand deficit.
- Kennet Valley and Henley: between 0.5 – 2Ml/d in by the end of AMP9 based on a reasonable minimum level of demand management for these WRZs in the absence of any supply demand deficit up to AMP9.

8.255 Using the minimum level of demand reduction as the base, IDM optimised for incrementally higher demand management programmes in each WRZ.

8.256 In total, 90 demand management programmes were created across the 6 WRZs. These were input into EBSD Plus to be assessed against the supply options (Section 10: Programme appraisal).

Metering

8.257 To confirm the deliverable level of metering, we needed to determine three points:

- Maximum number of meters possible
- Level of metering in our most cost effective demand management programme
- Deliverable level of metering in each AMP

8.258 These points were confirmed by optimising IDM for each scenario. These optimisations were done using the input data specified in Section 8.D relating to the type, quantity, benefits and costs of metering.

Maximum number of meters

8.259 To determine the number of meters that could be installed across our area, the IDM model was run unconstrained. This means that we did not put any demand constraints on the model, and instead told the model to achieve its maximum meter penetration based on the input data to the model(i.e. the 'internal and external split' and 'survey to fit' information, Section 8.D).

8.260 The results of the unconstrained IDM run showed that we could install just above 1 million household meters across our area from AMP7 onwards. This does not mean that every house will be metered but rather this is the level of metering physically achievable at reasonable costs based on the survey to fit information we had provided. It is possible that in future AMPs, as we improve our survey to fit ratio (e.g. find ways to access more customers with shared supplies and make it easier to access customers, especially those resistant to a smart meter, and fit a meter); the maximum number of meters could increase. This is something we will continue to work on over the planning period for review and incorporation into WRMP24.

Cost effective level of metering

8.261 To determine whether it was cost effective to undertake metering in comparison to the other demand management options, we ran IDM with constraints on total demand but no constraints on metering. This allowed the model to choose between metering and all other demand management options.

8.262 The results of this showed that, due to the cost effectiveness of metering, IDM chose to achieve almost full meter penetration by the end of the modelling period (i.e. by the end of AMP9 in 2034) for every demand scenario.

8.263 Using London WRZ as an example, the most cost effective programme included between 600,000 and 680,000 meter installations in AMP7 with the remaining meters (up to 190,000) being installed across AMP8 and AMP9. This showed that due to the low cost of metering relative to other options to achieve the expected benefits, it is cost effective to undertake the majority of metering at the beginning of the planning period. This leaves the meters that are more difficult and more costly to install until AMP8 and AMP9. In AMP8 and AMP9, in comparison with the other demand management interventions, they then become more cost effective.

Deliverable level of metering

8.264 Although the cost effective level of metering indicated up to 680,000 meters could be installed in AMP7 in London, we consider the level of risk around deliverability of this number of meters to be too high to adopt this programme in our plan.

8.265 The reasons for this are based on our AMP6 performance (Section 2: Water resources programme 2016-2020). We do not believe our teams can increase the rate of successful meter installations and remain cost effective by the beginning of AMP7. That is, there is an optimal level of metering which is the most cost effective. Too little metering and the cost per meter increases due to significant overheads. However, a significantly larger programme can also reduce in cost effectiveness due to inherent inefficiencies in delivery. Therefore, we need to plan for the most cost efficient delivery of meters in AMP7.

8.266 Also, for each demand scenario we set a limit on the level of demand the model needs to find. Since metering is cheaper than other solutions, the model will choose to do a majority of metering in one AMP at the expense of more costly but lower risk solutions (i.e. mains rehabilitation). This means we would be reliant on reducing our leakage level through finding and fixing a large volume of CSLs rather than a more balanced mixture of CSL fixes and mains rehabilitation. If we do not achieve the required CSL reduction, there is a risk we will not deliver the total demand savings required to meet the supply demand deficit in AMP7. In addition, metering becomes more difficult with time as we are required to do more internal installs and the external installs that remain unmetered are more difficult (i.e. not previously VMR areas or require permits to access the pavement). We have therefore spread our delivery risk across a number of demand solutions and over three AMPs.

8.267 Our teams can increase their performance over time to achieve a higher level of successful meter installations. Consequently, we have determined that an ambitious but realistic metering programme includes the constraints set out in Figure 8-11.

Figure 8-11: Metering Delivery Constraints

Type of Metering	Constraint
Household Meters	Up to 421,000 installations in each AMP. This aligns with our total meter installation programme to deliver just over 1 million household meters by the end of AMP9.
Replacement Meters	Up to 130,000 installations in AMP7 with an increase to 260,000 in subsequent AMPs.
SBF Bulk Meters	Up to 35,000 installations in AMP7 with no constraint on subsequent AMP's
LBF Bulk Meters	Up to 2,500 installations in AMP7 with no constraint on subsequent AMP's

This level of metering allows for a balanced mix between metering and other demand management solutions to achieve an acceptable delivery risk score for the overall demand management programme.

Options to reduce leakage

DMA enhancement

8.268 The available volume of DMA Enhancement across our area has been constrained to 30Ml/d in AMP7 and 20Ml/d in AMP8. We have not planned to undertaken any new DMA Enhancement schemes from AMP9 onwards but instead will invest in the maintenance of savings achieved from AMP7 and 8. This has been done to ensure we achieve the benefit from DMA Enhancement in early AMPs and minimise the uncertainty risk in further AMPs.

8.269 Since DMA Enhancement is a new option for the revised draft WRMP19, we have limited our commitment in AMP7. That is, the total leakage reduction we expect to achieve from DMA Enhancement is 50Ml/d by carrying out activity in 675 DMAs. To ensure we plan for a realistic and achievable target in AMP7, we have constrained the AMP7 leakage reduction from DMA Enhancement to 30Ml/d with the remaining 20Ml/d to be achieved in AMP8.

8.270 Although DMA Enhancement has a 'low' cost benefit in comparison to other demand management interventions, we considered it a high risk of delivery failure to plan to complete all 50Ml/d benefit in AMP7. We have used our lessons from the AMP6 DMA Enhancement trial to assess the approach, processes and tasks involved to achieve this leakage reduction to determine the optimum level of DMA Enhancement for AMP7 should be increased from the very limited constraint imposed in the revised draft WRMP19, to an ambitious but deliverable constraint which achieves just over half of all potential savings in AMP7.

Pressure management

8.271 We have a long history of implementing pressure management throughout our area. This means that opportunities for further pressure management in the next planning period are limited, but not yet exhausted.

8.272 There are two components to pressure management: pressure management to offset water network deterioration (asset health) and pressure management to achieve a leakage reduction (WRMP19). Due to the limited areas remaining that are available for pressure management, there is also a limited volume of pressure management that can be assumed for future planning.

8.273 In the PR19 plan we have assumed a portion of the available pressure management schemes across our area will contribute to offsetting water network deterioration. The remaining volume of pressure management available has been assumed to achieve a leakage reduction for WRMP19. Consequently, in the optimisation phase of demand management options appraisal, pressure management has been limited to AMP7 and London only as we will have exhausted all pressure management opportunities across our area by 2024. From AMP8 onwards, all pressure management activity will be to maintain the benefits achieved from pressure management schemes previously installed.

8.274 This is a significant reduction compared with WRMP14 but it emphasises the work we have already conducted in this area over previous planning periods.

Mains rehabilitation

8.275 Mains rehabilitation has one of the highest cost benefit ratio (second only to non-potable interventions) demand management options available in IDM. This means that, in earlier AMPs when all demand management options are available, IDM will select the cheaper demand management options in preference to mains rehabilitation. In later AMPs when IDM selects larger volumes of mains rehabilitation, the deliverability is managed by the total demand constraint. Consequently, mains rehabilitation has not been constrained in IDM for the revised draft WRMP19.

8.276 In comparison, for the draft WRMP19, mains rehabilitation was constrained to ensure the model chose a minimum number of mains rehabilitation each AMP. The benefits achieved from this minimum number of kilometres contributed to the Water Infrastructure (maintenance) side of the business rather than the WRMP. If the IDM model optimised to include additional mains rehabilitation above this minimum, then the benefit achieved from the additional kilometres of mains rehabilitation became the enhanced demand management programme for the draft WRMP19. This was done to ensure the deterioration of our network was considered reliably and the cost of mains rehabilitation was not underestimated. However, since IDM has been updated to only take account of the enhanced or WRMP19 demand management programme, this constraint is not necessary in the revised draft WRMP19.

Mains rehabilitation cost over time in the IDM model

8.277 The degree to which the IDM model optimises to include an enhanced mains rehabilitation programme depends on the availability and cost comparison of other demand management interventions and the total demand that has been requested in each AMP. For example, in AMP7, when all demand management interventions are available, IDM will optimise to only include enhanced mains rehabilitation where required because it is more expensive than the other interventions. However, in AMP8 and AMP9 as the other demand management interventions decline (i.e. there is no further Pressure Management or DMA Enhancement available and fewer new meter installations) IDM will optimise to include a higher proportion of enhanced mains rehabilitation activity. This is despite the cost of mains rehabilitation becoming increasingly expensive with each AMP.

8.278 To understand the relationship of mains rehabilitation costs over time, we optimised the IDM model for mains rehabilitation only. This showed that in the early part of the plan (AMP7), mains rehabilitation costs were cheapest as the model selected areas that were located in cheaper zones and had lower levels of communication pipes (i.e. to reduce the level of open cut activity required). As time progressed and we had undertaken the more cost effective rehabilitations, IDM selected areas with slightly more expensive mains rehabilitation costs (e.g. inner South London areas with slightly higher communication pipes numbers). Then, as that cost band of mains rehabilitation was completed, IDM was left to select the much more expensive mains rehabilitation.

8.279 The relationship of mains rehabilitation costs over time is also reflected in the Thames Water Mains Replacement Programme Independent Review[20]. This states that in the period to

[20] Black and Vetch, Chandlers KBS, GL Water, 2012, 'Thames Water Mains Replacement Programme Independent Review, Findings and Recommendations Report', Thames Water Utilities to Ofwat, July 2012

2010, we achieved an average leakage saving of 1Ml/d for each 12km of mains rehabilitated. Based on the projections in our final WRMP for 2009, amended and submitted to Defra in March 2012, the leakage savings associated with mains rehabilitation were projected to reduce to 1 Ml/d for approximately 13km of mains replaced for the period 2010-2015 and 1 Ml/d for approximately 33km of mains rehabilitated for the period 2015-2020.

8.280 This relationship is particularly significant in our ambition to reduce leakage further. We ran IDM for multiple scenarios to explore the cost and range of activities required to meet specific levels of leakage reduction. In all scenarios, in order to achieve a much higher leakage reduction, IDM optimised for a significant degree of enhanced mains rehabilitation which significantly increased the costs of the demand management programme, sometimes to prohibitive levels. This cost increase is due to the significant increase in cost of mains rehabilitation. These programmes have contributed to our final list of programmes (Section 8.J) that will be optimised against the supply side solutions in EBSD plus.

Options to reduce usage

Water efficiency and incentives

8.281 The Water Efficiency interventions are one of the most cost beneficial demand management options available in the IDM model. This means that when left unconstrained, IDM will choose to conduct as much water efficiency activity as possible.

8.282 However, due to the connection between an SHV and the level of metering, the volume of SHVs that the IDM model will select depends on meter penetration. This is because the number of SHVs that can be conducted on newly metered properties is dependent on the number of properties which become metered. Therefore, due to the modelling constraint that we will carry out up to 420,000 meter installations across our area per AMP, the number of SHVs to a newly metered property is also limited.

8.283 Smarter Business Visits (SBVs) have been constrained to up to 12Ml/d benefit across our supply area. This is because a SBV is a relatively new demand management option being undertaken in AMP6 with the added constraint of our business customers being moved to another entity. This means we don’t have direct access to billing our business customers and therefore, there is some risk to delivery of these savings in the longer term. Consequently, although SBVs are a cost efficient water efficiency solution, they have been constrained to ensure the planned savings are realised.

8.284 There are not constraints on Wastage Fixes and Housing Association Fixes. However, due the to mix of constraints applied for all demand management options in the model, there is a limit on the number of these water efficiency options. This together with the limit on metering and therefore SHVs, means the size of the water efficiency programme chosen by IDM is less than it would have been without the modelling constraints.

8.285 Since these constraints are required to ensure we develop a deliverable and reliable programme, this consequence is accepted. However, due to the substantial and widespread customer support, the long term educational value and the high cost benefit of our water efficiency interventions, it is plausible to opt for an enhanced programme above that chosen by IDM for water efficiency. This is something to be considered within the business as we further develop our preferred programme.

Non-potable water

8.286 Non-Potable water has the highest cost benefit ratio of all demand management options available in IDM. This means that, in earlier AMPs when all demand management options are available, IDM will select the cheaper demand management options in preference to non-potable water. In later AMPs when IDM starts to select non-potable water options, the deliverability is managed by the total demand constraint. Consequently, non-potable water has not been constrained in IDM for the revised draft WRMP19.

Tariffs

8.287 Tariffs have not been included in the IDM model as they are not applicable until AMP10, when the metering programme is complete. The application of tariffs has been discussed in Section 8.J: Long Term Demand Management.

I. Confidence in delivery

8.288 Sections 8.D to 8.F presented the costs and benefits expected from the implementation of each feasible demand management option and Section 8.H detailed the constraints used in the modelling process to ensure the deliverability of the demand management programmes.

8.289 Section 8.I details the basis for confidence in the delivery of demand management options that make up a demand management programme. This section also outlines the influence of lessons from AMP6 in informing the confidence in delivery for AMP7 and beyond.

Metering

Usage reduction

8.290 Section 8.D. described the metered consumption model to confirm the 17% average usage savings expected from household metering.

8.291 This dataset used in the metered consumption model was considered our most realistic and robust dataset to date and therefore a reliable prediction of usage savings that will be achieved from household metering. The four predominant foundations for this confidence are:

- **Savings decay is captured**. The data used in the metered consumption model includes a proportion of customers who had been paying on a metered tariff for up to 27 years. This was deemed to be more representative of the long term impact of customers paying on a metered tariff and would also take into account any potential decay in savings over time. As a result, we have assumed the 17% benefit will be sustained throughout the planning period.
- **The 17% is conservative and therefore lower risk of not being realised.** The data used is based on customers using a dumb rather than a smart meter meaning the savings achieved would be lower than that expected from a smart meter. Dumb

meter customers were used in the metered consumption model because a significantly large portion of customers on a smart meter where the property type and occupancy is known is not yet available. This dataset of smart metered customers is expected to be available as more customers are metered throughout AMP7.

- **Occupancy is known.** The metered properties all had a Smarter Home Visit in 2015 and therefore their occupancies were accurately recorded. Occupancy is the only information used in the metered consumption model that was obtained during the SHV (i.e. consumption after the SHV was not included in the metered consumption model to ensure it only included data on customer behaviour in response to being charged on a metered tariff). This means the savings derived by the metered consumption model are accurate and are not an over or underestimation of household use due to incorrect or absent occupancy figures.
- **The impact of Optants has been removed.** When unmeasured households opt to have a meter, on average they use water more carefully than other metered customers. This risks artificially increasing the savings achieved by having a meter. To ensure this risk is mitigated, the impact of optants is removed from the metered consumption model.

8.292 The dataset used in the metered consumption model is also considered to provide an underestimate of usage savings. This is due to two factors:

- The properties used in the metered consumption model were customers who had taken up an SHV (because these are the only metered customers for whom we have occupancy information – note that the meter readings after an SHV were **not** included). However, the 'Comparison of Households accepting and not accepting Smarter Home Visits'[21] study showed that customers who chose to have an SHV had a higher usage prior to their visit than customers who chose not to have an SHV. This means that the customers used in the study had not saved as much water by being on a meter as the customers who rejected a smarter home visit. Consequently, we may be potentially slightly underestimating the total usage savings by being on a meter
- As mentioned above, we have taken the lower end of the 95% confidence band around the 19% central estimate of savings. Although the study author recommended the 19% figure as more representative, we have chosen at this stage to apply the 17% figure in our IDM modelling to be conservative in our benefits and this percentage figure is more aligned with savings seen by other water companies, e.g. South East Water who quote figures of 15-18%

Monitoring our savings in AMP7

8.293 To continue to verify our metered consumption model, we will be targeting the customers who first entered our smart meter PMP for a SHV. Unfortunately, due to the extended adjustment period or 'two year journey' afforded to all customers on our PMP there was not a population far enough through the journey to assess as part of the metering consumption model that informed the revised draft WRMP.

[21] Cocks R, July 2017, 'Comparison of Households Accepting and not accepting Smarter Home Visits', Thames Water

8.294 To ensure these customers can verify our metered consumption model, we will be targeting customers who have completed their two year journey for a SHV. This will be done to confirm the occupancy of these properties since our billing system does not hold this information. We expect the first customers of the smart meter PMP to complete their two year journey in the summer of 2018 when they convert to a metered bill. Once they have received an SHV and we can confirm their occupancy, these customers can contribute to the metered consumption model used to verify meter usage reductions.

8.295 This monitoring will be in addition to the monitoring conducted by the SMOC team. Throughout AMP7, the SMOC team will continue to monitor meter data on a daily basis and follow up potential leaks and damaged meters. Previously, with traditional or 'dumb' metering technology, this would not have been possible and issues would only have been picked up reactively at the twice biannual meter readings.

AMP7 delivery based on AMP6 lessons

8.296 In WRMP14 we forecast that we would install 441,270 household meters, however, following an optimisation of the different metering programme types, delivery for the remainder of the AMP was revised to a programme of 300,000. The reduction in household meters was due to the higher than expected number of attempted internal meter installations in flats and converted houses which share supplies. A higher volume of properties requiring an internal installation, particularly in London, meant that the total cost of metering increased as the mix of installations changed from predominantly external to predominantly internal in the areas of London that were being targeted by the PMP programme.

8.297 Internal installations are at a higher cost because of the additional cost to get in touch with customers, book an appointment and the high rate of failure due to the customer not being at home for the time of that appointment. Internal installations also have a higher risk of being unmeterable due to communal water supplies and pipework being inaccessible. This incurs an abortive cost and also leads to poor customer satisfaction.

8.298 In response to these lessons from AMP6, planning for AMP7 has included varying the property mix we plan to meter which directly impacts the installation mix. That is, in addition to our household metering programme, we will be targeting bulk meters to minimise the disruption and risk of failure from internal installations on dwellings within flats. Shifting the short term focus from many internal installations to few shared supply installations (for leakage detection purposes) will also allow time for internal metering technology to evolve that would reduce the volume of properties deemed unmeterable, and subsequently moved on to an assessed household charge which is applicable for unmeterable properties.

8.299 Additionally, successful methods of customer engagement have prompted us to implement a multi channelled customer journey that utilises text messages, emails, and online appointment booking to secure appointments to complement with a higher tariff for customers who refuse to engage with us. This improved method of customer communication has resulted in us installing more than 10,000 meters per month in 2017. Consequently, we are confident that using this method of customer communication we can maintain and exceed this level of installation in AMP7.

Collaboration with energy companies

8.300 We are currently in discussions with two of the big six energy companies to understand whether we can collaborate on our smart meter roll outs. This includes smart meter installation through to how we use the data. Discussions are still in early stages and we need to understand how this could work including the differing skill set between plumbers and electricians. A big difference in the energy roll out is that customers already have a meter and they are being upgraded; for our customers they are going from no meter to a smart meter. Also energy retailers are not geographically rolling out meters in the same way Thames Water are rolling out a street by street installation programme and energy meters are predominantly external, which doesn't require an appointment or a customer to be in to carry out the install. Energy retailers have customers throughout the UK based on the customer selection of retailer, which does make collaboration and timing slightly more challenging. In the meantime, we are focussing our communications to customers that saving water also saves energy. We are clear that our free smarter home visits can help our customers to save water, energy and money from their bills and our online water energy calculator also supports with this messaging.

Vulnerable customers

8.301 Some of our customers will see an increase in their bill after the meter is installed. To manage this 'bill shock' we allow customers one year to switch over to a metered bill. For the first three years of AMP6, we allowed customers two years before switching to a metered bill. During this time, we use smart meter data to write to customers after three months, six months and one year to let them know what their metered bill is likely to be compared to their current bill based on the rateable value of their home.

8.302 The meter reads are also being used by our online customer platform 'my meter online', to populate daily usage graphs allowing customers to log in online regularly and view their water use. Educating our customers on how much water they use, when they use it and how they can reduce it is a hugely important part of our programme. All homes who receive a smart meter as part of our progressive metering programme will be offered a free smarter home visit, to help them save water, energy, and money.

8.303 Additionally, we continually communicate our affordability offering to customers through our metering journeys and literature, this includes setting up regular and manageable payment schemes, our social tariffs WaterSure and WaterSure plus, and grants. Our teams are also trained to identify customers who may be eligible for extra support, including our extra care services, and are able to refer these customers at any time. Through our Smarter Home Visits, we also undertake benefits entitlements checks where appropriate.

Options to reduce leakage

8.304 Section 8.E presented the costs and benefits expected from the implementation of each demand management option to reduce leakage; DMA Enhancement, Pressure Management, Mains Replacement and AMP6 Carry Over Leakage Reduction. Section 8.D detailed the costs and benefits expected to achieve a reduction in leakage from the repair of CSLs on newly metered properties. With the exception of the AMP6 carry over leakage reduction and the enhanced nature of DMA Enhancement above our current practice of Active Leakage Repair (ALC), the options to reduce leakage in our WRMP19 are identical to those being undertaken in AMP6.

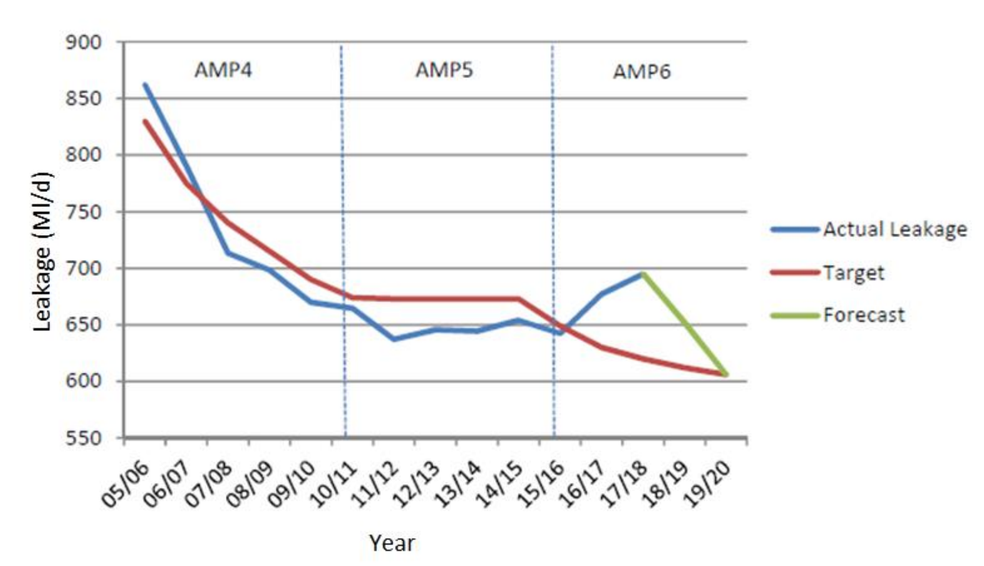
8.305 It follows that our confidence in delivery of future leakage reduction programmes is consequent upon our understanding of our ability to deliver leakage reductions in previous AMPs. Specifically, we have analysed and learnt from our performance in AMP6 where, in 2016/17, we missed our leakage target for the first time in 11 years.

8.306 Given this missed target, we acknowledge the views of some stakeholders that planning such large leakage reductions in the future is high risk. Nevertheless, we consider that we can manage and mitigate that risk in this and future plans.

Historical performance

8.307 Leakage reduction has historically been a key element of our WRMP to manage the balance between supply and demand. Since our peak leakage in 2003/04, we have reduced total company leakage by 30% and consistently delivered against our leakage targets from 2005/06 until 2016/17 (Figure 8-12).

Figure 8-12: Leakage reduction performance against target



8.308 Throughout AMP4 (2005-2010), we achieved our leakage reduction target through the implementation of a large mains replacement programme which delivery over 400km of replacement each year. This was supported by a programme of new pressure management schemes and a proactive plan to detect and repair leakage on both the distribution mains and trunk mains network. Large levels of find and fix activity continued to manage leakage recurrence.

8.309 In AMP5 (2010-2015), we predominantly maintained the low level of leakage achieved in AMP4 as we did not plan to significantly reduce leakage in this period. That is, company leakage was reduced by 2% in this AMP period. In this period, mains replacement expenditure was reduced to maintain asset condition only, smaller PMA schemes were implemented as the larger schemes had been delivered in AMP4 and work continued on find and fix activity to manage leakage recurrence.

8.310 In AMP6 (2015-2020), we committed to deliver an ambitious leakage reduction of 59Ml/d or 9% of total company leakage. This was driven by the supply demand position in London. WRMP14 detailed this reduction would be achieved through a combination of mains replacement, pressure management, repair of CSLs from newly metered properties and enhanced find and fix activity through better understanding of leakage using new smart meters. However, in 2016/17, we exceeded our target level of leakage by 46.8Ml/d, the first time we had missed our leakage target in 11 years (Figure 8-12)

8.311 Although we forecast the AMP6 leakage position will be recovered by 2019/20 (Figure 8-12), we understand the cause of our early AMP6 mistakes and incorporate these measures into the WRMP19 to ensure a high confidence level of delivery for our leakage plan in AMP7 and beyond.

AMP6 insight

8.312 In AMP6, the environment in which we managed our water network changed significantly. This was due to three factors; internal policies, internal structural arrangements and external pressures.

Internal Policies

8.313 For the duration of AMP6, we have focussed on keeping customers in supply as we fix leaks and bursts. In contrast, in previous AMPs we would consistently isolate customers' supply to conduct all repairs. To keep customers in supply during a repair requires a high level of internal planning that requires communication coordination between multiple departments and field resources. At the commencement of AMP6, we were not sufficiently equipped to execute this level of planning and consequently failed to undertake many planned repairs.

Internal Structural Organisation

8.314 Commencing in AMP6, we formed a new partnership alliance (the Infrastructure Alliance) to encourage better, smarter and more collaborative working. It was expected that this alliance would embed proficiently and provide company efficiencies within the first year of operation. Unfortunately, the alliance proved more complex than expected and consequently it resulted in inefficiencies in leakage detection and repair in terms of volume and time of repair for years 1, 2 and 3 of AMP6.

External pressures

8.315 Throughout AMP6, we have had increasing pressure from the Highways Authorities regarding street access to carry out repairs. This is in response to their increasing pressure to keep London moving whilst undertaking major infrastructure projects including the cycle super highway, Crossrail and HS2. Combined with our internal structural issues for planning, this has resulted in a lower level of planned repairs being undertaken.

8.316 In order to address the shortfall of repairs during the first three years of AMP6, we have a detailed leakage recovery plan in place which addresses these issues. We have also committed additional funding for further detection and repair, including the use of more advanced technologies, further pressure management and optimisation and more investment into improving understanding and accounting for water use which draws heavily on the increasing numbers of smart meters being installed in AMP6. This is all supported by improved governance, clearer accountability and reorganising the delivery model with the detection and repair service providers. This recovery plan sees us meeting our leakage target in 2019/20 to ensure we are back on track for AMP7.

AMP7 delivery based on AMP6 insight

8.317 AMP6 insight identified three main factors for our performance in the first three years of the AMP. These are being rectified in 2017/18 by undertaking the following actions:

- Governance and accountability returned to Thames Water from the Alliance Partners.
- New organisational design for the water networks team. The reorganisation clarified key activities in water networks in relation to other internal departments and clearly defined the governance and accountability roles that had been returned to Thames Water from the Alliance Partners.
- Internal processes embedded as part of the water networks organisational restructure to more effectively work with external stakeholders and coordinate work.

8.318 In addition, we are currently implementing the following enhancements:

- Better data: improved quality and speed with continual improvement from the field
- Better analysis: real time and dynamic analysis to identify and diagnose leakage issues and in some instances predict leakage through better joining of datasets
- Reduced unproductive field activity through better leakage targeting
- Well skilled field teams consistently supplied with the right information and the right tools
- Network assets being adequately maintained to meet service requirements and system health diagnostics that ensure assets are replaced at the end of their usable life.
- Ongoing optimisation of pumping regimes and network reconfiguration to meet growing customer demand whilst managing network pressures
- Deployment of permanent acoustic loggers to continuously monitor and highlight leaks as they occur, resulting in faster repairs and a reduced leakage detection resource effort.

8.319 These activities are moving us from the traditional approach of leakage reduction where we aimed to return DMAs to their historical level of leakage to our improved approach to leakage reduction where we will challenge the historical levels of leakage and where possible, drive DMA leakage lower.

8.320 In addition to AMP6 lessons, we have introduced some innovative ideas to drive leakage reduction into the future including:

- Progress our vision of a Smart Water System which will have multiple benefits including the identification of leakage patterns. In AMP6, we have installed many of the foundational sensors, meters and technology infrastructure required and developed pilots to help us learn and develop our thinking for future leakage detection and repair.
- Continue to transform our existing approach for detection and repair to drive efficiency. For example, satellite, gas detection, improved predictive algorithms as well as implement Exec Vac one dig technology.
- Continue to research the condition of our pipes and fittings and the modes of failure that lead to leakage to improve our targeting and ensure the investments we make drive the best customer value.

8.321 The combination of our understanding of historical leakage performance, the actions implemented to identify and rectify our AMP6 issues and the innovative ideas to drive leakage reduction in the future supports the high level of confidence that we can significantly reduce leakage in AMP7 and beyond as part of WRMP19.

8.322 Throughout AMP6, we have shown that in the instance of missing our leakage target early in and AMP, we have analysed, identified and rectified our errors to recover our position to deliver to our original leakage target.

The impact of weather

8.323 The winter of 2017/18 saw a significant freeze/thaw event which may become more frequent in the future. This event resulted from network infrastructure, rather than water resource availability issues. The resilience of Thames Water, water resource infrastructure to freeze/thaw events, as well as other factors such as flooding, is addressed through our resilience plans within the wider PR19 Business Plan. Continued investment in the network through AMP7 will improve resilience to such non-drought hazards in the future.

8.324 As part of the WRMP approach we have included a level of uncertainty against the benefit of each option, including leakage benefit. This is included in the overall headroom and protects us against a level of underperformance in the event of extreme weather events. We have also included a few smaller supply options to further protect our security of supply.

8.325 In advance of WRMP24, work will be completed to investigate the probability of freeze thaw events occurring simultaneously with a dry year. This will determine whether such an event falls within, or outside of the probabilities of resilience trends considered and planned to within the revised draft WRMP19. At this time we consider this is outside of a 1 in 200 year event but our future analysis will confirm this.

J. Long term demand management

Creating an 80 year demand management programme

8.326 Section 8.G describes the IDM model and the optimisation process to produce demand management programmes. This optimisation occurs over 15 years, or until the conclusion of AMP9 (2034/35).

8.327 To determine our long term ambition for demand management, we must optimise our demand management options over an 80 year period. This section describes how our 15 year optimised programme is developed into an 80 year demand management programme.

8.328 Figure 8-13 displays the relative cost benefit value of each demand management option that is optimised in the IDM model. It also shows the time step of each option and when that option will no longer be available. An option is no longer available either because we have run out of areas to implement that option, or, we have completed the roll out of that demand management intervention.

8.329 Figure 8-13 shows that, at the conclusion of the 15 year IDM optimisation, 7 of the 15 demand management options remain; CSL fixes from SBF bulk meter installations, Mains rehabilitation, Innovation, Financial tariffs, Non-potable water sources and Water efficiency and Incentives.

Figure 8-13: Availability of Demand Management Options each AMP

Demand Management Option	Relative Cost Benefit	Availability						
		AMP7	AMP8	AMP9	AMP10	AMP11	AMP12	AMP13
Metering								
Household	Medium	✓	✓	✓	✗	✗	✗	✗
Bulk - SBF	Medium	✓	✓	✓	✓	✗	✗	✗
Bulk - LBF	High	✓	✓	✓	✗	✗	✗	✗
Replacement	High	✓	✓	✓	✗	✗	✗	✗
Innovative Tariffs	Very Low	✗	✗	✗	✓	✗	✗	✗
Options to reduce leakage								
AMP6 Carry Over	No Cost	✓	✗	✗	✗	✗	✗	✗
DMA Enhancement	Medium	✓	✓	✗	✗	✗	✗	✗
Pressure Management	Medium	✓	✗	✗	✗	✗	✗	✗
Mains Rehabilitation	High	✓	✓	✓	✓	✓	✓	✓
Innovation	High	✗	✗	✓	✓	✓	✓	✓
Options to reduce usage								
Water Efficiency - Household	Low	✓	✓	✓	✗	✗	✗	✗
Water Efficiency - Business	Low	✓	✓	✓	✗	✗	✗	✗
Water Efficiency - Innovation	Low	✓	✓	✓	✓	✓	✓	✓
Incentives	Low	✓	✓	✓	✓	✗	✗	✗
Non-Potable	Very High	✓	✓	✓	✓	✗	✗	✗

8.330 To create the 80 year demand management programme, the relative cost benefit of each of these options was assessed and, similar to the IDM optimisation, the most cost beneficial options were included in earlier AMPs (e.g. AMP10) and the least cost beneficial options included in later AMPs. This means that high levels of usage options were added in AMP10 and 11, and then, as this ran out, more mains replacement was added to later AMPs (AMP12 to 14).

8.331 This process, together with the IDM model outputs were combined to produce a range of 80 year demand management programmes that were input to EBSD plus (Section 10: Programme Appraisal).

Demand management in the longer term – Policy Position

8.332 Section 8.I detailed the confidence in delivery of each demand management option that comprises our demand management programmes. However, in response to customer expectations and National Infrastructure Commission (NIC) requirements, our programmes include particularly ambitious targets for leakage and PCC in the longer term.

Leakage reduction

8.333 Within the development of our plan we have taken account of customer and stakeholder preferences and guidance. Customers have stated a preference for leakage reductions before moving to supply options. Defra have also provided guidance to Ofwat ('The Government's strategic priorities and objectives for Ofwat', September 2017, Defra) that states a need to 'promote ambitious action to reduce leakage and per capita consumption'. Further to this the National Infrastructure Commission (NIC) report recommends continued reduction in leakage to 50% by 2050 and full metering coverage in the 2030's ('Preparing for a drier future', 2018).

8.334 Due to these policy decisions, a large number of our demand management programmes include the provision to meet these higher leakage reductions.

8.335 To develop demand management programmes that included a 15% leakage reduction in AMP7, IDM was set to optimise for a higher demand management reduction in AMP7 as per the constraints detailed in Section 8.H. This meant that IDM was left to optimise different demand management options that would achieve a 15% leakage reduction in AMP7. This commitment aligns to customer preference to reduce leakage before supply options, and stakeholder expectation.

8.336 To develop demand management programmes that included both the 15% leakage reduction in AMP7 and the 50% leakage reduction by 2050, those IDM demand management programmes that achieved the 15% reduction were combined with the 15 to 80 year programmes that included the 50% leakage reduction. The 50% leakage reduction was achieved by combining cheaper demand management options such as CSL savings from Small Bulk Meters with Innovation in Leakage reduction and more traditional mains replacement (Figure 8-13).

8.337 Section 11 specifies the demand management options that make up the 15% leakage reduction in AMP7 and 50% leakage reduction by 2050 in our preferred programme. The confidence in delivery of each of these demand management options is detailed in Section 8.I.

Per capita consumption (PCC)

8.338 PCC targets will drive the direction of available demand reduction options from AMP7 onwards, such as metering, water efficiency, customer engagement campaigns, customer propositions and partnership projects.

8.339 To develop our reduction in customer usage, IDM was set to optimise for various demand management reductions over the planning period. IDM selected to implement metering, to achieve a customer usage reduction and, a selection of water efficiency options. The water efficiency options input into IDM are based on options that we currently implement in AMP6. This gives us confidence in their delivery and achievable benefits.

8.340 However, we also recognised there was opportunity to be more ambitious with our customer usage reductions. Consequently, to enhance customer usage reductions, specifically in AMP7, we included further water efficiency activity in the form of innovation. This innovation is based on our work with other water companies through the Water Efficiency Network, our role within the UK Water Efficiency Strategy Steering and Leadership Groups, and our efforts during the 2017/18 'heatwave'. Potential areas of demand reduction innovation to be considered could include; non-potable supply options, alternative water supply options for large irrigation users, innovative engagement through partner digital platforms, and working closely with Defra on water labelling.

8.341 To develop our longer term reduction in customer usage, further innovative water efficiency activity was included from AMP10 onwards together with the introduction of Tariffs in AMP10 (Figure 8-13). Tariffs have only been included once the metering programme is complete at the conclusion of AMP9.

8.342 Section 11 specifies the demand management options that make up the reduction in customer consumption in AMP7 and in our longer term demand management programme.

8.343 We have also reviewed the Artesia PCC study commissioned by Ofwat. This tests reductions in PCC down to 50l/p/d. We are reviewing the same study in detail for our own region. It is our belief, aligned to views given back to the recent government 25 year Environmental Review[22] , that water companies will need assistance to achieve lower PCC. This will require support with such things as water labelling on white goods (as per the system in Australia), recommending the strengthening of fittings regulations and the planning system to ensure that better toilet technology/mechanisms are installed in our region to reduce the growing problem of 'leaky-loos', and to assist the development of non-potable water systems in new builds.

[22] https://www.gov.uk/government/publications/25-year-environment-plan

Smart District Metered Areas

8.344 Smart District Metered Areas are DMAs where the water delivered, water consumed and the leakage level of the DMA is known and monitored in real time. Smart DMAs are achieved by combining the demand management options of DMA Enhancement and DMA Enhancement Plus, Metering (including household, bulk and replacement) and Water Efficiency.

8.345 This means that from AMP7 we will be aiming to achieve Smart DMAs by rolling out the metering and water efficiency programmes in conjunction with DMA Enhancement and DMA Enhancement plus activity. This will be done to target areas where we may know the amount of water feeding in to a DMA but not necessarily where all the water is consumed.

8.346 In this way, DMA Enhancement will ensure the volume of water entering a DMA is known and monitored in 'real' time, and the Metering and Water Efficiency activities will ensure the volume of customer usage is known in 'real' time and any wastage issues are resolved or accounted for.

8.347 Smart DMAs will also help us to improve:

- the accuracy of our water balance calculations
- our quantification of CSLs
- our understanding of night time consumption to more accurately account for leakage
- our prediction of active leakage before they become visible and cause disruption

8.348 In the longer term, smart DMAs will help us plan for future investment and ensure we target leakage repair and mains replacement in areas with significant leakage reduction benefits.

Maintenance of demand management savings

8.349 In order to maintain the savings achieved in both the IDM optimisation phase of demand management appraisal and the development of an 80 year demand management programme, a cost to maintain these benefits must be included in the programme.

8.350 This is done by factoring in the repeat costs for each demand management programme. Repeat costs are based on asset life, repeat frequency of demand management option and innovative solutions to maintain benefits. For example, the benefits achieved by DMA Enhancement will be maintained in the longer term by implementing mains replacement to maintain the same level of benefits achieved by DMA Enhancement in earlier AMPs. This is done to ensure both the leakage and usage reductions achieved in earlier AMPs are maintained throughout the 80 year demand management programme period.

8.351 In the revised draft WRMP19, we have also included a cost to maintain the benefits from pressure management beyond 20 years by maintaining the infrastructure. This is an improvement on WRMP14 where we assumed a pressure management scheme would provide no further benefit to leakage reduction at the end of its asset life of 20 years.

Option uncertainty

8.352 The uncertainties applied to each demand management option are presented in Section 5 and Appendix V.

Environmental and carbon appraisal

8.353 Strategic environmental assessments have been undertaken for each demand management option. These assessments are provided in revised draft WRMP19 Section 9: Environmental Appraisal.

8.354 It is also important that we assess the likely carbon emissions from both the construction (i.e. for mains rehabilitation and pressure management) and operational phases. In the construction phase, embodied energy is the energy expended in the process of sourcing, manufacturing and supplying a product, material or service. This product, material or service may then expend further energy in its operation. The embodied carbon is a one-off cost that goes with the construction phase of the option. This cost is calculated off-line as a unit rate, with the values given in tonnes of carbon. These costs together with the carbon associated with ongoing operation of demand management interventions (i.e. pressure management) are calculated for each demand management programme and included in the modelling for EBSD plus. These assessments are provided in Appendix R: Scheme Dossiers.

K. Demand management programmes

Summary of demand management programmes

8.355 For the revised draft WRMP19, we have optimised over 80 demand management programmes across the six Water Resource Zones. All of these programmes have been included in the next stage of development (Section 10: Programme Appraisal and Scenario Testing).

8.356 A selection of these demand management programmes have been summarised in Table 8-2. We have filtered the scenarios presented to include the demand management programmes around the lower, middle and upper end of the range of demand management programmes for each WRZ.

8.357 The details of the preferred programme, including the total benefit for each demand management option is summarised in Section 11: Preferred Plan. Further information about the range of demand management programmes is detailed in the attachment, 'EA Table Notes' to Appendix P: Options List Tables.

Table 8-2: Demand management programmes

Demand M'gement Programme	Demand Management Programme (DYAA)																							
	Usage Reduction (Ml/d)								Leakage Reduction (Ml/d)								Total Demand Reduction (Ml/d)							
	AMP 7	AMP 8	AMP 9	AMP 10	AMP 11	AMP 12	AMP 13	Total Usage Reduction	AMP 7	AMP 8	AMP 9	AMP 10	AMP 11	AMP 12	AMP 13	Total Leakage Reduction	AMP 7	AMP 8	AMP 9	AMP 10	AMP 11	AMP 12	AMP 13	Total Demand Reduction
LONDON																								
DMP_LON_80.A7M	17.29	0.00	0.00	0.00	0.00	0.00	0.00	**17.29**	62.76	0.00	0.00	0.00	0.00	0.00	0.00	**62.76**	80.05	0.00	0.00	0.00	0.00	0.00	0.00	**80.05**
DMP_LON_106.A7_SD	37.50	0.00	0.00	0.00	0.00	0.00	0.00	**37.50**	71.35	0.00	0.00	0.00	0.00	0.00	0.00	**71.35**	108.85	0.00	0.00	0.00	0.00	0.00	0.00	**108.85**
DMP_LON_123.A7	43.75	0.00	0.00	0.00	0.00	0.00	0.00	**43.75**	78.61	0.00	0.00	0.00	0.00	0.00	0.00	**78.61**	122.36	0.00	0.00	0.00	0.00	0.00	0.00	**122.36**
DMP_LON_159.A8_SD	23.41	33.65	0.00	0.00	0.00	0.00	0.00	**57.06**	82.40	20.81	0.00	0.00	0.00	0.00	0.00	**103.21**	105.81	54.46	0.00	0.00	0.00	0.00	0.00	**160.28**
DMP_LON_110_70_7	35.26	32.06	7.23	0.00	0.00	0.00	0.00	**74.54**	75.11	37.57	0.00	0.00	0.00	0.00	0.00	**112.69**	110.37	69.63	7.23	0.00	0.00	0.00	0.00	**187.23**
DMP_LON_225.A8	49.06	34.01	9.29	0.00	0.00	0.00	0.00	**92.35**	90.23	41.92	0.21	0.00	0.00	0.00	0.00	**132.35**	139.29	75.92	9.50	0.00	0.00	0.00	0.00	**224.71**
DMP_LON_244.A9	46.52	38.76	20.51	0.00	0.00	0.00	0.00	**105.79**	83.10	46.85	10.41	0.00	0.00	0.00	0.00	**140.36**	129.62	85.61	30.92	0.00	0.00	0.00	0.00	**246.15**
DMP_LON_270.A10	46.52	38.76	20.51	5.73	0.00	0.00	0.00	**111.52**	83.10	46.85	10.41	20.30	0.00	0.00	0.00	**160.66**	129.62	85.61	30.92	26.03	0.00	0.00	0.00	**272.18**
DMP_LON_329.A10	43.92	44.03	13.02	35.00	0.00	0.00	0.00	**135.96**	100.32	47.68	33.62	0.00	0.00	0.00	0.00	**181.61**	144.23	91.71	46.64	35.00	0.00	0.00	0.00	**317.57**
DMP_LON_355.A10	47.55	37.35	28.72	40.73	0.00	0.00	0.00	**154.34**	110.51	47.95	18.64	14.30	0.00	0.00	0.00	**191.40**	158.06	85.30	47.36	55.03	0.00	0.00	0.00	**345.74**
DMP_LON_411.A12	47.55	37.35	28.72	40.73	5.00	0.00	0.00	**159.34**	110.51	47.95	18.64	40.80	24.80	0.00	0.00	**242.70**	158.06	85.30	47.36	81.53	29.80	0.00	0.00	**402.04**
DMP_LON_S4b	54.85	46.94	20.04	43.98	5.00	5.00	0.00	**175.81**	85.70	46.73	29.42	40.80	24.80	10.00	7.50	**244.94**	140.55	93.67	49.46	84.78	29.80	15.00	7.50	**420.75**
DMP_LON_450	54.85	46.74	20.25	40.73	5.00	5.00	0.00	**172.57**	85.71	46.73	29.42	40.80	34.80	20.00	20.00	**277.46**	140.56	93.47	49.67	81.53	39.80	25.00	20.00	**450.03**
DMP_LON_585.A11	54.85	46.44	20.25	40.73	4.20	0.00	0.00	**166.47**	85.70	46.73	29.42	40.80	34.80	50.00	50.00	**337.45**	140.55	93.17	49.67	81.53	39.00	50.00	50.00	**503.92**
SWINDON AND OXFORDSHIRE																								
DMP_SWOX_6.A7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	**0.000**	5.670	0.000	0.000	0.000	0.000	0.000	0.000	**5.670**	5.670	0.000	0.000	0.000	0.000	0.000	0.000	**5.670**
DMP_SWOX_15.A8	3.100	1.000	0.000	0.000	0.000	0.000	0.000	**4.100**	5.670	2.220	0.000	0.000	0.000	0.000	0.000	**7.890**	8.770	3.220	0.000	0.000	0.000	0.000	0.000	**11.990**
DMP_SWOX_18_12_1	7.464	4.809	0.950	0.000	0.000	0.000	0.000	**13.223**	7.595	5.401	0.000	0.000	0.000	0.000	0.000	**12.996**	15.059	10.210	0.950	0.000	0.000	0.000	0.000	**26.219**

DMP_SWOX_45.A9	9.546	6.178	1.821	0.000	0.000	0.000	0.000	**17.545**	10.744	6.347	1.074	0.000	0.000	0.000	0.000	**18.166**	20.291	12.526	2.895	0.000	0.000	0.000	0.000	**35.711**
DMP_SWX_S4b	8.710	7.310	1.940	6.658	0.000	0.000	0.000	**24.618**	9.841	6.781	0.578	0.000	0.000	0.000	0.000	**17.200**	18.551	14.091	2.518	6.658	0.000	0.000	0.000	**41.818**
DMP_SWOX_70.A8	9.546	6.178	1.821	0.000	0.000	0.000	0.000	**17.545**	10.744	6.347	1.074	15.000	10.000	0.000	0.000	**43.166**	20.291	12.526	2.895	15.00	10.00	0.000	0.000	**60.711**
GUILDFORD																								
DMP_GUI_2	0.00	1.00	0.11	0.00	0.00	0.00	0.00	**1.11**	0.00	1.01	0.00	0.00	0.00	0.00	0.00	**1.01**	0.00	2.02	0.11	0.00	0.00	0.00	0.00	**2.13**
DMP_GUI_5	0.65	1.02	0.25	0.00	0.00	0.00	0.00	**1.92**	2.10	1.67	0.74	0.00	0.00	0.00	0.00	**4.51**	2.75	2.69	0.99	0.00	0.00	0.00	0.00	**6.44**
DMP_GUI_S4b	0.88	0.80	0.31	1.10	0.00	0.00	0.00	**3.09**	2.08	1.47	0.49	0.00	0.00	0.00	0.00	**4.04**	2.96	2.27	0.80	1.10	0.00	0.00	0.00	**7.13**
DMP_GUI_SD	0.00	1.14	0.81	0.00	0.00	0.00	0.00	**1.95**	0.01	0.98	5.51	0.00	0.00	0.00	0.00	**6.49**	0.01	2.12	6.32	0.00	0.00	0.00	0.00	**8.44**
SLOUGH, WYCOMBE AND AYLESBURY																								
DMP_SWA_SD.v2	0.00	0.57	1.91	3.21	0.00	0.00	0.00	**5.69**	0.00	1.99	0.00	0.39	0.39	0.00	0.00	**2.77**	0.00	2.56	1.91	3.60	0.39	0.00	0.00	**8.46**
DMP_SWA_0_5_9	0.00	1.27	4.56	0.51	0.00	0.00	0.00	**6.34**	0.00	3.94	1.90	0.06	0.06	0.00	0.00	**5.97**	0.00	5.21	6.47	0.57	0.06	0.00	0.00	**12.31**
DMP_SWA_S4b	0.00	5.39	1.83	4.01	0.00	0.00	0.00	**11.23**	0.00	4.70	0.72	1.08	0.00	0.00	0.00	**6.50**	0.00	10.09	2.55	5.09	0.00	0.00	0.00	**17.73**
KENNET VALLEY																								
DMP_KV_S4b	0.0	0.0	3.5	3.8	0.0	0.0	0.0	**7.3**	0.0	0.0	3.8	0.0	0.0	0.0	0.0	**3.8**	0.0	0.0	7.3	3.8	0.0	0.0	0.0	**11.1**
HENLEY																								
DMP_HEN_S4b	0.0	0.0	0.4	0.4	0.0	0.0	0.0	**0.8**	0.0	0.0	0.3	0.0	0.0	0.0	0.0	**0.3**	0.0	0.0	0.8	0.4	0.0	0.0	0.0	**1.2**

Annex 1 AMP6 Leakage reduction carry over

8.358 In the revised draft WRMP19, an additional leakage reduction option, 'AMP6 Leakage Savings Carry Over' has been introduced in year 1 of AMP7. That is, leakage in April 2020 is expected to be 21 Ml/d lower than the leakage in April 2019. This leakage reduction is applicable to year 1 of AMP7 at no additional cost to the programme.

8.359 When considering the 'carry over' of leakage benefit from one AMP to another, there are two resolutions to review:

- Monthly Leakage Profile
- Annual Average Leakage Profile

And two activities to consider:

- Offsetting Leakage Recurrence. i.e. maintaining leakage at the current level
- Leakage Reduction i.e. reducing leakage further from the current level

8.360 An explanation of these activities is detailed in the two subsections below; Offsetting leakage recurrence and Leakage reduction. The numbers used in these two sections have been provided for example purposes only.

8.361 The derivation of the AMP6 leakage reduction carry over benefit, 21Ml/d is detailed in subsection, 'Carry over' leakage level. The numbers used in this section are our forecast leakage levels for 2019/20 based on the activity in the leakage recovery plan.

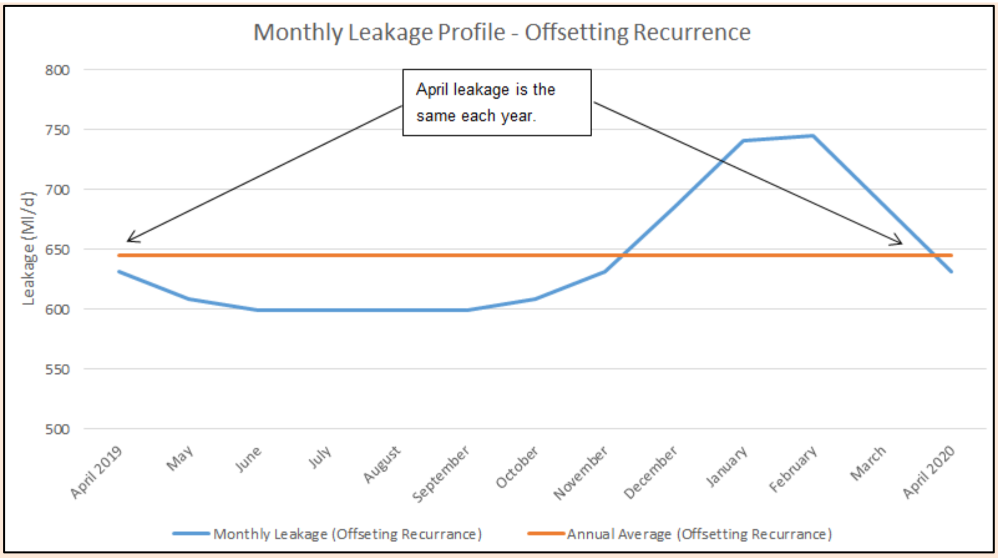
Offsetting leakage recurrence

8.362 The purpose of offsetting leakage recurrence is to ensure that sufficient activity is completed each year such that the annual average leakage level remains constant, year on year. That is, without sufficient leakage repair work, leakage will increase as more leaks occur than are repaired.

8.363 Offsetting leakage recurrence is a separate activity to offsetting leakage deterioration. This factor is offset by asset renewal rather than leak repair activity.

8.364 This is demonstrated in Figure 8-14 which shows the monthly and annual average leakage profile over a 13 month period. The monthly leakage profile shows that leakage increases over the winter months as more water mains develop leaks in the colder weather. This higher level of leakage is offset during the summer months where additional leakage reduction work is undertaken and monthly leakage is reduced. This means that, over the 13 month period, the annual average leakage level remains constant from April in one year to April in the next. If the same level of activity is undertaken to offset leakage recurrence in the following year, the annual average will also remain the same.

Figure 8-14: Offsetting Leakage Recurrence



Leakage reduction

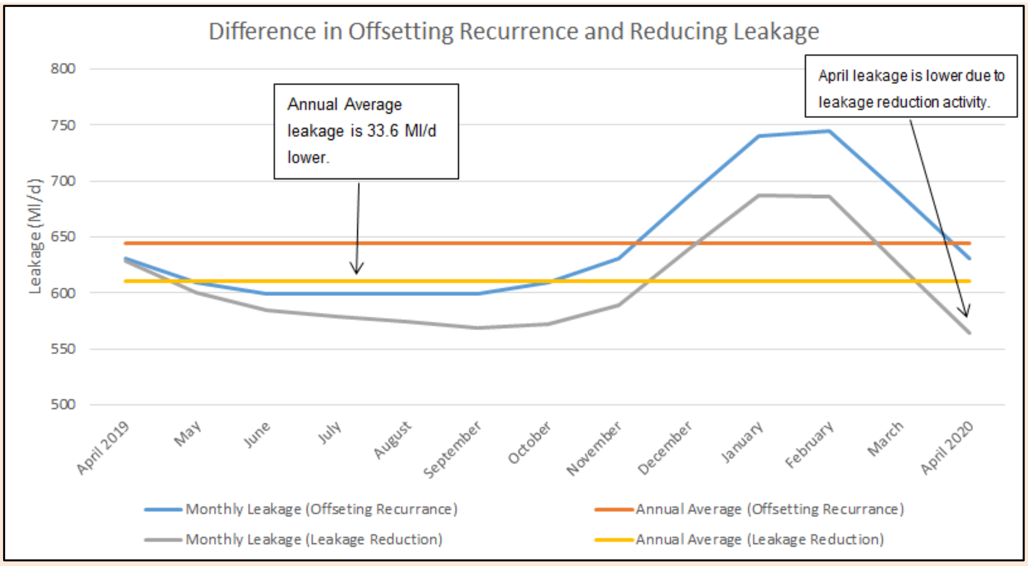
8.365 The purpose of leakage reduction is to achieve a reduction in the leakage level from April in one year to April in the next year and thereby reduce the annual average level of leakage

8.366 This is demonstrated in Figure 8-15 which shows the difference between offsetting leakage recurrence and achieving a reduction in the annual average leakage level. In this example, the monthly leakage profile to offset recurrence and the resulting annual average profile (Figure 8-14). That is, the level of activity required to offset leakage recurrence achieves an annual average leakage level of 645Ml/d. This is an example figure only.

8.367 To achieve a leakage reduction over this same period, the monthly leakage profile must be lower than the profile to offset leakage recurrence. In this scenario, an additional 67.2Ml/d of activity has been included above the level required to offset leakage recurrence. This has been distributed evenly across the year (i.e. equal amount in each month). This has two impacts:

- The annual average leakage is reduced by 33.6Ml/d.
- The monthly level of leakage in April 2020 is 67.2 Ml/d lower than the monthly level of leakage in April 2019. For comparison, when we only undertake activity to offset leakage, the monthly level of leakage April 2020 is the same as the monthly level of leakage in April 2019.

Figure 8-15: Difference between Offsetting Leakage Recurrence and Reducing Leakage



8.368 Figure 8-15 has been provided as an **example** to demonstrate the difference between offsetting leakage recurrence and achieving a leakage reduction. Note that this means the annual average lines on this figure will not exactly correlate to the annual average lines on Figure 8-16.

'Carry over' leakage level

8.369 Figure 8-16 below illustrates the impact of the 2019/20 leakage recovery plan on achieving a 'carry over' leakage benefit into the first year of AMP7. This includes the impact of activity included in 2018/19 on the April 2019 start position, which is not included in the examples in subsections offsetting leakage recurrence and leakage reduction

8.370 The inclusion of the impact of the 2018/19 plan activities is that the 2019/20 leakage recovery plan is expected to deliver a reduction in the monthly leakage level of 54.7 Ml/d. This means the April 2020 leakage level is expected to be 54.7 Ml/d lower than the April 2019 leakage level.

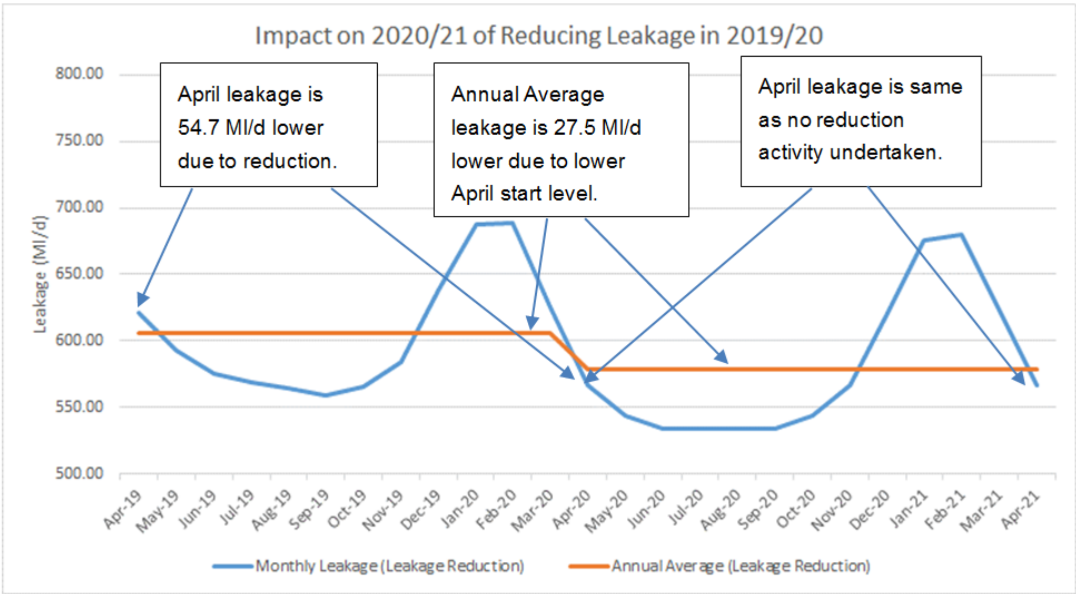
8.371 As a result of the activity in the last year of the leakage recovery plan (year 5 of AMP6) the April leakage in 2020 is expected to be 54.7Ml/d lower than the April leakage in 2019. The annual average for the period between April 2019 and April 2020 is expected to be 606 ML/d.

8.372 In the first year of AMP7, the April leakage in 2021 is expected to be the same as the April leakage in 2020. In this case, the level of activity undertaken in 2020/21 is sufficient to offset recurrence only. However, due to the lower start position in April 2020, the annual average for April 2020 to 2021 is expected to be 27.5 ML/d lower than the annual average for April 2019 to April 2020.

8.373 Therefore the annual average leakage position in 2020/21 (year 1 of AMP7) is 27.5 Ml/d lower as a result of the lower starting position in April 2020 due to the level of activity undertaken in 2019/20. This 27.5ML/d in April 2020 is referred to as 'Carry Over' leakage benefit into year 1 of AMP7.

8.374 The 'Carry Over' benefit used in the revised draft WRMP is 21Ml/d in year 1 of AMP7. Although Figure 8-16 identifies this benefit as 27.5 Ml/d, we have used a conservative forecast of 21 Ml/d to take account of the level of uncertainty in the impact of the severity of the weather in the winter of 2019/20. Some of the activity included in the plan may be required to offset a colder than average winter rather (resulting in higher levels of leakage) rather than reducing leakage between the April 2019 and April 2020.

Figure 8-16: 'Carry Over' leakage level



Section 9

Environmental appraisal

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Section 9.

Environmental appraisal

In this section we cover:

- Methodology overview
- Statutory framework to environmental appraisal
- The integration of environmental assessment within the draft WRMP process
- An outline of the assessment framework with regard to Strategic Environmental Assessment, Water Framework Directive and Habitats Regulation Assessment
- The approach to the assessment considering the potential of environmental valuation, the use of environmental and social metrics and cumulative effects
- A summary of the option elements results of the SEA, HRA and WFD assessments

We have made the following main changes in response to the points made in the public consultation on the draft WRMP, and to include new information since the draft WRMP was published:

- We have had regard to the 2018 European Court of Justice ruling[1] on the Habitats Directive (Section 0)
- We have included further information on the policy background guided by the Government's 25 year Environmental Plan (Section 0)
- We have included further details on our consideration of the potential of environmental valuation and the use of environmental and social metrics (Section C)
- We have included details on changes to option elements since the draft WRMP (Section D)
- We have updated the results of the SEA, HRA and WFD assessments in light of further information and comments received (Section E)

[1] Case C-323/17 (*People Over Wind*).

A. Introduction to environmental appraisal

Methodology overview

9.1 The Water Resources Planning Guideline (WRPG)[2], Defra guiding principles[3] and UK Water Industry Research Ltd (UKWIR) guidance[4] advises that water companies should consider the environmental and social effects (beneficial and adverse) of the options considered for balancing supply and demand, the preferred programme for each Water Resource Zone (WRZ) and the draft Water Resources Management Plan 2019 (dWRMP19) and revised draft Water Resources Management Plan 2019 (revised draft WRMP19) overall. Additionally, the Environmental Assessment of Plans and Programmes Regulations 2004 (the SEA Regulations)[5] and guidance on Strategic Environmental Assessment (SEA) require assessment of the environmental and social effects of the reasonable alternative programmes considered as part of developing both the draft WRMP19and the revised draft WRMP19.

9.2 Ofwat also expects companies to improve water supply resilience, while taking full account of what their customers tell them about priorities for investment and maintaining sustainable water services.

9.3 Knowledge of the environmental and social effects is used to help to identify the preferred (or 'best value') programme of options to achieve a supply-demand balance in each WRZ to ensure a balance is maintained between available water supplies and demand for water.

9.4 An integrated environmental and social assessment approach for the development of both our draft WRMP19and revised draft WRMP19 has been adopted as summarised in Figure 9-1, which has been implemented from the very outset of our planning.

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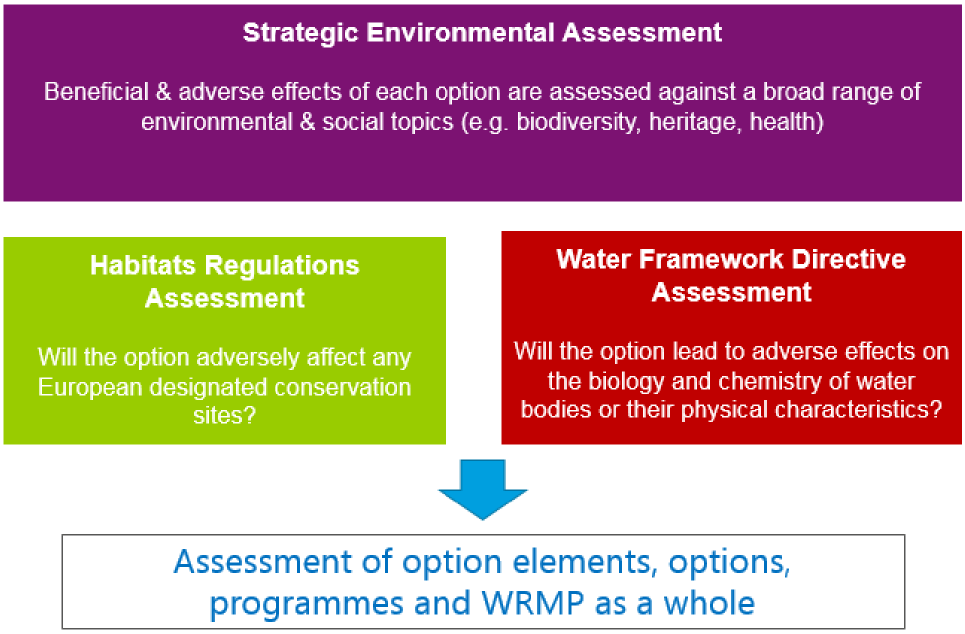
[2] Environment Agency and Natural Resources Wales, Water Resources Planning Guideline: Interim Update April 2017
[3] Defra, Guiding principles for water resources planning for water companies operating wholly or mainly in England, May 2016
[4] UKWIR, Strategic Environmental Assessment and Habitats Regulations Assessment - Guidance for Water Resources Management Plans and Drought Plans, 2012
[5] The Environmental Assessment of Plans and Programmes Regulations 2004 (Statutory Instrument 2004 No. 1633) apply to any plan or programme which relates solely or in part to England

Figure 9-1: The environmental assessment approach within the WRMP



Statutory framework to environmental appraisal

9.5 In line with the WRPG, water companies in England must assess whether a SEA is required of its WRMP to comply with the SEA Regulations[6]. A SEA became a statutory requirement in England following the adoption of Directive 2001/42/EC (the SEA Directive) on the assessment of effects of certain plans and programmes on the environment. The SEA Directive was transposed into national legislation by the SEA Regulations. The Government has produced national SEA guidance - the “Practical Guide”[7] - which sets out the stages of the SEA process and the key requirements at each stage. The Practical Guide is supported by water industry specific guidance for undertaking SEA of WRMPs[8]. We have also consulted other national SEA guidance, including Scottish and European Union (EU) guidance, in carrying out the SEA.

[6] The Environmental Assessment of Plans and Programmes Regulations 2004 (Statutory Instrument 2004 No. 1633) apply to any plan or programme which relates solely or in part to England

[7] Office of the Deputy Prime Minister, A Practical Guide to the Strategic Environmental Assessment Directive, 2005

[8] UKWIR, Strategic Environmental Assessment and Habitats Regulations Assessment - Guidance for Water Resources Management Plans and Drought Plans, 2012

9.6 SEA incorporates the following generic stages:

- **Stage A:** Setting the context, identifying objectives, problems and opportunities, and establishing the environmental baseline (scoping)
- **Stage B:** Developing and refining options and assessing effects (impact assessment)
- **Stage C:** Preparing the Environmental Report (recording results)
- **Stage D:** Consulting on the Draft Plan and the Environmental Report (seeking consensus)
- **Stage E:** Monitoring the significant effects of the plan or programme on the environment (verification)

9.7 The SEA provides the overarching structure of the assessment approach but has been integrated with the parallel statutory assessment requirements for the EU Habitats Directive[9] and EU Water Framework Directive (WFD), the results of which inform the SEA.

9.8 The Habitats Directive establishes the requirement for assessment of plans or projects (Articles 6(3) and 6(4)). The Habitats Directive is transposed into national legislation by the Conservation of Habitats and Species Regulations 2017. Under Regulations 63 and 105, any plan or project which falls within a potential zone of influence of a European site must be subject to a Habitats Regulations Assessment (HRA). If the plan or project is likely to have a significant effect on a European site (either alone or in-combination with other plans or projects) and is not directly connected with, or necessary for the management of the site, it must be subject to an Appropriate Assessment to determine the implications for the site in view of its conservation objectives.

9.9 Both the WRPG and the UKWIR SEA and HRA guidance recommend that all WRMPs should be subject to the first stage of the HRA process, i.e. screening for likely significant effects (LSE). The WRPG additionally states that an Appropriate Assessment (the second stage of the HRA process) is required if an option included in the WRMP could affect any designated European site and that companies must clearly test their plans using HRA where applicable.

9.10 A 2018 European Court of Justice ruling[10] has stated that Article 6(3) of the Habitats Directive must be interpreted as meaning that mitigation measures should be assessed within the framework of Appropriate Assessment and that it is not permissible to take account of measures intended to avoid or reduce the harmful effects of the plan or project on a European site at the screening stage. In consequence, Stage 1 HRA screening assessments no longer have regard to mitigation measures to conclude no Likely Significant Effect with mitigation measures being considered at Stage 2 Appropriate Assessment. We have considered this ruling in the revised draft WRMP19 and HRA assessment report contained in Appendix C: HRA – stage 1 screening.

9.11 We have applied the HRA process to all of the options considered for both our draft WRMP19 and revised draft WRMP19, from initial screening through to detailed assessment of the option elements, options and programmes. Details of the HRA can be found in paragraph 9.32 and Appendix C of the revised draft WRMP.

[9] Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora
[10] Case C-323/17 (*People Over Wind*).

9.12 In accordance with the WRPG and Defra's guiding principles, WFD assessments have also been carried out throughout the development of our plan: from the initial screening of options through to detailed assessment of the option elements, options and programmes. Details of the WFD can be found in paragraph 9.35 and Appendix BB of the revised draft WRMP.

9.13 In relation to the WFD, Defra expects that companies should take account of the government's objectives for the environment *"including the appropriate parts of the EU Water Framework Directive"*. Defra also expects that companies will:

- have regard to WFD River Basin Management Plans (RBMPs) and their objectives when making decisions that could affect the condition of the water environment
- ensure that future plans support the achievement of environmental objectives and measures set out in RBMPs
- prevent deterioration in WFD water body status
- support the achievement of protected area and species objectives
- support the achievement of water body status objectives

9.14 Both the WRPG and Defra's guiding principles refer to ensuring 'no deterioration' of water body status. A 2015 European Court of Justice ruling[11] clarified that 'no deterioration' means a deterioration between a whole 'status class' (e.g. 'good', 'moderate', etc.) of one or more of the relevant 'quality elements' (e.g. biological, physico-chemical, etc.). This definition applies equally to Artificial Water Bodies and Heavily Modified Water Bodies in respect of the relevant quality elements that relate to the defined uses of these water bodies. The European Court of Justice ruling further states that if the quality element concerned is already in the lowest class, any deterioration of that element constitutes a deterioration of the status. References to 'no deterioration' in our revised draft WRMP19 align to this European Court of Justice ruling.

9.15 Compliance with the statutory requirements of the SEA Directive, the HRA and WFD processes are the key outputs of the assessment process.

9.16 Additionally, the assessment approach takes account of national environmental legislative requirements (for example, those relating to Sites of Special Scientific Interest, Scheduled Monuments, Areas of Outstanding Natural Beauty) and associated relevant national guidance as illustrated in Figure 9-2. This has included consideration of the proposed Marine Conservation Zone in the lower River Thames estuary. The approach to the SEA has been informed by a review of other policies, plans and programmes including the Government's 25 Environment Plan (the 25 year plan) to improve the environment, published in 2018.

9.17 Net environmental gain has been included as a principle in the Government's 25 year plan. References to achieving environmental net gains across the three overarching objectives for sustainable development (economic, social and environmental) along with achieving net gain in biodiversity are set out in the National Planning Policy Framework (NPPF) 2018. The Government states that the 'net environmental gain' principle for development aims to deliver environmental improvements locally and nationally, primarily to "enable housing development

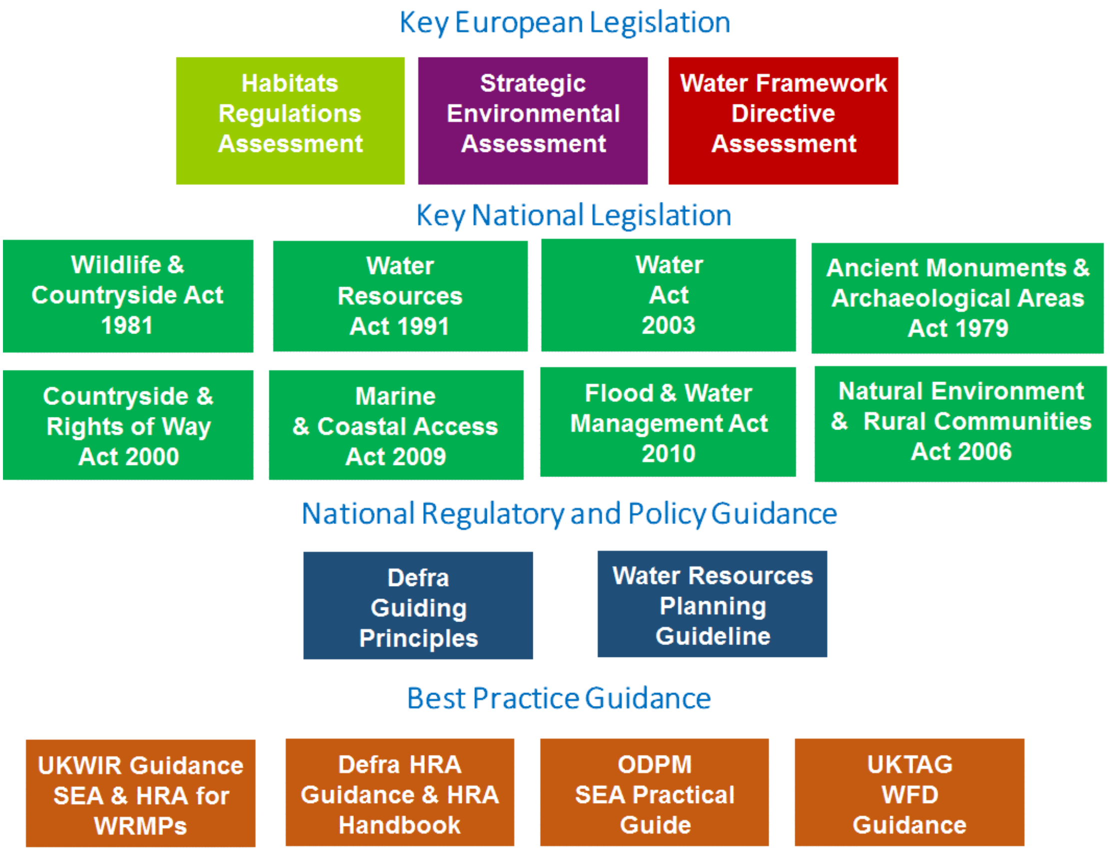
[11] European Court of Justice Case C‑461/13: Bund für Umwelt und Naturschutz Deutschland v Bundesrepublik Deutschland
http://curia.europa.eu/juris/document/document.jsf?docid=178918&mode=req&pageIndex=1&dir=&occ=first&part=1&text=&doclang=EN&cid=175124 [accessed 30.6.16]

without increasing overall burdens on developers". The benefits that are expected to arise as a result of implementing our WRMP and measures aimed at delivering overall net biodiversity and net environmental gain are set out in Sections 10 and 11 of the revised draft WRMP19.

9.18 In support of the net environmental gain principle, Thames Water is proposing a regulatory Performance Commitment as part of the 2019 Price Review process to achieving a net gain in biodiversity at its 253 Sites of Biodiversity Interest (SBIs), plus any net change from additional land where specific biodiversity offsetting has been implemented. We are committing to increase the total number of biodiversity units on our SBIs and offsetting sites by 5% during the period 2020-2025, and we expect to continue this commitment over the longer term, subject to customer support. Our proposed Performance Commitment commands strong support from our customers based on our recent customer research evidence.

9.19 Our plan complies with the requirement in the Water Resources Management Plan (England) Direction 2017 to consider the emissions of greenhouse gases (referred to in our plan as “carbon” emissions) that are likely to arise as a result of each measure included in the WRMP. Carbon emissions associated with both construction and operation of measures included in our plan has been assessed and a carbon value calculated in accordance with the latest government guidance and data on carbon pricing.

Figure 9-2: The statutory framework to environmental appraisal



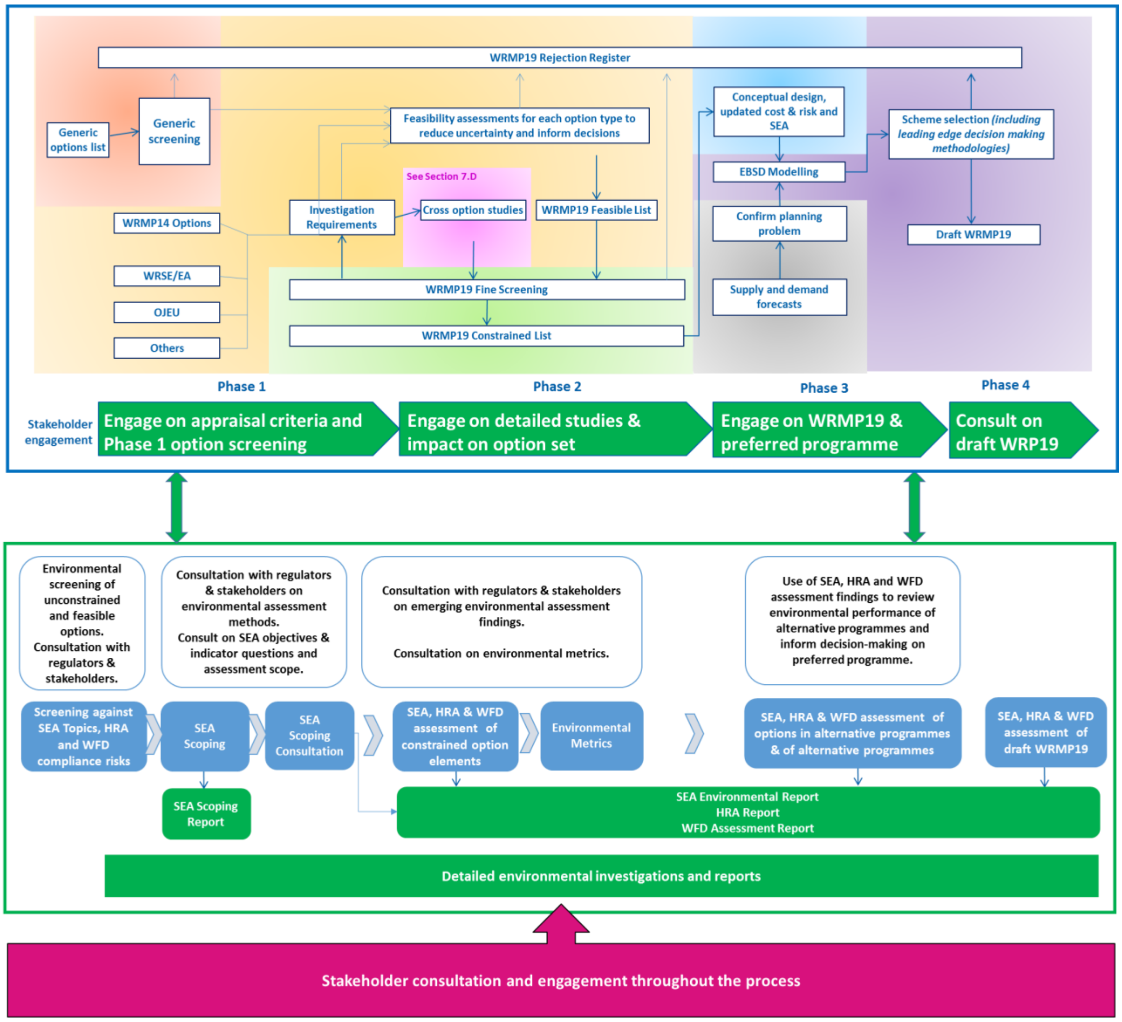
B. Assessment framework

9.20 We consulted extensively on our proposed assessment framework with regulators and stakeholders, supported by written Methodology Statements that were published for comment on our website together with the statutory SEA Scoping Report. Feedback received on our methodologies and SEA Scoping Report was used to inform our assessment framework and this was shared with regulators and stakeholders through a summary report plus presentations at stakeholder meetings[12]. Figure 9-3 summarises the overall framework we adopted and how it linked to the stages of development of the draft WRMP19. Section 7: Appraisal of water resource options provides details on each of the key stages.

9.21 The approach involved consideration of SEA topics (and HRA and WFD compliance criteria) from the very outset of the development of the draft WRMP19, starting with the initial screening assessment of a large number of unconstrained options. SEA topics plus HRA and WFD risks were considered as part of the screening of the unconstrained options to help develop a smaller 'feasible' list of options.

[12] Consultation documents available on the Thames Water website: https://corporate.thameswater.co.uk/About-us/Our-strategies-and-plans/Water-resources/Document-library/Assessment-of-environmental-and-social-impacts

Figure 9-3: Integration of environmental assessment within our draft WRMP19 process



9.22 These feasible options were then assessed against a suite of SEA topics and HRA and WFD compliance criteria to determine a constrained list of options for appraisal through SEA, HRA and WFD assessment processes, as described in Section 9.D and in accordance with the approach summarised below.

Strategic Environmental Assessment

9.23 The SEA has been fully integrated with the option appraisal process to help inform decisions on a best value set of options to balance supply and demand over the long-term planning period for both our customers and the environment. Appendix B: Strategic environmental assessment - environmental report (2018) accompanying our revised draft WRMP19 presents an assessment of the likely social and environmental effects of the Plan (both beneficial and adverse). It also identifies ways in which any adverse effects might be minimised or mitigated and how positive effects might be enhanced. The SEA has informed the consideration of each option element, option and the programme appraisal process, as well as development of the overall revised draft WRMP19. revised draft WRMP19

9.24 In order to incorporate the SEA considerations within our programme appraisal model, which is a mathematical model, an approach was developed to summarise the environmental and social performance of each option element in the constrained list in numerical form. These numerical summaries have been termed 'environmental and social metrics', further details of which are provided in Section 9.C. These environmental and social metrics were derived from assessments of all of the option elements in the Constrained List. The metric scores in themselves are relative and provide an important tool to ensure that environmental effects are actively considered within the programme appraisal modelling.

9.25 Following this short-listing process, each of the options identified in the reasonable alternative programmes and the programmes themselves were assessed through the SEA process so that the relative performance of each alternative programme against SEA objectives could be considered, with regard being given to potential cumulative and in-combination effects of components of options. SEA assessment of the options in the preferred programme as well as the programme itself was also undertaken.. Full details are provided in Sections 7 and 8 of Appendix B: SEA - environmental report.

9.26 As some of our options have the potential for cumulative effects, collaborative work with some of our neighbouring water companies during the development of the revised draft WRMP19 has taken place through the Water Resources South East (WRSE) group. Further discussions have taken place separately with individual companies, revised draft WRMP19, including a review of the draft WRMP19 preferred programmes of United Utilities, Severn Trent Water, Welsh Water and Bristol Water in the context of the Severn-Thames Transfer option set out in Thames Water's revised draft WRMP19.Environmental assessment of the range of feasible supply options in the draft WRMPs of these companies has indicated that there may be possible cumulative effects in the North Medway Chalk groundwater body and the Thames wider catchment.

9.27 The findings from this work concluded that no cumulative adverse effects have been identified in relation to other water companies outside of the WRSE group with the revised draft WRMP19.revised draft WRMP19. It should be noted that all of the draft 2019 WRMPs for water companies neighbouring our water supply area were still being finalised at the time of carrying out the SEA and therefore the cumulative effects assessment will need to be updated once these other WRMPs are finalised and the specific supply and demand management measures are confirmed.

9.28 The SEA process and emerging findings helped facilitate consultation and engagement during the development of our plan with customers, government, regulators and stakeholders on environmental and social considerations, in particular through our regular meetings with regulators and stakeholders at our Water Resources Forum and Technical Stakeholder Meetings.

9.29 The SEA was informed by the parallel assessment processes of the HRA and WFD assessments.

9.30 The SEA topics indicated by the SEA Directive and adopted in our environmental appraisal of the draft WRMP19 and the revised draft WRMP19 are:

- Biodiversity, flora and fauna
- Population and human health
- Material assets and resource use
- Water
- Soils, geology and land use
- Air and climate
- Archaeology and cultural heritage
- Landscape and visual amenity

9.31 We followed an objectives-led approach to the SEA. Section 5.A.12 of the Practical Guide explains that whilst SEA objectives are not specifically required by the SEA Directive, they are a 'recognised way of considering the environmental effects of a plan or programme and comparing the effects of alternatives'. The objectives-led approach is also recommended in the UKWIR Guidance on SEA of WRMPs. The objectives for each SEA topic were developed and informed by the key messages identified following a review of relevant policies, and other plans and programmes, along with stakeholder engagement through the SEA Scoping Report consultation in summer 2016 and regulatory and stakeholder meetings. Alongside each SEA objective a series of indicator questions were developed to ensure that the assessments were both comprehensive and consistent.

Habitats Regulations Assessment

9.32 We carried out HRA screening throughout the development of our plan to assess the potential effects on European sites (also known as Natura 2000 sites) of each of the option elements, options, programmes and the draft WRMP19 and the revised draft WRMP19 as a whole. European sites include those sites designated as Special Areas of Conservation (SAC) under the EU Habitats Directive, Special Protection Areas under the Birds Directive, and Ramsar sites under the international Ramsar Convention, as well as candidate or proposed sites.

9.33 We undertook screening assessment of the constrained list of options considered in developing the draft WRMP, which have been updated in the revised draft WRMP19 to have regard to the 2018 European Court of Justice ruling[13], and discussed the outcomes with Natural England and the Environment Agency, as well as stakeholders at our engagement meetings. The process and full assessment findings are summarised later in this section and fully documented in Appendix C: HRA stage 1 screening, which is published alongside our revised draft WRMP19. Outcomes of the HRA screening assessments informed the SEA, and in turn, helped inform our decision-making at each stage of developing the revised draft WRMP19.

9.34 For those options included in our preferred programmes for each WRZ, we carried out additional HRA screening to assess likely significant effects on any European sites either

[13] Case C-323/17 (*People Over Wind*).

alone or in combination with other options within the programme, during both construction and operation. The HRA Screening assessment concluded that, with the application of mitigation measures as set out in each assessment, the options included within the preferred programme, individually, and in combination, are not likely to have any significant adverse effect on site integrity or the ability of the site to achieve its conservation objectives. In light of the 2018 European Court of Justice ruling, a number of the screening assessments in the revised draft WRMP19 identified the need to undertake Appropriate Assessment. The findings of the HRA assessments are presented in detail in Appendix C: HRA stage 1 screening.

Water Framework Directive assessment

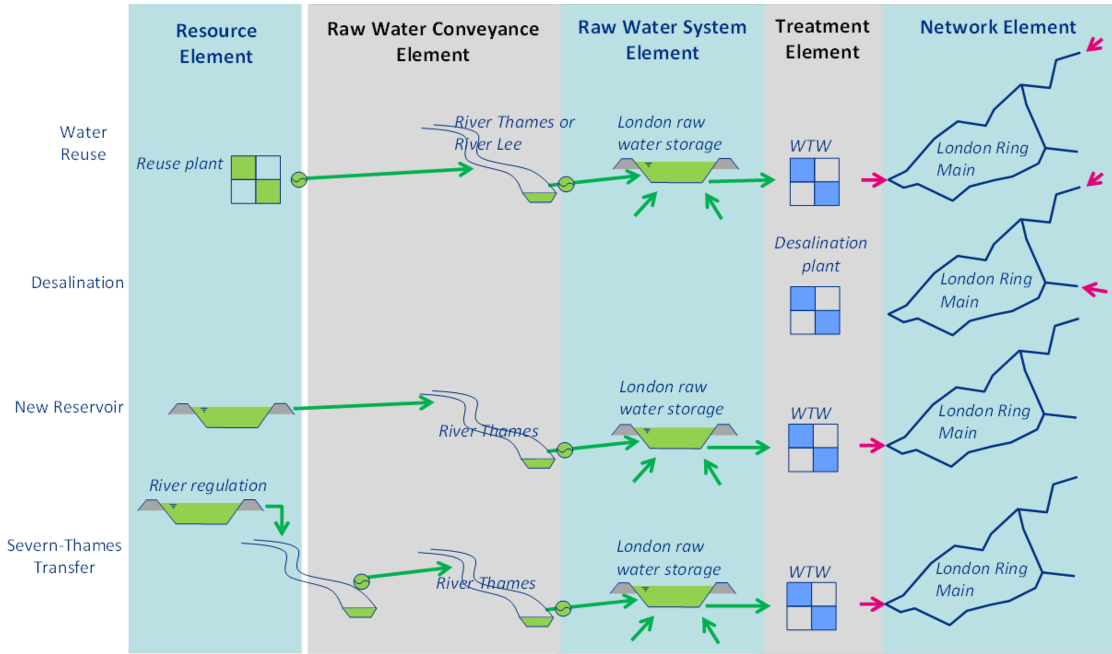
9.35 WFD assessments were carried out in a similar manner to the HRA at each stage of the plan development to assess the potential effects of implementing both the draft WRMP19 and the revised draft WRMP19 on designated WFD water bodies, River Basin Management Plan objectives and measures, as well as on WFD Protected Areas. In particular, for each option element, option and programme we assessed whether there was a risk of deterioration in the status class of any WFD water body. For those options included in our preferred programmes for each WRZ, we carried out additional WFD assessments of the residual effects of the options both alone and in combination with other options within the programme, both during construction and operation.

9.36 The findings of the WFD assessments are summarised later in this section and presented in detail in Appendix BB: WFD assessment.

C. Approach to environmental assessment

9.37 The assessment approach covered all stages of the development of the WRMP, commencing from the coarse screening of the very broad unconstrained list of options, through to the fine screening process which identified those option elements (e.g. new water sources, pipelines, pumping stations, water treatment works) to include in our Constrained List of options for more detailed assessment and consideration within our programme appraisal process. Figure 9-4 shows some examples of these option elements. This process ensured end-to-end consistency of the approach to environmental assessment throughout the plan development.

Figure 9-4: Illustration of the option elements approach



9.38 We carried out detailed environmental assessment for:

- each option element included in the Constrained List
- each of the options selected for inclusion in the reasonable alternative programmes under consideration
- each of the reasonable alternative programmes under consideration
- the overall 'best value' programme for each WRZ
- the draft WRMP19 and the revised draft WRMP19 as a whole (i.e. considering the cumulative environmental effects across our six WRZs)
- each of the supply-demand scenarios used to carry out sensitivity testing of the draft WRMP19 and the revised draft WRMP19

9.39 Cumulative effects with other programmes, plans and projects were also considered in relation to each of the reasonable alternative programmes and the preferred programme. This included assessing the potential for cumulative effects with:

- Thames Water revised Draft Drought Plan 2018
- Other water company draft WRMPs and Drought Plans, including information from the WRSE group
- Environment Agency Drought Plan and the Canal & River Trust Drought Plan
- Thames River Basin Management Plan (RBMP) 2015 and the Severn RBMP 2015
- Local development and land use plans
- Major planned infrastructure schemes, for example High Speed 2 and Crossrail 2

9.40 We are confident that the SEA, as updated, addresses at a strategic level, the full range of impacts from all options brought forward into the preferred programme and reasonable alternative programmes.

9.41 All option elements, options and programmes were assessed to the same level of detail involving an advanced level of qualitative assessment informed by detailed quantitative data within the boundaries of the SEA process. Importantly the level of detail and assessments undertaken did not stray into the statutory Environmental Impact Assessment (EIA) process. This is consistent with national guidance on SEA and EIA. Where required, detailed EIAs that will entail more detailed assessment work may be necessary for some of the options included in our revised draft WRMP19 as part of any development consent process at a later date.

9.42 It is important to note that the detailed SEA, HRA and WFD assessments we undertook were of the residual environmental and social effects of each option element, option and programme, after consideration of the mitigation measures and opportunities for environmental enhancement that have been included in the conceptual designs and costs for each option element/option.

9.43 For the SEA, the residual adverse and beneficial effects have been identified separately to avoid mixing (or trading) of adverse and beneficial effects, in line with SEA best practice. This enables adverse and beneficial impacts to be independently assessed, maintaining transparency throughout the WRMP decision-making process.

9.44 The findings from the HRA and WFD assessments informed the SEA and were actively considered alongside the SEA findings in the decision-making process, reflecting the statutory requirements and expectations of Government and regulators to carefully consider the effects of both the draft WRMP19 and the revised draft WRMP19 on European sites and WFD water bodies.

9.45 The SEA of the Constrained List of option elements, options, alternative WRZ programmes and the overall draft WRMP19 and revised draft WRMP19 were carried out using the effects assessment matrix shown in Figure 9-5, as well as taking account of, for both adverse and beneficial effects, the scale of effect (geographical and/or population affected) (small/medium/large), certainty of the effect, whether the effects arise in the short, medium or long term, and whether the effects are permanent or temporary.

9.46 Varying levels of uncertainty are inherent within the assessment process. The assessment has minimised uncertainty through the application of expert judgement. The level of the certainty of effects is identified within the SEA assessment tables as summarised within the Appendix E and Appendix F assessment tables of Appendix B: Strategic environmental assessment – environmental report. Within the SEA assessment tables there is a column headed “certainty of effect” which has been assessed on a scale from ‘low’ to ‘high’ certainty, and therefore recognises that some effects are more certain than others. In determining the certainty of the effect, regard is given to the level of information available, having consideration of the need for options to be assessed equally and to avoid duplication of assessments if more appropriately assessed at a different stage of the decision-making process. The definitions for the significance of the effects are explained in Figure 9-5.

Figure 9-5: Significance of effects matrix

Significance of Effect		Value/sensitivity of receptor: High	Value/sensitivity of receptor: Medium	Value/sensitivity of receptor: Low
Effect magnitude (includes scale of effect)	High	Major Beneficial / Major Adverse	Major Beneficial / Major Adverse	Moderate Beneficial / Moderate Adverse
	Medium	Major Beneficial / Major Adverse	Moderate Beneficial / Moderate Adverse	Minor Beneficial / Minor Adverse
	Low	(hatched)	Minor Beneficial / Minor Adverse	Negligible

(hatched) = Significance of effect dependent on value/sensitivity of receptor and magnitude

- **Major** - effects represent key factors in the decision-making process. They are generally associated with sites and features of international, national or regional importance. If adverse, such resources/features are generally those which cannot be replaced or relocated
- **Moderate** - effects are likely to be important considerations at a regional or district scale. If adverse, they are likely to be of potential concern
- **Minor** - effects are not likely to be decision-making issues. Nevertheless, the cumulative effect of such issues may lead to an increase in the overall effects on a particular area or on a particular resource
- **Negligible** - effects which are not perceptible, being within normal bounds of variation or the margin of forecasting error

9.47 For the '**high' effect magnitude** (top row), a major effect significance is assigned for both high and medium value receptors to reflect the magnitude of the effect.

9.48 For the **'low' effect magnitude and 'high' value receptor** (bottom left box), the significance of effect could be moderate or major dependent on the precise nature of the impact or benefit.

9.49 The colour coding shown in Figure 9-5 has been used to signify the residual effects in the summary assessment tables presented later in this section. These effects were considered in the selection of options and programmes of options, alongside the HRA and WFD assessment findings, for which the following colour coding system has been adopted in the summary assessment tables later in this section:

- Green (no adverse effects)
- Amber (potential risk of adverse effects but further mitigation is possible to reduce the effects to acceptable levels)
- Red (adverse effects cannot be ruled out and further mitigation unlikely to reduce effects to acceptable levels)

9.50 Further details of the assessment methodologies are provided in the accompanying Appendix B: SEA - environmental report, Appendix C: HRA – stage 1 screening and Appendix BB: WFD assessment.

Environmental valuation

9.51 In line with the WRPG, we have carefully considered the role of environmental valuation in supporting the development of both the draft WRMP19 and the revised draft WRMP19. In dialogue with the Environment Agency and stakeholders, we concluded that there would be little benefit to the decision-making process in calculating environmental and social costs for identified environmental and social effects of the alternative options for balancing supply and demand.

9.52 A current key limitation is that only certain effects of options can be valued through the benefits-transfer approach to environmental and social costing. As a consequence, many of the effects (both beneficial and adverse) identified through the SEA process cannot be assigned a monetary value, thereby hindering comparative assessment of alternative options. This risks the programme appraisal modelling being skewed and results in a mixed approach to how environmental and social effects are represented in the optimisation process: some options will have no monetised environmental and social costs whilst others will have material environmental and social costs assigned despite both options having the same overall significance of effect in the SEA. Adopting a partial valuation of the effects could lead to transparency issues due to the need to amend the SEA findings to address any double-counting of effects at the programme appraisal stage.

9.53 We consulted with stakeholders on the application of environmental and social costs for the draft WRMP19. The majority of stakeholders felt that monetisation of environmental and social effects would not materially improve the option assessment and programme appraisal process. Those who favoured monetisation of effects mostly expressed a view that a Natural Capital Accounting (NCA) and/or Ecosystems Services approach would likely be more appropriate. This is further discussed in paras 9.56 to 9.57.

9.54 We have therefore followed the "building blocks" approach to the assessment of environmental and social impacts advocated in the WRPG. The SEA (informed by the HRA and WFD assessments) provide qualitative and semi-quantitative assessments of the environmental and social effects at a detailed level. SEA has been used as the primary vehicle for assessing the effects at the option, programme and plan level, with the effects reported in the SEA Environmental Report.

9.55 Carbon consumption impacts of each option have been monetised using national UKWIR guidance and HM Treasury carbon prices. Valuation of carbon effects is being carried out because all of the effects can be valued using internationally recognised approaches and backed up by a strong methodology and Government carbon pricing data. The carbon costs were added to the AIC for each option and used in the programme appraisal modelling. The environmental metrics therefore do not reflect any carbon impacts to avoid double counting of the effects.

9.56 Defra's guiding principles for water resource planning (2016) state that water companies should demonstrate how they value natural capital in decision-making and report on environmental and social costs and benefits. Thames Water has been piloting the use of Natural Capital Accounting and associated ecosystem services assessment for application to water resource planning and our wider business planning processes. Currently, the available methods and evidence are not sufficiently robust to apply them to all of the options considered in the revised draft WRMP19 on a consistent basis to enable objective comparison to inform decision-making. We appointed consultants to trial applying a NCA assessment approach to our supply side options. We found that whilst it was possible to generate natural capital valuations for some of the options, the absence of an agreed methodology and a lack of data meant that we felt the results were not sufficiently robust to ensure consistency in our decision making. Thames Water has however considered potential effects on natural capital in a qualitative manner in the SEA and we have therefore focussed on using the SEA, WFD and HRA to ensure that environmental and social impacts and benefits are considered.

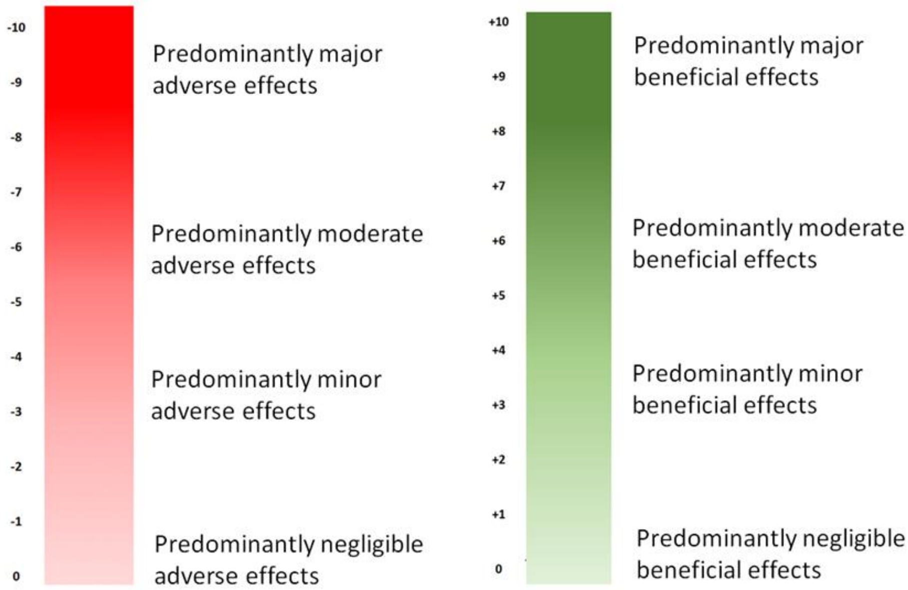
9.57 As members of the Natural Capital Coalition, we are keen to support the development of the NCA approach and will work with the sector to progress this, including through the current collaborative water industry research programme into the application of NCA for long-term planning. We have also examined the relationships between the SEA findings and ecosystem services as part of our investigations into how to integrate ecosystem services into the assessment of future water resources management plans. We will continue to develop our approach to NCA, working in partnership with the water sector, regulators and stakeholders. Once robust methodologies for applying NCA approaches to our long-term plans are available we will work with regulators and other stakeholders to embed them into our future planning activities.

9.58 Our approach to environmental assessment for both the draft WRMP19 and the revised draft WRMP19 has therefore been based on broad support from stakeholders and regulators, with a simple, clear and understandable assessment framework based on SEA, WFD and HRA processes that are familiar to both our regulators and stakeholders.

Environmental metrics

9.59 In order to incorporate environmental and social considerations directly into our appraisal optimisation model – which we used in short-listing reasonable alternative programmes and scheduling of options - we developed an approach to summarise the environmental and social performance of each option element in the Constrained List in numerical form, as necessary for a mathematical optimisation model. We called these numerical summaries ‘environmental and social metrics’. These environmental and social metrics were derived from assessments of all of the option elements in the Constrained List. The metric scores in themselves are relative and provide an important tool to ensure that the environment was actively considered within the programme appraisal modelling.

Figure 9-6: Environmental metrics: grading of effects



9.60 As shown in Figure 9-6, our environmental and social metrics were based on a grading scale of 0 to +10 (for characterising beneficial effects) and 0 to -10 (to characterise adverse effects), with 0 characterising negligible effects. These numerical summary values are not a means of accounting for the SEA in the programme appraisal, however, they inform the relative performance of each of the option elements and are a tool to provide an input to the mathematical optimisation model.

9.61 Importantly, the metrics were derived directly from the findings of the SEA, HRA and WFD assessments. As shown in Figure 9-6, the SEA findings of significance of effect (e.g. moderate adverse, minor beneficial) were used to determine the appropriate metric grading. The metric scores in themselves are relative and provide an important tool to ensure that the environment was actively considered within the programme appraisal modelling.

9.62 As with the SEA, the metrics kept the beneficial and adverse effects separate to avoid 'mixing' (or trading) of the beneficial and adverse effects within the model; this also enabled scenarios to be run within the programme appraisal model to investigate reasonable alternative programmes that maximise benefits or minimise adverse effects to inform decision-making. To help identify relative environmental risks and benefits the initial shortlisting of reasonable alternative programmes for further consideration had regard to the environmental metrics of each option element.

9.63 Following the shortlisting process, each of the options in the reasonable alternative programmes and the programmes themselves were assessed through the SEA process. The relative performance of each was assessed against SEA objectives with regard given to potential cumulative and in-combination effects of components of options. SEA assessment of the options in the preferred programme as well as the programme itself was also undertaken.

9.64 Options comprise one or more option elements (e.g. an option might comprise a source option element, a pumping station and pipeline element and a water treatment works element). Section 7 of Appendix B of our revised draft WRMP (SEA Environmental Report) provides the findings of these assessments. Environmental metrics were not derived for the options.

9.65 In response to stakeholder feedback on the draft methodology , it was agreed that in order to reflect the importance of international level environmental protection under EU or international law, major adverse impacts on internationally important sites, habitats or species would be reflected in the grading system of the environmental metrics.

9.66 Where the SEA (and HRA and WFD) assessments indicated that an option element would cause intractable issues or could not be mitigated and would therefore likely lead to adverse effects on a European site (after consideration of mitigation measures in an Appropriate Assessment), and/or lead to likely permanent deterioration of WFD status between status classes, the adverse effects grading was automatically assigned at the grading of -9 for adverse effects. The -9 adverse effects grade reflects the fact that these options would be unlikely to be acceptable compared to other available alternative options and therefore carry a "penalty" grading for the adverse effects metric. Generally, such options were rejected at the Feasibility Assessment stage, but a small number of options are included on the Constrained List of options where uncertainty led to the assignment of the -9 grade. This was done to flag potential risks and more detailed investigations may conclude that the option element would not be considered suitable for inclusion in the preferred programme.

9.67 Where an early assessment of the option elements identified possible risk of adverse effects to European sites or possible WFD status deterioration (after consideration of mitigation measures), a penalty grading of -7 was applied to the adverse effects metric. This grading of -7 applies where it was recognised that although mitigation is still considered possible, there could be significant challenges after mitigation to conclude no adverse effects on European sites or deterioration of WFD status between status classes. With regard to WFD this related to an uncertain finding in the WFD assessment where uncertainties were considered likely and where there could be challenges in ensuring no adverse effects through the application of mitigation measures. This did not include all elements where an uncertain finding in the WFD report was identified, with some uncertain findings recognising a level of uncertainty, which would be expected with further evidence to provide mitigation measures that will avoid WFD status deterioration. For the HRA assessment this comprised option elements where it was considered, based on the evidence available at HRA Stage 1 screening, that Appropriate Assessment would be required and where there could be challenges in ensuring no adverse effects through the application of mitigation measures.

9.68 This approach to compliance with EU or international law as part of the option element assessment process provided for such issues to be considered and flagged at an early stage, and for the metric grades to flag these issues within the programme appraisal model.

9.69 In order to avoid "double-counting" of the carbon effects, the environmental metric excludes consideration of carbon externalities as these were reflected as monetary (£) values in the programme appraisal model in line with government guidance on carbon pricing.

9.70 By including the environmental metrics in the programme appraisal model, the relative environmental performance of each option element could be taken explicitly into account within the model optimisation process to select a range of alternative programmes for each WRZ. Further details on the programme appraisal modelling are provided in Section 10: Programme appraisal and scenario testing.

9.71 It is important to note that these environmental metrics were only used to inform the programme appraisal model (a numerical model requiring numerical values to represent the environmental effects) and enabled the model to hold information on the environmental effects of each option element alongside other optimisation criteria (e.g. cost, resilience of each option element, etc.). The environmental metrics are not determinative in themselves, rather, they were generated to enable inclusion of environmental and social factors into the mathematical model to assist the short-listing of programmes.

9.72 The environmental metrics were not a substitute for carrying out full SEA, HRA and WFD assessments on the options determined from the programme modelling that were included in the WRZ reasonable alternative programmes. Following the short-listing process, each of the short-listed programmes was assessed through the SEA process. Full SEA, HRA and WFD assessments were undertaken on the options determined from the programme modelling that were included in the short-listed programmes. These detailed assessments informed the decision-making on the “best value” programme of options – not the environmental metric. Regulation 8 of the SEA Regulations requires account to be taken of the Environmental Report for the plan or programme. Schedule 2 of the SEA Regulations requires an Environmental Report to provide information about the way in which environmental protection objectives and any environmental considerations have been taken into account during the preparation of the plan or programme. Further details on how the SEA has influenced the choice of the preferred programme is provided in Section 10: Programme appraisal and Section 11: Preferred plan.

Cumulative environmental effects assessment

9.73 As explained earlier, the SEA, HRA and WFD assessments included consideration of any potential cumulative effects (adverse and beneficial) at key stages of both the draft WRMP19 and the revised draft WRMP19 development: feasible options assessment; fine screening process; assessment of the options included in the reasonable alternative WRZ programmes; assessment of the reasonable alternative programmes and the preferred programme; and for the overall plan.

D. Unconstrained to Constrained List Options: environmental assessment

9.74 The initial stages of the environmental assessment approach involved screening of a large number of options in the unconstrained list. The environmental performance of each option in respect of SEA principles, HRA and WFD were considered and this information used to help decide which options should be rejected and not taken further in the planning process. At this stage, several options were rejected on environmental grounds (and often alongside other factors such as planning or engineering feasibility), mainly due to their likely major adverse effects on international environmental designations (for example, European sites or UNESCO World Heritage Sites). Remaining options were then considered in more detail as part of the Feasible List of options through the Feasibility Assessment process (as described and summarised in our Feasibility Assessment Reports).

9.75 The Feasibility Assessment process included the assessment of each Feasible option against key SEA topics, HRA screening and WFD screening criteria. This process involved engagement with regulators and stakeholders through presentation and publication of the draft Feasibility Assessments, and we used the feedback from this engagement activity to help finalise our assessments. The environmental assessments formed part of a wider set of assessments of each option, including appraisal against economic, engineering, resilience and planning considerations. From these assessments, we made decisions about which options should be taken forward to the Fine Screening process.

9.76 The environmental assessments contributed to a range of options being rejected due either solely, or more often in part, to adverse environmental effects – when compared with other alternative options which performed much better against the environmental assessment criteria. For example, we evaluated 55 potential large reservoir options as part of the Reservoir Feasibility Assessment, but only three options (with sub-options reflecting different potential storage capacities) were taken forward to the Fine Screening assessment. Of the 52 options rejected, 34 options were rejected partly as a result of substantive adverse environmental effects (such as destruction to Ancient Woodland, and damage to a European site).

9.77 Options passing through the Feasibility Assessment stage were considered further as part of the Fine Screening stage, which included comparing options of the same option type (e.g. reservoirs, desalination schemes, water reuse schemes) against SEA, HRA and WFD criteria and considering potential cumulative effects with other options, projects, plans or existing schemes. The assessment approach is summarised in the Fine Screening Report, with the magnitude of the benefits or disbenefits for SEA (and disbenefits only for HRA and WFD) based on a scale from neutral to substantial. These assessments built on the findings of the Feasibility Assessment reports.

9.78 As denoted in Table 9-1 by the red letter ‘r’, the Fine Screening assessment considered whether disbenefits could be reduced through mitigation (as identified as part of the final stage of the Feasibility Assessment process).

9.79 Those options that performed best against all of the Fine Screening assessment criteria (i.e. not just environmental and social factors, but others such as cost and resilience) were taken forward to the Constrained List of options for further evaluation, including development of environmental mitigation measures where required as part of the conceptual design of each option.

9.80 In view of the preceding environmental assessment processes, in particular the Feasibility Assessments, no options were rejected solely in relation to adverse environmental issues at the Fine Screening stage. Some options were identified as performing less well environmentally compared with other options in the same option type, and these findings formed part of the reasoning for the option being rejected. Full details are provided in the Fine Screening Report[14].

9.81 The Fine Screening process was subject to extensive consultation with regulators and stakeholders, through the Water Resources Forum and associated open Technical

[14] Fine Screening Report, Mott MacDonald, January 2018

Stakeholder Meetings, as well as through written submissions on draft versions of the Fine Screening Report made available on our website. Feedback from this engagement activity helped to refine and finalise our decisions on which options to take forward to the Constrained List of options for further development and detailed environmental assessment. A number of options were added to, updated or removed from the list following submission of the draft WRMP19 and development of the revised draft WRMP19, as detailed below.

Table 9-1: Fine screening environmental assessment: example

Environmental & social screening of Option X	
SEA	◎ ●
HRA	○
WFD	◑ r
Cumulative effects	◉

Key to symbols:

- ● Substantial disbenefit
- ◑ Material disbenefit
- ○ Neutral
- ◎ Material benefit
- ◉ Substantial benefit
- r Disbenefit reducible through mitigation

Changes since the draft WRMP

9.82 Thames Water published the draft WRMP19 for public consultation in February 2018. The public consultation ran from 9 February to 29 April 2018.

9.83 Work has continued to develop the water resource options identified in the draft WRMP19 in parallel with the public consultation. As a result, some of the options on the Constrained List of options have been updated to:

- incorporate new information received
- take account of the output of ongoing investigations
- take account of consultee feedback
- take account of continuing dialogue with regulators and statutory bodies
- take account of continuing dialogue with other water companies about water trading and bulk water supplies (imports and exports)

9.84 Due to the above new options have been identified, which have been assessed and included in the revised draft WRMP19, and subject to SEA, HRA and WFD assessment using the same methodologies as the options considered for the draft WRMP19. Furthermore, options which have now been delivered by Thames Water, withdrawn by third parties or which have proved to be unsustainable on the basis of new information received and or in response to consultee comments have been removed from the revised draft WRMP19.

9.85 A summary of these changes to the water resource options since the publication of the draft WRMP19 in February 2018 is presented below.

9.86 The demand management programmes have been modified in light of the strong representations on the draft WRMP19 that these programmes should be enhanced to achieve greater demand savings, in particular to further reduce leakage levels. A 15% leakage reduction target by 2025 and 50% by 2050 is now included in the revised draft WRMP19, reflective of customer, regulatory and government expectations.

9.87 The following new water resource options have been identified:

- Groundwater
  - a. Horton Kirby aquifer storage and recovery (ASR);
  - b. Honor Oak groundwater development;
  - c. New River Head groundwater development;
  - d. Epsom removal of constraints;
  - e. Britwell removal of constraints;
- Removal of Constraints
  - f. Queen Mary removal of outlet constraint;
  - g. Queen Mary removal of low water constraint;
  - h. Queen Mary removal of baffle;
- Raw Water Purchase
  - i. Chingford raw water purchase.

9.88 The following existing water resource options have been updated:

- Raw Water Transfers
  - a. River Wye to Deerhurst (60.3 Ml/d) (previously listed as South-East Wales Resource)
  - b. Great Spring (previously listed as South-East Wales Resource)
  - c. Netheridge STW to River Severn 35 Ml/d
  - d. Minworth STW to River Avon 115 Ml/d
  - e. Minworth Canal Transfer 75 Ml/d
- Direct River Abstractions
  - f. Teddington DRA
- Reuse
  - g. Mogden Reuse
- Groundwater
  - h. Groundwater Datchet
  - i. Ashton Keynes removal of constraints to DO
  - j. North London Licence Trading

- Inter Zonal Transfers
    k. Henley to SWOX 5 Ml/d – Inter-zonal transfer
    l. Henley to SWA 5 Ml/d – Inter-zonal transfer
- Conveyance: Raw Water System
    m. Medmenham Intake – 53 Ml/d
    n. Abingdon to Farmoor pipeline
- Network Reinforcement
    o. SWOX to SWA (48 Ml/d)

9.89 The following elements have been removed:

- Raw Water Transfer Support
    a. Hayden STW to River Severn
    b. Draycote Reservoir Extension
- Groundwater
    c. Eton removal of constraints
    d. Datchet main replacement
- Direct River Abstractions
    e. Teddington DRA

9.90 Further details on the new, amended and removed option elements listed above are provided in the Fine Screening Report. A summary of the reasons for the option elements that subsequent to the draft WRMP19 have been removed from the Constrained List of options in the revised draft WRMP19 is provided below.

9.91 Both the Hayden STW to River Severn and Draycote Reservoir Extension Severn to Thames Transfer (STT) support options were offered by Severn Trent Water and listed in the Raw Water Transfers Feasibility Report (February 2018); however, the assessment was put on hold, pending a review of new information regarding the option. Further work was commissioned by Severn Trent Water and the option was also reviewed by Thames Water and discussed with the Environment Agency. This ultimately led to these two options being withdrawn.

9.92 Both the Eton removal of constraints and Datchet main replacement options have been removed from the revised draft WRMP19 as they have now been delivered.

9.93 Further work on the Teddington Direct River Abstraction (DRA) option was undertaken since the draft WRMP19 to understand the impact of the option on the hydrology and ecology of the River Thames upstream and downstream of Teddington Weir. The work undertaken set out both an ecological need for mitigation of the temperature effects of the DRA option on the freshwater River Thames and estuarine Tideway and potential mitigation approaches. The findings were discussed at meetings with the Environment Agency in May and July 2018. Based on these further discussions both parties agree that the compliance with WFD objectives of a Teddington DRA option remains uncertain. Uncertainty remains in a WFD context around the required extent of temperature mitigation. Research to date has not been sufficient to satisfactorily determine the required extent of, or to identify, a viable mitigation option to deliver this. In consequence a Teddington DRA option cannot be considered a feasible option in a proposed WRMP programme at this time.

E. Constrained List Options: environmental assessment

9.94 A number of options were added to, updated or removed from the list following submission of the draft WRMP19 and development of the revised draft WRMP19, as detailed above. For those options taken forward from the Fine Screening stage to the Constrained List, the options were disaggregated into key component elements (see Figure 9-4) and a conceptual design developed for each of these 'option elements'.

9.95 Findings from our preceding environmental assessment work, together with the initial findings of our detailed SEA, HRA and WFD assessments of each option element, were discussed with our design engineers to examine the requirements for specific mitigation measures as well as to identify opportunities for environmental enhancement and potential environmental gain.

9.96 Consideration of mitigation measures was a key component of the development of the conceptual designs, assessing the potential adverse effects and beneficial effects of the option element and identifying mitigation measures to reduce adverse effects or, where feasible, to enhance beneficial effects. There were two key elements of the mitigation considerations:

- **Modifying scheme design to eliminate or reduce adverse effects** (or provide enhanced beneficial effects). For example, this included measures such as moving the location of pipelines or adopting tunnelling for water conveyance rather than laying a pipeline through a sensitive terrestrial landscape. Particular attention was paid to optimising long-distance pipeline routes to avoid sensitive environmental or social receptors wherever feasible. Enhancement opportunities included consideration of improving biodiversity following construction activities and provision of recreational amenity as part of the option element development.
- **Mitigating where feasible the effects of the modified scheme design**. For example, this included consideration of additional measures (over and above standard mitigation methods) to minimise noise, dust or vibration effects on sensitive natural or human receptors in close proximity during construction work, such as ceasing noisy work during the bird breeding season or during the evenings to minimise effects on local residents. For operational effects, mitigation measures included consideration of landscaping and natural screening of new structures to minimise impacts on visual amenity. We also included additional water treatment processes to minimise impacts of water discharges to rivers and estuaries for reuse, desalination and some raw water transfer option elements.

9.97 The conceptual designs, including details on construction and operational requirements and the mitigation measures for each option element were developed in an iterative manner between the design engineers and the environmental assessment team. These were then used to inform the SEA, HRA and WFD assessment of each option element based on the residual effects after application of the mitigation measures and or inclusion of enhancement opportunities.

9.98 The residual effects of each option element were assessed in accordance with the stated methodologies for SEA, HRA and WFD. The appraisals drew on the Feasibility Reports, the Conceptual Design Reports, public domain environmental datasets and, in most cases, more detailed, option specific environmental assessment reports prepared as part of the development of the revised draft WRMP19.

9.99 In some cases, the residual effects assessment as well as consultation responses from consultees highlighted the requirement for additional mitigation requirements or enhancement opportunities beyond those included in the conceptual design of the option element. Such additional mitigation or enhancement measures were reviewed and agreed and costed for within the appraisal of each option. Further details on the mitigation measures included for within the SEA assessments of the option elements are contained in Appendix I of Appendix B: Strategic environmental assessment - environmental report. Where mitigation or enhancement measures have been identified as being required in the options identified within the preferred programme we will continue to work closely with the Environment Agency, Historic England, Natural England and other key stakeholders to develop and finalise the details of these measures.

9.100 Further assessment work and development of mitigation and enhancement opportunities will be also carried out as part of the detailed design and refinement of all of the other schemes in the revised draft WRMP19 preferred programme as they are brought forward for more detailed planning. This will be in order to seek opportunities to further reduce the identified adverse residual effects and increase beneficial residual effects. Further details are provided in Sections 7 and 10 of Appendix B: SEA environmental report.

9.101 The SEA, HRA and WFD assessment findings were set out in detailed assessment tables for each option element (for a wide range of options considered for the plan including demand management option elements), as presented in the accompanying Appendix B: SEA - environmental report, Appendix C: HRA – stage 1 screening and Appendix BB: WFD assessment.

9.102 An overall summary assessment matrix, ranked according to the magnitude of effects (adverse or beneficial) and the assessed environmental metric grading was produced as presented in Table 9-2 (for adverse effects) and Table 9-3 (for beneficial effects). An overall summary assessment matrix, ranked according to the magnitude of effects (adverse or beneficial) and the assessed environmental metric grading was produced as presented in Table 9-2 (for adverse effects) and Table 9-3 (for beneficial effects). For a small number of option elements, where they were identified after the programme appraisal modelling had been undertaken, no environmental metrics were produced. These option elements relate to measures decided during the programme appraisal stage to enable reduced abstraction from various vulnerable chalk streams and water courses (see Section 10). These option elements were however assessed through the same detailed SEA option element assessment process as all other option elements and the SEA findings are summarised at the bottom of Table 9-2 and Table 9-3. The detailed SEA findings for all of the option elements (rather than the environmental metrics) were used to aid decision-making on the selection of options within the preferred programme.

9.103 The key conclusions from these detailed assessments of the option elements are summarised in the following sub-sections.

HRA

9.104 The HRA provided in Appendix C: HRA stage 1 screening has been updated since the draft WRMP19 report to take account of the 2018 European Court of Justice "People over Wind" judgement[15] which held that mitigation measures should not be considered as part of the HRA screening assessment. The consequence of this judgement and as agreed at the meeting with Natural England held on 13th June 2018, any screening that previously at draft WRMP19 stage relied on mitigation measures to conclude no Likely Significant Effects has been declared a Likely Significant Effect and Stage 2 Appropriate Assessment recommended if it is included in the preferred programme.

9.105 In light of the revised approach to HRA screening and exclusion of consideration of mitigation measures at Stage 1 screening, a total of 44 option elements were identified at the option element level as having potential Likely Significant Effects. The HRA assessments are discussed as part of the programme appraisal assessment in Appendix B: SEA - environmental report, with full details provided in Appendix C: HRA stage 1 screening.

9.106 HRA assessments at option level (which includes combinations of option elements) are discussed as part of the programme appraisal assessment in Appendix B: SEA environmental report, with full details provided in Appendix C: HRA stage 1 screening.

WFD

9.107 Six of the option elements were found to have uncertain risks to WFD objectives when considered in isolation and at the individual operational capacities. Full details of the WFD findings are provided in Appendix BB: WFD assessment. Full details of the WFD findings are provided in Appendix BB: WFD assessment.

9.108 WFD assessments at option level (which includes combinations of option elements) are discussed as part of the programme appraisal assessment in Appendix B: SEA environmental report, with full details provided in Appendix BB: WFD assessment.

SEA

9.109 As would generally be expected, the adverse and beneficial effects of larger scale water source, conveyance and water treatment option elements are greater than for smaller scale options. The precise significance of adverse effects for the same option element type (e.g. desalination plant on the River Thames Tideway or large diameter tunnel in London) does however vary markedly between minor and major adverse effects as the impact significance is highly dependent on the specific geographical setting of the element and its proximity (or otherwise) to sensitive environmental, human and built environment receptors.

9.110 SEA assessments at the option level (which includes combinations of option elements) are discussed as part of the programme appraisal assessment in Appendix B: SEA - environmental report, with full details provided in Appendix F of Appendix B: SEA - environmental report.

[15] Case C-23/17 People Over Wind and Sweetman. Ruling of CJEU

9.111 The beneficial effects of the larger scale option elements also exhibit a wide range, reflecting several key factors:

- The resilience to climate change and water supply reliability afforded
- The opportunity for provision of co-benefits, for example enhanced biodiversity value, recreational and/or educational benefits
- The contribution to a more sustainable water resources management system

Conclusions

9.112 The draft conclusions of the detailed option element SEA, HRA and WFD assessments were discussed and presented to regulators and stakeholders, , through the Water Resources Forum and at an open workshop as part of the June 2017 Technical Stakeholder Meeting. The draft option element assessments were made available to regulators and stakeholders via our website: comments and challenges provided through this consultation activity helped to refine and finalise our assessments and the option element environmental metric gradings for use in the appraisal optimisation model. We have also considered the comments received from stakeholders to the consultation undertaken on the draft WRMP19 in updating the assessments contained within the revised draft WRMP19.

9.113 In conclusion, the earlier stages of the environmental assessment process had largely ensured that the Constrained List of option elements for selection within the programme appraisal process did not include options that would have led to unacceptable environmental or social impacts.,. No option elements from the Constrained List of option elements were therefore excluded from the programme appraisal process.

9.114 Some option elements for which the outcome of the HRA screening had identified a requirement for Appropriate Assessment and / or the outcome of the WFD assessment was uncertain, either because of a lack of available information or due to insufficient time being available to design adequate mitigation measures, were taken forward into the programme appraisal process. In these instances, where the option elements were selected as part of the reasonable alternative programmes and/or the preferred programme, the SEA, WFD and HRA processes involved further examination of the uncertainties and consideration of additional mitigation measures.

9.115 The contribution of the environmental assessment processes to the programme appraisal process and decision-making for the revised draft WRMP19 is described in Section 10: Programme appraisal and in Appendix B: SEA - environmental report.

9.116 Further detail from the SEA, HRA and WFD assessments are set out for a wide range of options considered for both the reasonable alternative programmes as well as for the preferred programme, as presented in the accompanying Appendix B: SEA environmental report, Appendix C: HRA – stage 1 screening and Appendix BB: WFD assessment.

Table 9-2: SEA, HRA and WFD assessment summary matrix for adverse effects of all option elements

Option type & sub-type	Element name	Element Ref			SEA objectives																						Adverse effects metric
			HRA	WFD	1.1	1.2	1.3	1.4	2.1	2.2	2.3	3.1	3.2	4.1	4.2	4.3	4.4	4.5	5.1	5.2	5.3	6.1	6.2	6.3	7.1	8.1	
Treatment: London	Coppermills WTW extension (100Ml/d)	WTW-LON-COP-100																									-7
Treatment: London	Coppermills WTW extension (150Ml/d)	WTW-LON-COP-150																									-7
Network: TWRM	Hampton WTW to Battersea Extension	NET-TWRM-HAM-BAT																									-7
Treatment: London	Kempton WTW expansion (100Ml/d)	WTW-LON-KEM-100																									-7
Treatment: London	Kempton WTW expansion (150Ml/d)	WTW-LON-KEM-150																									-7
Treatment: London	Kempton WTW expansion (300Ml/d)	WTW-LON-KEM-300																									-7
Sprint 2 Raw Water Transfer	Minworth STW to River Avon 115 Ml/d	RES-RWTS-MIN																									-7
Network: TWRM	Network Reinforcement – Kempton WTW New shaft	NET-TWRM-KEM																									-7
Network: TWRM	Network Reinforcement New Header tank at Coppermills WTW	NET-TWRM-COP-HEA																									-7
Conveyance: Raw Water System	Raw Water System Conveyance from Break Tank to Coppermills	CON-RWS-BT-COP-800																									-7
Sprint 3 Resource: Removal of	Britwell Removal of Constraints	RES-RC-BTW																									-7
Conveyance: Reuse	Beckton to Lockwood Covneyance (300 MLD)	CON-RU-BEC-LCK																									-6
Network: TWRM	Coppermills WTW to New Honor Oak Service Reservoir TWRM Extension	NET-TWRM-COP-HON																									-6
Resource: Desalination	Crossness Desal Treatment Plant 3 phases of 100Mld	RES-DES-CRO-100																									-6
Resource: Reservoir	South East Strategic Reservoir Option 100Mm3	RES-RRR-ABI-100Mm3																									-6
Resource: Reservoir	South East Strategic Reservoir Option 125Mm3	RES-RRR-ABI-125Mm3																									-6
Resource: Reservoir	South East Strategic Reservoir Option 150Mm3	RES-RRR-ABI-150Mm3																									-6
Resource: Reservoir	South East Strategic Reservoir Option 30+100Mm3 Phase 1	RES-RRR-ABI-30+100Mm3-P1																									-6
Resource: Reservoir	South East Strategic Reservoir Option 30+100Mm3 Phase 2	RES-RRR-ABI-30+100Mm3-P2																									-6
Resource: Reservoir	South East Strategic Reservoir Option 75Mm3	RES-RRR-ABI-75Mm3																									-6
Resource: Reservoir	South East Strategic Reservoir Option 80+42Mm3 Phase 1	RES-RRR-ABI-80+42Mm3-P1																									-6
Resource: Reservoir	South East Strategic Reservoir Option 80+42Mm3 Phase 2	RES-RRR-ABI-80+42Mm3-P2																									-6
Raw Water Transfer	Severn Thames Transfer – Deerhurst to Culham (300Ml/d) pipeline	CON-RWT-DEH-CLM-300																									-6
Raw Water Transfer	Severn Thames Transfer – Deerhurst to Culham (400Ml/d) pipeline	CON-RWT-DEH-CLM-400																									-6
Raw Water Transfer	Severn Thames Transfer – Deerhurst to Culham (500Ml/d) pipeline	CON-RWT-DEH-CLM-500																									-6
Resource: Desalination	Beckton Desalination treatment plant 150Ml/d	RES-DES-BEC-150																									-5
Resource: Reuse	Beckton Reuse 100 MLD	RES-RU-BEC-100																									-5
Resource: Reuse	Beckton Reuse 150 MLD	RES-RU-BEC-150																									-5
Resource: Reuse	Deephams Reuse 45Ml/d	RES-RU-DPH																									-5
Network: Desalination	Desalination – Crossness to Beckton tunnel	NET-DES-CRO-BEC																									-5
Network: Desalination	Desalination Beckton to Coppermills tunnel	NET-DES-BEC-COP																									-5
Conveyance: Raw Water System	Desalination – Beckton to Crossness tunnel	CON-RWS-BEC-CRO-300																									-5
Conveyance: Raw Water System	Raw Water System – Lockwood PS to KGV Reservoir Intake	CON-RWS-LCK-KGV-800																									-5
Conveyance: Raw Water System	Raw Water System – Queen Mary Reservoir to Kempton WTW site	CON-RWS-QMR-KEM-800																									-5
Sprint 3 SWA North	SWOX to SWA (48 Ml/d)	NET-IZT-AB-LC-48																									-5
Raw Water Transfer	SWOX to SWA (72 Ml/d)	NET-IZT-AB-LC-72																									-5
Sprint 3 Raw Water Systems	Abingdon to Farmoor	CON-RWS-ABI-FMR																									-4
Conveyance: Reuse	Deephams to KGV Conveyance	CON-RU-DPH-KGV																									-4
Resource: Inter-Zonal Transfers	Henley to SWOX 2.37 MLD	RES-IZT-HEN-SWX-NET-2.37																									-4
Sprint 3 Resource: Inter-Zonal Transfers	Henley to SWOX 5 MLD	RES-IZT-HEN-SWX-NET-5																									-4
Resource: Inter-Zonal Transfers	Kennet Valley to SWOX 2.3 MLD	RES-IZT-KEN-SWX-CLV-2.3																									-4
Resource: Inter-Zonal Transfers	Kennet Valley to SWOX 6.7 MLD	RES-IZT-KEN-SWX-CLV-6.7																									-4
Sprint 3 SWA South	Medmenham Intake-53	CON-RWS-MMM-53																									-4
Sprint 3 SWA South	Medmenham Intake-80	CON-RWS-MMM-80																									-4
Raw Water Transfer	Medmenham WTW (24Ml/d)	WTW-SWA-MMM																									-4
Sprint 3 Raw Water Transfer	Oxford Canal Duke's Cut to Farmoor 15Ml/d Pipeline	CON-RWS-DKC-FRM																									-4
Sprint 3 Network Reinforcement	Shalford to Netley Mill	NET-GUI-SFD-NML																									-4
Sprint 2 Raw Water Transfer	Wye to Deerhurst 60.3Ml/d	CON-RWT-ROW-DEH-60.3																									-4
Resource: Aquifer Recharge	ASR SE Lon Addington	RES-ASR-SEL																									-3
Treatment: SWOX	Abingdon WTW (24Ml/d)	WTW-SWOX-ABI																									-3
Treatment: SWOX	SWA North: Abingdon WTW (24Ml/d)	WTW-SWOX-ABI-SWA																									-3
Resource: Aquifer Recharge	SLARS 1 Kidbrooke	RES-AR-SLARS1-7																									-3
Resource: Aquifer Recharge	SLARS 2 Streatham	RES-AR-SLARS2																									-3

Conveyance: Reuse	Deephams to TLT extension Conveyance	CON-RU-DPH-TLTEX	-3
Resource: Inter-Zonal Transfers	Henley to SWA 2.37 MLD	RES-IZT-HEN-SWA-HAM-2.37	-3
Sprint 3 Resource: Inter-Zonal Transfers	Henley to SWA 5 MLD	RES-IZT-HEN-SWA-HAM-5	-3
Resource: Aquifer Recharge	SLARS 3 Merton Abbey	RES-AR-SLARS3	-3
Resource: Aquifer Recharge	Thames Valley Central ASR	RES-ASR-TV	-3
Resource: Groundwater	Addington Groundwater	RES-GW-ADD	-3
Resource: Groundwater	London confined Chalk north	RES-GW-LCC	-3
Resource: Groundwater	Mortimer Recommissioning	RES-GW-MOR	-3
Sprint 2 Raw Water Transfer	Netheridge STW to River Severn 35Mld	RES-RWTS-NTH	-3
Resource: Groundwater	Moulsford Groundwater	RES-GW-MOU	-3
Sprint 3 Raw Water Transfer	Oxford Canal to Cropredy Resource 15 Ml/d	RES-RWTS-OXC-CRP-15	-3
Sprint 3 Raw Water Transfer	Oxford Canal to Dukes Cut Resource 15 Ml/d	RES-RWTS-OXC-DKC-15	-3
Treatment: SWOX	Radcot WTW (24Ml/d)	WTW-SWOX-RAD	-3
Conveyance: Raw Water System	Raw Water System - Chingford South intake increase	CON-RWS-CHS-100	-3
Conveyance: Raw Water System	Raw Water System - Datchet intake increase	CON-RWS-DAT-300	-3
Conveyance: Raw Water System	Raw Water System – Increase capacity of Littleton intake PS	CON-RWS-LTN-300	-3
Conveyance: Raw Water System	Raw Water System - KGV Reservoir to Break Tank	CON-RWS-KGV-BT-300	-3
Conveyance: Raw Water System	Raw Water System KGV Reservoir intake increase	CON-RWS-KGV-360	-3
Resource: Inter-Company Transfers	SEW to GUI 10 MLD	RES-ICT-SEW-GUI-MNT-10	-3
Resource: Groundwater	Southfleet/Greenhithe License Disaggregation	RES-GW-SOU	-3
Resource: Inter-Company Transfers	Wessex to SWOX (Flaxlands)	RES-ICT-WSX-FLX	-3
Sprint 3 Groundwater Resource	Honor Oak Groundwater	RES-GW-HON	-3
Sprint 3 Groundwater Resource	Horton Kirby ASR	RES-ASR-HTK	-3
Sprint 3 Groundwater Resource	New River Head Removal of Constraints	RES-RC-NRV	-3
Resource: Groundwater	Merton Recommissionng	RES-RC-MTN	-2
Resource: Removal of Constraints	Ashton Keynes Borehole pumps	RES-RC-ASH	-2
Resource: Removal of Constraints	Dapdune removal of constraints	RES-RC-DAP	-2
Resource: Removal of Constraints	East Woodhay borehole pumps	RES-RC-EWO	-2
Resource: Removal of Constraints	Ladymead WTW removal of constraints	RES-RC-LAD	-2
Raw Water Purchase	Didcot	RES-RWP-DID	-2
Sprint 3 Groundwater Resource	Datchet Groundwater	RES-GW-DAT	-2
Resource: Raw water transfer support	Lake Vyrnwy - 148 Mld	RES-RWTS-VYR-148	-2
Resource: Raw water transfer support	Lake Vyrnwy - 180 Mld	RES-RWTS-VYR-180	-2
Resource: Raw water transfer support	Lake Vyrnwy - 60 Mld	RES-RWTS-VYR-60	-2
Sprint 3 Resource Removal of Constraints	Epsom Removal of Constraints	RES-RC-EPS	-2
Resource: Raw water transfer support	Mythe WTW	RES-RWTS-MYT	-2
Network: TWRM	Network Reinforcement – Barrow Hill Pump 6 replacement	NET-TWRM-BAR-PUM	-2
Network: TWRM	Riverhead Pump Replacement	NET-TWRM-NRV-PUM	-2
Conveyance: Raw Water System	Raw Water System – Increase capacity of Surbiton intake	CON-RWS-SUR-100	-2
Conveyance: Raw Water System	Raw Water System – TLT upgrade	CON-RWS-TLT-UPG-450	-2
Sprint 2 Raw Water Transfer	Vyrnwy Aqueduct Transfer to Shrewsbury via Oswestry 12Ml/d	CON-TWT-VYR-SWY	-1
Sprint 2 Raw Water Transfer	Vyrnwy Aqueduct Transfer to Shrewsbury via Oswestry 30Ml/d	CON-TWT-VYR-SWY	-1
Raw Water Purchase	Chingford RWP	RES-RWP-CHD	-1
Resource: Groundwater	Dapdune Licence Disaggregation	RES-GW-DAP	0
Raw Water Transfer	River Lee New Gauge pipeline (chalk streams)		
Raw Water Transfer	SWA pipelines (chalk streams)		
Raw Water Transfer	South West London pipelines (chalk streams)		
Raw Water Transfer	South East London pipelines (chalk streams)		
Raw Water Transfer	Culham to Farmoor Pipeline 180Mld	CON-RWS-CUL-FMR-180	

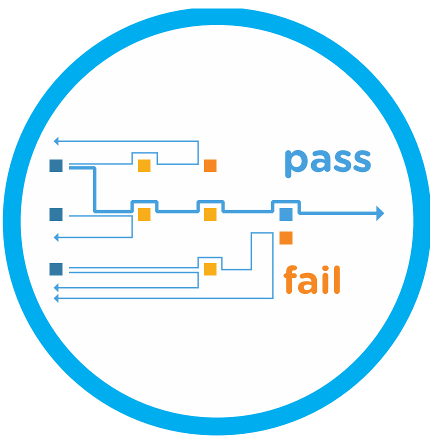
Table 9-3: SEA, HRA and WFD assessment summary matrix for beneficial effects of all option elements

Option type & sub-type	Element name	Element Ref	SEA objectives																						Beneficial effects metric
			1.1	1.2	1.3	1.4	2.1	2.2	2.3	3.1	3.2	4.1	4.2	4.3	4.4	4.5	5.1	5.2	5.3	6.1	6.2	6.3	7.1	8.1	
Resource: Reservoir	South East Strategic Reservoir Option 100Mm3	RES-RRR-ABI-100Mm3																							6
Resource: Reservoir	South East Strategic Reservoir Option 125Mm3	RES-RRR-ABI-125Mm3																							6
Resource: Reservoir	South East Strategic Reservoir Option 150Mm3	RES-RRR-ABI-150Mm3																							6
Resource: Reservoir	South East Strategic Reservoir Option 30+100Mm3 Phase 1	RES-RRR-ABI-30+100Mm3-P1																							6
Resource: Reservoir	South East Strategic Reservoir Option 75Mm3	RES-RRR-ABI-75Mm3																							6
Resource: Reservoir	South East Strategic Reservoir Option 80+42Mm3 Phase 1	RES-RRR-ABI-80+42Mm3-P1																							6
Resource: Desalination	Beckton Desal Treatment Plant 150Mld	RES-DES-BEC-150																							5
Resource: Reuse	Beckton Reuse 100 Mld	RES-RU-BEC-100																							5
Resource: Reuse	Beckton Reuse 150 Mld	RES-RU-BEC-150																							5
Treatment: London	Coppermills WTW extension (100Ml/d)	WTW-LON-COP-100																							5
Treatment: London	Coppermills WTW extension (150Ml/d)	WTW-LON-COP-150																							5
Resource: Desalination	Crossness Desal Treatment Plant 3 phases of 100Mld	RES-DES-CRO-100																							5
Treatment: London	Kempton WTW expansion (100Ml/d)	WTW-LON-KEM-100																							5
Treatment: London	Kempton WTW expansion (150Ml/d)	WTW-LON-KEM-150																							5
Treatment: London	Kempton WTW expansion (300Ml/d)	WTW-LON-KEM-300																							5
Sprint 2 Raw Water Transfer	Minworth STW to River Avon 115Mld	RES-RWTS-MIN																							5
Resource: Reservoir	South East Strategic Reservoir Option 30+100Mm3 Phase 2	RES-RRR-ABI-30+100Mm3-P2																							5
Resource: Reservoir	South East Strategic Reservoir Option 80+42Mm3 Phase 2	RES-RRR-ABI-80+42Mm3-P2																							5
Raw Water Transfer	Severn Thames Transfer – Deerhurst to Culham (300Ml/d) pipeline	CON-RWT-DEH-CLM-300																							5
Raw Water Transfer	Severn Thames Transfer – Deerhurst to Culham (400Ml/d) pipeline	CON-RWT-DEH-CLM-400																							5
Raw Water Transfer	Severn Thames Transfer – Deerhurst to Culham (500Ml/d) pipeline	CON-RWT-DEH-CLM-500																							5
Sprint 2 Raw Water Transfer	Wye to Deerhurst 60.3Mld	CON-RWT-ROW-DEH-60.3																							5
Resource: Reuse	Deephams Reuse 45Mld	RES-RU-DPH																							4
Resource: Raw water transfer support	Lake Vyrnwy 148Mld	RES-RWTS-VYR-148																							4
Resource: Raw water transfer support	Lake Vyrnwy 180Mld	RES-RWTS-VYR-180																							4
Resource: Raw water transfer support	Lake Vyrnwy 60Mld	RES-RWTS-VYR-60																							4
Sprint 2 Raw Water Transfer	Netheridge STW to River Severn 35Mld	RES-RWTS-NTH																							4
Sprint 2 Raw Water Transfer	Vyrnwy Aqueduct Transfer to Shrewsbury via Oswestry 30Ml/d	CON-TWT-VYR-SWY																							4
Treatment: SWOX	Abingdon WTW (24Ml/d)	WTW-SWOX-ABI																							3
Treatment: SWOX	SWA North: Abingdon WTW (24Ml/d)	WTW-SWOX-ABI-SWA																							3
Raw Water Purchase	Didcot	RES-RWP-DID																							3
Raw Water Transfer	Medmenham WTW (24Ml/d)	WTW-SWA-MMM																							3
Sprint 3 Raw Water Transfer	Oxford Canal to Cropredy Resource 15 Ml/d	RES-RWTS-OXC-CRP-15																							3
Sprint 3 Raw Water Transfer	Oxford Canal to Dukes Cut Resource 15 Ml/d	RES-RWTS-OXC-DKC-15																							3
Treatment: SWOX	Radcot WTW (24Ml/d)	WTW-SWOX-RAD																							3
Sprint 2 Raw Water Transfer	Vyrnwy Aqueduct Transfer to Shrewsbury via Oswestry 12Ml/d	CON-TWT-VYR-SWY																							3
Sprint 3 Raw Water Systems	Abingdon to Farmoor	CON-RWS-ABI-FMR																							2
Resource: Groundwater	Addington Groundwater	RES-GW-ADD																							2
Resource: Removal of Constraints	Ashton Keynes Borehole pumps	RES-RC-ASH																							2
Resource: Aquifer Recharge	ASR SE Lon Addington	RES-ASR-SEL																							2
Conveyance: Reuse	Beckton to Lockwood Covneyance (300 MLD)	CON-RU-BEC-LCK																							2
Sprint 3 Resource: Removal of Constraints	Britwell Removal of Constraints	RES-RC-BTW																							2
Raw Water Purchase	Chingford RWP	RES-RWP-CHD																							2
Network: TWRM	Coppermills WTW to New Honor Oak Service Reservoir TWRM Extension	NET-TWRM-COP-HON																							2
Resource: Groundwater	Dapdune Licence Disaggregation	RES-GW-DAP																							2
Resource: Removal of Constraints	Dapdune removal of constraints	RES-RC-DAP																							2
Sprint 3 Groundwater Resource	Datchet Groundwater	RES-GW-DAT																							2
Conveyance: Reuse	Deephams to TLT extension Conveyance	CON-RU-DPH-TLTEX																							2
Conveyance: Reuse	Deephams to KGV Conveyance	CON-RU-DPH-KGV																							2
Network: Desalination	Desalination – Crossness to Beckton tunnel	NET-DES-CRO-BEC																							2
Network: Desalination:	Desalination Beckton to Coppermills tunnel	NET-DES-BEC-COP																							2
Conveyance: Raw Water System	Desalination – Beckton to Crossness tunnel	CON-RWS-BEC-CRO-300																							2
Resource: Removal of Constraints	East Woodhay borehole pumps	RES-RC-EWO																							2

Sprint 3 Resource Removal of Constraints	Epsom Removal of Constraints	RES-RC-EPS	2
Network: TWRM	Hampton WTW to Battersea Extension	NET-TWRM-HAM-BAT	2
Resource: Inter-Zonal Transfers	Henley to SWA 2.37 MLD	RES-IZT-HEN-SWA-HAM-2.37	2
Sprint 3 Resource: Inter-Zonal Transfers	Henley to SWA 5 MLD	RES-IZT-HEN-SWA-HAM-5	2
Resource: Inter-Zonal Transfers	Henley to SWOX 2.37 MLD	RES-IZT-HEN-SWX-NET-2.37	2
Sprint 3 Resource: Inter-Zonal Transfers	Henley to SWOX 5MLD	RES-IZT-HEN-SWX-NET-5	2
Sprint 3 Groundwater Resource	Honor Oak Groundwater	RES-GW-HON	2
Sprint 3 Groundwater Resource	Horton Kirby ASR	RES-ASR-HTK	2
Resource: Inter-Zonal Transfers	Kennet Valley to SWOX 2.3 MLD	RES-IZT-KEN-SWX-CLV-2.3	2
Resource: Inter-Zonal Transfers	Kennet Valley to SWOX 6.7 MLD	RES-IZT-KEN-SWX-CLV-6.7	2
Resource: Removal of Constraints	Ladymead WTW removal of constraints	RES-RC-LAD	2
Resource: Groundwater	London confined Chalk north	RES-GW-LCC	2
Sprint 3 SWA South	Medmenham Intake-53	CON-RWS-MMM-53	2
Sprint 3 SWA South	Medmenham Intake-80	CON-RWS-MMM-80	2
Resource: Groundwater	Merton Recommissionng	RES-RC-MTN	2
Resource: Groundwater	Mortimer Recommissioning	RES-GW-MOR	2
Resource: Groundwater	Moulsford Groundwater	RES-GW-MOU	2
Resource: Raw water transfer support	Mythe WTW	RES-RWTS-MYT	2
Network: TWRM	Network Reinforcement – Barrow Hill Pump 6 replacement	NET-TWRM-BAR-PUM	2
Network: TWRM	Riverhead Pump Replacement	NET-TWRM-NRV-PUM	2
Sprint 3 Groundwater Resource	New River Head Removal of Constraints	RES-RC-NRV	2
Sprint 3 Raw Water Transfer	Oxford Canal - Duke's Cut to Farmoor 15Ml/d Pipeline	CON-RWS-DKC-FRM	2
Conveyance: Raw Water System	Raw Water System - Chingford South intake increase	CON-RWS-CHS-100	2
Conveyance: Raw Water System	Raw Water System - Datchet intake increase	CON-RWS-DAT-300	2
Conveyance: Raw Water System	Raw Water System – Increase capacity of Littleton intake PS	CON-RWS-LTN-300	2
Conveyance: Raw Water System	Raw Water System – Increase capacity of Surbiton intake	CON-RWS-SUR-100	2
Conveyance: Raw Water System	Raw Water System - KGV Reservoir to Break Tank	CON-RWS-KGV-BT-300	2
Conveyance: Raw Water System	Raw Water System – Lockwood PS to KGV Reservoir Intake	CON-RWS-LCK-KGV-800	2
Conveyance: Raw Water System	Raw Water System – Queen Mary Reservoir to Kempton WTW site	CON-RWS-QMR-KEM-800	2
Conveyance: Raw Water System	Raw Water System – TLT upgrade	CON-RWS-TLT-UPG-450	2
Conveyance: Raw Water System	Raw Water System Conveyance from Break Tank to Coppermills	CON-RWS-BT-COP-800	2
Conveyance: Raw Water System	Raw Water System KGV Reservoir intake increase	CON-RWS-KGV-360	2
Resource: Inter-Company Transfers	SEW to GUI 10Mld	RES-ICT-SEW-GUI-MNT-10	2
Resource: Aquifer Recharge	SLARS 1 Kidbrooke	RES-AR-SLARS1-7	2
Resource: Aquifer Recharge	SLARS 2 Streatham	RES-AR-SLARS2	2
Resource: Aquifer Recharge	SLARS 3 Merton Abbey	RES-AR-SLARS3	2
Resource: Groundwater	Southfleet/Greenhithe License Disaggregation	RES-GW-SOU	2
Raw Water Transfer	SWOX to SWA (48 Ml/d)	NET-IZT-AB-LC-48	2
Sprint 3 SWA North	SWOX to SWA (72 Ml/d)	NET-IZT-AB-LC-72	2
Resource: Aquifer Recharge	Thames Valley Central ASR	RES-ASR-TV	2
Resource: Inter-Company Transfers	Wessex to SWOX (Flaxlands)	RES-ICT-WSX-FLX	2
Network: TWRM	Network Reinforcement – Kempton WTW New shaft	NET-TWRM-KEM	1
Network: TWRM	Network Reinforcement New Header tank at Coppermills WTW	NET-TWRM-COP-HEA	1
Sprint 3 Network Reinforcement	Shalford to Netley Mill	NET-GUI-SFD-NML	1
Raw Water Transfer	River Lee New Gauge pipeline (chalk streams)		
Raw Water Transfer	SWA pipelines (chalk streams)		
Raw Water Transfer	South West London pipelines (chalk streams)		
Raw Water Transfer	South East London pipelines (chalk streams)		
Raw Water Transfer	Culham to Farmoor Pipeline 180Mld	CON-RWS-CUL-FMR-180	

Section 10

Programme appraisal and scenario testing



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Section 10.

Programme appraisal and scenario testing

In this section we set out our programme appraisal for each of our water resource zones (WRZs).

We have continued to engage with and brief stakeholders, regulators and interested parties as we have updated this section. We have explained our approach and taken into account, where appropriate, their comments and feedback.

In defining a preferred programme for London, Swindon and Oxfordshire (SWOX) and Slough, Wycombe and Aylesbury (SWA) Water Resource Zones (WRZs), we have identified a plan which facilitates synergies between them and also with other water suppliers in the south east of England.

We have also adopted this approach in defining the plans for the other WRZs Henley, Guildford and Kennet Valley WRZs, thereby delivering a consistent messaging to all our customers.

The following updates have been made:

- We have updated the inputs to programme appraisal regarding the baseline supply demand forecast (Sections 2-6) and assimilated and applied the latest information on the demand management and resource development options available to meet any deficits (Sections 7-9). Notable changes from the draft WRMP19 include:
  - Reduction in long-term population forecast
  - Teddington DRA is no longer a feasible option
  - Sustainability reductions are confirmed as included in the baseline supply forecast
  - A greater range of demand management programmes have been assessed including additional interventions.
- The methodology and processes used for programme appraisal (Section 10: A-C) are largely unchanged from the draft WRMP19.
  - We have incorporated as part of programme appraisal the system simulation modelling and adaptability analysis that we were unable to complete in time for the published draft WRMP19.
  - We have revised the derivation of three (deliverability, resilience and intergenerational equity) of the eight metrics used in programme appraisal to aid clarity.
  - We have expanded on the role of the Expert Panel in the programme appraisal process and included their report as Appendix Y.
- We have repeated and re-written, where necessary, the programme appraisal itself for all WRZs (Section 10: D-I).
  - We have updated our Sustainable Economic Level of Demand Management analysis and included in our preferred programme a policy that will deliver greater and longer-term reductions in demand.
  - We have confirmed with our neighbours their future water resources needs.
  - We have repeated the modelling using EBSD+ and identified new reasonable alternative programmes
  - We have undertaken a substantial programme of performance testing of the reasonable alternative programmes, including assessment of alternative futures

thorough adaptability and 'what if' analysis.
  - We have tested a wide range of drought return periods using IRAS-MCS to more fully understand drought resilience.
  - We have sought to clarify further the key decision-making points throughout the process and have set out our rationale for the decisions we've taken.
- We have repeated and re-written, where necessary, the SEA, HRA and WFD assessments at option and programme level and expanded upon how they have influenced the selection of the preferred programme (Section 10: D-I).
- We have selected a new preferred best value programme.

Outcomes:

- **Our overall preferred best value programme remains one that addresses and resolves the baseline supply demand problem arising over the 80 year planning period, allows for an enhancement in system resilience to a 1 in 200 year drought (by 2030) and enables greater sharing of water resources with neighbouring companies to meet regional needs across the south east of England.**
- It also will enable us to make changes to our abstractions to improve vulnerable chalk stream ecosystems in our supply area.
- The preferred programme is demand management focussed in the short-term, comprising an integrated package including significant reductions in leakage, the metering of all water supply connections and an enhanced water efficiency programme.
- The demand management programmes (DMPs) however are not enough to resolve the supply demand deficit on their own, consistent with the general duty to develop and maintain an efficient and economical system of water supply in the Thames Water area.
- There have been changes in some of the water resource options selected in the draft WRMP19 following the use of the latest information on available options, as detailed in Sections 1 to 9 of our revised draft WRMP19.
- We have planned accordingly for water resource development in the period to 2030, 2037 and the 2080s.

A. Introduction

- Minor amendments to references.

10.1 In this Section 10 of the revised draft WRMP19 we set out our demand /supply programme appraisal for each WRZ.

10.2 Programme appraisal is the process by which we seek to address and resolve the demand/supply problems identified in Section 6, by appraising the water management options available over the planning period that are detailed in Sections 7 and 8.

10.3 The environmental assessment of the options, which has informed both the selection of options to make up programmes and the preferred programme itself, is set out in Section 9: Environmental assessment.

10.4 For Water Resources Management Plan 2014 (WRMP14), we assessed the then water resources planning problem by reference to a twenty-five year planning period for all six WRZs, using the Economics of Balancing Supply and Demand (EBSD) methodology. However, the latest WRPG[1] advocates selecting a planning period for our Water Resources Management Plan 2019, that is appropriate to the risks we need to account for. This is both in terms of the complexity of the supply and demand problem and the options available to solve the problem, so as to ensure a secure and sustainable supply of water.

10.5 We have followed a structured programme appraisal process in producing our plan, which has been reviewed and assessed by a panel of industry experts (Appendix Y):

Problem characterisation

(Section B below and Appendix W: Programme appraisal methods)

10.6 Problem characterisation is carried out to guide water resource planners toward the appropriate method of assessment proportionate to the size and complexity of their demand/supply planning problem. An analysis of the size and complexity of the planning problem also guides planners towards the appropriate length of planning period of the plan to be adopted. Accordingly, the determination of both the assessment methodology to be used and the planning period of the plan are outcomes of the problem characterisation analysis.

Identification and assessment of potential programmes

(Section C-H and Appendices W and X)

10.7 For many years, 'least-cost' was the primary factor advocated by regulators in devising WRMPs. The preferred programme was the cheapest practicable solution to the planning problem. There is now wide support from regulators, stakeholders[2] and our customers[3], to develop *best value*[4] demand/supply plans which take account of a wider range of factors over

[1] Environment Agency and Natural Resources Wales, Water Resources Planning Guideline: July 2018
[2] Technical Stakeholder Meetings, March 2016 and November 2016
[3] Customer research, Britain Thinks, September 2016
[4] WRPG (July 2018) Section 6

the long term including the environmental impacts of programmes, resilience to drought, and customer water management preferences, in addition to cost. We have, accordingly, worked with other water companies and industry regulators to develop a more advanced decision making framework and have applied this in developing our revised draft WRMP19.

10.8 Potential programmes have been identified to solve the baseline demand/supply planning problem as presented in Section 6. We have then repeated the analysis for two alternative scenarios. Firstly, reflecting a greater resilience position to drought and secondly, providing greater resilience to drought and, additionally, allowing for transfers to neighbouring companies in the south east of England.

10.9 **It is the latter scenario, providing greater resilience to drought (to the Environment Agency's suggested 1:200 reference level) and allowing for regional transfers (as contributing to best value planning for water supply/demand in the south east of England) that has been adopted as our preferred scenario for WRMP19.**

10.10 The above scenarios have been assembled in response to clear policy drivers from Government and regulators, such that decisions can be made on their inclusion or not in the WRMP19 at the outset.

Performance testing the programmes

(Section C-H Step 4 and Appendix X)

10.11 Having identified a shortlist of potential reasonable alternative programmes of demand management/resource development options, we have tested them for their adaptability and robustness to future demand/supply uncertainties. This exercise has included:

a) Inclusion of option uncertainty (Final planning headroom)
b) Adaptability analysis
c) Stress testing ('What if' analysis)
d) System simulation modelling (drought resilience)
e) Strategic Environmental Assessment
f) Local resilience and practicality checks

Selection of the preferred programme

(Section I)

10.12 Having completed the performance testing we have then been able to propose a best value preferred programme of demand management and resource development interventions to solve the water supply demand planning problem identified.

10.13 Summarised in Section I and in full in our revised draft WRMP19 Section 11: Preferred programme.

B. Understanding the planning problem

This section explains our understanding of the water resources problems in each of our WRZs.

It sets out the framework for addressing them through problem characterisation, deciding the assessment period and the appropriate decision support tools and approaches to resolve to risks identified.

There are only minor changes to this section from the draft WRMP19:

- Problem characterisation is unchanged.
- We have retained the extended 80-year planning period.
- Decision support tools: We have updated the text to confirm that we have now used both aggregated and system simulation modelling approaches in carrying out our programme appraisal.

Approach

10.14 Problem characterisation is carried out to guide water resource planners towards the most appropriate method of assessment for the size and complexity of their water supply/demand planning problem. Analysis of the size and complexity of the planning problem also guides planners as to the choice of the appropriate length of planning period for their plan; and therefore both the adoption of the assessment methodology and the planning period for the plan are informed by outcomes of the problem characterisation exercise.

10.15 UKWIR's WRMP 2019 Methods – Decision Making Process: Guidance[5] provides a decision making framework for both defining the water resources planning problem and selecting the best method to address and resolve it using the full array of feasible techniques. We have followed this approach in drafting our plan.

10.16 The statutory minimum planning period for a WRMP is 25 years. In recognition of the longer term pressures, and the time it can take to develop necessary infrastructure, Government has encouraged water companies to adopt a longer planning period where this is considered to be appropriate[6,7].

10.17 In light of the complexity of the water resource planning problem in the south east and the ongoing pressures associated with population growth and the impacts of climate change, we commissioned NERA Economic Consulting to develop a framework for assessing the most appropriate time horizon for water resource planning[8] in the Thames Water area. NERA was part of the team which developed the UKWIR Decision Making Process Guidance. Their conclusions were fed into our problem characterisation assessment which is summarised below.

[5] UK Water Industry Research WRMP 2019 Methods – Decision Making Process: Guidance Report Ref. No. 16/WR/02/10
[6] Environment Agency and Natural Resources Wales, Water Resources Planning Guideline: Interim Update July 2018
[7] Defra, Guiding principles for water resources planning: For water companies operating wholly or mainly in England, May 2016
[8] NERA, What is the Appropriate Horizon for Integrated Water Resource Planning?, November 2016

Characterising the problem for each WRZ

10.18 For each WRZ, the UKWIR Guidance requires planners to address a set of questions that can be used to define the strategic risk in each WRZ, namely, demand complexity, supply complexity and investment complexity. Answers can then be scored and put in a matrix to define an overall high, moderate and low level of concern. The scores from the analysis we undertook are shown in Table 10-1 to Table 10-4. Our detailed consideration of each question is provided in Appendix W.

10.19 We shared this analysis with stakeholders in March 2016 and November 2017. As a part of this engagement in March 2016 we included an exercise where stakeholders could characterise the complexities of the London WRZ for themselves. Their conclusions largely agreed with our own.

Table 10-1: Problem characterisation - strategic risk

How big is the problem?				
Strategic WRMP Risks (Score 0-2 each)				
Water Resource Zone	Customer Service could be significantly affected by current or future supply side risks, without investment	Customer Service could be significantly affected by current or future demand side risks, without investment	Investment programme likely to be unacceptably costly or contain contentious options	**Strategic Risk Score**
London	2	2	2	**6**
SWOX	1	2	2	**5**
SWA	1	2	2	**5**
Kennet	0	1	0	**1**
Guildford	0	1	1	**2**
Henley	0	0	0	**0**

Table 10-2: Problem characterisation - supply complexity

How complex is it to solve? (1)					
Supply Side Complexity (Score 0-2 each)					
Water Resource Zone	Concern about near term supply (Reliable/ resilient to drought)	Concern about future supply (climate change/ water quality)	Concern about near/ medium term step changes to supply (sustainability reductions)	Concern DO may fail to represent resilience	**Supply Complexity Score**
London	2	2	2	2	**8**
SWOX	1	2	1	2	**6**
SWA	0	0	1	1	**2**
Kennet	0	0	0	0	**0**
Guildford	0	1	1	0	**2**
Henley	0	0	0	0	**0**

Table 10-3: Problem characterisation - demand complexity

How complex is it to solve? (2)				
Demand Side Complexity (Score 0-2 each)				
Water Resource Zone	Changes in current or near-term demand	Forecast uncertainty	Demand versus critical drought timing critical	**Demand Complexity Score**
London	2	2	1	**5**
SWOX	1	1	1	**3**
SWA	1	1	1	**3**
Kennet	1	1	1	**3**
Guildford	1	1	1	**3**
Henley	1	1	1	**3**

Table 10-4: Problem characterisation - investment complexity

How complex is it to solve? (3)					
Investment Programme Complexity (Score 0-2 each)					
Water Resource Zone	Does uncertainty around capital expenditure affect the investment decision?	Do factors such as lead time and promotability affect the decision?	Can wider non-monetisable considerations be properly considered?	Is the investment programme sensitive to assumptions about the utilisation of new resources?	**Investment Complexity Score**
London	2	2	1	2	**7**
SWOX	2	2	1	1	**6**
SWA	2	2	1	1	**6**
Kennet	0	0	1	0	**1**
Guildford	0	0	1	0	**1**
Henley	0	0	1	0	**1**

10.20 The above scores have been combined into the problem characterisation heat map, as advised in the Guidance, to give an indication of the complexity per WRZ as presented in Table 10-5.

Table 10-5: Problem Characterisation - Summary

Problem Characterisation		Strategic risk score			
		0-1	2-3	4-5	6
Complexity factors score	Low <7	Henley Kennet Valley	Guildford		
	Med 7-11			SWA	
	High (11+)			SWOX	London

10.21 This analysis demonstrates that the London and Swindon and Oxford (SWOX) WRZs have a water resource planning problem of high concern. The Slough, Wycombe and Aylesbury (SWA) WRZ has a moderate level of concern, while the remaining zones have planning problems of low concern.

Planning period extension

10.22 *"The time horizon should be chosen so that events beyond the horizon end would be unlikely to affect the decisions about what to do initially"* (NERA, 2016).

10.23 Where there is no relevant deficit, or the availability of sufficient robust, low-cost effective water management options which can be quickly implemented, then the statutory minimum 25-year planning period is sufficient.

10.24 However, where there is a large potential deficit, and options to address that deficit have long lead times and long asset lives, extension of the planning period may be necessary to ensure equitable comparable assessment; this need must be weighed against the decreased reliability of forecasts over a longer time horizon. One of the key limiting factors for extension of the planning period is the impact of the discount rate on investment in the distant future. NERA state that events beyond horizons of 100 years are most unlikely to influence the initial steps, and therefore a planning horizon beyond this limit is unlikely to be justified.

10.25 In order to assess the correct planning period for a complex demand/supply problem, NERA advocate use of a stepwise approach for extending the 25-year planning period in five year time-steps, by a flow chart of questions, which can be translated into a score. The scoring (of 1-4 based on answers to questions regarding asset types and the extent of the emerging deficit) for each WRZ is presented in Appendix W: Programme appraisal methods and is summarised in Table 10-6 from 25 to 100 years. The appropriate planning period can be selected from the range showing the highest score for each zone.

Table 10-6: Summary of scoring for extending planning period assessment

Is the current planning period appropriate?																	
Potential planning period (years)																	
Water Resource Zone	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**100**	**Appropriate period**
London	0	0	0	0	0	0	0	0	2	2	2	2	X				65-80
SWOX	1	1	1	1	1	1	0	0	2	2	2	2	X				65-80
SWA	1	1	1	1	1	1	0	0	2	2	2	2	X				65-80
Kennet	4	4	4	4	4	4	4	4	4	4	4	4	X				25
Guildford	4	3	3	3	3	3	3	3	3	3	3	3	X				25
Henley	4	4	4	4	4	4	4	4	4	4	4	4	X				25

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10.26 The analysis demonstrates that a planning period of between 65 and 80 years would be most appropriate for London, SWOX and SWA. Our remaining zones could remain at 25 years, but we have decided to forecast all zones to 2100 for consistency and robustness.

10.27 An 80-year planning period also aligns with that chosen by the Environment Agency when settling its strategy of flood protection for London. The economic and social consequences of water supply failure in London would be equally as catastrophic as those associated with flood inundation and, as such, it is appropriate to work to the same planning period when deriving the strategy for future water supply.

10.28 We have demonstrated the impact of choosing an alternative, shorter planning period as a part of 'What if' testing, see Appendix X.

10.29 It should also be noted that the iterative nature of the WRMP planning process is also relevant here. This allows us to refine our understanding of the future and make regular adjustment to track and review plans as appropriate. The flexibility of our potential programmes over time is also investigated through the use of adaptive assessment as a performance test in the programme appraisal.

Regional context

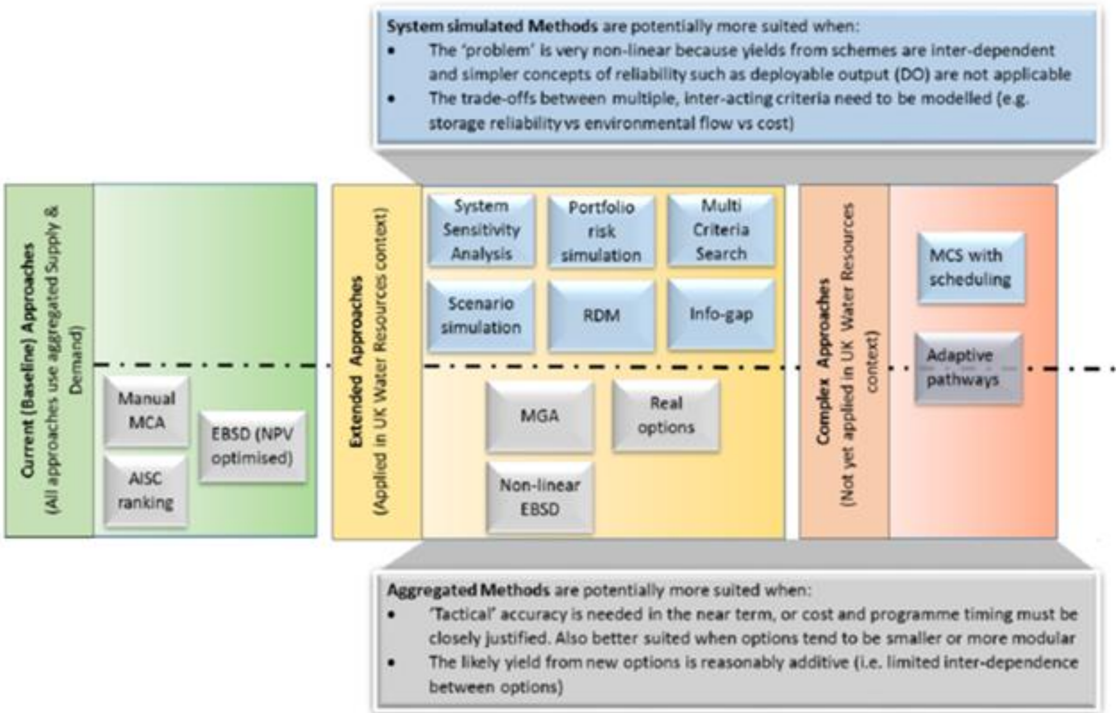
10.30 While problem characterisation should be carried out at WRZ level, the problems apparent in one zone may well be transferred to another and, accordingly, selected supply/demand planning methods for connected or potentially connected neighbouring zones should ideally be as closely aligned as possible to enable best analysis of inter-zonal transfer capabilities and shared water resource planning where a management problem is significant and widespread. This is the remit of the Water Resources in the South East (WRSE) group, which also collaborates with Water Resources East (WRE) to tackle the demand/supply water resource issue across the whole south east region.

Assessment methods

10.31 There is a wide range of decision support tools which extend from simple to more advanced tools to support more thorough analysis of the demand/supply planning problem and solutions to it.

10.32 The problem characterisation matrix (Table 10-1 to Table 10-5) demonstrates that both London and SWOX WRZs have a demand/supply problem of high concern and that SWA has a problem of moderate concern. In these circumstances, the UKWIR Guidance recommends the use of extended or complex risk-based techniques to enable a thorough analysis of the planning problem, as can be seen in Figure 10-1, which is colour coded to match the problem characterisation matrix (Table 10-5).

Figure 10-1: Decision making methods and tools for problems of different complexity



Source: UKWIR WRMP 2019 Methods

10.33 It should be appreciated that the techniques detailed in the UKWIR WRMP 2019 Methods guidance are decision support tools and that they should be used as such. The outputs need to be carefully appraised by knowledgeable experts and the information used to help inform the decision making process to select a best value investment programme (see Sections D-I and supporting information in Appendix W, X and Y).

10.34 The other WRZs have low complexity problems. The analysis of Guildford, Henley and Kennet Valley WRZs has therefore been carried out using the current EBSD[9] approach where the Net Present Value (NPV) of the investment programme is optimised.

10.35 We have developed two decision support tools (EBSD+[10] and IRAS-MCS[11]) that use both aggregated and system simulation methods to develop potential demand/supply solutions which have been evaluated using a range of performance metrics (see Part C below). The models are coupled to optimisers which use Modelling to Generate Alternatives or Multi Criteria Search (MCS) to find a range of potential solutions which will then be evaluated using professional judgement to find the best value solution. A detailed description of these tools can be found in Appendix W Part B.

Summary

10.36 London and the SWOX WRZs have significant and complex demand/supply water resource challenges. The SWA WRZ has moderate challenges. The solutions required in these WRZs will be high cost, with long lifespans. As such, we have planned over an 80 year plan period and used advanced decision support tools to enable a thorough analysis of the demand/supply planning problem and to develop multiple feasible programmes of investment to address it.

10.37 The remaining three WRZs (Kennet Valley, Guildford and Henley) have demand/supply planning problems of comparatively lesser complexity. Relatively low-cost options are available and are relatively quickly implemented. As such, less complex EBSD approaches to the identification of supply/demand options have been used to develop the preferred programmes in these zones.

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[9] **EBSD** combines cost analysis with single objective least-cost optimisation

[10] **EBSD+** combines analysis of multiple parameters including cost, with single objective optimisation for each successive parameter. A second search uses a dual-objective search to find the best solution for each metric within a threshold increase of cost from the least-cost solution (SCS). The third search finds near-optimal solutions for each parameter in relation to the SCS results, an approach which is known as modelling to generate alternatives (MGA).

[11] Interactive River-Aquifer Simulation (IRAS) **IRAS_MCS** combines system simulation modelling to assess multiple parameters with multiple criteria search (MCS).

C. Identifying and assessing demand/supply programmes

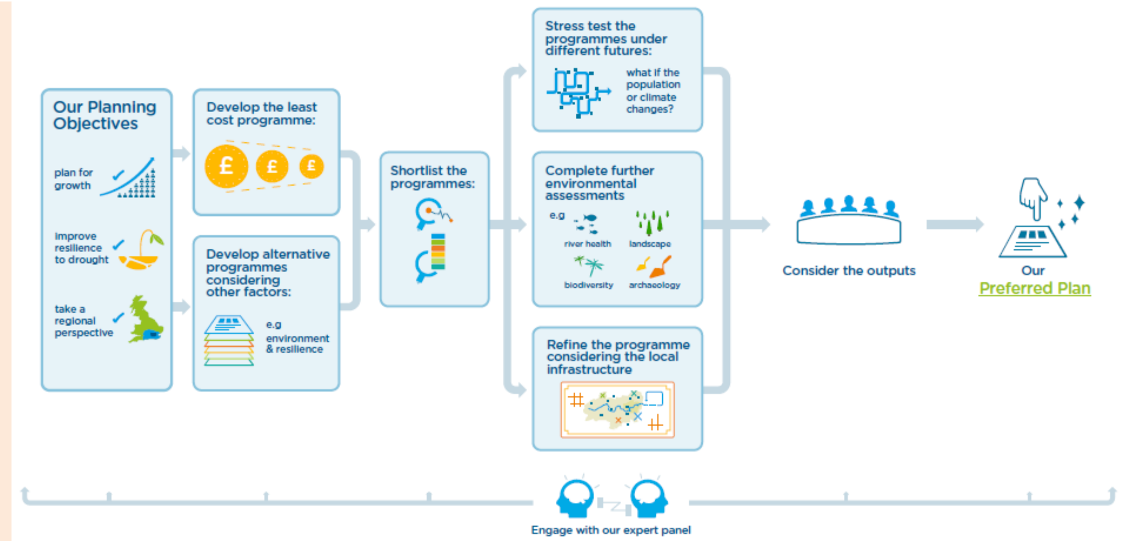
- The overall approach to identifying reasonable alternative programmes is unchanged from the draft WRMP19.
- Text and figures updated to accommodate availability of both aggregated and system simulation modelling methods and where in the process they are used.
- Updated derivations for the following metrics:
  - Deliverability
  - Resilience
  - Intergenerational equity (IGEQ)
- Performance testing of potential programmes has expanded significantly since the draft, with the inclusion of adaptability testing and a greater range of potential alternative futures tested.

Approach

10.38 In this section we provide an overview of our programme appraisal method. Full details of the method used are available in Appendix W: Programme appraisal methods.

10.39 As in our previous WRMPs, we have developed an approach to plan making (Figure 10-2) that starts with the least-cost (lowest 80yr NPV) programme, then takes account of a wide range of factors, objectives and performance testing to lead to the identification of a preferred best value programme.

Figure 10-2: Approach to programme appraisal



10.40 Our programme modelling approach for the revised draft WRMP19 is as set out in Figure 10-3. The steps are described below. The key decision points in the programme appraisal process are shown in Table 10-7.

Figure 10-3: Modelling the programme appraisal

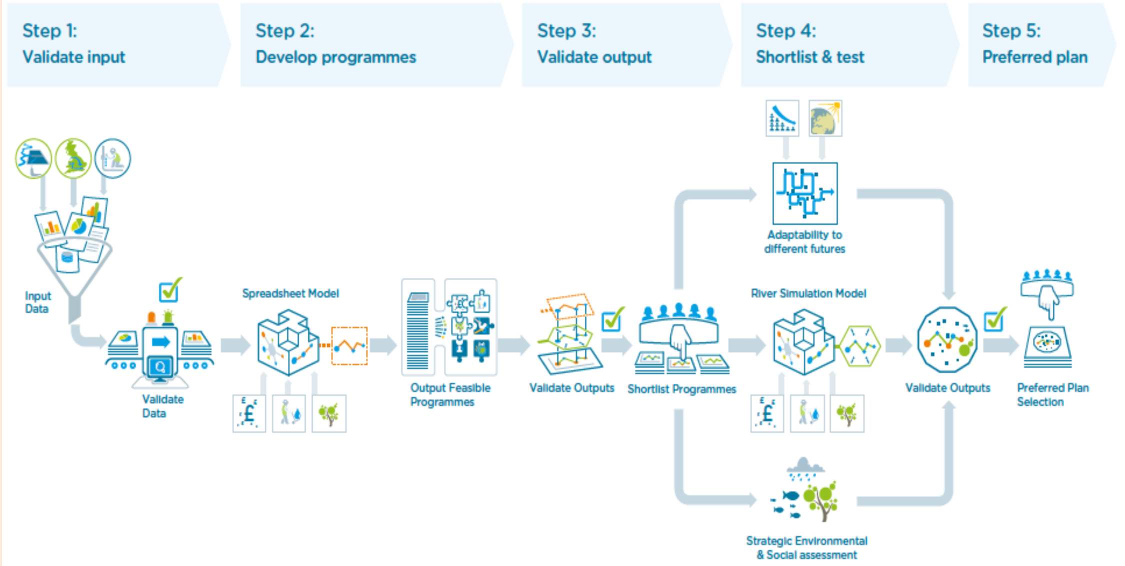


Table 10-7: Key decision points

Decision Point	When?	What?	Who?	Reviewed by	Signed off
DP1	Step 1: Pre-modelling	- Problem characterisation (i.e. risk-based modelling complexity) - Number and type of metrics - Number and type of optimisations - Number of scenarios - Establishing a demand management policy	Thames Water	Thames Water Expert Panel	
DP2	Step 3: After initial optimisation runs	Identifying Reasonable Alternative Programmes (for the preferred scenario)	Thames Water Ricardo[12]	Thames Water Expert Panel	
DP3	Step 4: After uncertainty testing	Identifying themes emerging from the following testing: - Option uncertainty - Adaptability testing - IRAS-MCS outputs - What if stress testing - SEA Assessment - Local resilience and practicality checks	Thames Water Ricardo	Thames Water Expert Panel	
DP4	Step 5: Preferred Programme	Identifying the preferred programme	Thames Water Ricardo	Thames Water Expert Panel	TW Exec Team TW Board

[12] Ricardo-AEA, our consultant environmental specialists.

Step 1 - Collation and validation of input data

10.41 We have undertaken detailed work to update our baseline supply demand position (revised draft WRMP19 Sections 3-6) and to identify and assess feasible demand management and resource options, in terms of cost, lead times and environmental impact, among other matters (Sections 7-9). These assessments have provided the main input data to the decision support tools.

10.42 We have also developed metrics that can be used to assess our programmes as they are developed.

Step 2 – Develop programmes

10.43 The approach to developing supply demand programmes combined methods for evaluating programme performance with methods for searching for the best programme. The decision support tools, ranging from simple to complex, are shown in Figure 10-1.

10.44 There are two main types of model used for water resource planning, firstly aggregate or spreadsheet models; these are less complex and established tools, such as EBSD[13]. Secondly, system simulation models; these are more complex tools and are set up based on simulating the resilience of the current operating system to drought.

10.45 In Henley, Guildford and Kennet Valley WRZs we used an enhanced EBSD+ model which includes assessment against a series of performance metrics, but remains optimising solely on least-cost NPV.

10.46 In London, SWOX and SWA WRZs, we have used aggregated methods (EBSD+[14]) in Step 2 and system simulation methods (IRAS-MCS) in Step 4. Both are able to test multiple parameters.

Step 3 – Validate output

10.47 Numerous feasible solutions to the demand/supply deficit were generated by the EBSD+ model runs, across multiple scenarios. We consolidated the output provided by the different EBSD+ model runs to assess differences and similarities.

Step 4 – Shortlist and test

10.48 We assessed the demand /supply problem solutions in respect of their performance against a range of metrics and shortlisted a set of reasonable alternative programmes for further testing.

10.49 Note that steps 1 to 4 (Figure 10-3, i.e. up to and including shortlisting) were carried out for three scenarios (Baseline, Baseline + Increased drought resilience and Baseline + Increased drought resilience + Regional transfers), as set out in the Introduction.

[13] Optimising solely on least-cost NPV
[14] Able to optimise against a range of performance metrics, not just least-cost.

10.50 We identified a preferred planning scenario and subjected the reasonable alternative programmes for that scenario to a suite of stress tests and checks for robustness:

- **Option uncertainty:** We assessed the additional uncertainty around options selected in the programmes to understand if any changes to the timing of options or if further interventions would be required to maintain the balance of supply and demand.
- **Adaptability:** In developing a long-term plan there are inevitably uncertainties. It is important, therefore, to test the effect that these could have on the plan and ensure the plan is flexible and robust in the face of an uncertain future. We have used a similar approach to the 'adaptive pathways' method, first used by the Environment Agency to manage tidal flood risk in the Thames Estuary.
- **'What if' analysis:** 'What if' analysis is a simplified version of adaptability testing whereby one, or a combination of uncertainties are tested to give a specific output, i.e. using a different population forecast or the removal of certain option types.
- **System simulation using IRAS-MCS:** Whilst our EBSD+ model is designed to solve the supply demand problem for specific drought return periods, system simulation modelling allows us to take a closer look at the resilience of our system to a wider range of droughts. We have developed an IRAS-MCS system simulation model with the University of Manchester to develop programmes of options that shows performance against service Level 3 and Level 4 failures and recovery times. This is used to sense check the EBSD outputs and help establish a robust best value preferred programme.

  Further information on the methodology is provided in Appendix W.
- **Strategic Environmental Assessment:** A programme-level Strategic Environmental Assessment (SEA) for each reasonable alternative programme to meet our preferred scenario has been completed. This ensures that the environmental impacts of the programmes can be understood and we have used the SEA process to assist in identifying preferred option types, as well as, trade-offs that could improve the environmental performance of each alternative programme. The SEA ensures that neither the quantification of effects for the environmental metrics, nor the cumulative impact from multiple options has skewed the assessment of the environmental impacts of the overall programmes.
- **Local resilience and practicality checks:** The reasonable alternative programmes are raw modelled outputs at WRZ level. In identifying a preferred programme (see below) we check to see if there are any practicality issues with the option set (mutual exclusivities, interdependency) and also consider if any sub-WRZ level local resilience issues would favour the inclusion of certain options.

Step 5 – Preferred programme

10.51 The outputs from the performance testing of the reasonable alternative programmes are assessed to identify a preferred programme. This could be the same as one of the reasonable alternative programmes, but it is more likely to be a variant or amalgamation of several in order to arrive at a 'best value' outcome.

Step 1: Collation and validation of input data

10.52 The EBSD+ and IRAS-MCS models were adopted as appropriate to guide decision making having regard to the scale and complexity of the planning problem. The EBSD+ model (for Step 2) and IRAS-MCS model (for Step 4) were given as inputs:

- The baseline supply demand balance, including headroom (rdWRMP Section 6).
- The range of water resource and transfer options (rdWRMP Section 7).
- Demand Management Programmes (DMPs) optimised in the Integrated Demand Management (IDM) model (rdWRMP Section 8).
- Information supporting the efficacy of the metrics (see below) used by each model, e.g. environmental performance data (rdWRMP Section 9).

10.53 These were visually checked for outliers and inconsistencies on upload to each model. There are also flags in each model that prevent it from running if there are infeasibilities in the inputs, for example demand saving profiles that are higher than the baseline demand.

10.54 A large number of iterations of the models were produced in the programme appraisal exercise so the stability of the input data was of fundamental importance.

Metrics

10.55 The WRPG presents clear guidance for water companies to move from least-cost development of WRMPs towards a best value plan for the WRMP19, taking into account metrics beyond financial cost.

10.56 It is important that customers are at the heart of our decision making process. We need to consider equity of investment costs and benefits for current and future generations, taking full consideration of the environmental and social impacts of individual schemes but also the combined programme impacts of our plan, over the planning period and beyond.

10.57 We also need to take account of Government policies and aspirations for growth and for water and the environment.

10.58 Additionally, we assess our plan against measures of reliability and resilience; there will be parameters that we can plan for in terms of risk and other factors that are outside of our control, such as potential population increases, the impacts of climate change and potential future sustainability reductions. Whilst we can forecast potential changes in terms of power increases and chemical costs, we need to challenge these assumptions for different future scenarios.

10.59 These aspirations and constraints were reflected in our approach to programme appraisal and development; we assessed the environmental and social impacts of our plan, and took account of our customers' and stakeholders' preferences and the full range of impacts on the way we operate as a business.

10.60 Metrics have been developed to provide understanding of the wider value of any potential programme of investment, enabling those appraising the programmes to shortlist reasonable alternative programmes. The selection of metrics is therefore determined by what customers, regulators, government, key stakeholders and we value. There are three sources from which our metrics have been distilled:

- Our WRMP14 programme appraisal process
- Water Resources Planning Guideline: Interim Update July 2018
- Our WRMP19 option selection and screening process (Section 7: Appraisal of resource options and Section 8: Appraisal of demand options).

10.61 We selected seven metrics for development and evaluation of the WRMP19 programmes (Table 10-8). They are described briefly in the following sub-sections, with further detail provided in Appendix W: Programme Appraisal Methods.

Table 10-8: WRMP19 Metrics

Performance metric	Description	Interpretation
Cost	NPV of the total cost of a proposed programme across the 80 year planning period.	Lower score is better
Adverse environmental impact	Numerical grading of SEA significance	Lower negative score is better
Environmental benefit	Numerical grading of SEA significance	Higher positive score is better
Deliverability	Probability that a proposed investment programme will deliver the volume of water within the timescale	Higher score is better
Resilience	The resilience of the proposed investment programme against a variety of hazards e.g. more severe droughts than in the historical record	Higher score is better
Intergenerational equity (IGEQ)	Evaluation of the impact of a proposed investment programme on current and future generations	Lower score is better
Customer preference	Evaluation of the programme in relation to customers' preferences and priorities	Higher score is better

Cost

10.62 The cost metric is the NPV of the total cost of a proposed programme across the 80 year planning period. This is discussed further in Step 2 of the process, below.

Environmental benefit and adverse environmental impact

10.63 Development of environmental metrics was carried out after an initial screening of options to see whether they met Water Framework Directive (WFD) and Habitats Regulation Assessment (HRA) requirements. Those which passed screening or were considered to be worthy of further evaluation because of uncertainty in their definition or impacts, were subject to a SEA to qualify the environmental impact of construction and operation.

10.64 Two environmental grades were developed from the SEA of each option. They represented a guide to the overall environmental impacts, both **adverse and beneficial**, of the development and operation of that option.

10.65 For each SEA objective, an effects assessment was made against a significance matrix (Figure 10-4) which took account of the value/sensitivity of the receptor (e.g. air quality, river water quality, landscape value) and the significance of the assessed effect. This significance matrix comprised effects from 'major beneficial' to 'major adverse'. Hatching has been added to the box relating to low significance and high value as this could result in a greater than 'moderate' effect dependent on the sensitivity/value of the receptor. These effects are reported in the final column of the assessment matrix, which are detailed in Appendix B (Strategic Environmental Assessment).

Figure 10-4: Significance matrix used to assess effects of each option on each SEA objective

Significance of Effect		Value/ sensitivity of receptor		
		High	Medium	Low
Effect magnitude	High	Major beneficial / Major adverse	Major beneficial / Major adverse	Moderate beneficial / Moderate adverse
	Medium	Major beneficial / Major adverse	Moderate beneficial / Moderate adverse	Minor beneficial / Minor adverse
	Low		Minor beneficial / Minor adverse	Negligible

Key

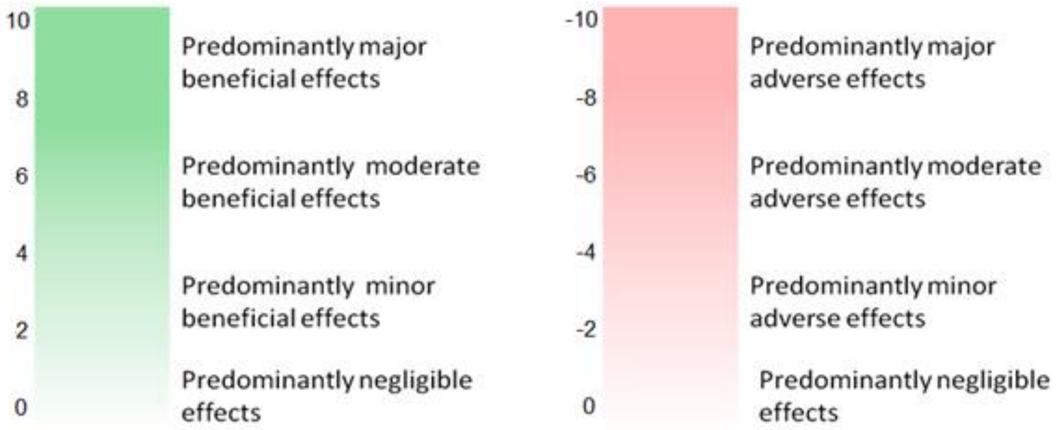
Significance of effect is dependent on vale/sensitivity of receptor

10.66 The assessment matrix provides information on the significance of effects and value/sensitivity of receptors. It also identifies the scale of the effects (spatial extent and/or population size affected) and their permanence (e.g. temporary, short-term; permanent). Scale and permanence were taken into account in confirming the effects assessment assigned for each SEA objective.

10.67 Varying levels of uncertainty are inherent within the assessment process. The assessment sought to minimise uncertainty through the use of expert judgement. The level of uncertainty of the scheme assessment against each SEA objective is shown in the assessment matrix. Where there is significant uncertainty which precludes an effects assessment category being assigned, an "uncertain" label is applied to that specific SEA objective.

10.68 Based on this qualitative (supported where feasible by detailed quantitative data) assessment approach, two scores referred to as "grades" were then assigned to each option by the SEA expert assessors using a scale of +1 to +10 for overall beneficial effects across the SEA objectives and -1 to -10 for overall adverse effects across the SEA objectives (Figure 10-5). Where effects across the SEA objectives are predominantly negligible a grade of 0 was applied to both beneficial and adverse effects grades. The numerical grades therefore reflect the qualitative assessment of individual options in isolation.

Figure 10-5: Qualitative grading to reflect environmental and social effects of each option



10.69 Option grades between 0 (no impact) and ±10 (major impact to several receptors), are combined within the programme development models to enable a general understanding of the relative environmental impacts of each programme, and this enables comparison during programme appraisal.

10.70 As well as the individual water resource option itself, the associated infrastructure required to make water available at customers' taps is also evaluated. Hence the values taken into programme appraisal are the sum of the option and associated infrastructure. A programme that contains many small options and infrastructure could therefore score highly in comparison to one that has a large option, even though the environmental effects are the same. The programme appraisal assessment process ensures it is correctly taken into account in any evaluation.

10.71 The use of environmental metrics informs but does not substitute the SEA process. It does have the benefit however of ensuring environmental and social impacts plays an influential part in the derivation of alternative programmes.

10.72 A full SEA was carried out for all the shortlisted reasonable alternative programmes in the preferred scenario. This ensures that we have a full understanding of impacts and a full understanding of the cumulative and in-combination environmental impacts of the various options.

Deliverability

10.73 Programme deliverability is the probability that the programme will deliver sufficient water on time across the planning period.

10.74 The calculation is based on a yield probability profile developed for each option based around the central estimate, which takes into account both the possibility of delay or early commissioning of any new resource option/demand management scheme, and the possibility of reduced or increased final yield/ savings.

10.75 For each year across the planning horizon, EBSD+ calculates the probability of there not being sufficient additional water to meet the baseline supply demand gap, using the probability density function for all selected options for the year relevant to commissioning for that option.

10.76 The total programme deliverability is 1 - the maximum probability of failure to satisfy the supply-demand gap across the 80 year planning horizon.

10.77 Please see Appendix W for details of this calculation.

Resilience

10.78 The resilience metric evaluates the ability of a proposed investment program to maintain supply during drought.

10.79 The WARMS2 model has evaluated the probable reduction in DO during different drought events for each WRZ. Probable reduction in DO of new option types to the same droughts has also been evaluated. EBSD then calculates the probability that each proposed investment programme will continue to deliver the required yield across the planning period in event that a 1:200 or 1:500 year drought occurs. The probable consequence in each year is adjusted by the probability of either drought occurring across the planning horizon, in order to give a program resilience score between 1 (no risk of failure during a 1:500 drought in any year), and 0 (failure in all years).

10.80 Please see Appendix W for details of this calculation.

Intergenerational Equity (IGEQ)

10.81 Sustainability in water resource planning requires an equitable evaluation of the impact of investment on current and future generations. Specific parameters are the sustainability of water use (e.g. leakage and per capita consumption (PCC) reduction) and the social impact (e.g. bill increase).

10.82 Taking account of IGEQ ensures our preferred plan delivers best value for both present and future generations, in terms of affordability in the medium to long term and protecting the most vulnerable.

10.83 Supporting enhanced demand management is a key policy in the revised draft WRMP19. The demand management programme is determined by company policy with the progressive metering programme (PMP) continuing, alongside leakage reduction and water efficiency enhanced through household metering. As such this is a fixed programme and is therefore not included in the IGEQ optimisation or assessment.

10.84 Social impacts, in terms of equitable affordability for present and future generations can be assessed however. Costs are already well defined in the cost metric, with future costs discounted using the Social Time Preference Rate (STPR) based around the principle that society as a whole prefers to receive goods and services sooner rather than later, and to defer costs to future generations (HM Treasury, 2003). However, our customer research[15] has shown that there is a unanimous view across our water customers that costs for major water infrastructure investment should be fairly spread over generations, in reflection of how the current generations benefit from past investment.

10.85 The affordability element therefore assesses the cost impact of any proposed plan using an Intergenerationally Equitable discount rate, IEDR (proposed at 1.0%). Equitable affordability can then be appraised in comparison with the NPV cost developed using the STPR.

10.86 Please see Appendix W for details of this calculation.

Customer preference

10.87 Customer research has been carried out as part of a wider analysis of Business Planning for Thames Water.

10.88 The first phase was qualitative research, enabling customers to better understand business planning and water resource management planning within the wider context of climate and population change, and express their views on the relative importance of different investment areas.

10.89 The second phase focused on quantitative assessment of customer preferences for specific options or boundary conditions used for draft WRMP19 planning. A preference metric for a plan has been calculated using the results of the quantitative assessment, based on a combination of two elements:

- customer preference for type of option
- customer preference for level of service

10.90 Preference for one type of water resource option over another is shown in Table 10-9.

Table 10-9: Customer preference for option types

Option type	Preference %
Demand management	100
Direct river abstraction	55
Reuse	26
Reservoir	15
Transfer / desalination	10
Groundwater	10
Aquifer recharge	9

[15] Thames Water, Long term investment and intergenerational fairness, prepared by Britain Thinks, 2016

10.91 Customers also gave their views on the acceptable frequency of restrictions to water supply we plan for, such as media campaigns, non-essential use bans, and drought permits and orders.

10.92 A key level of service underpinning the definition of the water resource supply/demand planning problem is the acceptable frequency at which level 4 restrictions would occur. Previously the supply-demand problem has been based on ensuring sufficient capacity to withstand the worst historic drought on record without requiring level 4 restrictions, which would occur approximately once in every one hundred years.

10.93 For WRMP19, stochastically derived drought libraries have been developed which allow assessment of more severe droughts than the worst on record, and allow better understanding of the supply required to withstand extreme droughts which typically occur only once in 200, 300 or 500 years.

10.94 We have sought customer views on how desirable it is to plan for these more extreme droughts. The research findings (Table 10-10) are used in the Preference metric to promote an acceptable level of drought resilience within the WRMP19.

Table 10-10: Customer preference for Level 4 restriction frequency

Level 4 restriction	1:100	1:200	1:300	1:500
Preference %	88.3	10.4	0.8	0.5
Standby capacity (Ml/d)	0	140	187	280

10.95 A further element, affordability, was to be assessed for the shortlisted programmes available after the first stage of programme appraisal. It cannot be included for programme development due to the complexity of the bill impact calculation, which cannot easily be embedded in the programme development models. Additionally, it is the combined impact of all of our proposals in our Business Plan which will impact on customers' bills, so a partial analysis of WRMP19 impacts only would be potentially misleading.

Step 2: Develop programmes

10.96 Sets of programmes are developed for the following purposes:

- Least cost assessment – To establish the least cost solution to the Section 6 supply demand deficits.
- Demand management programme assessment – To examine the impact of alternative programmes of demand management measures.
- Alternative baseline assessment - To examine the solution to alternative desirable baselines.

Least-cost assessment

10.97 The first programme we generated, and the starting point for creating other programmes, was the least-cost programme. The least-cost programme was created through a mathematical optimisation process using EBSD+ which finds the plan with the lowest total cost (long-term NPV).

10.98 Optimisation is a mathematical process for determining the best solution to a defined problem. We used a technique known as linear programming in the optimisation process for the draft WRMP19 programme appraisal. For a problem to be solved by linear programming it must be defined in a specific manner; but the process will then guarantee that the output is extremely close to the best possible answer. For more detail on the linear programming and how and why it was applied in the draft WRMP19 programme appraisal please refer to Appendix W: Programme appraisal methods.

10.99 There were two optimisation stages. Firstly, the Integrated Demand Management (IDM) model developed a range of DMPs by optimisation of a suite of demand management interventions to find the least-cost DMPs that can achieve target demand reductions within a specified period. This process is described in greater detail in Section 8: Appraisal of demand management options. Secondly, the EBSD+ model optimised data to find which programme of options were best employed to balance supply and demand.

10.100 The model will only select a feasible schedule of water resource and transfer options, i.e. considering earliest delivery date, dependence, precedence and mutual exclusivity with other options. Where there are no feasible options available to maintain the supply demand balance the model will indicate there is a remaining deficit.

10.101 The objective set for a least-cost optimisation exercise is to ensure there is sufficient supply to meet demand plus target headroom in all years whilst minimising the cost to customers, society and the environment of the programme selected. This cost is assessed as the 80-year NPV of the whole life cost of the programme.

10.102 The whole life cost of the programme includes not just the cost to build the options selected but also to operate and maintain them to continue to supply water until they reach the end of their useful life and need to be replaced.

10.103 Operating costs are not incurred just by virtue of delivering an option but are also incurred in proportion to how much the option is utilised. For example, in constructing a new borehole to abstract water we must purchase the abstraction pump and employ a member of staff to operate and maintain the site; these costs are fixed and incurred regardless of how often or how much the borehole is used. When we need to produce water from this new borehole we must also pay for the power to operate the abstraction pump and the chemicals to disinfect the raw water produced; these costs vary in direct proportion to how much water the option is used to produce.

10.104 The volume of water produced (or saved) by each option is calculated in each year to satisfy two rules which ensure the total variable cost is minimised:

- The total volume of water produced must equal the weighted average distribution input
- Options are utilised in ascending order of total unit variable cost

10.105 Operating costs for existing baseline water resources are included, as an average level for the WRZ, in the model. This means that new options can be used to substitute for existing options where the total unit variable cost is lower; and demand management measures which reduce the weighted average demand will reduce the total variable cost of the programme. The total operating cost to supply water to meet the weighted average demand for water is included in the NPV of the whole life cost of the programme being optimised in EBSD+.

10.106 For new sources of water such as third party and/or other water company options, we treat the scheme charges as operational costs (fixed and variable elements) and these would be compared with the operational costs (plus any maintenance capex element) of our own schemes. If the third party scheme requires a pipeline, or other infrastructure to be constructed within the company boundary, these costs would be our capex and would be included within the overall cost comparison.

10.107 The comparison of the options is undertaken using our standard cost benefit analysis, considering the present value of costs. The EBSD+ model operates over a fixed assessment period of 80 years, and new and existing sources are utilised in ascending order of variable cost per Ml/d.

10.108 The cost of an option, and therefore the programme, is assessed not just as the direct financial cost but also by reference to the impact on the environment. This includes costs for impacts such as carbon emissions. The Government has provided guidance on the methodology for valuing carbon emissions and UKWIR has provided additional guidance on the estimation of emissions from construction. The Government has also provided guidance on the environmental impact of greenhouse gas emissions and forecasts of the costs of:

- Energy from the National Grid
- The value to society of the emission of greenhouse gases

10.109 We have followed the Government and industry guidance for assessing the amount of greenhouse gases emitted by each feasible option. We have followed Government guidance in the valuation of energy use and carbon emissions. More detail of the costs for each option can be found in Appendix A: WRMP Tables and greater detail of how the cost to the environment of the emission of carbon is calculated can be found in Section 7: Appraisal of Resource Options. However, other environmental and social costs have not been monetised (and not readily capable of monetisation) these have been evaluated on a qualitative basis in our options assessment, as discussed in Section 9: Environmental appraisal.

10.110 The NPV of whole life costs for a programme has been calculated over a fixed 80 year period, April 2020-March 2100. Costs incurred over this span were converted into present values by applying the Treasury declining discount rate of 3.5 to 2.5% per annum as specified in the WRPG. The NPVs contained in this document are expressed using a base year of 2016/17. More details of the process of discounting including an example calculation can be found in Appendix W: Programme appraisal methods.

10.111 Discounting is a separate process from indexing. Indexing, and expressing costs in a common price base, removes the effects of inflation from the analysis performed. Inflation is the general rise of prices in the economy over time, for example in 1980 a loaf of bread may have cost 30p whereas today it could cost £1. When we compare costs they are always compared in 2016/17 prices to ensure that two identical items purchased at different times still have the same cost.

Demand management programme assessment

10.112 The EBSD+ model can be used to select the optimum demand management programme per WRZ and a schedule of as many water resource and transfer options (inclusive of resource, treatment and conveyance elements) as are required to balance supply and demand. We have carried out a Sustainable Level of Demand Management (SELDM) assessment to examine the impact of varying sizes of demand management programme in our London WRZ. We have then tested this against our policy drivers and known customer and stakeholder priorities to select a preferred demand management option.

10.113 Our assessment is set out in Section E below.

Alternative Baseline Assessment

10.114 The following scenarios were tested:

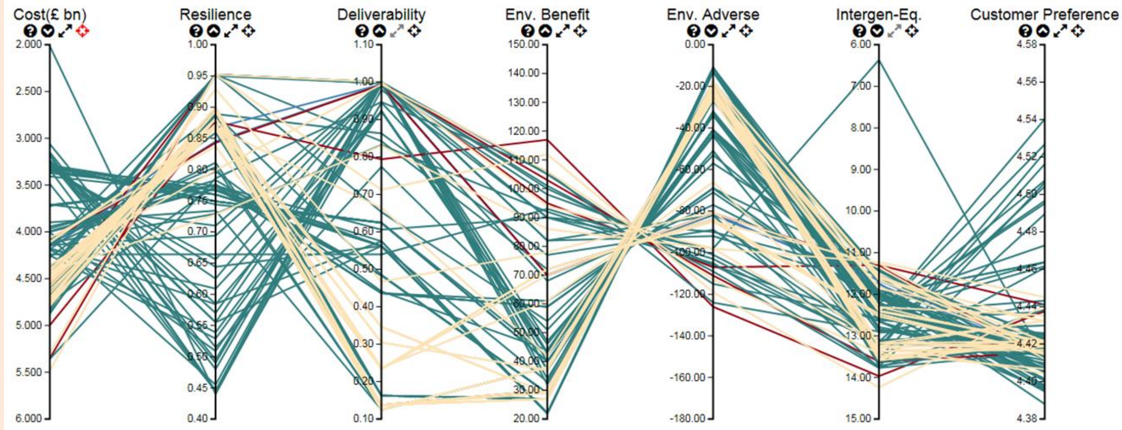
- **Baseline (BL)**: the baseline problem presented in Section 6: Baseline supply demand position
- **Baseline + Increased drought resilience (BL + DRO)**: allowing us to be resilient to a drought with a 1:200 return period
- **Baseline + Increased resilience + South East regional transfers (BL + DRO + WRSE):** allowing us to be resilient to a drought with a 1:200 return period and provide transfers to neighbouring companies in the South East

Step 3: Validate output - comparison of programmes

10.115 The programme development models generate hundreds of feasible programmes, each with seven metrics to be evaluated in parallel. To facilitate the evaluation of programmes against metrics, we commissioned the development of a web-based tool, PolyVis, to allow assessment of multiple programmes. It is also being used by WRE as part of their WRMP19 programme appraisal process. The tool allows the user to access the data supporting each metric for each programme.

10.116 An illustrative output of PolyVis is shown in Figure 10-6. Each line represents an investment portfolio (a set of options selected by the programme development models that meet the supply demand requirement), and so comparison and filtering of different programmes across the metrics can be carried out.

Figure 10-6: Illustrative output from PolyVis



10.117 Comparison requires understanding of the significance of the range for each metric. Appendix W: Programme appraisal methods, Part C covers this in detail.

Reasonable alternative programmes

10.118 Reasonable Alternative Programmes (RAPs) were shortlisted on the basis of their performance across all the metrics and their likelihood of providing a reasonable alternative solution to the least-cost programme. PolyVis helped us to identify trade-offs and consider if these trade-offs would be acceptable to our stakeholders and represent best value to customers. Judgment is used. No formal weighting system was applied.

10.119 The outputs of all the runs are provided in Appendix X: Programme appraisal outputs.

Step 4: Performance testing

Expert Panel

10.120 An Expert Panel was established at the outset of our preparation of the WRMP19, with the remit to challenge our processes, methods and actions and to provide input and opinion on our approach to developing a preferred plan.

10.121 The Expert Panel members are:

- **Professor Adrian McDonald (Panel spokesman)**

  Professor McDonald, Leeds University, is an internationally respected and widely published water demand expert. Until 2016 he was a member of Yorkshire Water's Customer Challenge Group

- **Dr Bill Sheate**

  Dr Sheate, Imperial College London and Collingwood Environmental Planning, has worked, lectured and published widely on EIA for over 30 years. He has worked as a practising ecologist, in consultancy, academia and in the voluntary sector. His experience lies in the development and application of EIA/SEA/SA legislation in the

European Union, assessment procedures, methodologies, and public and NGO participation.

- **Dr Colin Fenn**

  Dr Fenn, Managing Director of Hydro-Logic Services, chaired CIWEM's Water Resources Expert Panel for 12 years. A world-renowned water resources expert, Dr Fenn has provided high-level advice and consultancy services to: numerous water companies, the Environment Agency, Ofwat, DEFRA, UKWIR, National Audit Office, Greater London Authority, Parliamentary Environmental Audit Committee, WWF-UK and the World Commission on Dams.

- **Professor Julien Harou**

  Professor Harou, University of Manchester, was appointed as Chair in water engineering on 1st November 2013. His research interests relate to water resources planning and management. His group builds modelling tools to help utilities and governments manage water resources in the UK and worldwide. His research focuses on managing water scarcity and planning infrastructure investments using hydro-economic and multi-criteria approaches.

10.122 The Panel has been represented at Stakeholder Forums.

10.123 The members provided a provisional report[16] with their comments on the draft WRMP19.

10.124 They have further produced further report for the revised draft WRMP19 which forms Appendix Y of this submission.

Performance testing

10.125 We have performance tested the reasonable alternative programmes identified from the shortlisting process in respect of the following (list is not intended to indicate priority):

- Option uncertainty (Final planning target headroom)
- Adaptability
- 'What if' analysis
- IRAS-MCS system simulation modelling
- SEA (and HRA and WFD compliance)
- Local resilience and practicality

10.126 How these tests and additional elements have influenced the development of the preferred plan is discussed later in Sections E-I below.

Option uncertainty (Final planning target headroom)

10.127 The effects of demand management activities, new water resources or new water transfer options on the forecasts of supply and demand are uncertain and hence planning to deliver these options also changes the amount of target headroom that is required.

[16] Expert Panel's Report, dWRMP, November 2017

Adaptability

10.128 An adaptability analysis method (explained in Appendix W) was developed for use as part of the WRMP19 planning to supplement our 'What if' analysis.

10.129 We were not able to finalise this approach for use in the draft WRMP, however we have now done so for the revised draft for the London, SWOX and SWA WRZs.

10.130 We have produced a range of alternative futures for the following inputs to the supply and demand forecasts:

- Population forecasts (ONS 2016 trend based forecasts, high and low variants)
- PCC forecasts (no usage savings and alternative long-term savings by 2065[17])
- Climate change (medium emissions 5 and 95%iles by 2050 and 2080)
- Additional potential WRSE transfers (ranging from 50 to 185 Ml/d)
- Leakage uncertainty (a long term reduction of 33% by 2050 instead of 50%)

10.131 We have produced decision points and links covering the range of futures and established 256 potential future pathways over the planning period.

10.132 We have given the EBSD+ model each reasonable alternative programme and then re-optimised it at each decision point to see how robust the programme is.

What if analysis

10.133 'What if' analysis is a simplified version of adaptability testing whereby one, or a combination of uncertainties is tested to give a single specific run output, for example, using a different population forecast or the removal of certain option types.

10.134 This method has the benefit of providing a specific output for a specific challenge.

10.135 In the draft plan we tested five scenarios, in the revised draft we have expanded this to over 30 different runs covering the 16 uncertainties listed in Table 10-11.

[17] Taken from Artesia Consulting (for Ofwat) (2018) The long term potential for deep reductions in household water demand AR1206

Table 10-11: What if analysis topics

Uncertainty	Topic
Timing of 1:200 drought resilience	Resilience
1:500 drought resilience in 2040	Resilience
Reservoir Outage/Replacement	Resilience
Remove outages >90 days from record	Supply change
Reduction in contribution from the West Berks Groundwater Scheme (WBGWS)	Supply change
Shortened Planning Periods	Economics
Alternative use of existing bulk supply (Affinity Water, Fortis Green)	Supply change/WRSE
Alternative new WRSE transfers (Affinity Water, Timing and Volume)	WRSE
Potential new WRSE transfers (Other companies)	WRSE
No Reservoir options available for selection	Supply option change
WINEP – WFD No Deterioration	Environmental
Reduction in abstraction from vulnerable chalk streams	Environmental
Population Uncertainty	Demand forecast
PCC Uncertainty	Demand forecast
Leakage uncertainty	Demand forecast
Climate change impacts (2050s instead of 2080s)	Climate change

IRAS-MCS system simulation modelling

10.136 In conjunction with the University of Manchester, we have developed a system simulation model that is able to simulate the performance of our supply system and optimise potential solutions to the supply demand planning problem. It is especially useful in being able to provide a more detailed assessment of drought resilience.

10.137 We have used the model to produce alternative solutions across a large range of drought return periods. This has enabled us to sense check the groups of options being selected by EBSD and IRAS-MCS and allows us to see how the programmes of options change with differing levels of drought resilience.

SEA (and HRA and WFD compliance)

10.138 Each of the reasonable alternative programmes has been assessed against the SEA objectives and for HRA and WFD compliance, both in respect of each of the individual options in the programme and then collectively as a single programme of measures.

10.139 Colour-coded assessment tables (see Appendix B) have been produced to provide an overall summary of the environmental performance of each programme, indicating the significance of effect of each option against a scale ranging from major beneficial to major adverse for each of the SEA objectives, together with a red/amber/green risk rating for WFD and HRA compliance.

10.140 These assessments have been used to compare the environmental performance of each of the reasonable alternative programmes to help inform decision-making alongside other key criteria.

10.141 SEA assessment criteria have also been applied to set out how each of the programme's environmental performance could be improved. These have been collated and summarised to enable the identification of the preferred programme.

Practicality and local resilience

10.142 The reasonable alternative programmes are raw modelled outputs at WRZ level. In identifying the preferred programme (see below) we have checked to see if there are any practicality issues with the option set (mutual exclusivities, interdependency) and also considered if any sub-WRZ level local resilience issues would favour the inclusion of certain options.

Step 5: Preferred programme

10.143 Having assessed the outcomes of Step 4, the overall best value preferred programme is identified and reported in overview in Part J, below. A full description of the preferred programme is provided in Section 11: Preferred plan.

D. Programme appraisal

This section provides the structure for the description of our programme appraisal in the following sub-sections

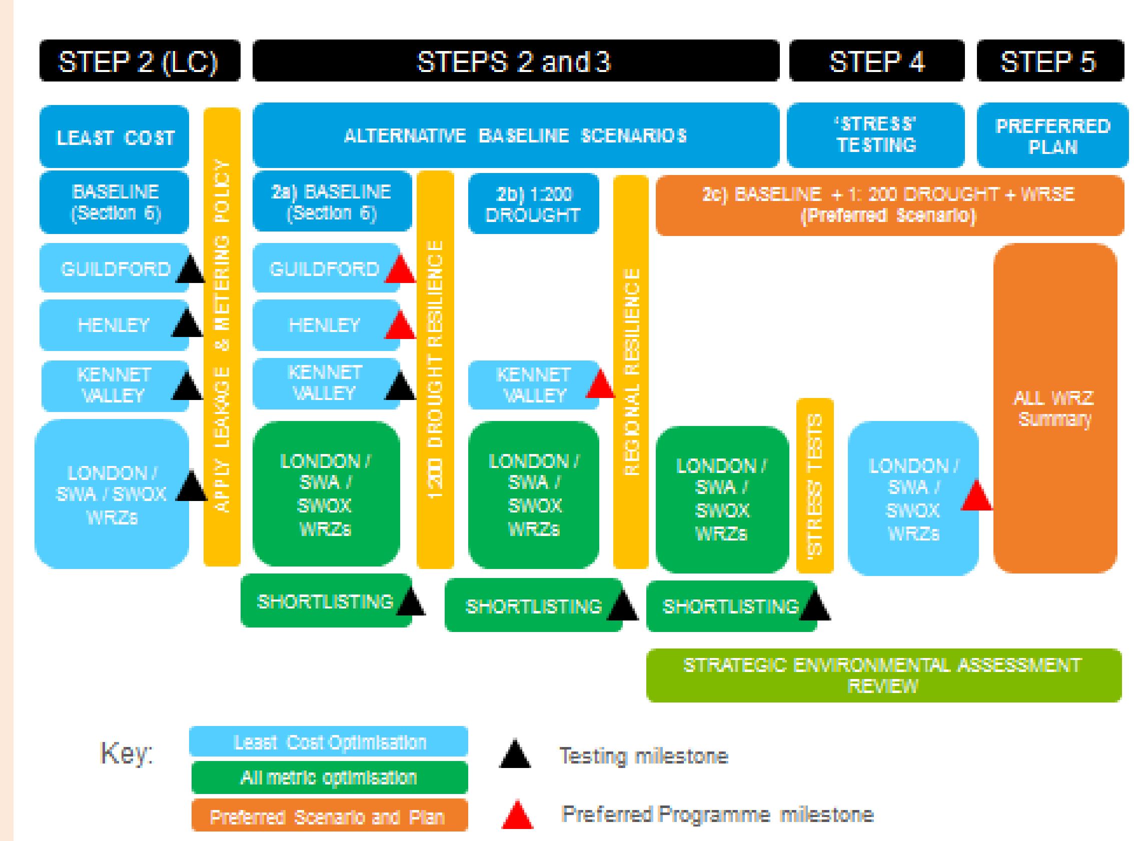
- We have clarified the structure to be consistent with sub-section C and to confirm that stress testing comes before the identification of the best value preferred plan.
- The performance testing is now, accordingly, described within each WRZs assessment.

Section structure

10.144 To achieve our objective of identifying an overall best value WRMP19 preferred plan, we have undertaken a number of structured steps. These are shown in Figure 10-7, building on Figure 10-3 shown earlier in sub-section C.

10.145 The steps express how the programme appraisal has been undertaken for each WRZ, from the least-cost solution to baseline deficits (Section 6), through scenario testing and identification of a preferred scenario and programme (shown in orange in Figure 10-7 below), to the selection of an overall best value plan and the testing of 'What if' scenarios.

Figure 10-7: Programme appraisal – stepped development



10.146 The remainder of this section is structured as follows:

Programme appraisal: London, SWOX and SWA WRZs

- The London, SWOX and SWA appraisals are presented first, as they are the higher risk zones as identified through problem characterisation and require a more complex multi-metric assessment.
- **Step 2 (LC) -** Taking the baseline water supply/demand problem as set out in Section 6, we set out the least-cost solution for the combined London/SWOX/SWA (LSS) zone.
- The sustainable economic level of demand management (SELDM) is considered in the context of policy and customer and stakeholder preferences, having regard to the need to strike a balance between practicality and aspiration in the delivery of demand management measures.
- We identify and constrain a demand management policy into the Step 2 optimisation runs for subsequent comparison (Step 3).
- **Step 2/3a -** We optimise against **all metrics** to solve the baseline supply demand deficit. A set of programmes are produced, examined and shortlisted.
- We then describe and assess more challenging scenarios than the baseline assessment. The appraisal process is repeated. The scenarios evaluated are a supply system more resilient to drought **(Step 2/3b)** and additionally, one more resilient to drought but also able to share water with our neighbouring water companies as part of a regional solution for the south east of England **(Step 2/3c).**
- We then shortlist and describe our preferred scenario and the **reasonable alternative programmes** that can 'solve' the deficits.
- **Step 4 -** We then **stress test** the reasonable alternative programmes against a variety of alternative futures, incorporating strategic environmental assessment.
- **Step 5 -** Lastly we set out our **preferred best value programme.**

Programme appraisal - Kennet Valley, Guildford, Henley WRZs

- These three zones were identified as exhibiting low risk supply/demand problems and so a simpler programme assessment methodology was used which focussed on the least-cost solutions for all scenarios.
- The Henley and Guildford zones are already resilient to a 1:200 drought and are potential donor zones for WRSE transfers, so only a solution to the baseline planning problem is required.
- The analysis for Kennet Valley WRZ includes for 1:200 drought resilience.

Summary

- A brief summary of the preferred programme is provided, with further details in Section 11.

E. Programme appraisal: London, SWA, SWOX

In this section we present the programme appraisal exercise that led to the development of the preferred programme for London, SWOX and SWA (LSS) WRZs.

Updates:

This section has been substantially re-written to include the latest datasets and to address comments made in public consultation on the draft WRMP where appropriate.

- The programme appraisal has been re-assessed and enhanced with the inclusion of system simulation modelling, adaptability testing and expert review.
- Our preferred programme enables us to improve drought resilience for our customers, play a significant role in providing a solution to the water needs of the South East of England and to reduce impacts on our fragile chalk stream ecosystems.
- Demand management and the reduction of wastage remains central to our strategy with substantial reductions planned in leakage alongside an acceleration of the roll-out of metering and water efficiency programmes.
- We have applied a company policy of 15% reduction in leakage between 2020-2025 and to halve leakage by 2050. We acknowledge the views of some stakeholders that such large reductions are high risk, but we consider that we can manage and mitigate that risk in this and future plans.
- There remains three points in the planning period where resource development will additionally be required to balance supply and demand:
    - 2030 – driven by the increase to 1:200 drought resilience
    - 2037 – driven by regional resource need
    - 2080s – driven by growth and future uncertainties
- We believe the best value solution balancing future certainties includes:
    - a water re-use plant at Deephams, a raw water transfer via the Oxford canal and a set of groundwater options by 2030 (replacing the Teddington DRA option which is no longer feasible),
    - the development of a South East Strategic Reservoir in 2037 (brought forward from 2043 in response to regional water resource needs)
    - the Severn-Thames Transfer in the 2080s (replacing re-use in London), due to the potential need for availability of water in the West of the catchment rather than the East.
- The development of these strategic schemes will enable us to manage growth in water demand and the forecast impacts of climate change as well as to make a set of abstraction reductions affecting the chalk streams of the River Cray, Wandle and Wye. It will also give us flexibility to make other improvements to our abstractions for environmental benefit affecting the Thames at Farmoor and the Lee at Amwell Magna.

10.147 In this section we present the programme appraisal process that led to the development of the preferred programme for the London, SWA and SWOX WRZs.

10.148 As set out in our draft WRMP19 we plan and model these resource zones conjunctively rather than individually to exploit potential efficiencies due to overlaps in potential options available to meet demands in the three zones.

10.149 As described in the previous section, we start with the least-cost scenario solution to the baseline problem (Step 2 LC) and then we examine different sizes of demand management programme to identify the preferred demand management programme. We then assess reasonable alternative programmes produced based on metrics additional to cost. Having done this we shortlist and identify an initial preferred programme (Step 2/3a).

10.150 We then repeat the analysis for alternative baseline scenarios providing increased resilience to drought (Step 2/3b) and allowing for that increased resilience but also for regional transfers to other companies in the South East (Step 2/3c).

10.151 Having identified a preferred scenario and the reasonable alternative programmes (RAPS) able to solve that scenario, we subject them to further performance or stress testing (Step 4). We bring this exercise to a conclusion to derive the overall best value preferred programme in Step 5.

Step 2 (LC): Least-cost

10.152 The starting point for programme appraisal is a least-cost solution to the supply/demand planning problem (as described in Section 6). We used the EBSD+ model to optimise the cheapest (lowest 80-year NPV) way to balance supply and demand for the three zones combined, as set out in the draft WRMP19. Raw outputs are shown in Table 10-12.

10.153 In the short and medium term period the model selects a minimal least-cost demand management in all WRZs, followed in the London WRZ with extension of the existing water trades with RWE NPower (2020) and Essex and Suffolk Water (2035), the removal of network constraints, innovative small scale groundwater development and a new water trade with the Canal and River Trust (2035).

10.154 The first option, a wastewater reuse scheme at Deephams (45 Ml/d), is selected in 2038, with further large scale phased wastewater reuse at Beckton (100 Ml/d) in the 2040s, 50s and 70s, as well as ongoing small scale groundwater development.

10.155 In the SWOX and SWA WRZs resource development is not required until the 2080s and this includes the removal of network constraints, groundwater development, an intra zonal water transfer scheme and a small water trade with Wessex Water (2098).

Table 10-12: Step 2 (LC): Least-cost programme (London, SWOX, and SWA)

LEAST-COST		LONDON	SWOX	SWA
The least-cost (lowest 80yr NPV) programme selected by the EBSD+ model for the baseline scenario.				
Metrics				
Financial (£m NPV)			2,014	
Environmental +			90	
Environmental -			98	
Deliverability			0.98	
Resilience			0.44	
IGEQ			6.36	
Customer preference			4.41	
Option[18]	**Benefit (Ml/d)**	**Implementation date**		
DMP_LON-110-70-7[19]	187	2020-35		
DMP_SWOX-18-12-1	31		2020-30	
DMP_SWA-0-5-9	14			2025-35
RWP_Didcot	18	2020		
NTC_New River Head	3	2020		
NTC_Epsom	2	2035		
RWP_Chingford (E&S)	20	2035		
RWP_Oxford Canal to Cropredy	11	2035		
ASR_Horton Kirby	5	2036		
GW_Southfleet/Greenhithe	8	2037		
IPR_Deephams 45	45	2038		
GW_Addington	1	2041		
ASR_South East London (Addington)	3	2047		
IPR_Beckton 100	95	2043		
IPR_Beckton 100	95	2055		
GW_London confined chalk	2	2069		
AR_Kidbrooke (SLARS1)	7	2070		
GW_Honor Oak	1	2071		
IPR_Beckton 100	95	2072		
GW_Datchet	5.4			2083
GW_Moulsford	3.5		2088	

[18] Resource development and demand management only
[19] The notation 105-25-0 refers to the level of demand management targeted in AMP periods 7, 8 and 9 respectively, set as inputs to the IDM model.

LEAST-COST		LONDON	SWOX	SWA
NTC_Aston Keynes	1.5		2089	
NTC_Britwell	1.3		2096	
ASR_Thames Valley/Thames Central	3	2096		
IZT_Henley WRZ to SWA WRZ	5			2097
GW_Merton	2	2098		
RWP_Wessex Water to SWOX	2.9		2098	
AR_Streatham (SLARS)	4	2099		

10.156 Whilst the investment programme set out in Table 10-12 is least-cost, that does not necessarily mean that it is a balanced, robust or resilient plan. It does not take into account regulator and stakeholder expectations for delivery of a demand management programme which takes into account other factors than just financial cost. Whilst there is a phased development of wastewater reuse, there appears to be an undue reliance on the option (>300 Ml/d) without any consideration of the potential impact this may have on the ecology of the Thames Tideway or robustness of the plan. The programme also only provides resilience to the worst droughts in the historic record and there is a regulatory expectation that resilience should be increased to cover for droughts with a 1 in 200 year frequency.

10.157 Hence we have developed a number of alternative baseline scenarios in line with regulator, customer and stakeholder preferences. These are set out below and consider (1) the need to improve the resilience of our supply system to more extreme drought events, (2) the requirements for enhanced supply resilience and environmental improvement across the wider South East area, and (3) the expectations to evaluate demand management policies that are broader and more balanced than simply focussing on financial cost.

10.158 It is the latter requirement to which we focus our attention first.

Step 2 (SELDM): Sustainable economic level of demand management

10.159 One of the key decisions in developing a WRMP is the balance of demand management and resource development measures in a preferred programme.

10.160 Leakage has been a used as an indicator of company performance for many years and previous WRMPs have introduced the concepts of Economic Level of Leakage (ELL) and Sustainable Economic Level of Leakage (SELL). They each seek to find the point where reducing leakage further would cost more than a resource development option which would balance supply and demand.

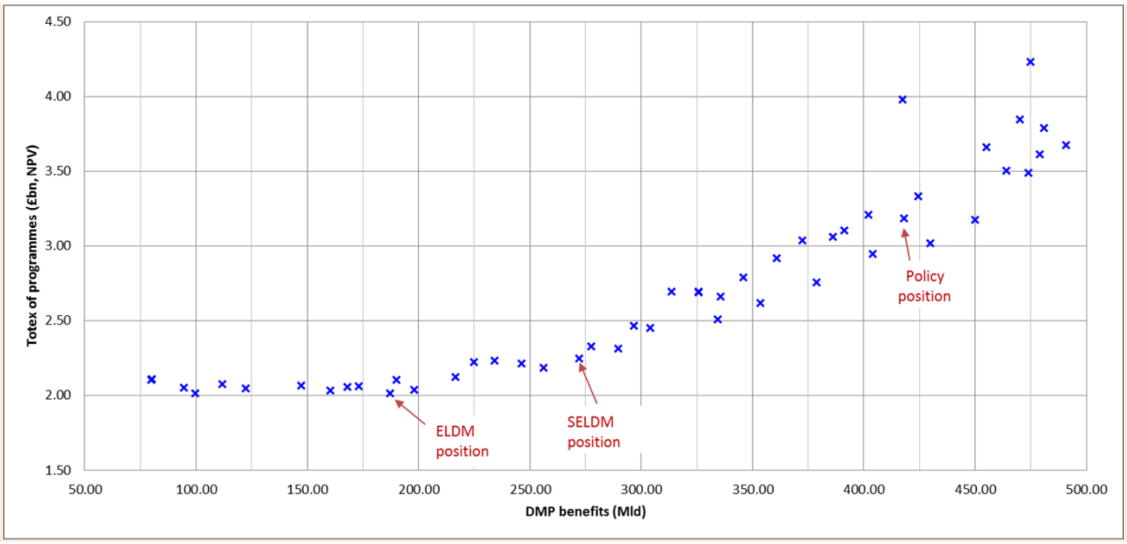
10.161 The delivery of leakage reduction and demand management activities can be synergised to provide greater efficiency than separate delivery. We believe that integrated planning of these activities in combination enhances the robustness of our resulting plan. Therefore the modelling framework we have used to build our plan integrates the planning of leakage reduction and other demand management activities. As such we are not able to present a pure ELL or SELL analysis. Instead we have used our tools to produce an analysis of the economic level of demand management (ELDM) and the sustainable economic level of demand management (SELDM).

10.162 We believe our approach to SELDM analysis represents good practice and is consistent with guidance for SELL analysis[20]. It is fully integrated using the same economic analysis tools we use for the rest of our programme appraisal process. It includes DMPs featuring a full range of demand management options and considers costs and benefits over an 80 year planning period.

10.163 We have produced 50 demand management programmes for London, SWOX and SWA WRZs combined (LSS) from our Integrated Demand Management model. We have input these into our EBSD+ model and run each one in turn through the model to identify a least-cost programme featuring each of them that resolves the baseline deficit as described in rdWRMP19 Section 6.

10.164 Figure 10-8 shows the results plotting total demand savings over the planning period against 80 year NPV of cost for the combined LSS WRZ.

Figure 10-8: SELDM analysis – LSS



10.165 The minimum point (by cost) is the ELDM position. It delivers 187 Ml/d of demand savings and at the lowest overall cost, hence why it is selected in the least-cost run.

10.166 Above 187 Ml/d, initially the cost of leakage reduction appears to be in balance with the increasing cost of resource development. The 'curve' is relatively flat. However, eventually the cost of the DMP programme begins to be greater than the equivalent resource development and the curve rises. This is to be expected because of the increasing reliance on mains replacement (which costs more for each unit of benefit received) to bring about greater demand savings.

[20] Environment Agency (August 2017) Leakage in WRMPs, revised guidance note.

10.167 The SELDM position represents the point on the curve where the most improvement in DMP benefits can be achieved for an incremental uplift in cost. This is a judgement based on the shape of the curve. Between 187 and 250 Ml/d of benefit the 'curve' remains reasonably flat. Delivering more demand management at a similar overall programme cost is a clear benefit. We have shown a SELDM position that goes further than that, closer to 275 Ml/d, recognising the wider benefits to the environment of reducing wastage, whilst keeping the overall cost within £300m NPV of the ELDM position.

10.168 The Policy Position is a balance of ambition and practicality and the priorities of our customers and stakeholders, which we discuss below.

10.169 A limitation of the ELL/SELL and ELDM/SELDM method is that only impacts which can be monetised with at least a minimum level of confidence can be included in the assessment. As a result we believe it is good practice to seek to test whether the results of any SELDM analysis supports a plan that can be considered ambitious with regard to demand management and reflective of the general attitude that leakage should be minimised.

10.170 The ELDM position does not align with our own ambition to reduce the demand for water in our supply area.

10.171 Our regulators and Government take into account the level of ambition in a plan as a key factor in their assessment of a quality plan. There is an expectation for each water company to actively achieve reduction in both leakage, beyond SELL, and customer consumption, beyond SELDM.

10.172 Customer attitudes to other demand management activities should also be borne in mind when testing the results of SELDM analysis where, as is the case with our analysis, we do not believe we have been able to adequately monetise the strength of customer attitudes.

10.173 We have, through an extensive and continuing programme of customer and stakeholder engagement, found that:

- Customers generally support demand management activity[21], which includes leakage reductions, in preference to developing new water resources. Customers believe we should use what we have more efficiently and effectively before we look for new sources.
- Customers are supportive of us providing help to be more water efficient. Our Smarter Home Visit water efficiency programme has been designed with this objective in mind.
- Customers generally accept that metering is a fair way to pay for water bills, but would prefer choice in being metered progressively. They see metering as an essential part of reducing water usage and agree that the roll-out should be given priority.

10.174 This feedback indicates customers and stakeholders, as with our regulators, support effective water resource management beyond the ELDM and SELDM positions produced by the monetised analysis presented above.

[21] Thames Water (September 2018) What customers want.

Other Thames Valley WRZs

10.175 In the other Thames Valley WRZs there are insufficient options available to undertake an EBSD-type analysis to determine the SELDM.

10.176 Our DMPs for the Thames Valley WRZs are focussed on the continued delivery of progressive metering and associated leakage and water efficiency activity, and the timing thereof. This is expected to represent a SELDM position.

10.177 Going beyond this position, post metering, would require mains replacement activity.

10.178 The network in Thames Valley is in better condition than in London and a large programme of mains replacement is unlikely to be cost effective beyond the need to manage deterioration.

Our policy position

10.179 Our Policy position seeks to strike a balance between practicality and ambition.

10.180 We hear the message from all sides that leakage should be reduced and that we should be as ambitious as possible, without over-promising and risking security of supply. Our customer research has shown that customers consider a leakage level of approximately 15% of the water put into supply is more appropriate than current levels which they consider are unacceptably high.

10.181 Ofwat has set out a leakage reduction challenge for companies of 15% from 2020 to 2025[22]. The NIC expand on this recommending a reduction from current levels of 50% by 2050[23].

10.182 We have made achieving both our policy position for leakage reduction. In the longer-term this equates to a level of approximately 15% of the forecast total water put into supply and therefore aligns with customer expectations. Within our London WRZ, delivering a leakage reduction programme of this magnitude will require significant mains replacement and as such is a high cost option. We will continue to undertake research on innovative techniques for replacing and rehabilitating our ageing water infrastructure in London to deliver our future programme as cost effectively as possible and minimising any potential disruption that it might cause.

10.183 Our demand management policy also delivers significant reductions in consumption. It includes the continuing roll out of our progressive household metering programme so that all property connections will be metered. The programme involves installing Smart water meters on properties which will give customers much greater visibility and understanding of their existing water use. It will also provide us an improved understanding of the demand component of our water balance. By helping customers understand their water use and by showing them how they can reduce their consumption without impacting on their lifestyle we forecast that household water consumption can be reduced in the region of 20%.

10.184 As well as installing Smart meters, we will also offer our customers a free water audit service to help them be more water efficient. We will also offer incentives to household customers to encourage reduction in usage. Essentially we are establishing a working partnership role between Thames Water and its customers. Through understanding where and how much

[22] Ofwat, Delivering water 2020: Consulting on our methodology for the 2019 Price Review, July 2017
[23] NIC (2018) Preparing for a drier future: England's water infrastructure needs

water is being used we in turn will be able to target our leakage control activity much more effectively and thereby help us achieve our ambitious target of halving the amount of water lost from our network by 2050.

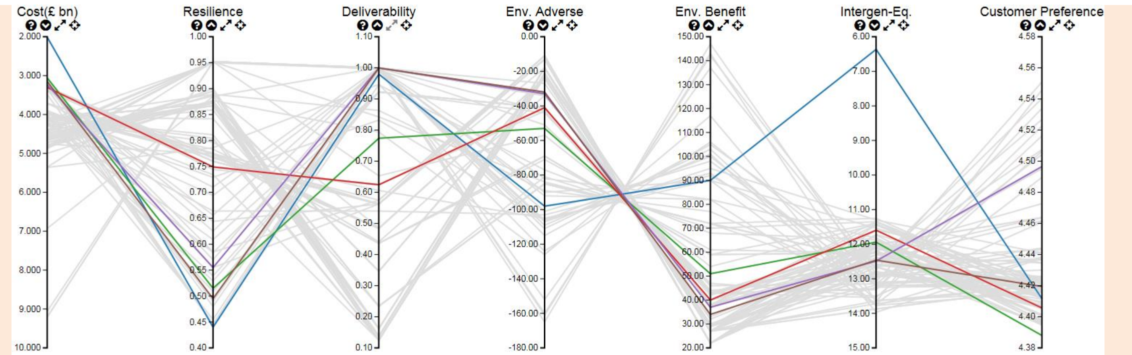
10.185 The demand management programme that matches our policy position is used in all subsequent runs of the EBSD+ and IRAS-MCS model.

Step 2/3a: Scenario assessment: Baseline

10.186 Having established the policy position on demand management, further batches of EBSD+ optimisation runs (Least-cost, Max/Min, Multi-objective and Near Optimal) were produced to solve the Baseline planning problem for each of the assessment metrics.

10.187 The outputs were uploaded to PolyVis for analysis as shown in Figure 10-9. They are also available in tabular form, including option implementation dates in Appendix X, Part B.

Figure 10-9: Step 2a PolyVis output - Baseline scenario runs



Key:
- Step 2 (LC): Least-cost position
- Step 2a: Least-cost (including policy DMP)
- Favouring intergenerational equity (Max_IGEQ)
- Favouring customers' preference for option type within 120% of least cost (NearO_TP)
- Favouring customers' preference for frequency of restrictions within 120% of least cost (NearO_FP)

10.188 We observe the following:

- The introduction of the policy demand management programme increases the cost of the solution to the baseline supply demand problem by £1,045m NPV (52%).
- The optimisations using the resilience (RES) and customer preference for frequency of restrictions (FP) metrics produce more costly programmes than other metrics. This is to be expected as these metrics favour having more surplus available than necessary to meet our current levels of service.
- The Max_Res run seeks to build as much as it can as soon as it can, hence why it is the most expensive programme (£9.2bn NPV) and has high environmental dis-benefit.
- However, when these metrics are jointly optimised with cost (Multi-obj) or constrained by cost (NearO) then the options begin to be deferred to match more closely the profile of the deficit. This reduces the overall programme cost from to £4.4bn NPV in the case of the RES runs and from £4.1bn to £3.1bn in the FP runs.

- The remaining runs all produce programmes that are between £3.1-3.4bn NPV. This is a reduced range compared to the draft WRMP19 due to the reduction in the long-term population forecast and the increased amount of the deficit which is being met through the policy demand management programme.
- With the reduced cost variance the decision on which runs to shortlist becomes more focussed on the types of options selected to meet the deficit.
- Despite the reduced cost variance there is considerable variety in the choices of options made by the model to meet the deficit.
- The Least-cost (Phased_LC) does so implementing many smaller options and re-use at Deephams, deferring the need for a larger scheme, a desalination plant, to the 2080s. By doing so it is able to produce a programme that most tightly matches the increasing deficit.
- Other runs bring in re-use or desalination or a reservoir. The Severn-Thames transfer is rarely selected.

Shortlisting

10.189 When looking across all the metrics we see that there are alternative plans that could provide a better overall solution than the least-cost programme.

10.190 We identified the programmes to shortlist by using PolyVis to screen out poorly performing programmes. For example, programmes that were not considered good value, meaning they were too costly given their comparatively limited benefits scored against the other metrics.

10.191 With the relatively higher cost programmes removed as being unaffordable, the remainder were then tested against other key metrics: the programmes where investment costs are equally balanced between current and future generations (intergenerational equity); a comparison of the options selected against customer preference; programmes where surplus is created to manage uncertainty (resilience), or those which have minimised adverse environmental effects.

10.192 Other programmes offered either no improvement compared to the shortlisted programmes or marginal improvements in some metrics and significant detriment in respect of others. As such the shortlisted programmes were considered to cover the range of reasonable alternatives to the least-cost programme available in these WRZs.

10.193 We have shortlisted a number of reasonable alternative programmes, alongside least-cost, on the basis of their performance across all the metrics and to provide choices in terms of options types used in the solutions.

10.194 The reasonable alternative programmes identified for comparison with the least-cost are listed below, with their characteristics shown in Table 10-13:

- Favouring intergenerational equity (Max_IGEQ[24])
- Favouring customers' preference for option type (NearO_TP[25])
- Favouring customers' preference for frequency of restrictions (NearO_FP[26])

Table 10-13: Step 2a Reasonable Alternative Programmes

BASELINE SCENARIO (Combined LSS)		Least-cost (Step 2a)	Max _ IGEQ	Near O_TP	Near O_FP
The metric outputs of the four shortlisted programmes Note this post the application of the company preferred DMP in each zone.					
Metrics					
Financial (£m NPV)		3,061	3,303	3,231	3,149
Environmental +		51	40	37	34
Environmental -		53	41	33	32
Deliverability		0.92	0.98	1.00	0.99
Resilience		0.52	0.75	0.56	0.50
IGEQ		11.94	11.59	12.49	12.46
Customer preference		4.39	4.41	4.50	4.44
Options[27]	**Benefit (Ml/d)**	**Implementation date**			
DMP_LON_S4b	421	2020	2020	2020	2020
DMP_SWX_S4b	51	2020	2020	2020	2020
DMP_SWA_S4b	22	2025	2025	2025	2025
NTC_New River Head	3	2020	2020		
RWP_Didcot	18	2020	2020	2020	
RWP_Chingford (E&S)	20	2035	2035	2035	2035
NTC_Epsom	2	2060	2060		
RWP_Oxford Canal to Cropredy	11	2060			
ASR_Horton Kirkby	5	2061	2044		
GW_Southfleet/Greenhithe	8	2062	2060		
GW_Addington	1	2063	2062		
IPR_Deephams 45	45	2064			2060

[24] Max_IGEQ = (Maximum intergenerational equity) An optimisation run that uses a 1% discount rate instead of 3.5% in order to decrease the incentive to defer spend to the future.
[25] NearO_TP = (Near optimal type preference) An optimisation run that meets customer preferences for option type, constrained to within 120% of the Least-cost
[26] NearO_FP = (Near optimal frequency preference) An optimisation run that meets customer preferences for frequency of restriction, constrained to within 120% of the Least-cost
[27] Resource development and demand management only

BASELINE SCENARIO (Combined LSS)	Least-cost (Step 2a)	Max _IGEQ	Near O_TP	Near O_FP
GW_London confined chalk	2	2074	2061	
AR_Merton (SLARS3)	5	2075	2062	
ASR_South East London (Addington)	3	2076		
ASR_Thames Valley/Thames Central	3	2077		
AR_Streatham (SLARS)	4	2078		
AR_Kidbrooke (SLARS1)	7	2079		
DSL_Beckton 150	142	2081		
GW_Datchet	5	2090	2090	2090
DSL_Crossness 100	95			2060
DSL_Crossness 100	95			2068
DSL_Crossness 100	95			2090
GW_Moulsford	4		2060	
RES_Abingdon 150 Mm3	294		2063	
NTC_Britwell	1		2065	
IZT_North SWX to SWA 48	48			2061
IPR_Beckton 100	95			2067
IPR_Beckton 150	138			2092

10.195 Examining these alternative programmes:

- All programmes have similar characteristics through to 2060. Demand management and the extension of existing trading agreements at Didcot (RWE NPower) and Chingford (Essex and Suffolk Water).
- For programmes that are optimised on cost, New River Head is also brought in. This is because it is the cheapest option and cheaper than the cost of existing supply (hence it is selected as soon as possible).
- Beyond 2060 the Least-cost programme selects further small, relatively cheap options in order to defer the need for a large scheme until the 2080s (Beckton desalination 150 Ml/d in 2081). The intergenerational equity programme also selects small options but only does so for a few years until a reservoir is selected in 2063. The customer preference scenarios respond by building phased re-use or desalination plants.

- The cumulative impacts of 400 Ml/d of desalination (NearO_TP) or 395 Ml/d of combined desalination and re-use (NearO_FP) (including the 150 Ml/d from our existing plant) would be a concern for the environment of the Thames Tideway. Consequently we would not favour these programmes.

Step 2a: Preferred programme (Baseline)

10.196 In Step 2 (LC) we developed a Least-cost programme for the LSS WRZ costing £2.014bn NPV. This has been developed further in Step 2a to meet customer, regulator, Government and our own objectives to continue to reduce demand on our supply system at a cost of £3.061bn NPV (a 52% increase).

10.197 For this additional investment there is a reduction in leakage so that it is reduced to approximately 15% of the water put into supply in the long-term, a fully metered supply network and a supporting water efficiency programme, as evidenced by improvements in environmental and resilience metrics.

10.198 After the completion of the demand management programme, there is little to choose between the least-cost and the intergenerational equity programme. In both programmes the key decision points are effectively deferred for several decades as demand management and transfers are able to meet the needs of our customers at our current levels of service.

10.199 If this was our preferred scenario, we would probably choose a modified least-cost plan which favours water re-use over desalination in the 2080s. We would also bring forward some of the small scheme investment to balance the risk of delivery of the demand management programme and to maintain both strands of the twin track approach of resource development alongside demand management.

10.200 We know however that we want to do more than just provide a solution at our current levels of service which ignores our desire to give our customers an improved resilience to drought and the needs of the wider South East region. As such we have tested two further baseline scenarios.

Explaining the additional baseline scenarios

10.201 Two additional scenarios have been run through EBSD+ to assess their cumulative impact on the initial programme:

- Increasing resilience (to cover a drought with a 1:200 return period)
- Increasing resilience + Regional transfers (WRSE)

Increased drought resilience

10.202 Our customers have also expressed a preference for improved resilience to drought, where affordable, as our climate changes[28]. Increasing resilience of water supply systems to drought

[28] Thames Water, Draft WRMP19 Appendix T - Our customer priorities and preferences; Section D; Levels of Water Service – Water Use Restrictions

is a key company policy objective. We have also received guidance from the Defra, Environment Agency and Ofwat to increase our resilience.

10.203 As we set out in Section 4 Part D and Appendix I, our system is currently resilient to a drought with a return period of 1:100. A return period of 1:200 years has been used as the new level of protection as it provides a greater level of service and remains more affordable than even more resilient options. Our regulators have also suggested 1:200 as a test case[29].

10.204 We have assessed that a 1:200 drought would result in a dry year reduction in baseline supply of ~150 Ml/d across our supply area[30] as shown in Table 10-14:

Table 10-14: Impact on supply of a 1:200 drought

Drought frequency	Start year	WAFU profile	Annual/peak WAFU reduction (Ml/d)					
			LON	SWOX	SWA	KEN	GUI	HEN
1 in 200	2030	DYAA	140	5.9	1.9	2.8	0	0
1 in 200	2030	DYCP	140	6.9	3.3	3.4	0	0

10.205 It will take time to build water supply options that are capable of positioning us to move to a higher level of resilience. For the purposes of this assessment we have targeted being resilient in the year 2030. This allows enough time for wastewater reuse, desalination, and the Severn-Thames transfer options to be available, allowing the optimiser a choice of how to respond to this requirement.

10.206 In the years preceding 2030, a 1:200 year drought would not necessarily result in failure of supply, but could result in significant environmental damage and economic impact as a result of the imposition of severe usage restrictions and additional abstraction requirements in drought conditions.

Increased resilience and regional transfers

10.207 Regional water resources modelling (via WRSE, as discussed in Section 4E) has indicated that future development of options in our supply area may be required to support other water companies in the south east of England as part of a regional best value programme.

10.208 Affinity Water has requested that we include future exports to them from our supply area in our planning process to correspond with imports they are including in their WRMP. These are shown in Table 10-15 below.

[29] 'Water Resources Planning Guideline: Interim update'; page 13; Environment Agency; July 2018; Ofwat 'Delivering Water 2020: Consulting on our methodology for the 2019 price review'; page 59 and Appendix 3; page 48 July 2017
[30] Thames Water, Draft WRMP19 Section 04 - Current and Future Water Supply; Section D; Drought and Risk;

Table 10-15: Impact on supply of a 1:200 drought and regional transfers

Element	Start year	WAFU profile	Annual/Peak WAFU reduction (Ml/d)					
			LON	SWOX	SWA	KEN	GUI	HEN
1 in 200	2030	DYAA	140	5.9	1.9	2.8		
1 in 200	2030	DYCP	140	6.9	3.3	3.7		
Affinity (Raw)	2037	Both		100*				
	Total	**DYAA**	**140**	**105.9**	**1.9**	**12.8**	**0**	**0**
	Total	**DYCP**	**140**	**106.9**	**3.3**	**13.4**	**0**	**0**

** Additional abstraction required from the River Thames*

10.209 Southern Water has requested that we run 'What if' scenarios with transfers to its supply area. This is a potential, but not confirmed need (see Step 4) and Southern Water has advised that its revised draft WRMP preferred plan does not include the transfer.

Scenario assessment: Impact on least-cost solutions

10.210 Before going into the full appraisal of each of these scenarios separately it is informative to take a moment initially to observe how the least-cost solution produced by the EBSD+ model changes with the increasing stress on the supply system. This is because it gives an indication of the stability of the solution.

10.211 Table 10-16 below demonstrates that on a least-cost basis:

- Including the policy demand management increases programme cost by £1,045m NPV (52% higher)
- Including moving to 1:200 resilience further increases the programme cost by £426m NPV (73% higher than Step 2 (LC))
- Allowing for transfers to help meet regional demand needs further increases the programme cost by £618m NPV (104% higher than Step 2(LC))
- As the deficit in supply and demand is increased, the demand management programme is then supported by a number of smaller resource development schemes that are regularly chosen. This suggests that there are a number of 'no regrets' options, including a re-use plant at Deephams, a transfer via the Oxford Canal and a number of groundwater schemes.
- In the medium and long-term desalination is initially selected, then re-use, then a reservoir. Alternative options including the Severn-Thames transfer may be required should the stress on the system be increased further or certain option types be unavailable (See 'What if' analysis in Step 4 and Appendix X).
- Appendix X also contains a relative frequency analysis of the options chosen across optimisation runs for all metrics and scenarios.

Table 10-16: Least-cost programmes by scenario (Combined LSS)

LEAST-COST (Combined LSS)		**Step 2 (LC):**	**Step 2a: BASELINE**	**Step 2b: BL + DRO**	**Step 2c: BL + DRO + WRSE**
The least-cost (lowest 80 yr NPV) only programmes selected by the EBSD+ model. Note Step 2a-c include the application of company's preferred demand management policy.					
Metrics					
Financial (£m NPV)		2,014	3,061	3,487	4,105
Environmental +		90	51	68	70
Environmental -		98	53	77	81
Deliverability		0.98	0.92	0.89	0.96
Resilience		0.44	0.52	0.45	0.84
IGEQ		6.36	11.94	11.87	11.33
Customer preference		4.41	4.39	4.40	4.41
Option[31]	**Benefit (Ml/d)**	**Implementation date**			
DMP_LON_110-70-7	187	2020			
DMP_SWX_15-10-1	26	2020			
DMP_SWA_0-5-7	12	2025			
DMP_LON_S4b	421		2020	2020	2020
DMP_SWX_S4b	51		2020	2020	2020
DMP_SWA_S4b	22		2025	2025	2025
NTC_New River Head	3	2020	2020	2020	2020
RWP_Didcot	18	2020	2020	2020	2020
NTC_Epsom	2	2035	2060	2030	2030
RWP_Oxford Canal to Cropredy	11	2035	2060	2030	2030
IPR_Deephams	45	2038	2064	2030	2030
AR_Merton (SLARS3)	5	2098	2075	2050	2030
GW_Southfleet/Greenhithe	8	2037	2062	2031	2031
RWP_Chingford (E&S)	20	2035	2035	2035	2035
RES_Abingdon 125 Mm3	253				2037
ASR_Horton Kirkby	5	2035	2061	2048	2080
GW_Datchet	5	2083	2090	2082	2082
GW_Moulsford	4	2088			2082
NTC_Aston Keynes	2	2089			2082
GW_London confined chalk	2	2069	2074	2051	2083
NTC_Britwell	1	2096			2083

[31] Resource development and demand management only

LEAST-COST (Combined LSS)		Step 2 (LC):	Step 2a: BASELINE	Step 2b: BL + DRO	Step 2c: BL + DRO + WRSE
GW_Addington	1	2041	2063	2052	2085
RWP_Wessex Water to SWX (Flaxlands)	3	2098			2085
AR_Streatham (SLARS)	4	2099	2078	2052	2086
ASR_South East London (Addington)	3	2047	2076	2049	2087
GW_Merton	2	2098			2087
ASR_Thames Valley/Thames Central	3	2096	2077	2051	2088
DSL_Beckton 150	142		2081		2089
IZT Henley WRZ to SWA WRZ	5	2097		2095	
IZT_R Thames to Medmenham	24				2095
AR_Kidbrooke (SLARS1)	7	2070	2079		
GW_Honor Oak	1	2071		2092	
IPR_Beckton 100	95	2043		2053	
IPR_Beckton 100	95	2055		2067	
IPR_Beckton 100	95	2072		2093	

Preferred scenario

10.212 In the draft WRMP we set out why our preferred scenario should be one that goes beyond addressing the baseline problem set out in Section 6. The responses we received to our public consultation from our stakeholders have supported maintaining this approach in the revised draft WRMP.

10.213 We believe that we should aim to deliver a plan that offers greater resilience to drought and also works in partnership with our neighbours, stakeholders and customers over the 80 year planning period to provide an overall best value plan for the south east of England. In this pursuit we acknowledge that resources developed in our supply area could be used to support regional transfers and provide greater resilience to the south east region.

10.214 **As such our preferred planning scenario is as set out in Step 2c, baseline plus increased drought resilience plus regional (WRSE) transfers.**

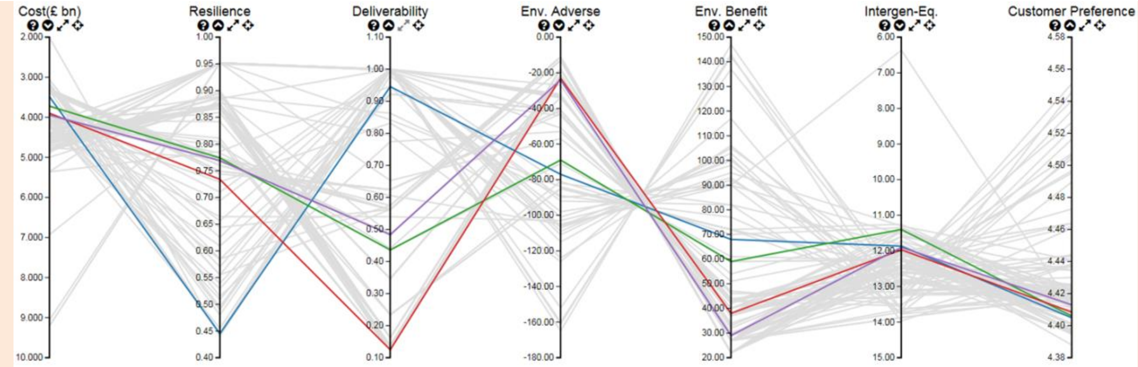
10.215 We have however updated the assessment for baseline plus increased resilience (Step 2b), because it remains helpful to illustrate the progression of the plan and because it represents what a preferred programme may look like if there was no wider regional need.

Step 2/3b: Scenario assessment: Baseline + increased resilience

10.216 As well as the least-cost run shown above, further batches of EBSD+ optimisation runs (Least-cost, Max/Min, Multi-objective and Near Optimal) were produced to solve the Baseline planning problem for each of the assessment metrics.

10.217 The outputs are uploaded to PolyVis for analysis as shown in Figure 10-10. They are also available in tabular form in Appendix X, Part B. Shortlisted runs are highlighted and discussed below.

Figure 10-10: Step 2b PolyVis output - Baseline + Increased Resilience scenario



Key:
Step 2b: Least-cost (including policy demand management)
Step 2b: Favouring intergenerational equity (Max_IGEQ)
Step 2b: Favouring environmental benefit (options only) alongside cost (Multi-obj_ENVB)
Step 2b: Favouring deliverability alongside cost (Multi-obj_DEL)

10.218 As in Step 2a, when looking across all the metrics it appears that there are alternative plans that could provide a better overall solution than the straight least-cost option.

10.219 We identified the programmes to shortlist by using PolyVis to filter poorly performing programmes. For example, programmes that were not considered good value, meaning they were too costly given their comparatively limited benefits scored against the other metrics.

10.220 With the relatively higher cost programmes removed as unaffordable, the remainder were then tested against key metrics: the most sustainable, the highest resilience offered, or minimised adverse environmental effects.

10.221 Other programmes offered either no benefit improvement compared to the shortlisted programmes or marginal improvements in some metrics and significant detriment in respect of others. As such the shortlisted programmes were considered to cover the range of reasonable alternatives to the least-cost programme available in these WRZs.

10.222 As noted similarly in Step 2a, we make the following observations:

- The introduction of moving to 1:200 resilience in 2030 has increased the cost of the solution by £426m NPV (16%), compared to Step 2a.
- The optimisations using the resilience (RES) and customer preference for frequency of restrictions (FP) metrics produce more costly programmes than other metrics. This is to be expected as these metrics favour having more surplus available than necessary to meet our current levels of service.
- The Max_Res run seeks to build as much as it can as soon as it can, hence why it is most expensive programme (£9.1bn NPV) and has high environmental dis-benefit.
- However, when these metrics are jointly optimised with cost (Multi-obj) or constrained by cost (NearO) then the options begin to be deferred to match more closely the profile of the deficit. This reduces the overall programme cost from £9.1bn to £4.1bn NPV in the case of the RES runs and from £5.4bn to £4.1bn in the FP runs.
- The remaining runs produce programmes that are between £3.5bn -4.7bn NPV. A wider range than in Step 2a, but still reduced compared to the draft WRMP19.
- With the reduced cost variance the decision on which runs to shortlist becomes more focussed on the types of options selected to meet the deficit.
- Despite the reduced cost variance there is considerable variety in the choices of options made by the model to meet the deficit.
- As you would expect with 150 Ml/d additional water to find in order to provide the 1:200 resilience, the model brings forward options selected in Step 2a and/or upsizes them.

Shortlisting

10.223 We have shortlisted a number of reasonable alternative programmes, alongside least-cost, on the basis of their performance across all the metrics and to provide choices in terms of options types used in the solutions to resolve the supply demand problem in this scenario.

10.224 The reasonable alternative programmes identified for comparison with the least-cost are listed below, with their characteristics shown in Table 10-17 below:

- Favouring intergenerational equity (Max_IGEQ)
- Favouring environmental benefit (options only) alongside cost (Multi-obj_ENVB[32])
- Favouring deliverability alongside cost (Multi-obj_DEL[33])

[32] Multi-obj_ENVB = (Multiple objective Environmental Benefit) An optimisation run optimises the environmental benefits of the options and cost simultaneously.
[33] Multi-obj_DEL = (Multiple objective Deliverability) An optimisation run optimises the deliverability and cost simultaneously.

Table 10-17: Step 2b Reasonable Alternative Programmes

BASELINE + DRO SCENARIO (Combined LSS)		LEAST-COST (Step 2b)	Max_ IGEQ	Multi-obj_ ENVB	Multi-obj_ DEL
The outputs of the four shortlisted programmes – Baseline + Increased Resilience Scenario (Combined LSS)					
Metrics					
Financial (£m NPV)		3,487	3,722	3,899	3,944
Environmental +		68	59	38	29
Environmental -		77	69	23	24
Deliverability		0.89	0.95	1.00	1.00
Resilience		0.45	0.77	0.73	0.77
IGEQ		11.87	11.40	11.97	11.90
Customer preference		4.40	4.41	4.41	4.41
Options[34]	**Benefit (Ml/d)**	**Implementation date**			
DMP_LON_S4b	421	2020	2020	2020	2020
DMP_SWX_S4b	51	2020	2020	2020	2020
DMP_SWA_S4b	22	2025	2025	2025	2025
NTC_New River Head	3	2020	2020		
RWP_Didcot	18	2020	2020		2020
IPR_Deephams 45	45	2030	2030		
NTC_Epsom	2	2030	2048		
RWP_Oxford Canal to Cropredy	11	2030	2031		
GW_Southfleet/Greenhithe	8	2031	2030		
RWP_Chingford (E&S)	20	2035	2035		2035
ASR_Horton Kirkby	5	2048	2030		
ASR_South East London (Addington)	3	2049	2049		
AR_Merton (SLARS3)	2	2050	2050		
ASR_Thames Valley/Thames Central	3	2051	2051		
GW_London confined chalk	2	2051	2051		
AR_Streatham (SLARS)	4	2052	2052		
GW_Addington	1	2052	2052		
IPR_Beckton 100	95	2053			2030
IPR_Beckton 100	95	2067			
GW_Datchet	5	2082	2082		
GW_Honor Oak	1	2092			

[34] Resource development and demand management only

BASELINE + DRO SCENARIO (Combined LSS)		LEAST-COST (Step 2b)	Max_ IGEQ	Multi-obj_ ENVB	Multi-obj_ DEL
IPR_Beckton 100	95	2093			
IZT Henley WRZ to SWA WRZ	5	2095			
IZT_R Thames to Medmenham	24		2095	2082	
DSL_Beckton 150	142			2029	
RES_Abingdon 150 Mm3	294		2053	2058	
RES_Abingdon 125 Mm3	253				2053
GW_Moulsford	4		2060		
NTC_Britwell	1		2065		
IZT_North SWX to SWA 72	72				2082

10.225 The Least-cost programme chooses multiple re-use schemes, which as we stated in Step2a would place cumulative stresses on the Thames Tideway and be a concern for compliance with environmental legislation.

10.226 The Multi-objective environmental benefit run selects a desalination plant to meet the extra need to provide resilience in 2030 and then a reservoir. The Multi-objective deliverability run does similar but chooses re-use in 2030 alongside the continuation of existing transfers and a slightly smaller reservoir.

10.227 The consideration with the shortlisted multi-objective runs would be that they do not include any of the smaller options and are therefore less flexible to changes in need. There is insufficient evidence to suggest that with the inclusion of additional demand management in the programme a single large option is needed as early as 2030. This is discussed further in Step2c in the assessment of adaptability.

Step 2b: Preferred programme (Baseline + 1:200 drought resilience)

10.228 The Max_IGEQ programme would likely form our preferred programme for this scenario as it provides a useful balance of small and large schemes for a reasonable increment in cost compared to the least-cost run.

10.229 Minor groundwater schemes remain available to handle deviation from the programme and further re-use or the reservoir brought forward to cover any significant step changes, depending on whether the call for water is from the west or the east of our region.

10.230 One such step change would be the provision of further bulk supplies to our neighbours as part of a regional supply demand solution for the south east of England, as assessed below.

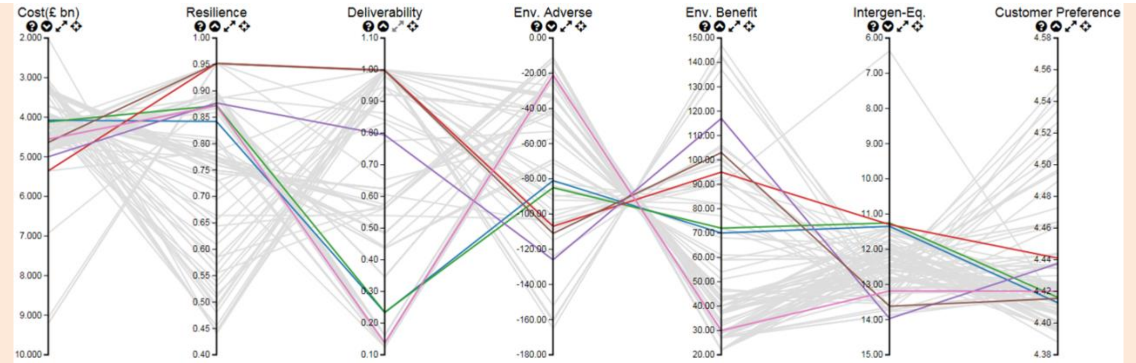
Step 2/3c: Scenario assessment: Baseline + increased resilience + WRSE transfers

10.231 In Step 2c we introduce a need to provide a further 100 Ml/d to Affinity Water from 2037. As well as the least-cost run discussed earlier, a further batch of EBSD+ optimisations runs have been produced to test optimal and near optimal performance against each of the assessment metrics in this scenario.

10.232 The outputs are uploaded to PolyVis for analysis as shown in Figure 10-11. In Figure 10-12 we also show the relative proportion of each option type in each output run. The outputs are shown in full in tabular form in Appendix X, Part B.

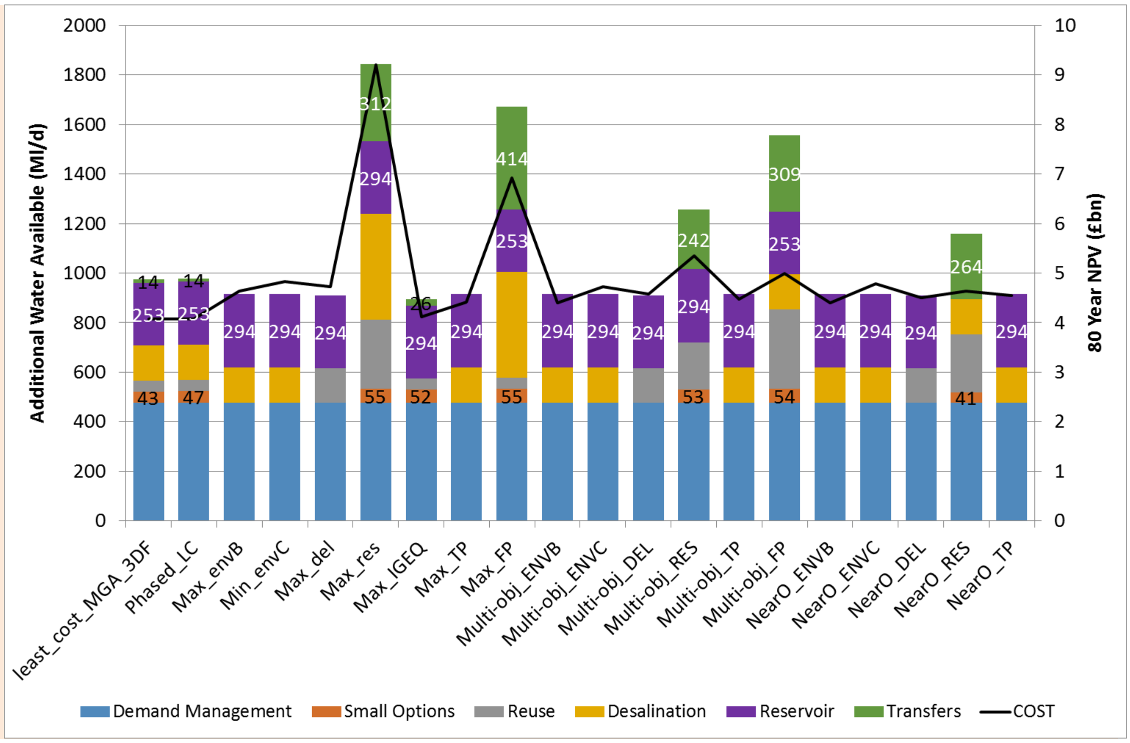
10.233 Reasonable alternative programmes (RAPs) runs are highlighted in both figures. The reasons for their selection are discussed in the shortlisting section below.

Figure 10-11: Step 2c: PolyVis output - Baseline + DRO + WRSE scenario



Key
- Step 2c: Least-cost (including policy position)
- Step 2c: Favouring intergenerational equity (Max_IGEQ)
- Step 2c: Favouring customer preference for type of options within 120% of least-cost (NearO_TP)
- Step 2c: Favouring resilience within 120% of least-cost (NearO_RES)
- Step 2c: Favouring customer preference for the frequency of restrictions alongside cost (Multi-obj_FP)
- Step 2c: Favouring resilience alongside cost (Multi-obj_RES)

Figure 10-12: Step 2c: Optimisation outputs by option type



**Values are Ml/d; used as a guide to which/how many options are selected*

10.234 We observe similar patterns as seen in Steps 2a and b:

- The introduction of providing for 100 Ml/d of regional need has increased the cost of the least-cost solution by £586m NPV (19%).
- The optimisations using the Resilience (RES) and Customer preference for frequency of restrictions (FP) metrics produce more costly programmes than other metrics. This is to be expected as these metrics favour having more surplus available than necessary to meet our current levels of service.
- The Max_Res run seeks to build as much as it can as soon as it can, hence why it is most expensive programme (£9.2bn NPV) and has high environmental dis-benefit.
- However, when these metrics are jointly optimised with cost (Multi-obj) or constrained by cost (NearO) then the options begin to be deferred to match more closely the profile of the deficit. This reduces the overall programme cost from £9.2bn to £4.6bn NPV in the case of the RES runs and from £6.9bn to £5bn in the FP runs.
- The remaining runs all produce programmes that are between £4.1bn and £4.8bn NPV. This is a reduced range compared to the draft WRMP19 due to the reduction in the long-term population forecast and the increased amount of the deficit which is being met through the policy demand management programme.
- With the reduced cost variance, the decision on which runs to shortlist can be focussed on the types of options that are selected to meet the deficit.
- Despite the reduced cost variance there is considerable variety in the choices of options made by the model to meet the deficit.

Shortlisting

10.235 When looking across all the metrics it appears that there are alternative plans that could provide a better overall solution than the straight least-cost programme.

10.236 As with the other scenarios, we have shortlisted a number of reasonable alternative programmes, alongside least-cost. We have done so on the basis of their performance across all the metrics.

10.237 Given the number of runs producing programmes within a relatively narrow cost band, we also wished to maintain a range of options types that can be taken forward for further performance testing in Step 4:

- Favouring intergenerational equity (Max_IGEQ)
- Favouring resilience alongside cost (Multi-obj_RES)
- Favouring customer preference for the frequency of restrictions alongside cost (Multi-obj_FP)
- Favouring resilience within 120% of least-cost (NearO_RES)
- Favouring customer preference for type of options within 120% of least-cost (NearO_TP)

10.238 The characteristics of these programmes are shown in Table 10-18 below:

Table 10-18: Step 2c Reasonable Alternative Programmes

BASELINE+DRO+WRSE (Combined LSS)		**Least-cost (Step 2c)**	**Max _IGEQ**	**Multi-obj _RES**	**Multi-obj _FP**	**NearO _RES**	**NearO _TP**
The metric outputs of the six shortlisted programmes – Baseline + Increased resilience + Regional transfers (Combined LSS)							
Metrics							
Financial (£m NPV)		4,105	4,188	5,353	4,997	4,634	4,554
Environmental +		70	70	95	117	103	30
Environmental -		81	82	107	126	111	21
Deliverability		0.96	0.96	1.00	1.00	1.00	1.00
Resilience		0.84	0.87	0.95	0.88	0.95	0.87
IGEQ		11.33	11.66	11.30	13.97	13.62	13.18
Customer preference		4.41	4.42	4.44	4.44	4.42	4.42
Options[35]	**Benefit (Ml/d)**	**Implementation date**					
DMP_LON_S4b	421	2020	2020	2020	2020	2020	2020
DMP_SWX_S4b	51	2020	2020	2020	2020	2020	2020
DMP_SWA_S4b	22	2025	2025	2025	2025	2025	2025
NTC_New River Head	3	2020	2020	2020	2020	2020	
RWP_Didcot	18	2020	2020	2020	2020	2020	2020
ASR_Horton Kirby	5	2030	2030	2026	2047	2026	
GW_Southfleet/Greenhithe	8	2031	2030	2026	2031	2026	
GW_Addington	1	2030	2031	2096	2057	2094	
IPR_Deephams 45	45	2030	2030		2026	2063	
NTC_Epsom	2	2030	2031	2026	2030	2031	
RWP_Oxford Canal to Cropredy	11	2030	2031	2026	2028	2026	
GW_Merton	2	2087	2031	2069	2081		
AR_Merton (SLARS3)	5	2030	2031	2026	2050	2072	
ASR_South East London (Addington)	3	2087		2033	2049	2062	
RWP_Chingford (E&S)	20	2035	2035	2035	2035	2035	2035
RES_Abingdon 125 Mm3	253	2039			2039		
RES_Abingdon 150 Mm3	294		2039	2063			2039
GW_Datchet	5	2082	2081	2029	2082	2026	
IZT_R Thames to Medmenham	72	2095	2095			2095	2082
RWP_STT Vyrnwy 60	110			2030	2055	2030	
RWP_STT Mythe	12			2030	2055	2055	
RWP_STT UU/ST Opt A	6				2055	2030	
RWP_STT UU/ST Opt B	15				2093	2059	

[35] Resource development and demand management only

BASELINE+DRO+WRSE (Combined LSS)		**Least-cost (Step 2c)**	**Max _IGEQ**	**Multi-obj _RES**	**Multi-obj _FP**	**NearO _RES**	**NearO _TP**
RWP_STT Netheridge	18			2030	2055	2030	
GW_Moulsford	4	2082	2051	2026	2039	2026	
NTC_Aston Keynes	2	2082	2097	2026	2039	2026	
GW_London confined chalk	2	2083	2080		2057	2071	
NTC_Britwell	1	2083	2060	2041	2037	2026	
RWP_Wessex Water to SWX	3	2085	2097	2063			
AR_Streatham (SLARS)	4	2086	2080	2091	2052		
ASR_Thames Valley/Thames Central	3	2088	2031	2031	2052	2073	
DSL_Beckton 150	142	2089	2098		2065	2029	2030
AR_Kidbrooke (SLARS1)	7			2063	2053		
GW_Honor Oak	1		2093	2068			
IPR_Beckton 100	95			2029		2074	
IPR_Beckton 100	95			2029		2095	
IPR_Beckton 150	138				2085		
IPR_Beckton 150	138				2085		
IZT_North SWX to SWA 48	48				2095		
IZT_North SWX to SWA 72	72			2095			
RWP_STT Minworth	70			2039	2055	2039	
RWP_STT Welsh 60	45				2086		

10.239 addition to the demand management programme, inspection of the alternative programmes reveals that there are a number of water resource options that are consistently selected in five or more of the programmes. These are the *'no regret'* options and include extension of existing water trades with RWE NPower and Essex and Suffolk Water, many of the groundwater and network constraint options, the Oxford canal raw water transfer, the Deephams wastewater reuse scheme and the Abingdon reservoir.

10.240 A number of the other larger strategic options are also selected in three or four of the programmes. Beckton desalination is chosen in four programmes. Beckton wastewater reuse and the Severn-Thames transfer are selected in three programmes.

10.241 In these six reasonable alternative programmes we have selected the full range of option types for more detailed evaluation through the strategic environmental assessment (SEA) and performance testing in Step 4 of our programme appraisal process.

Step 2c: SEA review of shortlisted programmes

10.242 To this point the choice of shortlisted programmes has been achieved using metrics which include environmental benefits and adverse effects. This however does not replace the detailed environmental analysis carried out for each option and element shown in Section 9: Environmental appraisal, and Appendices B: SEA – environmental report, C: HRA – stage 1 screening and BB: WFD.

10.243 For each shortlisted programme shown in Table 10-18 above, programme-level SEA assessment has been completed with our environmental partners Ricardo, to provide the details of the cumulative environmental effects of each programme. The relative environmental performance of the shortlisted programmes is discussed below, looking particularly at the WFD risks, planning risks and where geographically the impacts fall. A full strategic environmental assessment of each shortlisted programme is provided in Appendix B: SEA – Environmental Report.

Figure 10-13: Summary SEA findings of the reasonable alternative programmes

Multi_Obj RES	Phased_LC	Multi_Obj_FP	NearO_ RES	NearO_TP	Max_IGEQ	
Several WFD Risks	One small WFD Risk	Several WFD Risks	Several WFD Risks	No WFD Risks	One small WFD Risk	
Multiple material planning risks	Single material planning risk	Multiple material planning risks	Single material planning risk	Single material planning risk	Single material planning risk	
Impacts mostly fall in Thames Valley and River Severn catchment	Impacts mostly fall in Thames Valley and Thames Tideway	Impacts mostly fall in Thames Valley, Thames Tideway and River Severn	Impacts mostly fall in Thames Valley, Thames Tideway and River Severn	Impacts fall in Thames Valley and Thames Tideway	Impacts fall in Thames Valley and Thames Tideway	
Major Adverse	Moderate Adverse	Major Adverse	Major Adverse	Moderate Adverse	Moderate Adverse	Cumulative Programme SEA
5	3	6	4	1	2	Indicative Ranking
"Challenging"	"Some difficulties"	"Extremely challenging"	"Fairly challenging"	"A few difficulties"	"A few difficulties"	

10.244 Three of the six RAPs are assessed as having cumulative major adverse effects, with the Multi_Obj_FP programme having the greatest adverse effects. All of these programmes have several WFD compliance risks. They would present significant challenges for promotion and obtaining required permissions and approvals.

10.245 Effects are geographically spread across the Thames river basin, but some programmes also affect the Severn River basin, increasing the overall magnitude of cumulative effects (mainly due to the inclusion of the Minworth support option for the STT).

10.246 The other three RAPs are assessed as having the potential for cumulative moderate adverse effects – these are broadly similar in overall scale of effects with little to choose between them, but a relative ranking has been provided in Figure 10-13. WFD risks can be addressed if the Britwell groundwater option is removed from relevant programmes and mitigation measures are applied where identified in the WFD assessment and WFD Report for specific other options.

10.247 Programmes that involve both the reservoir and STT give rise to possible WFD cumulative compliance risks in the Middle River Thames. Discharges to the river would exceed the approximate 500 Ml/d threshold above which changes to the low flow regime may start to adversely affect aquatic ecology and geomorphology of the river reach downstream of Culham.

10.248 Programmes that involve both desalination and reuse schemes at a cumulative capacity above 275 Ml/d give rise to possible WFD compliance risks in the Thames Tideway due to potential effects on saline-sensitive aquatic species, and may also affect the recommended Thames Estuary Marine Conservation Zone.

10.249 On the other hand, given the scale of the supply deficit and the options available to address it, it is unlikely that a programme could be developed that would lead to only minor adverse cumulative effects.

10.250 The RAPs shown are a 'raw' model output. There are modifications to the output that could be made to refine each of them to make their environmental performance better. This is picked up in Step 4.

Step 4: Performance testing

10.251 Performance testing the reasonable alternative programme in order to identify the preferred best value programme has 6 elements (as shown in Figure 10-14, below):

Figure 10-14: The elements of performance testing

Option uncertainty (Final planning Headroom)

10.252 The baseline analysis of target headroom is discussed in Section 5: Risk and Uncertainty.

10.253 Baseline analysis is performed without knowledge of what options may be selected in the preferred programme and therefore only includes consideration of uncertainty around the baseline supply and demand forecasts. The options that are selected to be part of a plan also have uncertainties associated with them so target headroom must be re-assessed to ensure supply and demand still balance when the uncertainty around options is taken into account.

10.254 This section discusses the application of final plan target headroom to solving the supply demand planning problem. In line with the baseline analysis, final headroom is calculated up to 2045 and then kept constant to 2100.

10.255 The six reasonable alternative plans contain options that each has their own additional uncertainties associated with them. The uncertainty in these options should also be taken account of when developing a preferred programme.

10.256 Because the additional uncertainty component for new options is relatively small compared to the uncertainty in baseline forecasts, particularly in the early years of AMP7, we found that this could lead to the final plan target headroom being lower than the baseline target headroom, which is counter intuitive.

10.257 Therefore we have taken the decision to simply add 5% of the benefit of the schemes selected up to 2045 to the baseline headroom allowance to account for option uncertainty.

10.258 Uncertainty around the reservoir and the Severn-Thames transfer options is not included as the significant uncertainties around those schemes would be clarified well in advance of their construction and substantial uncertainty analysis has already been undertaken on the yields associated with these schemes and allowed for in the calculation of deployable output values.

10.259 The four RAPs that are optimised including elements other than cost are unaffected by the inclusion of this additional uncertainty. This is because they favour retaining surplus and thus can absorb the minor changes.

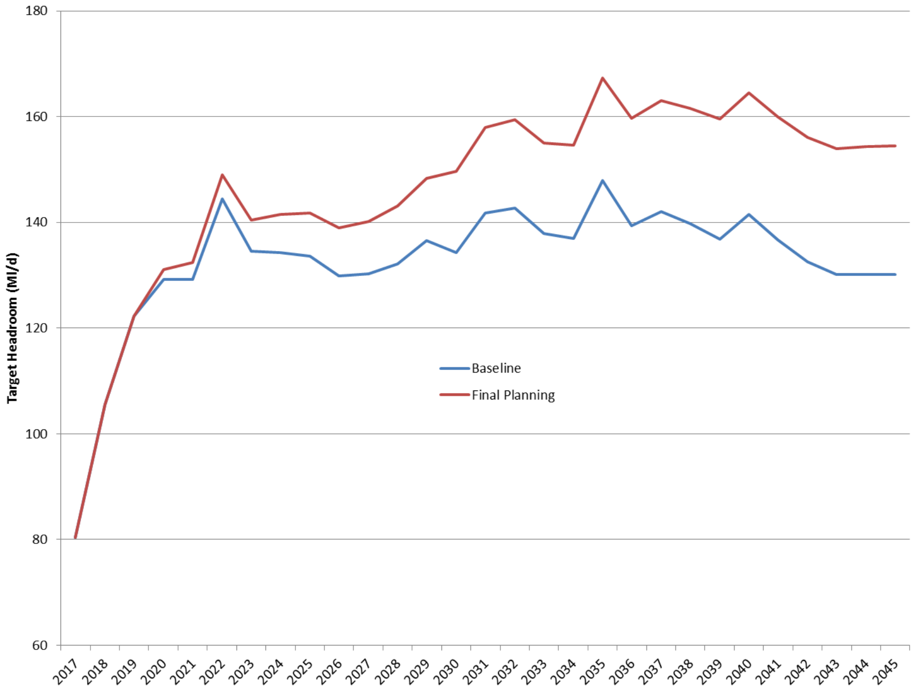
10.260 The Phased_LC and Max_IGEQ programmes that are more strongly influenced are changed marginally because a few small schemes come forward in time and others are added to meet the extra need.

10.261 The results of target headroom for London WRZ are shown in Figure 10-15 below, where the variance between baseline and final lines represents the uncertainty around options in the plan.

10.262 The impact on the other WRZs are discussed in Appendix X and also shown in Appendix A: dWRMP19 planning tables (Table 9).

10.263 Company-wide the maximum impact is approximately 28 Ml/d.

Figure 10-15: London target headroom



Adaptability testing

10.264 One way of analysing multiple futures simultaneously is through the use of adaptability testing of the reasonable alternative programmes (RAPs).

10.265 We have developed a method that takes the key uncertainties across the planning horizon and assesses them to form a spread of potential alternative futures around the baseline plus drought plus WRSE supply demand deficit forecast.

10.266 The uncertainties used in adaptability testing are:

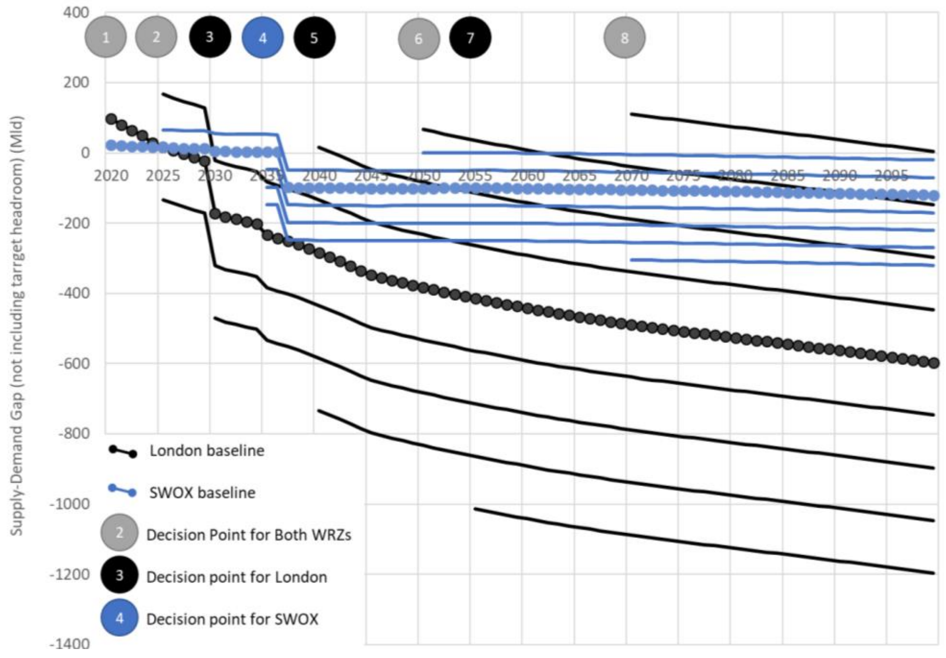
Table 10-19: Adaptability datasets

Uncertainty	Alternative dataset
Population	ONS 2016 Trend based forecast High and Low variations
PCC forecast	No demand savings from Policy DMP, Future PCC scenarios of 105 and 86 l/head/d by 2065
Leakage uncertainty	Assuming that we only reduce leakage by a third by 2050
WRSE	Allowing for future regional needs beyond that included in our central WRSE scenario (Affinity Water 100 Ml/d at 2037)
Climate change	Taking the Medium emissions 5% and 95% percentile impact on deployable output. Also that the impact occurs by 2050 instead of 2080

10.267 The first stage is to create alternative future pathways. We do this by splitting the planning horizon up into decision points, and link them. We then take each RAP and use least-cost optimisation in EBSD to assess how the investment program may change with the changing future from each of the decision points, until all of the pathways have been analysed.

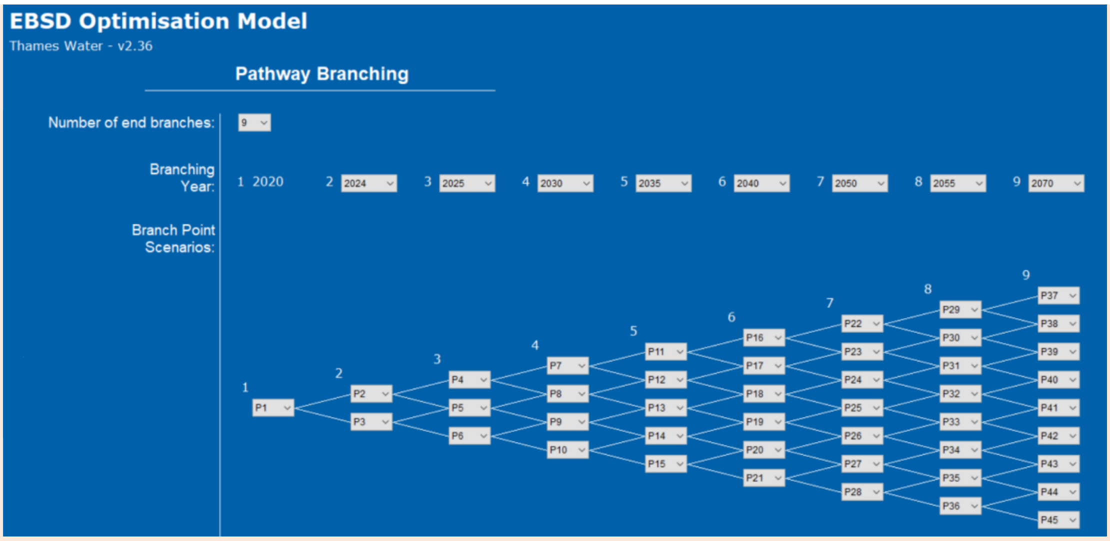
10.268 Eight decision points were determined from the widening of the gap between different potential futures in London and SWOX WRZs (Figure 10-16).

Figure 10-16: London and SWOX future pathways and decision points



10.269 At each decision point, the pathway under consideration can move to either the path immediately above or below. There are 45 different links leading to 9 different endpoints (Figure 10-17) making a total of 256 pathways across which each RAP is analysed. Path_N1 has the smallest final supply-demand gap, and Path_N256 the largest. For further information on how the pathways were constructed see Appendix W.

Figure 10-17: Adaptability: Pathway Links and endpoints



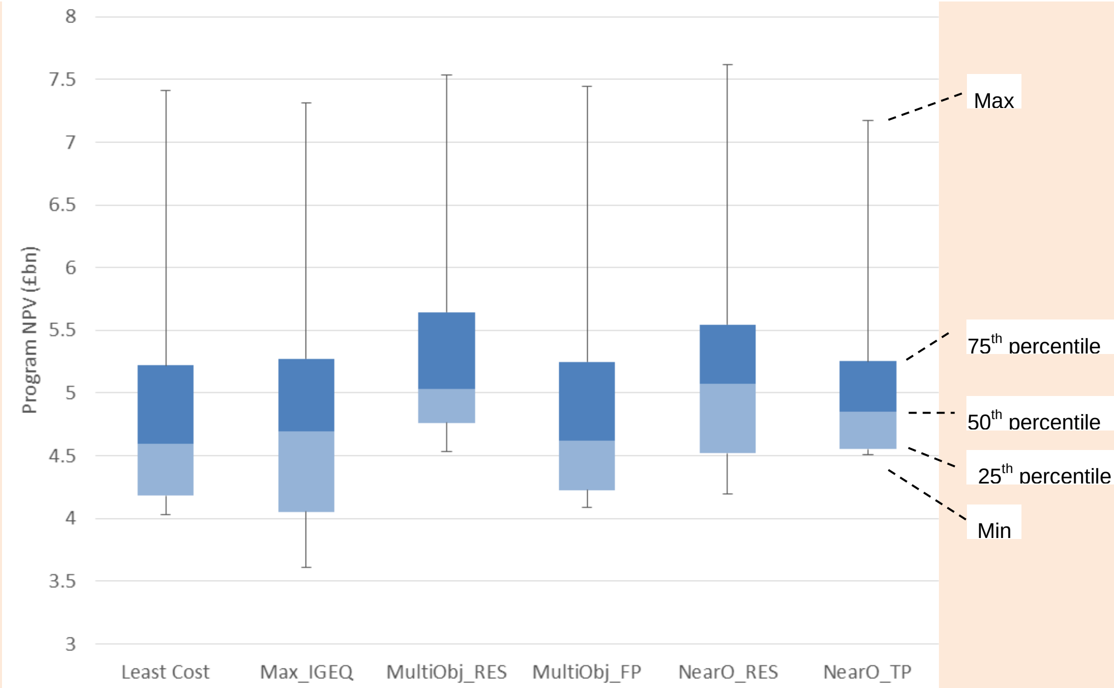
10.270 Three outputs generated that are useful to consider in summary:

- Overall cost ranges
- Risk variability
- Standby costs

Overall cost range

10.271 Having tested each of the RAPs, results show that the range of investment required for different futures varies significantly. Costs are best compared on a box-and-whisker diagram showing the percentile ranges (Max, Min, 25%, 50% and 75%iles) (Figure 10-18).

Figure 10-18: Adaptability Outputs: Cost ranges



10.272 The 50th percentile reflects investment to meet the BL+DRO+WRSE deficit in the combined LSS zone. There are 70 different pathways which can reach this same end point. The 75th percentile endpoint deficit is 200 Ml/d greater than the baseline, and the 25th 150 Ml/d less. The minimum supply demand gap (4 Ml/d) and maximum (1554 Ml/d) investment required are shown by the whiskers.

10.273 The Max_IGEQ program has the widest range in terms of cost of dealing with different futures, both from minimum to maximum and across the central 25th-75th percentiles. Investment can be reduced for less challenging futures; however, the costs for dealing with most likely or more challenging futures are higher than for those programs which commence with a more stable investment program initially (Least-cost, MultiObj_FP).

Risk variability

10.274 We can examine the outputs to assess when the RAPs fail to balance supply and demand across the various future pathways. Failures are to be expected given the wide range of stresses applied, so it is not that failures occur but when and why that is of interest in this analysis.

10.275 Beyond the late 2030s the trends for cumulative failures are broadly similar across the RAPs, showing that providing challenges up to the mid-thirties can be met, the investment programmes have a similar level of risk in the longer term regardless of strategic asset selected. Small differences reflect size of assets selected.

10.276 Up to the mid-30s it is, unsurprisingly, the RAPs that contain the most resource development (MultiObj_RES and NearO_RES) that have the lowest risk of failure. Because they select a large option early (desalination or re-use) they are better suited to respond to additional stress. Although NearO_TP also invests in a large London desalination plant, the longer wait for completion of the strategic resource (reservoir or transfer) pushes up potential risk consequences in the early 2030s.

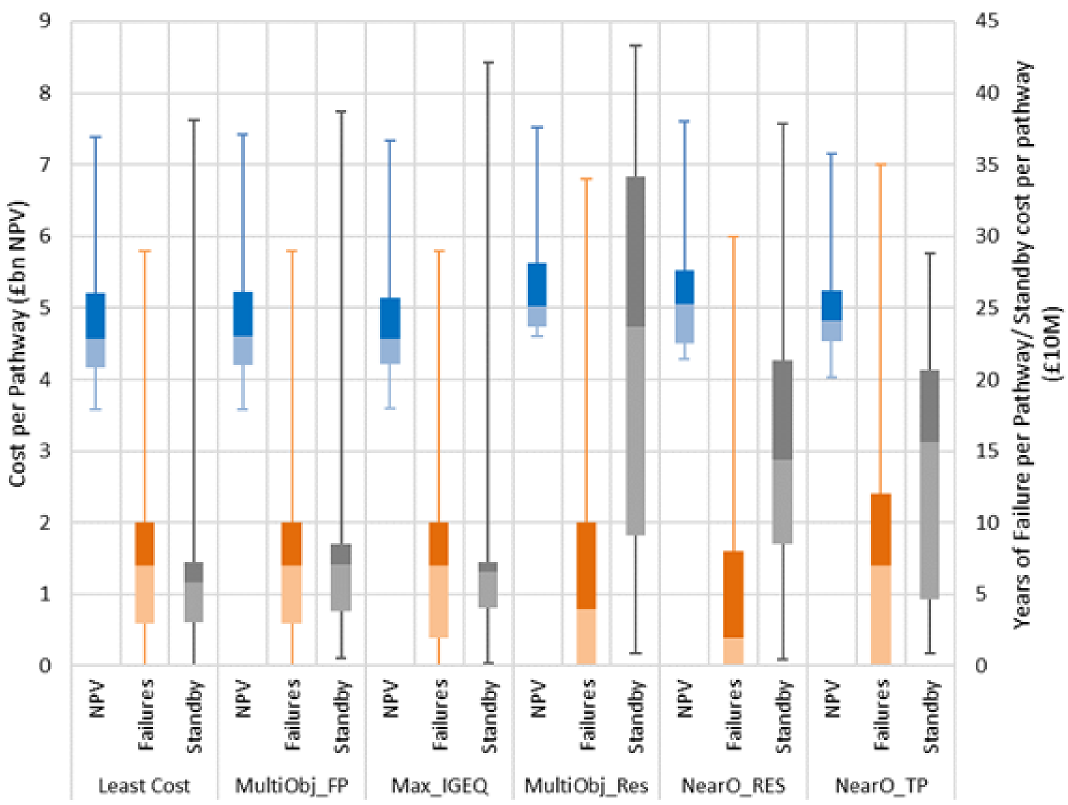
10.277 The flip-side to being able to cover this risk is the extra cost of having built assets that may not be used, i.e. the cost of standby.

Standby costs

10.278 When planning for long term assets to provide resilience, the third aspect to consider beyond total investment cost and risk variability, is the cost of maintaining assets on standby. This has been calculated in each year as the fixed opex and capital maintenance costs for any asset not utilised in that year, summed across all years for each pathway (Figure 10-19). As some pathways become more challenging before turning back towards the most likely, or less challenging, this evaluates both the potential cost of maintaining plant on standby against need and the cost of potential over-engineering.

10.279 Standby costs are best viewed in conjunction with the risk of not having the resilience on standby, and can also be compared with the total cost of the program, as such the three parameters are combined in Figure 10-19 to allow analysis of the trade-offs between them.

Figure 10-19: Adaptability Outputs: Trade-offs



10.280 Least Cost and Multi_Obj_FP both begin investment in Deephams reuse and the 125Mm^3 reservoir initially (before the first decision point), with MultiObj_FP also including the Oxford Canal transfer. They have very similar totex cost ranges and failure risk, but the MultiObj_FP-based programmes have slightly higher standby costs due to the additional capacity.

10.281 Max_IGEQ builds Deephams reuse in conjunction with the 150Mm^3 reservoir initially, which results in a narrower range of costs (higher 25th percentile, lower 75th percentile), set against very slightly fewer failures at the 25th percentile and worst futures. The standby cost range is again the narrowest, although the worst futures standby costs are higher than Least Cost or MultiObj_TP.

10.282 The programmes optimised for resilience not surprisingly both have lower risk at higher cost. MultiObj_RES and NearO_RES both build the Severn-Thames transfer together with reuse or desalination, respectively. Both of these initial investment programmes only fail to meet the most challenging of futures. The cost is a median ~£500 million in totex NPV, which is higher for the NearO_RES program because desalination, unlike reuse, is not a modular option whereby the plant capacity can be increased at a later date. The NearO-based program therefore develops the reservoir for approximately half of the pathways as they become more challenging, while the MultiObj_RES program only builds the reservoir for approximately quarter of the most challenging futures. This is reflected in the significantly higher standby cost of MultiObj_RES, although both have substantially higher standby than the first three programs.

10.283 In contrast, NearO_TP invests in Beckton desalination plant and the reservoir initially, with no small options. The median failures are only slightly lower than Least Cost, and significantly lower than the resilience programmes mainly due to risk during the longer construction period for the reservoir in comparison to the Severn-Thames transfer. However, both totex and standby cost ranges are generally lower than Multi-Obj_RES and NearO_RES and this program has the narrowest cost range, from highest minimum cost for the least challenging future to lowest maximum cost for the most challenging future. However, it also has the highest risk of failure at 75th percentile and worst case futures.

Summary

10.284 In summary, the adaptability analysis shows the trade-offs between future costs and risks dependent on the investment choices made now.

- Initial investment in a range of smaller options to meet the initial drought challenge, rather than one large resource, is more cost-effective across the widest range of futures. This is offset by a higher risk of failure in the early years.
- Investment in a reservoir as strategic resource reduces costs of meeting more challenging futures while requiring higher cost for less challenging futures. Increasing the reservoir size narrows this range further.
- Initial investment in a desalination plant instead of reuse plant reduces the cost of standby for all but the least challenging futures, partly because the desalination plant is more frequently supported by a reservoir.

10.285 Taking a precautionary approach, adaptability analysis supports investment in a larger reservoir to mitigate the cost risk of adapting to more challenging futures, coupled with a range of smaller options to allow resilience to a 1:200 drought.

10.286 Full details of the method for developing adaptability pathways, evaluation of each RAP across all pathways, and more in-depth results are given in Appendix W.

What if testing

10.287 As well as testing multiple uncertainties at once, we have also carried out simpler, single What if tests i.e. what were to happen if one aspect of the supporting information or input data were to change.

10.288 To do this we keep the same model configuration steady but change the input data accordingly. Only the least-cost metric is run as the intention is to examine the impact of a change.

10.289 We carried out a limited selection of What if testing in the draft WRMP. We then had a significant number of requests for consideration of alternative what ifs in our consultation responses. Clearly there are a very large number of potential scenarios that could be assessed.

10.290 Table 10-20 lists the tests we have performed for this revised draft WRMP. The configuration of each run and the outputs can be found in full in Appendix X. The comments in the table relate to the impact on the supply demand balance both in terms of increasing the gap (+) or reducing it (-).

Table 10-20: 'What if' analysis ranges

Uncertainty	Topic	Comment
Timing of 1:200 drought resilience	Resilience	Timing only
1:500 drought resilience in 2040	Resilience	+130 Ml/d
Reservoir Outage/Replacement	Resilience	+108 Ml/d
Remove outages >90 days from record	Supply change	-19Ml/d
Reduction in contribution from the West Berks Groundwater Scheme (WBGWS)	Supply change	+40 Ml/d (LON); +27 Ml/d (SWOX)
Shortened Planning Periods	Economics	50, 55, 60 years
Alternative use of existing bulk supply (Affinity, FG)	Supply change/WRSE	Varies +15/-10 Ml/d
Alternative new WRSE transfers (Affinity, Timing and Volume)	WRSE	2027, 2035, 50 Ml/d, Phased reduction
Potential new WRSE transfers (Other companies)	WRSE	50-185 Ml/d
No Reservoir options available for selection	Supply option change	Remove Reservoir options
WINEP – WFD No Deterioration	Environmental	a) 32 Ml/d b) 107 Ml/d
Reduction in abstraction from Chalk Streams	Environmental	a) 34 Ml/d b) 77 Ml/d
Population Uncertainty	Demand forecast	+100, -250 Ml/d
PCC Uncertainty	Demand forecast	+210, -380 Ml/d
Leakage uncertainty	Demand forecast	+125 Ml/d
Climate change (2050s instead of 2080s)	Climate change	Timing only

10.291 A selection of What if test outputs are included in Table 10-21.

Table 10-21: 'What if' scenarios: Example outputs

		LEAST-COST					
LSS COMBINED ZONE		**Reservoir outage 2040/41[36]**	**50-year planning period[37]**	**WBGW scheme reduction[38]**	**No Reservoir[39]**	**WINEP WFD[40]**	**Climate Change 2050s[41]**
What if scenario outputs for the combined LSS zone, for comparison with the preferred plan.							
Metrics							
Financial (£m NPV)		4,066	3,872	4,380[42]	4,089	4,327[43]	4,066
Environmental +		79	89	70	103	79	79
Environmental -		83	93	71	102	79	83
Deliverability		0.99	0.99	0.99	0.99	0.99	0.99
Resilience		0.84	0.72	0.84	0.67	0.90	0.84
IGEQ		12.54	11.75	12.81	11.79	11.19	12.49
Customer preference		4.41	4.38	4.42	4.39	4.42	4.41
Option	**Benefit (Ml/d)**	**Implementation date**					
ASR_Horton Kirkby	5	2080	2050	2076	2050	2073	2081
ASR_South East London	3	2084	2056	2080	2056	2075	2086
ASR_Thames Valley/Thames Central	3	2087	2066		2066	2077	2087
AR_Merton (SLARS3)	5	2086	2055		2055	2076	2084
AR_Kidbrooke (SLARS1)	7		2068			2080	
AR_Streatham (SLARS)	4	2088	2067			2079	2088
DMP_LON_S4b	421	2020	2020	2020	2020	2020	2020
DMP_SWA_S4b	21	2025	2020	2020	2025	2025	2025
DMP_SWX_S4b	55	2020	2020	2020	2020	2020	2020
DSL_Beckton 150	142	2089			2067	2082	2089
GW_Addington	1	2083	2055	2079	2055	2074	2083
GW_Datchet	5.4	2082		2082	2082	2082	2082
GW_Honor Oak	1		2067				
GW_London confined	2	2083	2066	2079	2066	2078	2086

36 An existing storage reservoir is offline for 2 years (2040 and 2041) at 108 Ml/d
37 The planning period is reduced from 80 to 50 years
38 The West Berkshire Groundwater Scheme is permanently reduced by 40 Ml/d (LON) and 23 Ml/d (SWOX, for KV) from 2031
39 Reservoir options unavailable for selection
40 A reduction of 107 Ml/d from 2035 for potential WFD No Deterioration
41 Climate change in the 2050s instead of the 2080s
42 Does not include the cost of providing the water to Kennet Valley.
43 Resource costs only. Does not include treatment and distribution elements.

LSS COMBINED ZONE				LEAST-COST			
chalk							
GW_Merton	2	2085	2069		2099	2075	2083
GW_Moulsford	3.5	2082	2045	2032	2045	2072	2082
GW_Southfleet/ Greenhithe	8	2031	2031	2077	2031	2031	2031
IPR_Beckton 100	95			2030			
IPR_Beckton 100	95			2081			
IPR_Deephams 45	45	2030	2030		2030	2030	2030
IZT_R Thames to Medmenham	72	2095		2095	2095	2095	2095
NTC_Aston Keynes	1.5	2082	2049	2031	2049	2074	2080
NTC_Britwell	1.3	2083	2049	2080	2049		2083
NTC_Epsom	2	2030	2030	2075	2030	2030	2030
NTC_New River Head	3	2020	2020	2020	2020	2020	2020
RES_Abingdon 125 Mm3	253	2037		2037			2037
RES_Abingdon 150 Mm3	294					2035	
RWP_Oxford Canal to Cropredy	11	2030	2030	2031	2030	2030	2030
RWP_Chingford (E&S)	20	2035	2035	2035	2035	2035	2035
RWP_STT Minworth	70		2057		2057		
RWP_STT Mythe	12		2037		2039		
RWP_STT Netheridge	18		2037		2039		
RWP_STT UU/ST Opt A	6		2037		2039		
RWP_STT UU/ST Opt B	15		2051		2051		
RWP_STT Vyrnwy 60	110		2037		2039		
RWP_Wessex to SWX	2.9	2085	2056		2056	2078	2085

10.292 In general, if the predicted deficits are worse than the base case then the outputs tend to favour the construction of a desalination plant instead of small options before 2030. In the medium to long-term, a reservoir is regularly selected. Once this is fully utilised, desalination, phased re-use or the Severn-Thames transfer is chosen, depending on the size of the need and whether the need is required in the east or west of the region.

10.293 If the deficit eases then less small options can be delivered and phased options are preferred including the Severn-Thames Transfer.

10.294 Similarly, regional transfers could be brought forward to 2035, the earliest reservoir start date. Providing significant transfers before 2035 would require an alternative option that could be delivered more quickly.

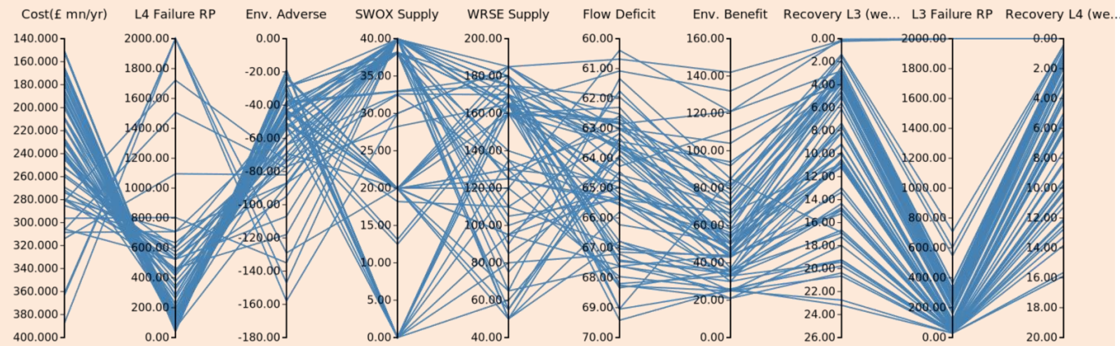
10.295 However front end loading the plan would increase cost and the put pressure on the delivery of savings through the demand management programme.

IRAS-MCS (System simulation modelling)

10.296 IRAS-MCS is a system simulation model that is able to examine system performance across a wide range of drought return periods. Specific metrics have been developed to show how each run performs against Level 3 and Level 4 service failure and also recovery times.

10.297 Sixty-six programmes were developed that could be used to meet the deficits set out in the BL+DRO+WRSE scenario across a range of return periods and uploaded to Polyvis (Figure 10-20).

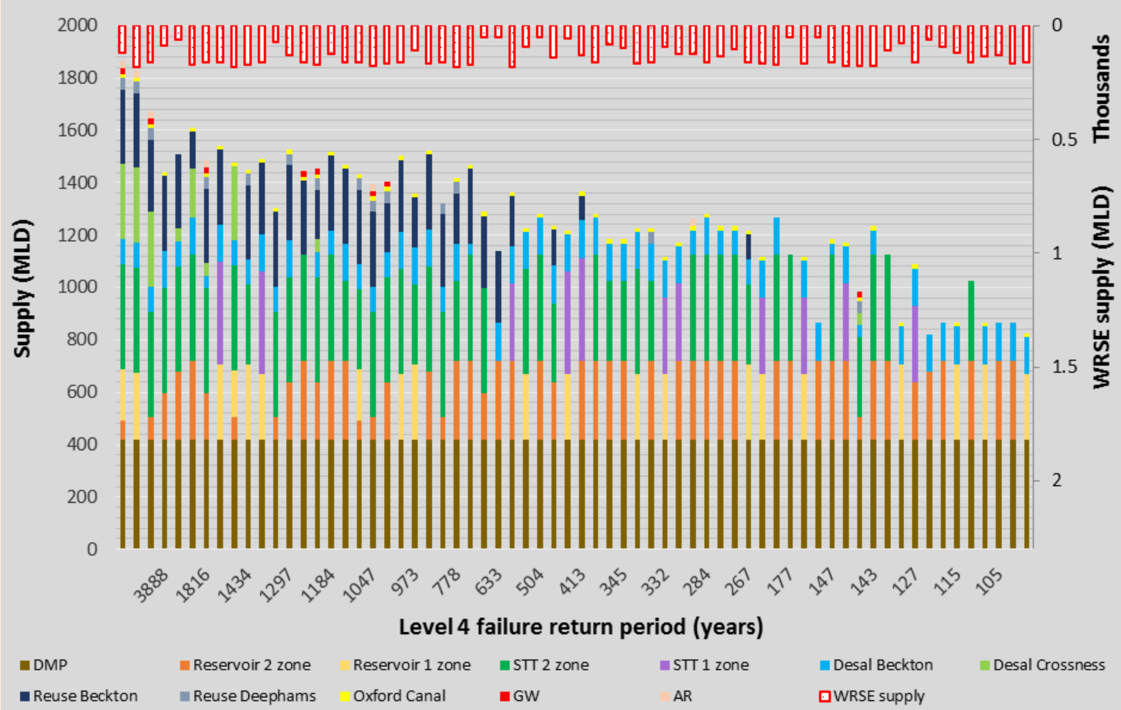
Figure 10-20: IRAS-MCS Programmes



10.298 The 'L4 Failure RP' axis (second left) shows the return period for L4 restrictions, the most severe drought restrictions, from <1:100 to 1:2000. As expected, trade-offs can be seen: for example, the lower the cost of the solution, the lower the resilience to L4 failure (and vice versa).

10.299 Examining this further, if we rank the programmes by L4 return period and look at the options that make up each of the programmes it is possible to pick out patterns in the frequency of selection of options (Figure 10-21).

Figure 10-21: IRAS-MCS Programmes ranked by L4 return period



10.300 The policy demand management programme is fixed in the model, just as it is in EBSD.

10.301 We can see that a reservoir is selected in every run. Desalination is chosen 92% of the time. As the resilience to L4 failure increases the Severn-Thames transfer is chosen (85%) and then water re-use (47%).

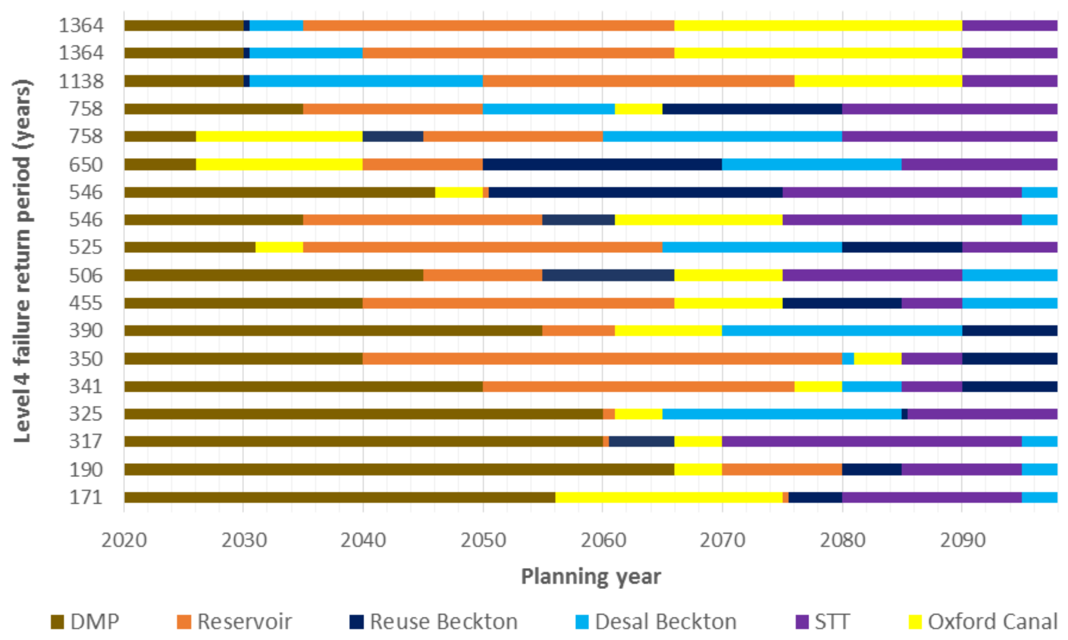
10.302 We have compared the outputs from the EBSD+ model with the IRAS-MCS model and noted alignment in the programmes of options selected to meet the supply demand deficits.

10.303 The smaller options that feature in the EBSD+ runs are not chosen as they have been aggregated in IRAS-MCS to reduce model run times (a set of runs takes 3 days).

10.304 We selected four of the 66 programmes to see how IRAS-MCS would schedule the schemes in the portfolio across the planning period and how the timing and usage of the schemes would vary with increasing drought severity.

10.305 An example run (No.14655) is provided in Figure 10-22 below. The options available are the policy DMP, a two zone reservoir 150Mm^3, a single zone STT, a 150 Ml/d desalination plant, a 100 Ml/d re-use plant and the Oxford Canal.

Figure 10-22: Portfolio 14655 with options scheduled and ranked by L4 return period



10.306 For the highest return periods (above 1000 years) both reuse and desalination plants are active from 2030, preferred before the reservoir. The Severn-Thames transfer is delayed till 2090.

10.307 For return period between 500 and 1000 years, the Oxford Canal is selected generally early on instead of desalination and reuse, the reservoir is online between 2035 and 2045 and preferred before reuse and desalination.

10.308 For the lowest return periods the activation of all supply resources of all supply schemes is deferred until ~2060.

10.309 Severn-Thames transfer is generally active towards the end of the planning period (from ~2080).

Strategic Environmental Assessment (in development of preferred programme)

10.310 We demonstrated in Step 2/3c how we have applied SEA to the options selected in the six Reasonable Alternative Programmes and to the potential cumulative effects of each of these programmes.

10.311 The following key findings have been drawn out of the SEA review of the RAPs to help inform the selection of the preferred best value plan:

- Demand Management Programmes provide material benefit to the environment and should be delivered early in the planning period.
- There are several residual WFD uncertainties/risks included in most of the RAPs that should be avoided unless it can be demonstrated there are no reasonable alternatives:

  - Britwell groundwater option due to uncertainty over mitigation measures to avoid WFD deterioration risks.
  - Minworth effluent support for the Severn-Thames transfer due to challenges in securing acceptable mitigation measures to ensure no WFD deterioration risks.
  - Scheme capacities that lead to potential cumulative WFD risks if combined flow support discharges to the Middle River Thames exceed a threshold value of approximately 500 Ml/d.
  - Scheme capacities that lead to the potential for cumulative WFD risks and Marine Conservation Zone (MCZ) risks to the Thames Tideway if water reuse and/or desalination schemes exceed a cumulative capacity in excess of 275 Ml/d due to potential adverse effects on the salinity regime of the Tideway and consequent effects on saline-sensitive species.
- Small schemes (less than 50 Ml/d) – except Britwell groundwater scheme – have fewer adverse effects than the larger strategic schemes both individually and cumulatively. Environmentally, these should be preferred to larger schemes but it has to be recognised that strategic schemes are still needed to address the supply deficit.
- Water reuse options are marginally preferable to desalination options – construction effects are similar but operational effects are marginally worse for the desalination options. Non environmental factors will be more important in deciding which of these options to include in the preferred programme.
- Options that can deliver environmental benefits with overall minor adverse effects are preferable if there are real choices to be made between options.
- Consider opportunities for net environmental gain in developing the preferred programme having regard to Defra's 25 Year Plan[44] policy objectives, the policies included in the revised National Planning Policy Framework 2018[45] and stakeholder feedback on the draft WRMP19. This could include, for example, considering measures to reduce abstraction from those chalk streams in the Thames Basin assessed as being sensitive to existing abstractions.
- The material planning and/or public inquiry (or DCO process under NSIP regime) risks likely to arise in respect of the STT and South East Strategic Reservoir option (SESRO)
- In terms of phasing of options, the SEA conclusions only influence consideration of minimising cumulative construction effects. The SEA of the RAPs indicated that, if at all possible, overlapping construction periods should be avoided in respect of:
  - South East Strategic Reservoir with Severn-Thames Transfer conveyance pipeline
  - Beckton reuse and Beckton desalination schemes
  - Pipeline to Southern Water (if required) and South East Strategic Reservoir

[44] H M Government 2018 A Green Future: Our 25 Year Plan to Improve the Environment
[45] Ministry of Housing, Communities & Local Government July 2018 National Planning Policy Framework

- In relation to key decision points over the planning period, SEA considerations would indicate:
  - 2030 - SEA favours the smaller schemes rather than a larger scheme (desalination/reuse) as there would be some uncertainty about need for the larger schemes which might turn out not to be needed (and so avoids developing larger schemes too early that carry greater adverse environmental effects)
  - 2037 – The SESRO option has a lower level of adverse environmental effects compared to favoured over the STT option. Additionally, since there is little material environmental differences between the 125 and 150 Mm3 reservoir capacity options, it may be beneficial to construct the larger capacity since this provides additional supply benefit as well as facilitates measures elsewhere in the system to secure net environmental gain.
  - 2080s – any remaining small schemes are favoured, but otherwise water reuse schemes are marginally preferable to desalination schemes. The Severn-Thames Transfer is the least favoured option environmentally, mainly due to large scale effects of the pipeline construction on the Cotswolds AONB and also the WFD deterioration risks associated with the Minworth flow support element (if selected as part of the supported transfer scheme). However, if additional water resources are required in the west of the Thames Water supply area by this time, then it would be important to avoid cumulative WFD risks from flow discharges to the Middle River Thames of greater than approximately 500 Ml/d from a Severn-Thames Transfer scheme operating in conjunction with discharges from the South East Strategic Reservoir. .

Local resilience and practicality

10.312 The output of the EBSD+ is a modelled output. There are practicalities regarding delivering schemes in combination that cannot be easily modelled or where to do so would increase run-times unnecessarily.

10.313 Additionally there can be local resilience needs that are not easily covered by WRZ-level modelling. As part of our routine monitoring of our supply system we can identify property and population growth hot-spots and understand where resources are stretched in extreme conditions, and there is a potential detrimental impact on vulnerable ecosystems.

10.314 This knowledge can be used to reasonably justify changes to modelled output to provide a better overall solution.

10.315 In London, South East London is a known growth hotspot (Thamesmead). We can mitigate some of this pressure through distribution improvements funded by developers, but if we are also to be able to improve local supply availability by implementing more schemes and deliver them earlier than they would otherwise be needed to meet general growth in London, that would be beneficial. This can also remove pressure from sources that potentially cause stress to the environment.

10.316 In SWA and Guildford, where we predict to go into deficit in the first year of an investment period, it makes practical sense to bring that investment forward to the preceding AMP period to reduce delivery pressure and secure supplies earlier.

Step 5: Selection of a preferred programme

10.317 We concluded Step 2/3c of our analysis by confirming that our preferred programme would need to be a hybrid of the 6 RAPs identified through EBSD+ modelling. None of the programmes was suitable to be adopted directly without modification.

10.318 The outputs from the decision support tools were carefully appraised and the information used to help inform the decision making process to select the best value investment programme. Our Executive and selected Board members were also informed and engaged in the decision making process.

10.319 We further performance tested the RAPs in Step 4 to better understand how each would change if future forecast scenarios turns out to be different. This gave us an enhanced insight into what we should look to include in the selection of a preferred best value programme i.e. the no regret options that are consistently selected in a variety of different futures.

10.320 The number and range of alternative views and data analysis available to us to inform our decision is significantly greater than in the draft WRMP19. This is a good thing; it means that our selection of a preferred programme has an improved narrative and has a more informed justification arrived at through a balance of judgements. The exercise has included reviewing the responses to the public consultation and responding to the points made where they are supported by robust evidence.

10.321 In making our preference judgement we have shared extensively our thinking with internal teams, regulators, our CCG, our consultant partners, stakeholders and interested parties and with the Expert Panel.

10.322 We have demonstrated that our revised draft WRMP19 can be seen as a series of decisions covering different points in time over the 80 year planning period. These are tabulated below in Table 10-22:

Table 10-22: Decision points over the planning period

From 2020	
Demand Management Focus	In the next 5 years and continuing to 2050 we intend to undertake a substantial and ambitious demand management programme. We believe this is the right thing to do and aligns with the expectations of our customers, regulators and stakeholders.
2030	
Providing 1:200 drought resilience	Providing 1:200 year drought resilience in 2030 will require resource development. Our programme appraisal suggests this could be provided by a series of relatively small options (re-use, Oxford canal raw water transfer and innovative groundwater development) or a single larger desalination or reuse plant. We favour the phased construction of small options as it: • is less costly

	• is less risky (it is spread over a range of options) • allows greater flexibility to future needs • enables us to gain practical understanding of implementing options types such as re-use, canal transfers and aquifer storage at a smaller scale, rather than immediate reliance on one larger option.
2037	
Regional need and the South East Strategic Reservoir Option (SESRO)	The SESRO is the leading option to meet regional need across the South East and secure supplies in the medium term. • The implementation date is driven by regional need (Affinity Water) • The option is most regularly chosen across RAPs, adaptability, What if analysis and system simulation modelling. • It maximises the capture and storage of water resource already available in the Thames Basin. Delivering this option will provide sufficient headroom to enable us to cost effectively deliver a series of environmental improvements to vulnerable chalk streams and water courses through the reduction and re-location of abstraction. This responds to a number of stakeholder concerns raised during the consultation process.
Long-term (beyond 2080)	
Managing potential long-term changes	Once the SESRO has been fully utilised (2080s) further options are required to secure supplies to the end of the planning period. Re-use, desalination and the Severn-Thames Transfer are all available to meet this demand. We favour the Severn-Thames Transfer on the basis of: • The potential future need in the west of the Thames catchment, namely: — Greater South East regional transfer need e.g. Southern Water requirements — The uncertainty of the yield of the West Berks Groundwater Scheme — Further sustainability reductions — The Cambridge, Milton Keynes Oxford growth corridor (e.g. CaMKOx) • SESRO and the Severn-Thames Transfer are regularly selected by system simulation modelling at higher drought return periods. • There is potential for in combination benefits with storage. The SESRO provides regional storage and is a transfer hub for the South East. Its benefit will be enhanced through the Severn-Thames transfer. The risk and high cost associated with the yield of the transfer is mitigated when there is capacity to store water during periods of surplus.

10.323 Our overall preferred programme for the LSS combined zone, covering London, SWA and SWOX WRZs, is shown below in Table 10-23, including for chalk stream reductions in 2037.

Table 10-23: London, SWOX, SWA Combined Zone – Preferred Programme

BL + Increased Resilience + WRSE transfers + Chalk Streams (Combined LSS)		OVERALL LSS PREFERRED PROGRAMME	
Metrics			
Financial (£m NPV)		4,628	
Environmental +		81	
Environmental -		77	
Deliverability		0.99	
Resilience		0.95	
IGEQ		11.19	
Customer preference		4.42	
Options[46]	**Benefit (Ml/d)**	**Implementation date**	
DMP_LON_S4b	421	2020	
DMP_SWX_S4b	51	2020	See Note 1
DMP_SWA_S4b	22	2025	
RWP_Didcot	18	2020-25	
NTC_New River Head	3	2020	
ASR_Horton Kirby	5	2024	See Note 2
GW_Southfleet/Greenhithe	8	2024	
GW_Addington	1	2030	
GW_Merton	2	2030	
IPR_Deephams 45	45	2030	
NTC_Epsom	2	2030	
RWP_Oxford Canal to Cropredy	11	2030	
AR_Kidbrooke (SLARS1)	7	2030	
AR_Merton (SLARS3)	5	2031	
ASR_South East London (Addington)	3	2031	
RWP_Chingford (E&S)	20	2035-2060	
RES_Abingdon 150 Mm3	294	2037	See Note 3
GW_Datchet	5	2038	
IZT_R Thames to Medmenham	24	2066	
RWP_STT Vyrnwy 60	110	2083	See Note 4
RWP_STT_Mythe	12	2089	
RWP_STT UU/ST Opt B	21	2092	
RWP_STT Netheridge	18	2096	

46 Resource development and demand management only

Note 1

10.324 The RWP_Didcot option is included to provide extra support in the short-term to maintain security of supply in the event of demand management savings not being realised as forecast. A commercial agreement is in place with RWE Npower regarding this supply.

Note 2

10.325 The ASR Horton Kirby and Southfleet/Greenhithe groundwater developments are located in South East London. They are selected for delivery in the AMP7 period because (1) they offer potential to reduce reliance on the traditional groundwater sources in South East London and thereby reduce any perceived environmental impacts on the vulnerable chalk streams and water courses in the area. This responds to concerns expressed by a number of environmental groups during the public consultation and (2) they offer resources to cope with any possible short fall in the demand management programme.

Note 3

10.326 We have included the largest (150 Mm^3) South East Strategic Reservoir Option (SESRO) option in 2037, timed with the need from Affinity Water. We consider that if a reservoir is selected it should be built to maximise its potential benefit to the supply demand balance.

10.327 The delivery of largest SESRO creates sufficient surplus in the supply demand balance which can be used to facilitate a reduction in some of our abstractions that are perceived to have an adverse impact on vulnerable chalk streams and water courses (Table 10-24). Our groundwater abstractions at Pann Mill (River Wye), Waddon (River Wandle) and North Orpington (River Cray) have previously been examined for environmental impact but the investigations concluded that it was not cost beneficial to reduce abstraction at these sites. The SESRO with its low annual operating costs will help to more cost effectively reduce abstraction at these sites and thereby address the concern voiced by environmental groups.

Table 10-24: Changes to abstraction on vulnerable chalk streams and watercourses

Source	Waterbody	WRZ	Reduction		Scheme (2037)
			Average (Ml/d)	Peak (Ml/d)	
Farmoor	Thames	SWX	0	0	Re-location of abstraction point to downstream of Oxford at Culham,
New Gauge	Lee (Amwell Magna Loop)	LON	0	0	Reduce abstraction at New Gauge and increase at other lower Lee intakes.
Pann Mill	Wye	SWA	9.8	9.8	
Waddon	Wandle	LON	7.2	15.1	
North Orpington	Cray	LON	8.8	8.8	

10.328 There is also an opportunity to reduce abstraction at Farmoor and New Gauge which should not result in a loss of deployable output if infrastructure is built downstream to subsequently capture and store the increased river flow which would then become available.

10.329 The SESRO could facilitate an abstraction reduction at Farmoor if new infrastructure is installed during construction of the scheme. The *saved water* can be abstracted downstream through the reservoir intakes and transferred back to Farmoor to be put into supply during periods of low flow. The reduced abstraction at Farmoor would enable flows through the Oxford watercourses to increase.

10.330 In the River Lee, reduced abstractions at New Gauge could facilitate increased flow along the Amwell Magna reach. This water can be subsequently abstracted downstream into the Lee Valley reservoirs but will require a new tunnel to transfer the water back to the New River and Coppermills water treatment works if an impact on deployable output is to be avoided. There is an important assumption here that water not abstracted at New Gauge is subsequently available for downstream abstraction. This assumption will need to be confirmed through field investigations.

10.331 Environmental groups have called for further reductions in our abstractions at a number of other selected locations. These particular sites will be the subject of further WFD investigations during AMP7 and we will review the results of these studies before determining the next steps at these locations.

Note 4

10.332 In the 2080s further strategic resource development is required. The timing is driven by population and climate change impacts, as well as the reductions we make in our abstractions near vulnerable water courses.

10.333 The Severn-Thames transfer is selected in the preferred investment programme, rather than desalination or reuse options, given its western location which supports WRSE transfers as well as further growth in both the Thames Valley and London resource zones. If our existing abstractions are further reduced in response to the results of the AMP7 WFD investigations the timing of the Severn-Thames transfer would be brought forward.

SEA of preferred programme for London, SWOX and SWA WRZs

10.334 Strategic Environmental Assessment (SEA) has been carried out of the preferred programme for the London, SWOX and SWA WRZs. The key findings are summarised below.

10.335 Further details are available in Section 11: Preferred plan and Appendix B: SEA – Environmental Report.

10.336 The schemes forming this programme are compliant with Habitats Regulations with delivery of specified construction mitigation measures for the Deephams reuse scheme, the downstream treatment requirements at Coppermills WTW and Kempton Park WTW, and the South West London "chalk stream" pipelines.

10.337 The schemes forming this programme are compliant with the WFD objectives, with no risk of WFD status deterioration. Mitigation measures may be necessary to be implemented in the form of additional flow augmentation support and/or abstraction licence controls to avoid WFD deterioration risks in respect of the Epsom groundwater option once more detailed investigations of the effects of increasing abstraction within existing licence limits are completed in dialogue with the Environment Agency.

10.338 Overall, the environmental and social effects of this programme are predominately of minor to moderate significance (both adverse and beneficial effects). However, some major adverse effects have been identified, which is to be expected given the scale of the schemes necessary to address a very large supply deficit. Many of these major effects are temporary in nature and largely unavoidable while construction works take place. However, some of the major effects are related to extended construction periods over a number of years (in respect of the Severn-Thames transfer scheme pipeline and the South East Strategic Reservoir) or may be permanent in nature. In these circumstances, we would consider whether further additional mitigation measures can be applied to reduce the identified effects in dialogue with regulators, planners, stakeholders and any local communities affected. Where this is not feasible, appropriate compensation measures would be considered that can be taken in response to these effects.

10.339 This programme presents several challenges in delivery and operation from a planning and environmental perspective, requiring agreement of extensive mitigation measures for several schemes to avoid adverse effects in relation to European Sites and national environmental designations (including SSSIs, AONBs and heritage designations).

10.340 The environmental performance of this programme is characterised by moderate adverse effects but has the advantage over the reasonable alternative programmes considered by:

- Removing schemes with WFD compliance risks (Minworth and Britwell options)
- Reducing the scale of the cumulative effects of the Severn Thames transfer and South East Strategic Reservoir at Culham to an acceptable level that avoids cumulative WFD compliance risks
- Avoids cumulative WFD and Recommended MCZ compliance risks for the Thames Tideway by only developing the Deephams reuse scheme
- Provides for a material reduction in abstraction by Thames Water in low flow conditions from various vulnerable chalk streams and water courses by creating sufficient supply headroom and developing additional water supply transfer infrastructure from 2037. This measure materially improves the overall environmental performance of the revised draft WRMP19.

I. Programme appraisal: Kennet Valley

- The programme appraisal for Kennet Valley WRZ has been updated since the draft WRMP
- Demand management is sufficient to balance supply and demand
- The main risk to the zone is the future ownership and operation of the Environment Agency's West Berkshire Groundwater Scheme and any reductions to its output.

10.341 As a low risk zone, a simpler programme appraisal approach can be used for Kennet Valley. There are four steps:

- Least-cost
- Scenario testing (Increased resilience)
- Stress testing (West Berks Groundwater Scheme)
- Preferred programme

Step 2 (LC): Least-cost

10.342 The starting point is a least-cost solution to the baseline planning problem.

10.343 The zone is in surplus throughout the planning horizon, so no intervention is required.

Step 2/3: Scenario assessment

10.344 Increasing drought resilience to a 1:200 return period in 2030 has a 3.36 Ml/d impact on supply.

10.345 The impact of increasing resilience is shown in Table 10-25. A requirement for removal of network constraints and a small groundwater scheme is triggered in the 2090s.

10.346 There are no requirements for exports to neighbouring zones.

10.347 The results of our programme appraisal set out in Table 10-25 demonstrate that the application of the leakage and metering policy (bringing the start date forward to 2030) is sufficient to balance supply and demand allowing for a 1:200 drought resilience position. The overall cost of the programme rises significantly (but not materially in context of the overall company-level programme), but conversely the environmental performance is improved.

Step 4: Performance testing

10.348 The main risk to supply demand balance of the zone is the potential reduction of output from the Environment Agency's West Berkshire Groundwater Scheme. This scheme, where in times of drought water is abstracted from underground aquifers in order to augment flows in the River Kennet, supports our abstraction at Fobney and further downstream in London.

10.349 The ownership, operation and long-term viability of these assets are unclear and the Environment Agency has requested we assess the impact of changes to the scheme on our plan.

10.350 The full scheme has a supply benefit of 43 Ml/d to the Kennet Valley WRZ. We believe that complete loss of the entire scheme benefit would be unlikely, so we have developed a scenario that reduces output by 27 Ml/d based on the contribution of sustainable drought sources in the confined chalk aquifer.

10.351 Currently there are insufficient options in the Kennet Valley to meet a reduction in supply of that scale and we would likely need to develop a new surface water intake on the Thames near Reading in order to support Fobney.

Step 5: Preferred programme

10.352 The Kennet Valley WRZ is a low risk zone. Its baseline position is to be in surplus throughout the planning period. A small deficit is predicted in the 2090s once an increase in resilience to a 1:200 drought is planned for.

10.353 Options are therefore required to provide surplus to the end of the planning horizon.

10.354 The cheapest way to meet the deficit would be to develop two small groundwater schemes, however we propose to defer that development by fully metering the zone as part of our wider metering and water efficiency programme.

10.355 In our WRMP14 we set out the case for metering across our entire supply area. This was supported by stakeholders and customers. Defra approved the plan in July 2014.

10.356 It is our intention to continue to promote a progressive metering programme (PMP) which drives further water efficiency and leakage reduction activity as part of delivering IDM in this plan, to be delivered as soon as practicably possible.

10.357 We propose the roll-out of the metering programme between 2030-40, given that in the first 10 years priority will be given to other higher priority WRZs.

10.358 We believe this to be an equitable solution, in keeping with the needs of the wider Thames catchment and the wider south east.

10.359 We will continue to work with the Environment Agency to clarify the potential risks associated with the WBGWS.

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Table 10-25: Kennet Valley WRZ – Programme development

KENNET VALLEY WRZ		LEAST-COST			Step 5: PREFERRED PROGRAMME
		Step 2a: Baseline	Step 2b: Baseline + DRO	Step 4: WBGWS test	
Programme development in Kennet Valley WRZ					
Metrics					
Financial (£m NPV)		0	0.5	N/A	**40.7**
Environmental +		N/A	7		**6**
Environmental -			6		**1**
Deliverability			0.95		**1**
Resilience			0.44		**0.44**
IGEQ			0.22		**0.33**
Customer preference			4.54		**4.39**
Option	**Benefit (Ml/d)**	**Implementation date**			
DMP_KV S4b	13.7	None required		Insufficient Options Available	**2030-40**
NTC_East Woodhay	2.1		2091		
GW_Mortimer re-commission	4.5		2098		

10.360 A breakdown of the supply and demand components for the preferred plan is available in Appendix A: dWRMP19 planning tables.

SEA of preferred programme for Kennet Valley WRZ

10.361 The schemes within the preferred programme for Kennet Valley WRZ have been subject to the same environmental and social assessment process as set out for the preferred programme for the combined LSS WRZ.

10.362 The schemes forming the preferred programme for Kennet Valley WRZ are compliant with Habitats Regulations and with WFD objectives. Overall, the environmental and social effects of this programme are predominately of **a minor to moderate significance** (both adverse and beneficial effects).

10.363 Further details are available in Section 11: Preferred plan and Appendix B: SEA – environmental report.

J. Programme appraisal: Guildford

- The programme appraisal for Guildford WRZ has been updated since the draft WRMP
- The preferred programme is to roll out metering, with resource development (favoured in the least-cost solution) deferred to the 2080s.
- To improve local resilience the preferred programme still includes a transfer main, constraint release and treatment enhancements necessary to connect the Shalford and Netley sub-zones.

10.364 As a low risk zone, a simple programme appraisal approach can be used for Guildford WRZ.

Step 2 (LC): Least-cost

10.365 The starting point for programme appraisal is a least-cost solution to the planning problem. We use the EBSD+ model to optimise the cheapest (lowest NPV) way to balance supply and demand. The solution identified, as shown in Table 10-26 below consists of release of constraints in the supply system in 2024 and 2031, groundwater development in the 2030s, with an import from South East Water in the 2040s.

10.366 Currently the zone is operated as two sub-zones. A western zone that is primarily served by surface water abstractions from the rivers Wey and Tillingbourne at Shalford and an eastern zone that utilises local groundwater sources (zonal configuration is further discussed in Appendix D). Consequently, a transfer main, constraint release and additional treatment is also required to provide interconnectivity between the two sub-zones and improve resilience in response to growth.

10.367 The majority of options available to the zone are in the western sub zone, so the transfer is anticipated to operate from west to east.

Step 2/3: Scenario assessment

10.368 There are currently no impacts predicted in the Guildford WRZ from the alternative baseline scenarios. The zone is already resilient to a 1:200 drought and there is no requirement for a regional transfer (export).

10.369 In our WRMP14 we set out the case for metering across our entire supply area. This was supported by stakeholders and customers.

Step 4: Performance testing

10.370 No additional testing has been carried out for the Guildford zone. No significant challenges are expected that cannot be handled in future iterations of our WRMP. We will continue to assess potential threats using business as usual processes.

Step 5: Preferred programme

10.371 The Guildford WRZ is a low risk zone. Although there is deficit in the baseline scenario by 2025, it can be addressed with in-zone solutions of relatively low complexity.

10.372 Our preferred programme for the Guildford WRZ modifies the least-cost programme through the inclusion of a demand management programme. We propose to fully meter the zone as part of our wider programme of progressive metering from 2020-30.

10.373 Although not needed to be started until 2025, it is our intention to start the programme in from 2020, recognising that early delivery will help to reduce the operational risk in the first year of the next business plan.

10.374 Delivering this programme enables the deferral of most of the resource development to the 2080s.

10.375 We believe this to be an equitable solution, in keeping with the needs of the wider Thames catchment.

10.376 The transfer main, network constraint and associated treatment scheme to improve intra-zonal connectivity so that water can be shared between the Western (Shalford) and Eastern (Netley) sub-zones and increase resilience is retained.

Table 10-26: Guildford WRZ – Least-cost and preferred programme

GUILDFORD WRZ		Step 2: LEAST-COST	Step 5: PREFERRED PROGRAMME
The least-cost (lowest NPV) programme and preferred programme			
Metrics			
Financial (£m NPV)		22.3	52.6
Environmental +		11	**12**
Environmental -		8	**5**
Deliverability		0.96	**0.98**
Resilience		0.44	**0.44**
IGEQ			
Customer preference			
Option	**Benefit (Ml/d)**	**Implementation date**	
DMP_GUI S4b	8.3		2020-30
NTC_Ladymead (+ Shalford to Albury transfer main)	4.6	2024	**2024**
NTC_Dapdune	1	2031	**2081**
GW_Dapdune	2.2	2031	**2091**
Import from South East Water	10	2043	

10.377 A breakdown of the supply and demand components for the preferred plan is available in Appendix A: dWRMP19 planning tables.

SEA of preferred programme for Guildford WRZ

10.378 The schemes within the preferred programme for Guildford WRZ have been subject to the same environmental and social assessment process as set out for the preferred programme for the combined LSS WRZ.

10.379 The schemes forming the preferred programme for Guildford WRZ are compliant with Habitats Regulations and with WFD objectives. Overall, the environmental and social effects of this programme are predominately of **a minor to moderate significance** (both adverse and beneficial effects).

10.380 Further details are available in Section 11: Preferred plan and Appendix B: SEA – environmental report.

K. Programme appraisal: Henley

- The programme appraisal for Henley WRZ has been updated since the draft WRMP
- There are no material changes to the preferred programme

10.381 As a low risk zone, a simple programme appraisal approach can be used for Henley WRZ.

Step 2 (LC): Least-cost

10.382 There is no supply demand deficit in Henley WRZ, so the least-cost option requires no intervention.

Step 2/3: Scenario assessment

10.383 There are currently no impacts predicted in the Henley WRZ from the alternative baseline scenarios. The zone is resilient to a 1:200 drought and there is no requirement for a regional transfer.

Step 4: Performance testing

10.384 No additional testing has been carried out for the Henley zone. No significant challenges are expected that cannot be handled in future iterations of our WRMP. We will continue to assess potential threats using business as usual processes.

Step 5: Preferred programme

10.385 The Henley WRZ is a low risk zone. Although it is in surplus throughout the planning period, we propose to fully meter the zone as part of our wider programme of progressive metering. See Table 10-27.

10.386 In our WRMP14 we set out the case for metering across our entire supply area. This was supported by stakeholders and customers.

10.387 It is our intention to continue to promote a progressive metering plan (PMP) in this plan, which drives further water efficiency and leakage reduction activity as part of delivering IDM.

10.388 We believe this to be an equitable solution, in keeping with the needs of the wider Thames catchment.

10.389 The roll-out of the metering programme will be 2030-40, given that in the first 10 years priority will be given to other higher priority WRZs.

Table 10-27: Henley WRZ – Least-cost and preferred programme

HENLEY WRZ		Step 2: LEAST-COST	Step 5: PREFERRED PROGRAMME
The least-cost (lowest NPV) programme and preferred programme			
Metrics			
Financial (£m NPV)		0	4.089
Environmental +		N/A	**3**
Environmental -			**1**
Deliverability			1
Resilience			**0.44**
IGEQ			
Customer preference			
Option	**Benefit (Ml/d)**	**Implementation date**	
DMP_HEN S4b	1.5	None	**2030-40**

10.390 A breakdown of the supply and demand components for the preferred plan is available in Appendix A: dWRMP19 planning tables.

SEA of preferred programme for Henley WRZ

10.391 The scheme forming the preferred programme for Henley WRZ is compliant with Habitats Regulations and with WFD objectives. Overall, the environmental and social effects of this programme are predominately of **a minor to moderate significance** (both adverse and beneficial effects).

10.392 Further details are available in Section 11: Preferred plan and Appendix B: SEA – environmental report.

L. Preferred programme summary

- This section contains a summary of the outputs of the programme appraisal.
- It has been re-written to take account of changes since the draft WRMP as set out in the previous sections.

10.393 Our programme appraisal journey can be summarised in five steps (Table 10-28):

- **The least-cost solution to solve the baseline deficit (Step 2 (LC))**

  Cost = £2.0bn (80yr NPV).

  Outcome: Solution does not contain enough demand management to meet regulator, government, company and stakeholder expectations and customer wishes. Wastewater reuse at Deephams and Beckton form the major resource schemes.

- **The reasonable alternative programmes to solve the baseline deficit (Step 2/3a)**

  Minimum cost = £3.1bn (80yr NPV) (increase of 52%)

  Outcome: Maximises deliverable demand management to facilitate a long-term reduction in leakage so that it is reduced to approximately 15% of the water put into supply and aligns with the recommendations of the National Infrastructure Commission. Material additional cost but better performance across a range of metrics and provides a programme more in line with expectations. A modified least-cost plan would choose reuse rather than desalination in the 2080s but it in any case, it does not address the desire of all parties to be more resilient to extreme drought events.

- **The reasonable alternative programmes to solve the baseline deficit plus 1:200 drought resilience (Step 2/3b)**

  Minimum cost = £3.5bn (80yr NPV) (increase of 73% of initial least cost)

  Outcome: The solution provides resilience to a 1:200 drought from 2030. Resource option types remain largely unchanged in the early years but are brought forward at additional cost. The long-term supply demand balance is maintained through wastewater reuse from the 2050s.

  The programme does not facilitate inter-zonal transfers as part of a regional solution.

- **The reasonable alternative programmes to solve the baseline deficit plus 1:200 drought resilience and providing for regional transfers. (Step 2/3c)**

  Minimum cost = £4.1bn (80yr NPV) (increase of 104% of initial least cost)

  Outcome: Preferred scenario. Resource option types unchanged in the early years, but the South East Strategic Reservoir Option at Abingdon is selected in 2037 to fulfil the transfer requirement, again at additional cost, although part of this cost would be recovered through commercial agreements with recipient companies.

- **The overall best value preferred programme (Step 5)**

  Minimum cost = £4.7bn (80yr NPV) (increase of 134% of initial least cost)

  Outcome: Following a substantial programme of performance testing (Step 4), the preferred programme is identified through judgement.

Table 10-28: All WRZ summary of programmes

Programmes		Step 2 (LC):	Step 2a: BL	Step 2b: BL + DRO	Step 2c: BL + DRO + WRSE	Step 5: PREFERRED PROGRAMME (BL+DRO+WRSE +Chalk Streams)
Note: Step 2a-c and Step 5 include the application of company's preferred demand management policy.						
Metrics						
Financial (£m NPV)		2,014	3,061	3,487	4,105	4,726[47]
Environmental +		90	51	68	70	**81**
Environmental -		98	53	77	81	**77**
Deliverability		0.98	0.92	0.89	0.96	**0.95**
Resilience		0.44	0.52	0.45	0.84	**0.88**
IGEQ		6.36	11.94	11.87	11.33	**11.19**
Customer preference		4.41	4.39	4.40	4.41	**4.42**
Option[48]	**Benefit (Ml/d)**	**Implementation date**				
DMP_LON_110-70-7	187	2020-35				
DMP_LON_S4b	421		2020-50	2020-50	2020-50	**2020-50**
NTC_New River Head	3	2020	2020	2020	2020	**2020**
RWP_Didcot	18	2020-25	2020-25	2020-25	2020-25	**2020-25**
ASR_Horton Kirkby	5	2035	2061	2048	2030	**2024**
GW_Southfleet/Greenhithe	8	2037	2062	2031	2031	**2024**
NTC_Epsom	2	2035	2060	2030	2030	**2030**
RWP_Oxford Canal to Cropredy	11	2035	2060	2030	2030	**2030**
IPR_Deephams	45	2038	2064	2030	2030	**2030**
GW_Addington	1	2041	2063	2052	2030	**2030**
GW_Merton	2	2098			2087	**2030**
AR_Kidbrooke (SLARS1)	7	2070	2079			**2030**
AR_Merton (SLARS3)	5	2098	2075	2050	2030	**2031**
ASR_South East London (Addington)	3	2047	2076	2049	2087	**2031**
RWP_Chingford (E&S)	20	2035-60	2035-60	2035-60	2035-60	**2035-60**
RES_Abingdon 125 Mm3	253				2037	
RES_Abingdon 150 Mm3	294					**2037**
RWP_STT Vyrnwy 60	110					**2083**
RWP_STT Mythe	12					**2089**
RWP_STT UU/ST Opt B	21					**2092**
RWP_STT Netheridge	18					**2096**
IPR_Beckton 100	95	2043		2053		
IPR_Beckton 100	95	2055		2067		

[47] Including £0.097bn for the preferred programme in Kennet Valley, Guildford and Henley WRZs
[48] Resource development and demand management only

Programmes		**Step 2 (LC):**	**Step 2a: BL**	**Step 2b: BL + DRO**	**Step 2c: BL + DRO + WRSE**	**Step 5: PREFERRED PROGRAMME (BL+DRO+WRSE +Chalk Streams)**
IPR_Beckton 100	95	2072		2093		
GW_London confined chalk	2	2069	2074	2051	2083	
GW_Honor Oak	1	2071		2092		
ASR_Thames Valley/Thames Central	3	2096	2077	2051	2088	
AR_Streatham (SLARS)	4	2099	2078	2052	2086	
DSL_Beckton 150	142		2081		2089	
SWOX						
DMP_SWX_18-12-1	31	2020-30				
DMP_SWX_S4b	51		2020-30	2020-30	2020-30	**2020-30**
GW_Moulsford	4	2088			2082	
NTC_Aston Keynes	2	2089			2082	
NTC_Britwell	1	2096			2083	
RWP_Wessex Water to SWX (Flaxlands)	3	2098			2085	
SWA						
DMP_SWA_0-5-9	14	2025-35				
DMP_SWA_S4b	22		2025-35	2025-35	2025-35	**2025-35**
GW_Datchet	5	2083	2090	2082	2082	**2038**
IZT Henley WRZ to SWA WRZ	5	2097		2095		
IZT_R Thames to Medmenham	24				2095	**2066**
KENNET VALLEY						
DMP_KV S4b	13.7					**2030-40**
NTC_East Woodhay	2.1			2091		
GW_Mortimer recommission	4.5			2098		
GUILDFORD						
DMP_GUI S4b	8.3					**2020-30**
NTC_Ladymead (+ Shalford to Netley transfer main by 2026)	4.6	2024				**2024**
NTC_Dapdune	1	2031				**2081**
GW_Dapdune	2.2	2031				**2091**
Import from South East Water	10	2043				
HENLEY						
DMP_HEN S4b	1.5					**2030-40**

10.394 We consider that the overall best value plan for our customers only is one that delivers more demand management and greater resilience to drought.

10.395 We also strongly support working with our neighbours and stakeholders to provide an overall best value plan for the south east of England. We acknowledge that resources developed in our supply area could be used to support regional transfers and provide greater resilience to the region.

10.396 Demand management is confirmed in all zones. It will provide an integrated solution to reduce leakage, roll out metering of all connections (over 80% of individual properties are metered) and continue an ambitious programme of water efficiency activity. Our highest and immediate priority is to make the most effective use of the water we already have. This is includes being even more ambitious in our plans to cut leakage – a reduction of approximately 100 Ml/d in the next 5 years and an overall reduction in line with the National Infrastructure Commission's call of 50% by 2050 – plus fitting more smart meters to help customers use less water and provide the information we need to pinpoint leaks.

10.397 We believe that more needs to be done to protect customers from the real long-term risk of severe drought. Restrictions on water use in London alone could cost the economy more than £300 million a day.

10.398 Customers strongly favour demand management before resource development. However demand management alone will not be enough and resource development will be necessary in addition.

10.399 We will begin work on nine water resource schemes that will need to be delivered by 2030 to enable our water supplies to be resilient to a 1:200 drought.

10.400 Overall, there are three important periods over the 80 years of the forecast where significant resource developments will need to delivered:

- Up to 2030 – A combination of groundwater solutions, wastewater reuse and a small raw water transfer to enable greater resilience.
- 2037 – The period in which a reservoir is consistently selected to maintain the supply demand balance and facilitate greater sharing of resources across the South East.
- 2080 onwards – The period in which staged development of the Severn-Thames transfer is preferred over desalination or re-use.

10.401 We have tested the adaptability of our preferred programmes against a wide range of uncertain futures and 'What if' scenarios which have helped us identify the potential changes we would need to make as part of adaptive planning.

10.402 For the most part, the programme for the next 5-10 years is stable, with demand management, third party water trades and groundwater schemes balancing supply and demand until the Deephams wastewater reuse scheme and Oxford canal raw water transfer are delivered.

10.403 Should demand management not deliver the expected savings, or underlying demand from population growth or PCC increases, further groundwater schemes would be able to cope with minor variability until the South East Strategic Reservoir Option (SESRO) is delivered in 2037.

10.404 Our proposal for a major new reservoir will allow the transfer of surplus winter rainfall from the wetter west of our region to the drier east, and so benefit customers of several companies in London and the South East (Figure 10-23).

Figure 10-23: SESRO as a regional resource

10.405 In the long-term we propose supporting the SESRO and existing sources in the Thames Basin with a transfer from the River Severn.

10.406 Should the SESRO not be available, the Severn-Thames Transfer would be brought forward and further re-use or desalination would be required in the long-term to take its place.

10.407 Further details on the content of the preferred plan, particularly with respect to the demand management programme and the environmental assessment of the preferred programme, are provided in the following section, Section 11: Preferred programme.

Section 11

Preferred plan

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Preferred plan

- This section of the revised draft WRMP19 reports the outcome of the programme appraisal process outlined in section 10. The preferred plans for addressing the supply/demand deficits in each of the six water resource zones (WRZ) in the planning period to 2100 are presented and discussed and, in particular, we explain why we have chosen our overall preferred plan over alternatives.
- The preferred plan has been adopted as representing the long term best value overall water management balance of schemes for the Thames Water area. It addresses and resolves the predicted water supply/demand deficit over the planning period, having regard to affordability, the preferences of customers, impacts on the environment, the need for flexibility in managing a range of risks including a 1:200 drought, the best value planning of water supply in south east England and uncertainties, and the need to facilitate, where possible, sustainable development.
- Our revised draft WRMP19 adopts a twin track approach to addressing the supply demand balance, namely demand management and resource development to ensure a resilient and robust plan. In the longer term, when demand management of the use of water can no longer keep pace with the increasing deficit, the plan turns to strategic resource development for the South East region as a whole.
- London has a baseline supply-demand deficit starting from 2021, increasing to 106 Ml/d by the end of AMP7. In order to address this deficit, the preferred plan is to focus on demand management, water trading and the development of small groundwater schemes in the short to medium-term, as well as to start development of a small raw water transfer option and an innovative wastewater reuse scheme.
- As well as ongoing demand management and continued groundwater development, the delivery of the Deephams reuse scheme (45 Ml/d) and the Oxford Canal raw water transfer (15 Ml/d) in 2030 will maintain security of supply in London during the early part of the 80-year planning period and improve resilience against extreme 1 in 200 year drought events, achieving a drought resilience protection of 0.5%. Additional water resources then become available in the mid-2030s associated with the development of the South East Strategic Reservoir Option (SESRO), which, over time, provides a maximum 294 Ml/d to supply London, the Thames Valley and the regional demands of other Water Resources in the South East (WRSE) water companies. In the long-term the plan looks to the supported Severn Thames transfer to maintain sufficient resilience for London and the South East region to the end of the planning period in 2100.
- Three of the five Thames Valley WRZs have supply-demand deficits within the 80-year planning period; these zones are Swindon and Oxfordshire (SWOX), Slough, Wycombe and Aylesbury (SWA) and Guildford. Kennet Valley and Henley are the remaining zones and are in surplus throughout the planning period.
- SWOX goes into deficit as early as 2022/23 in peak week conditions which grows to 31 Ml/d by the end of the planning period; SWA has a peak week deficit starting in 2033/34 and increasing to over 8 Ml/d by 2059/60 with ongoing growth thereafter and finally Guildford has

a growing peak week deficit from 2025/26.

- Our preferred plan water management strategy in Thames Valley is to rollout our progressive household metering programme (PMP) from 2020, with further support from groundwater scheme development in Guildford and SWA WRZs. For SWA, inter-zonal water transfers will be available from 2037 via the new SESRO scheme in south west Oxfordshire. When the reservoir is operational from the mid-2030s it will provide up to 294 Ml/d raw water supply for London, the Thames Valley and regional water demand from Affinity Water. With its low ongoing running costs, the reservoir will facilitate reduced abstraction from perceived environmentally sensitive sources during normal years and in drought years without incurring extra costs.
- Our preferred plan for London and Thames Valley WRZs resolves the forecast supply/demand deficits in the plan period, provides resilience to 1 in 200 year extreme drought events, and provides a regional water resource for the wider south east England.

A. Overview

11.1 In this section the preferred planning water management programmes for the plan period for each WRZ are presented and discussed. These programmes are referred to collectively as the preferred plan.

11.2 Our preferred plan represents the long term best value balance of water management schemes for the Thames Water area. It takes into account the need to address and resolve the predicted water supply/demand deficit in the plan period whilst having regard to affordability, the preferences of our customers, impacts on the environment, the need for flexibility in managing a range of risks including a 1:200 year drought, best value planning of water supply in south east England and uncertainties, and the need to facilitate, where possible, sustainable development.

11.3 There are alternative plans that, compared with our preferred plan, show higher and lower costs and risks. However, as shown in this section, our preferred plan is towards the lower end of the cost range whilst achieving sustainable water resource management. This gives our plan a different risk profile from previous water resource plans which we consider strikes the most appropriate water management balance throughout the planning period. In striking that balance, we have ranked affordability in providing an economical system of water supply as one of the major factors to be weighed in deriving our preferred plan.

11.4 The starting point for building preferred water management programmes for our six WRZs has been the least cost plan (Section 10: Programme appraisal and scenario testing). From this common base we used the programme appraisal approach described in Section 10 to develop the long term best value plan which has become our preferred plan.

11.5 For London, our preferred plan follows the theme of striking a balance between the least cost plan and incorporating the benefits to be obtained from optimising against the other six metrics we set out in Section 10. The preferred plan focuses first on demand management, water trading and the introduction of small resource schemes in the early stages of the planning period. This allows for the construction of larger resource options for the medium and long-term period from 2030 onwards.

11.6 For Thames Valley WRZs, we have identified demand management as the key building block for the maintenance of a long-term and sustainable approach to future water resource management over the planning period.

11.7 As Henley and Kennet Valley WRZs have no forecast supply-demand deficit and is already resilient to a 1 in 200 year severe drought event, the proposed investment in this zone is minimal. A demand management programme for both zones is included in our preferred plan to make equitable provision across all of our supply areas in terms of customers paying for water used on a measured tariff.

11.8 In this section we first describe the preferred plan for each WRZ and then list the components of the plan in detail together with an overview of the environmental assessment of the preferred plan. We then provide a broader overview of the demand management programme we intend to deliver over the first 25 years of the planning period, and describe the greenhouse gas emissions and carbon accounting attributable to the preferred plan.

11.9 The charts and tables summarising the preferred plan for each WRZ exclude the treatment and conveyance elements associated with the supply options. This is because this information is not used to differentiate the merits of the preferred plan from alternatives during programme appraisal as the requirement for these elements is common and thus their inclusion does not provide a reason to prefer one water management programme over another. We have chosen to reduce the information presented by excluding these elements to improve transparency, in circumstances where the summary tables already contain a large volume of information.

11.10 It is important to note that whilst we have not listed these option elements as components of the options chosen, their delivery does have costs and in some cases benefits attached. These costs and benefits are included in the EBSD+[1] run and are also included in the summary performance metrics for each run referenced throughout our plan.

11.11 From 2030 in London the delivery of the combined demand reduction programme and smaller water resource supply options provides an improvement in drought resilience from 1% (1 in 100 year) to 0.5% (1 in 200 year), achieving risk composition 3 status[2]. The demand management programme in the Thames Valley achieves a similar outcome for those zones which are not already resilient to 1 in 200 year severe drought events.

11.12 Strategic network reinforcement is not included in the table of options selected nor is it reflected in the metric scores. This is because the EBSD+ model does not currently have the capability to perform the complex intra-zonal hydraulic modelling that would be required to facilitate scheduling of such options. Essentially these types of options account for perturbations in the future distribution of demand and treatment within a WRZ.

[1] A modelling method that combines Economics of Balancing Supply and Demand (EBSD) and MGA (Modelling to Generate Alternatives)
[2] UKWIR (2016) WRMP 2019 methods - risk based planning (Report Ref. No. 16/WR/02/11).

B. London

The preferred plan for London

11.13 As shown in Figure 11-2, there is a significant supply-demand deficit against the dry year annual average (DYAA) demand in London throughout the planning period. Without investment, security of supply would not be maintained in this zone.

11.14 The deficit is largely driven by the combination of population growth and reductions in raw water availability due to the impacts of climate change.

11.15 By the implementation of our preferred plan (combining demand management and resource development), the supply / demand deficit will be removed in AMP7 and the supply and demand for water will remain in balance throughout the remainder of the planning period.

11.16 The key features of the preferred plan are:

Short-term (2020/21-2024/25) - demand management

- Continue our progressive metering programme (PMP) with 365,000 household meters being installed in AMP7, achieving total household meter penetration of 59% by the end of AMP7. We will continue using smart meter technology, the policy we introduced in WRMP14.
- Introduction of a reward based incentive scheme in AMP7 to promote water efficiency.
- Reduce leakage by 85.7 Ml/d between 2020-2024 through a combination of mains rehabilitation, pressure management, DMA Enhancement and customer side leakage reduction.
- Continue to promote water efficiency activity to help customers use water wisely and promote behavioural change that will stem the underlying increase in water use shown in our baseline forecast. Further detail relating to this programme is provided in Appendix O: Water efficiency.

Short-term plan (2020/21-2024/25) – water resource development

- Water trading agreement with RWE NPower to use the abstraction licence surplus created by the closure of Didcot A coal fired power station to provide a deployable output (DO) gain of 18 Ml/d from 2020 to 2025
- Release of a network constraints and groundwater development providing approximately 16 Ml/d additional water available for use by 2024

Medium-term plan (2025-2045) - demand management

- Continue to roll out our PMP to deliver 684,800 meter installations by the end of AMP9 (2034/35), achieving 76% of individual household penetration in London WRZ
- Implement a financial incentive based tariff scheme from 2035 when household meter penetration is widespread. The scheme will incentivise lower household consumption and assumes a 5% reduction in usage
- Deliver a further 76 Ml/d leakage reduction in London across AMP8 and AMP9 through a combination of customer-side leakage reduction, pressure management, DMA Enhancement and mains rehabilitation

Medium-term plan (2025-2045) – water resource development

- Delivery of further innovative groundwater schemes, the Deephams wastewater reuse scheme, Oxford canal raw water transfer and release of network constraints in South London, providing more than 75 Ml/d additional supply in London from 2030 onwards.
- Extension of the existing water import trade with Essex and Suffolk Water, due to expire in 2035, until 2060.
- The SESRO150 Mm^3 scheme in 2037 to secure long-term resilience. This solution allows us to maintain supply resilience and be able to support 100 Ml/d of regional raw water demand from Affinity Water.
- Reduce existing abstraction at Waddon, North Orpington and New Gauge to improve flows in the River Wandle, River Cray and River Lee (Amwell Magna reach), respectively.

Long-term plan (2045-2099) – water resource development

- From the 2080s delivery of the supported Severn Thames Transfer to improve long-term resilience in the face of ongoing growth, the forecast impacts of climate change on available water resources, any additional loss of existing resources due to environmental requirements associated with the Water Framework Directive, and any further WRSE regional water requirements

Plan description

11.17 Our supply-demand balance is in deficit as early as the first year of AMP7 (2020/21) and grows rapidly thereafter. In line with our twin-track approach we will use demand management as much as possible to resolve the deficit, but we will require new water supply resources in due course.

11.18 In AMP7, we will continue to deliver our integrated demand management approach by rolling out the PMP that has been established in AMP6, aiming to install 365,007 household meters by the end of AMP7. In addition, a comprehensive water efficiency programme, engaging and enabling customers to reduce water usage will be an integral part of delivering the benefits. We anticipate that significant behavioural change will result from a high profile metering and water efficiency campaign. This is accompanied by a mains rehabilitation programme and pressure management and DMA Enhancement for leakage reduction. At the end of AMP7, meter penetration in London will have increased to 59% of individual household properties. The demand management programme will continue across London beyond AMP7 with a combination of interventions that will provide benefits of reduced usage as well as leakage reduction.

11.19 Asset Health mains rehabilitation activity is not covered in the revised draft WRMP19 but it has benefits for daily network maintenance activity. We will look for synergies between our revised draft WRMP19 Enhancement Programme and the Asset Health Programme in the PR19 Business Plan to achieve holistic benefits for our customers.

11.20 Water resource development in the first five-year period (2020/21-2024/25) is dominated by groundwater schemes and the Didcot water trading scheme. Options which provide higher resilience such as the Deephams wastewater reuse scheme. This scheme has been jointly reviewed with the Environment Agency and the findings can be found in Appendix L: Water Reuse. The Oxford canal raw water transfer and the SESRO will also be available in the medium to long-term period (2030-2040).

Impact of the plan on customer bills

11.21 As shown in Table 11-7, the preferred plan is £0.5 billion NPV higher than the least cost plan by reason of its delivery of significantly greater benefits when assessed against a number of additional relevant metrics, whilst affording the same value in terms of customer preference. The preferred plan is more flexible, makes a better contribution to sustainable development and is better aligned to customers' priorities and Government objectives for only a small cost premium. In our view this is a good example of how we spend our customers' money wisely and sustainably, to produce a best value plan.

Performance of the preferred plan

11.22 The preferred plan for London ensures that security of supply is maintained throughout the 80-year planning period and removes the supply-demand deficit in the baseline forecast shown in Figure 11-1 and Figure 11-2. The waterfall diagram illustrates how the interventions from both the demand management programme and resource schemes come together to remove the deficit.

11.23 The requirement for a large supply resource in the 2030s provides flexibility in the WRMP planning process to clarify and accommodate future uncertainties with respect to population growth, requirements of the Water Framework Directive, regional requirements for water from WRSE water companies (e.g. Affinity Water) and the enhancement of our growing understanding of the implications and timing of climate change on water available for use.

Table 11-1: London preferred plan – Overall plan (DYAA) for demand management

London		Delivery date and ongoing supply demand benefit (Ml/d)							
		AMP7	AMP8	AMP9	AMP10	AMP11	AMP12	AMP13	AMP14-AMP22
		2020-2024	2025-2029	2030-2034	2035-2039	2040-2044	2045-2049	2050-2054	2055-2100
Total benefit from DMP		**140.5**	**93.7**	**49.5**	**84.8**	**29.8**	**15.0**	**7.5**	**Benefits maintained**
Leakage reduction	**Total leakage reduction**	**85.7**	**46.7**	**29.4**	**40.8**	**24.8**	**10.0**	**7.5**	**Benefits maintained**
	AMP6 Carry-over leakage	18.2							
	Household metering CSL	22.7	9.7						
	Bulk metering CSL								
	AMP7: 36,001 meters	3.0							
	AMP8: 122,081 meters		15.4						
	AMP9: 0 meters			0.0					
	AMP10: 87,505 meters				6.0				
	Replacement metering CSL	3.5	3.5	3.5					
	Mains replacement	6.2	0.9	21.1	30.0	20.0	10.0	7.5	
	Pressure management	6.3							
	Innovation			4.8	4.8	4.8			
	DMA enhancement	26.0	17.3						
Usage reduction	**Total usage reduction**	**54.9**	**46.9**	**20.0**	**44.0**	**5.0**	**5.0**	**Benefits maintained**	
	Household metering								
	AMP7: 365,007 meters	28.7							
	AMP8: 319,793 meters		28.1						
	AMP9: 0 meters			2.4					
	Water efficiency	24.8	18.1	16.9	5.0	5.0	5.0		
	Incentive scheme	0.8	0.2	0.2	0.2				
	Non-potable water	0.5	0.5	0.5	0.5				
	Innovative tariffs				38.2				

Table 11-2: London preferred plan – Overall plan (DYAA) for resource management

London	Delivery date and ongoing supply demand benefit (Ml/d)												
	AMP7	AMP8	AMP9	AMP10	AMP11	AMP12	AMP13	AMP14	AMP15	AMP19	AMP20	AMP21	AMP22
	2020-2024	2025-2029	2030-2034	2035-2039	2040-2044	2045-2049	2050-2054	2055-2059	2060-2064	2080-2084	2085-2089	2090-2094	2095-2099
Groundwater schemes													
Network constraint removal New River Head	3	3	3	3	3	3	3	3	3	3	3	3	3
Aquifer storage and recovery – Horton Kirby	5	5	5	5	5	5	5	5	5	5	5	5	5
Groundwater Southfleet/ Greenhithe	8	8	8	8	8	8	8	8	8	8	8	8	8
Groundwater Addington			1	1	1	1	1	1	1	1	1	1	1
Groundwater Merton			2	2	2	2	2	2	2	2	2	2	2
Network constraint removal Epsom			2	2	2	2	2	2	2	2	2	2	2
Artificial recharge – Kidbrooke (SLARS1)			7	7	7	7	7	7	7	7	7	7	7
Artificial recharge – Merton (SLARS3)			5	5	5	5	5	5	5	5	5	5	5
Aquifer storage and recovery – South East London (Addington)			3	3	3	3	3	3	3	3	3	3	3
Raw water purchase schemes													
RWE Didcot	18												
Oxford Canal			11	11	11	11	11	11	11	11	11	11	11
Reduced raw water export													
Chingford				20	20	20	20	20					
Indirect potable reuse													
Deephams reuse			45	45	45	45	45	45	45	45	45	45	45
Reservoir													

London	Delivery date and ongoing supply demand benefit (Ml/d)												
	AMP7	AMP8	AMP9	AMP10	AMP11	AMP12	AMP13	AMP14	AMP15	AMP19	AMP20	AMP21	AMP22
	2020-2024	2025-2029	2030-2034	2035-2039	2040-2044	2045-2049	2050-2054	2055-2059	2060-2064	2080-2084	2085-2089	2090-2094	2095-2099
SESRO 150Mm³ transfer from SWOX to London						22.1	46.6	75.2	119.8	198.1	216.3	234.8	254.2
Severn-Thames transfer													
Lake Vyrnwy 60 Ml/d[3]										110	110	110	110
Severn Trent Mythe											12	12	12
United Utilities Option B												21	21
Netheridge													18
Total additional water resource	**34**	**16**	**92**	**112**	**112.0**	**134.1**	**158.6**	**187.2**	**211.8**	**320.147**	**350.292**	**389.811**	**427.2**
Baseline deficit	-105.9	-158.5	-199.5	-269.1	-325.6	-366.4	-398.0	-426.7	-452.3	-530.6	-548.7	-567.3	-586.7
Additional reduction in DO													
1:200 drought resilience			-140	-140	-140	-140	-140	-140	-140	-140	-140	-140	-140
Vulnerable chalk stream reductions (Waddon and North Orpington)				-15.97	-15.97	-15.97	-15.97	-15.97	-15.97	-15.97	-15.97	-15.97	-15.97
Raw water transfer to WRSE				-100	-100	-100	-100	-100	-100	-100	-100	-100	-100

[3] DYAA benefit is 110 Ml/d due to inclusion of the unsupported flow element of the STT. DYCP includes supported element from Vyrnwy only = 30 Ml/d

Table 11-3: London preferred plan – Water resource schemes (delivery year in chronological order)

Resource schemes	DYAA yield (Ml/d)	Delivery year
Raw water purchase RWE Didcot	18	2020
Removal of network constraint New River Head	3	2020
ASR Horton Kirby	5	2024
Groundwater Southfleet/ Greenhithe	8	2024
Groundwater Addington	1	2030
Groundwater Merton	2	2030
Indirect potable reuse Deephams	45	2030
Removal of network constraint Epsom	2	2030
Raw water purchase Oxford Canal to Cropredy	11	2030
AR Kidbrooke (SLARS1)	7	2030
AR Merton (SLARS3)	5	2031
ASR East London (Addington)	3	2031
Reduced raw water export Chingford (E&S)	20	2035
SESRO 150Mm3 transfer from SWOX to London	294	2037
Severn-Thames transfer – Vyrnwy	110	2083
Severn Trent Mythe licence transfer	12	2089
Severn-Thames transfer – United Utilities/ Severn Trent Option B	21	2092
Severn-Thames transfer – Netheridge	18	2096

Table 11-4: London preferred plan – Annual average leakage forecast

London	End AMP6	End AMP7	End AMP8	End AMP9	End AMP10	End AMP11
	2019/20	2024/25	2029/30	2034/35	2039/40	2044/45
Average leakage forecast (Ml/d)	494	408	361	332	291	266

Table 11-5: London preferred plan – Meter penetration (including voids)

London	End AMP6	End AMP7	End AMP8	End AMP9	End AMP10	End AMP11	End AMP22
	2019/20	2024/25	2029/30	2034/35	2039/40	2044/45	2099/2100
Household meter penetration (%) (incl. voids)	42	59	73	74	75	76	82

Table 11-6: London preferred plan – Per capita consumption (PCC) (DYAA)

London	End AMP6	End AMP7	End AMP8	End AMP9	End AMP10	End AMP11	End AMP22
	2019/20	2024/25	2029/30	2034/35	2039/40	2044/45	2099/2100
PCC (l/h/d)	142	136	131	129	124	124	121

Figure 11-1: London preferred plan over the 80-year planning horizon

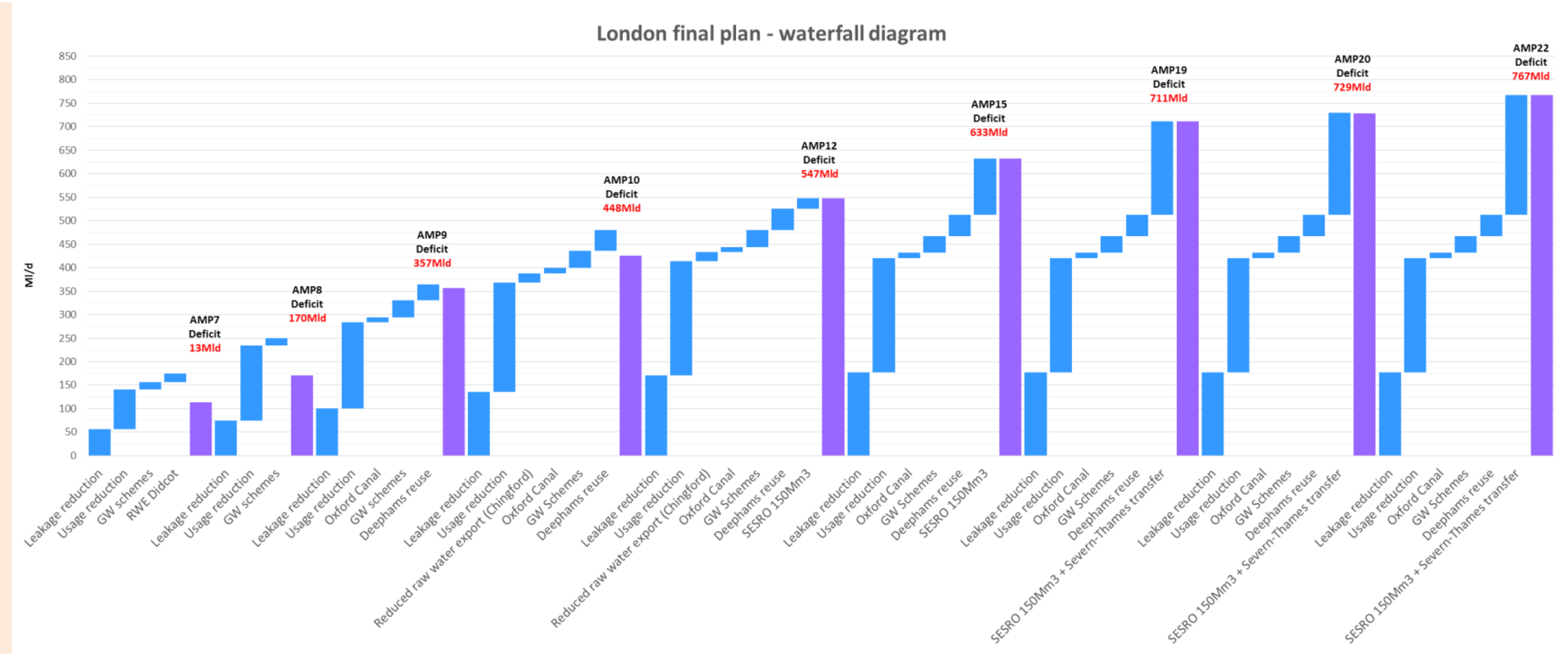
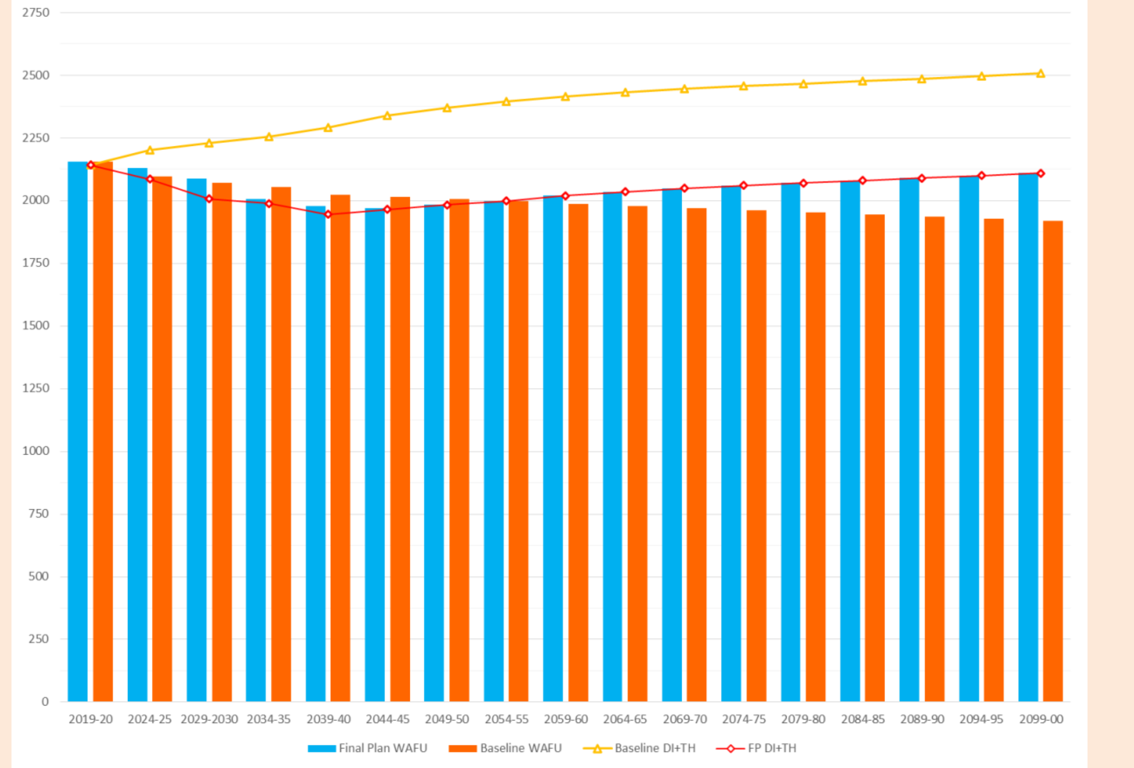


Table 11-7: Programme appraisal metric scores[4]

Programme \ Metrics	Cost (£bn NPV)	Resilience	Deliver-ability	Environ. benefit	Environ. adverse	Customer Preference	IGEQ
Least cost[5]	4.105	0.84	1.00	70	81	4.41	11.33
Preferred	4.628	0.88	0.95	81	77	4.42	11.19

Figure 11-2: London supply-demand balance (DYAA) over 80-year planning horizon



Selection of the preferred plan

11.24 In selecting our preferred plan we had regard to the results and learning from the programme appraisal process reported in Section 10: Programme appraisal and scenario testing, feedback from our Customer Challenge Group, feedback from stakeholders and interested parties, guidance from our expert panel members, and the outputs of environmental assessments including the Strategic Environmental Assessment (SEA).

11.25 We presented our analysis of our programme appraisals and explained the emergence of our preferred plan to the Thames Water Executive and Board between April 2017 and August 2018. We held a series of detailed technical sessions with individual Board members to

[4] London, SWOX and SWA WRZ are modelled together, so these scores are for the combined zone
[5] For the preferred “Baseline + Drought + WRSE” baseline scenario.

describe our recommended preferred plan and highlighted the risks and costs of the plan. We also discussed the interactions of the plan with the Thames Water Price Review 2019 Business Plan to ensure we would be securing long term best value for our customers.

11.26 We have summarised the decision making process in Section 10: Programme appraisal and scenario testing, with the programmes evaluated shown in Appendix X: Programme appraisal outputs.

11.27 Our preferred plan is considered the long term best value plan for the 80 year plan period when compared with alternatives; it is more resilient, makes an overall greater contribution to intergenerational equity and is more closely aligned to the achievement of Government objectives contained in guidance and to relevant outcomes of our customer research.

11.28 To improve resilience to a 1 in 200 year drought, water resource schemes with relatively short lead times are required in the medium term. The primary contending options were a combination of schemes comprising small groundwater sources, the Oxford canal raw water transfer and the Deephams re-use scheme versus a single larger desalination or reuse scheme at Beckton. The combination of small schemes is selected as preferred because it is cheaper and more flexible than one larger scheme, retaining option value to bring in some schemes sooner or later if advantageous; the total NPV of the preferred plan is £0.087 million NPV lower than that comprising a single large desalination or reuse option. The ongoing opex running costs of the combined scheme are also lower.

11.29 The output of the programme appraisal process reported in Section 10 shows that our preferred plan:

- Meets customer expectations for continuous reduction in leakage, and builds resilience against extreme weather with greater focus on the sustainable use of water resources
- Aligns well to Government policy objectives set out in the Water Resources Planning Guideline (WRPG)[6] and Defra's 25 Year Plan[7]
- Is flexible in so far as the plan has a spread of 'no regrets' water supply options which can be adapted as required
- Reduces the demand for water and also supports present and emerging south east regional raw water requirements
- Given the higher cost and performance uncertainties of a large indirect potable water reuse or desalination scheme, together with the wider environmental sustainability constraints in our supply zones as well as in the South East region, the outputs indicate that the SESRO is to be preferred as a sustainable water resource scheme to provide resilience against climate change and an increasing regional demand from WRSE

11.30 As discussed above, the long-term leading strategic option selected through the programme appraisal process for supply to the London WRZ is the SESRO in south west Oxfordshire. The option is located to the west of London and therefore is able to supply the SWOX and

[6] Environment Agency and Natural Resources Wales, Water Resources Planning Guideline: Interim Update July 2018
[7] H M Government 2018 A Green Future: Our 25 Year Plan to Improve the Environment

SWA WRZs as well as use the River Thames as a natural conveyance route to transfer raw water to London. The option is also able to supply the WRSE raw water needs of Affinity Water (100 Ml/d in 2037) and potentially South East Water if required in the future, both companies having existing intakes on the River Thames.

11.31 Were the SESRO not to be a feasible option, the alternative water supply option selected through the programme appraisal process is the supported Severn Thames Transfer. Both options have potential to supply similar volumes of water and could be delivered in combination, but the reservoir is preferred to be delivered first on the basis of least cost and higher reliability. Ongoing opex associated with the reservoir is also significantly lower than the Severn Thames Transfer, which supports usage in non-drought conditions to enable (with new connectivity) reduced abstraction from existing sources perceived to be putting hydrological pressure on vulnerable chalk streams and water courses. The opex cost ratio of the transfer in comparison to the reservoir (at P50 cost confidence) is approximately 3.3 to 1 which illustrates the significantly higher running costs of the transfer option.

11.32 Each of these two options has its own strengths and weaknesses and these are set out in Table 11-8 to facilitate consideration of relevant factors other than cost, namely resilience, environmental impacts, intergenerational equity, customer preference, deliverability and adaptability (see Section 10 for details). Our WRMP19 customer research revealed that customers' top three criteria for devising Thames Water's WRMP are cost, type of option and reducing risk of severe water use restrictions. The reservoir scores higher marks against each of these water resource management considerations than does the supported Severn Thames transfer, as shown in Table 11-8.

Table 11-8: Strengths and weaknesses of the South East strategic reservoir and supported Severn Thames transfer options

South East strategic reservoir	Supported Severn Thames transfer
Advantages	**Advantages**
Least cost, reliable and proven option selected through EBSD+ programme appraisal analysis with potential for significant recreational benefits. Storage and transfer hub for the South East region.	Supports inter-basin transfers and increases size of catchment from which water resources can be drawn
Low ongoing running costs which facilitates reduced abstraction from perceived environmentally sensitive sources during normal years without incurring extra cost.	No loss of agricultural land
Facilitates unplanned and routine maintenance of existing raw water storage reservoirs, without incurring additional cost.	
Offers opportunities for secondary activities, including recreation and solar power generation.	
Disadvantages	**Disadvantages**
Loss of agricultural land and displacement of 20 households and businesses. Strong opposition from local pressure group.	Environment Agency hands-off flow on lower Severn creates risk of non-availability of water for abstraction at times of low flow. Increasing risk of coincident drought affecting both the South East and West areas, as occurred during the drought of 1976. As part of the MaRIUS project, CEH Wallingford found that droughts in the Thames and Severn regions are going to be more coincident in the future as a result of climate change. A major drought in both the Severn and Thames catchments at the same time is projected to increase by 56% in the near future (2022-2049) and 135% in the far future (2072-2099).
Eight year construction period with disruption to local residents	Long conveyance route increases risk associated with pollution.
	Phosphorous from agricultural lower Severn catchment contributes to high algal loading, which risks changing the characteristics of the upper Thames. Transfer could potentially further increase Thames Water's exposure to this risk, to which we are particularly vulnerable because of our reliance on surface water abstraction (80% in London and 40% in SWOX WRZs).
	Potential opposition from stakeholders against water transfer to England. Disruption to Cotswolds AONB during construction period.
	Customers' least favoured option and no opportunities for recreational benefits linked to the pipeline.
	Requires alternative resource development in donor area to free up water resources for transfer with potential for WFD deterioration.
	Cost used in EBSD+ analysis is for a single pipeline only, which is at higher risk than a dual pipeline.

11.33 The supported Severn Thames Transfer supports inter basin transfers between water companies, albeit United Utilities would need to develop new water resources in its own supply area to facilitate a large transfer and, therefore, resource development would still be required. The long conveyance route of the option would in its own right constitute a substantial capital investment project (for the pipeline section). The long route is also at risk of pollution events in the rivers Severn and Vyrnwy and, as such, it can be considered less resilient than the South East strategic reservoir option, which is located within the Thames catchment. On the other hand, it is acknowledged that inter-basin transfer increases the size of the catchment from which water resources can be drawn, which could have a positive effect on resilience, due to the lower probability of there being a coincident drought across several companies' regions compared with a drought in one region (although coincident droughts are likely to become more frequent). Professor Jim Hall (Oxford University) was funded by NERC to look at drought risk under climate change (the MaRIUS[8] project). As part of that work, CEH Wallingford found that droughts in the Thames and Severn regions are forecast to be more coincident in the future as a result of climate change[9]. A major drought in both the Severn and Thames catchments at the same time is projected to increase by 56% in the near future (2022-2049) and 135% in the far future (2072-2099).

11.34 The Environment Agency has indicated that in order to protect the Severn Estuary Special Area of Conservation it will impose a hands off flow constraint on any abstraction licence from the lower Severn. This effectively means that there is no guarantee that water released from Vyrnwy reservoir will be available for abstraction in the lower Severn when required for supply to the South East and, as such, the risk to security of supply associated with this option is significantly increased. The scheme falls under the jurisdiction of Natural Resources Wales and will require support from the Welsh Government.

11.35 There are no opportunities for recreational benefits and environmental enhancements associated with the pipeline transfer of raw water from the River Severn.

11.36 The South East strategic reservoir option is more flexible with regard to water supply and cheaper than the Severn Thames Transfer option. It would provide additional raw water storage, which improves resilience in the South East and enables other Thames Water raw water storage reservoirs to be taken out of service for routine and unplanned maintenance. A number of Thames Water's existing raw water storage reservoirs are more than 100 years old. Work undertaken by engineering consultants W S Atkins and AECOM has identified that there is an increasing risk that these assets will need to be taken out of supply in response to unplanned maintenance requirements. If the volume of the existing raw water storage capacity is reduced the yield of the Severn Thames transfer will be lower, because there is reduced capacity to store the water that is transferred and increasing reliance is placed on the remaining storage reservoirs.

11.37 Both adverse and beneficial effects can arise during construction and operation but the main disadvantages with the reservoir option are that its development will require the loss of agricultural land, as well as the displacement of approximately 20 households and businesses currently on the site. The construction period would be approximately eight years and during

[8] **Ma**naging the **R**isks, **I**mpacts and **U**ncertainties of drought and water **S**carcity, NERC funded research project
[9] Rudd A.C., Bell V.A. and Davies H.N., Severn Thames Transfer Study Final Report July 2018, Centre for Ecology & Hydrology 2018

this time there is a need to use large volumes of materials. During this construction period there is the potential to cause disruption and adverse effects on heritage assets as well as adverse impacts on the visual amenities nearby residents, in particular, the inhabitants of the villages of Steventon, Drayton, Marcham and East Hanney. Such construction activities including the routeing of construction traffic would need to be carefully managed with mitigation measures put in place.

11.38 Over the longer term and once the reservoir landscaping is fully established, the scheme has the potential to offer landscape benefits. Significant benefits from the option are also expected in terms of recreational opportunities, compensatory habitat provision as well as the provision of opportunities to reduce abstraction from perceived environmentally sensitive chalk streams in the River Thames catchment.

11.39 The Severn Thames Transfer scheme is included in our preferred plan but is not called upon as a source of supply until the 2080s. We are, however, committed to further developing transfer options with third party suppliers, and with the support of government and regulators. Our 2019 Business Plan includes funding for further ongoing work to examine the feasibility of the transfer, most notably work on establishing the magnitude of water losses that could occur during transfer, environmental and water quality concerns and the changes that would be required to the hydraulic regulation of the River Severn. Details of this further work that is to be undertaken on the Severn Thames Transfer are set out in Appendix J of our Statement of Response to the consultation on our draft WRMP19.

11.40 The relatively late timing of the Severn Thames Transfer in the revised draft WRMP19 is driven by growth, the forecast impacts of climate change and the proposed reductions in our abstractions from vulnerable chalk streams and water courses. Any addition to these needs, or if the promotion of the reservoir option was unsuccessful, or if increased resilience was required by Government for the WRSE water companies as recommended within the 2018 National Infrastructure Commission (NIC) study[10], would be likely to bring the timing of the transfer forward in the planning period; similarly. Our ongoing work on the feasibility of the transfer continues, accordingly, to be undertaken jointly with regulators (Natural Resources Wales, Environment Agency and Natural England) and other water companies, with the scope and funding requirements shared between all parties.

11.41 The issues associated with the higher cost and lower reliability of the Severn Thames Transfer option can be mitigated to a certain extent through the construction of the SESRO in the preferred plan. The SESRO will provide increased storage capacity to store surplus water during periods of high flow where algal ratings will be lower and thereby reduce the dependency on the need to take more expensive water from the River Severn during periods of drought and low flow. It also reduces the need to implement flow augmentation options to support the transfer which are likely to have a potential detrimental environmental impact within the River Severn catchment (e.g. Minworth effluent transfer to the upper reaches of the River Avon) since the total amount of water required from the transfer scheme will be lower. Furthermore, the increased storage capacity which the SESRO creates in the Thames catchment helps mitigate the growing risk of unplanned reservoir outage and the inability to store River Severn flows when they are available. Essentially given the risks, it is logical and

[10] Preparing for a drier future, National Infrastructure Commission, April 2018

pragmatic to increase existing storage capacity in the Thames catchment by the construction and operation of the SESRO before implementing a transfer so as to reduce financial and environmental costs and improve the reliability of the transfer scheme.

11.42 The delivery of the SESRO in 2037 creates surplus in the supply / demand balance which can be used to facilitate a reduction in some of our existing London groundwater abstractions that are perceived to have an impact on vulnerable chalk streams and water courses. Our groundwater abstractions at Waddon (7.2 Ml/d) and North Orpington (8.8 Ml/d) are perceived to have a detrimental impact on the River Wandle and River Cray, respectively, but investigations undertaken to date have concluded that it is not cost beneficial to reduce abstraction at these sites. The SESRO with its low annual opex costs will help more cost effectively to reduce abstraction at these sites and thereby address the perceived concerns.

11.43 There is also an opportunity to reduce abstraction at New Gauge on the River Lee which should not result in a loss of deployable output if infrastructure is built downstream to subsequently capture and store the increased river flow which would then become available.

11.44 In the River Lee, reduced abstractions at New Gauge could facilitate increased flow along the Amwell Magna reach. This water can be subsequently abstracted downstream into the Lee Valley reservoirs but will require a new tunnel to transfer the water back to the New River and Coppermills water treatment works if an adverse impact on deployable output is to be avoided. There is an important assumption here that water not abstracted at New Gauge is subsequently available for downstream abstraction. This assumption will need to be confirmed through field investigations.

Risks and uncertainties in the preferred plan

11.45 Although we are confident that our preferred plan is appropriate for the London WRZ, there are a number of risks and uncertainties which have been evaluated.

11.46 In line with the WRPG, these are described below.

Risk: demand management, including leakage reduction

11.47 The 106 Ml/d supply demand deficit in London in AMP7 is planned to be addressed through demand management interventions. However, we do not have full control with respect to the potential benefits that will be achieved through this activity. In particular, there is uncertainty relating to the performance of our ageing infrastructure network given its proven fragility to extreme climatic events. We have therefore included limited, cost effective resource development and water trading in AMP7 to help manage this risk and maintain a resilient supply system. This is an important risk management measure given the current supply system in London has been shown to be currently resilient only to a 1 in 100 year drought event.

11.48 We do not have full control over the benefits achievable through metering and the promotion of water efficiency. To mitigate these risks, in AMP6 we have set up a dedicated metering team to review the end-to-end delivery of the metering programme from supply-chain management to customer communications and queries. This is to be combined with a very proactive and ambitious water efficiency programme.

11.49 We are also working closely with stakeholders, such as the Greater London Authority, to ensure we have a consistent water conservation message across London.

Risk: metering and tariffs

11.50 The plan includes the introduction of a reward based incentive scheme in AMP7 as this has the potential to be highly cost-effective in reducing the long-term cost of water supply. The plan also includes financial tariffs from 2035 to penalise high water usage when household meter penetration is widespread. Our customer research has shown customers perceive such tariffs to be unfair and we welcome stakeholder feedback on the inclusion of this option within our revised draft WRMP19. We have assumed a 5% saving associated with the financial tariff but it is possible that additional savings could be delivered through varying the financial incentives utilised.

Risk: long-term resilience and regional demand

11.51 On the balance of evidence, our forecasts point to a complex supply-demand problem in London that demand management and small scale resource schemes will not be enough to resolve on their own. We believe that long-term resilience can be secured through the introduction of the SESRO in south west Oxfordshire. This mitigation approach equips us to respond to regional demands for water as well as potential long-term sustainability reductions in supply. Early delivery of the scheme in the planning period also addresses risks posed by early reductions in water available for supply linked to climate change.

Uncertainty: long-term sustainability reductions and West Berkshire Groundwater Scheme

11.52 There remains uncertainty in the long-term level of potential sustainability reductions that could affect the London WRZ, as well as the ongoing reliability of output from the West Berkshire Groundwater Scheme (WBGS). Although publication of the Water Industry National Environment Programme (WINEP) in March 2018 gave clarity to the status of the Lee Valley reservoir abstractions, a number of our groundwater abstractions in north east and south east London are subject to ongoing investigation in AMP7. Furthermore, the ownership, operation and long-term viability of the WBGS remains uncertain and the Environment Agency has requested that we assess the impact of the scheme on our plan. We have tested the sensitivity of the preferred plan to uncertainty linked to the Water Framework Directive as part of our programme appraisal process and also a reduction in output from the WBGS (Section 10: Programme appraisal and scenario testing). Results from 'What-if' scenario testing in Table 10-20 show that the plan is robust to the further loss of resources linked to achieving Water Framework Directive compliance, as well as reductions in output from the WBGS.

11.53 To achieve the long term best value solution for supply resilience in London (and the South East region) we consider it is important to confirm any further potential sustainability reductions in the next five years so that efficient and cost effective planning can be undertaken.

Uncertainty: climate change

11.54 As shown in Section 5 Allowing for risk and uncertainty, climate change is likely to have a significant impact on water resource availability in London. This is due to a combination of the likely reduction in the availability of water resources and in the quality of water abstracted from surface water sources and stored in our raw water storage reservoirs.

11.55 Whilst we believe this change is manageable in the short-term, the potential large adverse impacts that substantial and more frequent drought events could have on the London water supply system means that it is important to plan ahead and look at long-term solutions to maintain resilience. HR Wallingford has recently completed sensitivity analysis for us, examining uncertainty in the timing of the impacts of climate change on available water resources.[11] This work has shown that there is significant uncertainty which presents a challenge to the scheduling of options and to anticipating the rate of the onset of climate change impacts. The degree of impact on system performance that might be considered very likely in the 2080s could be considered equally likely by the 2050s and quite likely by the 2030s. The work has demonstrated that the Environment Agency's assumption of linearity in climate change impacts back cast from the 2080s may not be a robust assumption and significant impacts could occur much sooner than forecast. This has implications for the timing of no regrets water resource options where it could be considered prudent to invest in them sooner.

11.56 We have undertaken further sensitivity analysis on the timing of climate change impacts and this is set out in Section 10: Programme appraisal and scenario testing. Both the 'What-if' scenario analysis and the adaptive pathways approach confirmed that the preferred programme is robust to changes in the timing of the impact of climate change on water availability.

11.57 The approach of combining demand management and the parallel introduction of large-scale water resource development helps to mitigate this long-term uncertainty.

London – preferred plan summary

11.58 The above paragraphs describe the content of the revised draft WRMP19 preferred plan for London. From the work we have undertaken we consider the preferred plan achieves the long term best value overall balance between demand management and resource development, in that it is affordable, takes account of relevant output of our customer research, is resilient, adaptable, and contributes to sustainable water supply/demand management in the South East over the plan period.

11.59 We believe the underlying strategy of reducing water losses from our network, being innovative to reduce overall water demand and to understand where and when water is being used is an appropriate short and medium-term management strategy if we are to meet the challenges of the forecast water supply / demand in the Thames Water area.

[11] HR Wallingford (2017) Thames Water MCS Support Trajectory of climate change impacts and scaling MAM8070-RT002-R1-00

C. Swindon and Oxfordshire

The preferred plan for SWOX

11.60 As illustrated in Figure 11-3, SWOX has a supply/demand deficit in dry year critical period (DYCP) starting from 2022/23 and growing throughout the planning period.

11.61 The deficit at peak demand is driven by a combination of population growth and the impact of climate change on available water for use.

11.62 Our preferred plan removes the supply-demand deficit in AMP7 and the zone will remain in balance throughout the planning period. We propose to maintain the water supply / demand balance through demand reduction, including leakage reduction, and the implementation of a new strategic water resource scheme to provide resilience and to facilitate the export of water to the London and SWA WRZs, as well as meeting WRSE regional water demands in the medium-term. The plan is presented in Table 11-9 to Table 11-15.

11.63 The key features of the preferred plan are:

Short term (2020/21-2024/25) demand management

11.64 From 2020 we will roll out our progressive metering policy (PMP). Our aim is to achieve total SWOX household meter penetration of 94% by 2035.

11.65 We will continue to promote water efficiency and metering to help customers use water wisely (in direct response to customer research findings). By the end of AMP7, we aim to deliver circa 8.8 Ml/d benefits through the water efficiency campaign.

Medium-term plan (2024-2040) demand management and water resource development

11.66 We will also include an incentive based financial tariff across the WRZ, commencing in 2035.

11.67 As set out in the preferred plan for our London WRZ, the SESRO will be available from 2037 to provide raw water benefits for SWOX, as well as facilitating transfer to the London and SWA WRZs and to Affinity Water.

11.68 The reservoir also creates an opportunity to reduce abstraction at Farmoor which should not result in a loss of deployable output if new infrastructure to facilitate the reduction is installed during construction of the scheme. The *saved water* from a reduction at Farmoor can be abstracted downstream through the reservoir intakes, stored, and then transferred back to Farmoor to be put into supply during periods of low flow. Reduced abstraction at Farmoor would enable greater flows through the Oxford watercourses.

Long-term plan (2040 to 2099) water resource management

11.69 An inter-zonal raw water transfer from SWOX to SWA WRZ via the River Thames and a new surface water intake at Medmenham will reduce available water resources in SWOX by up to a maximum of 24 Ml/d and will help SWA to mitigate its long-term deficit from 2066 onwards.

11.70 Increased population projections associated with the new Cambridge, Milton Keynes and Oxford (CaMKOx) growth corridor are not currently included in our baseline supply demand forecasts for the SWOX WRZ given that to date the additional housing has not been formally adopted within local plans. As such the forecast supply demand deficit in the SWOX WRZ should be considered to be conservative and there may be a requirement for additional supply sooner than currently allowed for within our preferred plan. The timing of the reservoir in the preferred plan allows for any further growth beyond that allowed for in the baseline forecasts.

Performance of the preferred plan

11.71 The preferred plan for SWOX ensures that security of supply is maintained through the planning period and removes the forecast baseline supply-demand deficit, as shown in Figure 11-3.

Table 11-9: SWOX preferred plan – Overall plan (DYCP) for demand management

SWOX		Delivery date and ongoing supply demand benefit (Ml/d)				
		AMP7	**AMP8**	**AMP9**	**AMP10**	**AMP11-AMP22**
		2020-2024	**2025-2029**	**2030-2034**	**2035-2039**	**2040-2100**
Total benefit from DMP		**22.0**	**16.9**	**3.3**	**9.3**	**Benefits maintained**
Leakage reduction	**Total leakage reduction**	**9.8**	**6.8**	**0.6**	**Benefits maintained**	
	AMP6 Carry-over leakage	2.3				
	Household metering CSL	3.9	3.6			
	Bulk metering CSL					
	AMP7: 3,161 meters	0.3				
	AMP8: 5,526 meters		0.5			
	AMP9: 321 meters			0.03		
	Replacement metering CSL					
	Mains replacement		0.4	0.5		
	Pressure management					
	DMA enhancement	3.3	2.2			
Usage reduction	**Total usage reduction**	**12.1**	**10.2**	**2.7**	**9.3**	**Benefits maintained**
	Household metering					
	AMP7: 46,475 meters	3.3				
	AMP8: 44,708 meters		4.3			
	AMP9: 0 meters			0.7		
	Water efficiency	8.8	5.9	2.0		
	Incentive scheme					
	Non-potable water					
	Innovative tariffs				9.3	

Table 11-10: SWOX preferred plan – Overall plan (DYCP) for resource management

SWOX	Delivery date and ongoing supply demand benefit (Ml/d)										
	AMP7	AMP8	AMP9	AMP10	AMP11	AMP12	AMP14	AMP16	AMP18	AMP22	
	2020-2024	2025-2029	2030-2034	2035-2039	2040-2044	2045-2050	2055-2059	2065-2069	2075-79	2095-2099	
Reservoir											
SESRO 150Mm^3				294	294	294	294	294	294	294	
Reservoir											
SESRO 150Mm^3 - London export to meet WRSE demand						-22.1	-75.2	-142.0	-180.2	-254.2	
Inter-zonal transfer											
River Thames to Medmenham								-24	-24	-24	
Total additional water resource				**294**	**294**	**272**	**219**	**128**	**90**	**16**	
Baseline deficit	-2.2	-6.6	-10.0		-11.9	-11.3	-11.2	-11.3	-15.3	-19.9	-31.2
Additional reduction in DO											
1:200 Drought resilience			**-6.9**		**-6.9**	**-6.9**	**-6.9**	**-6.9**	**-6.9**	**-6.9**	**-6.9**

Table 11-11: SWOX preferred plan – Water resource schemes (delivery year in chronological order)

Resource schemes	DYCP yield (Ml/d)	Delivery year
SESRO 150Mm^3	294	2037

Table 11-12: SWOX preferred plan – Annual average leakage forecast

SWOX – DYAA	End AMP6	End AMP7	End AMP8	End AMP9	End AMP10	End AMP11
	2019/20	2024/25	2029/30	2034/35	2039/40	2044/45
Average leakage forecast (Ml/d)	63	54	47	46	46	46

Table 11-13: SWOX preferred plan – Meter penetration

SWOX	End AMP6	End AMP7	End AMP8	End AMP9	End AMP10	End AMP11	End AMP22
	2019/20	2024/25	2029/30	2034/35	2039/40	2044/45	2099/2100
Household meter penetration (%) (incl. voids)	67	79	92	94	94	94	95

Table 11-14: SWOX preferred plan – PCC (DYAA)

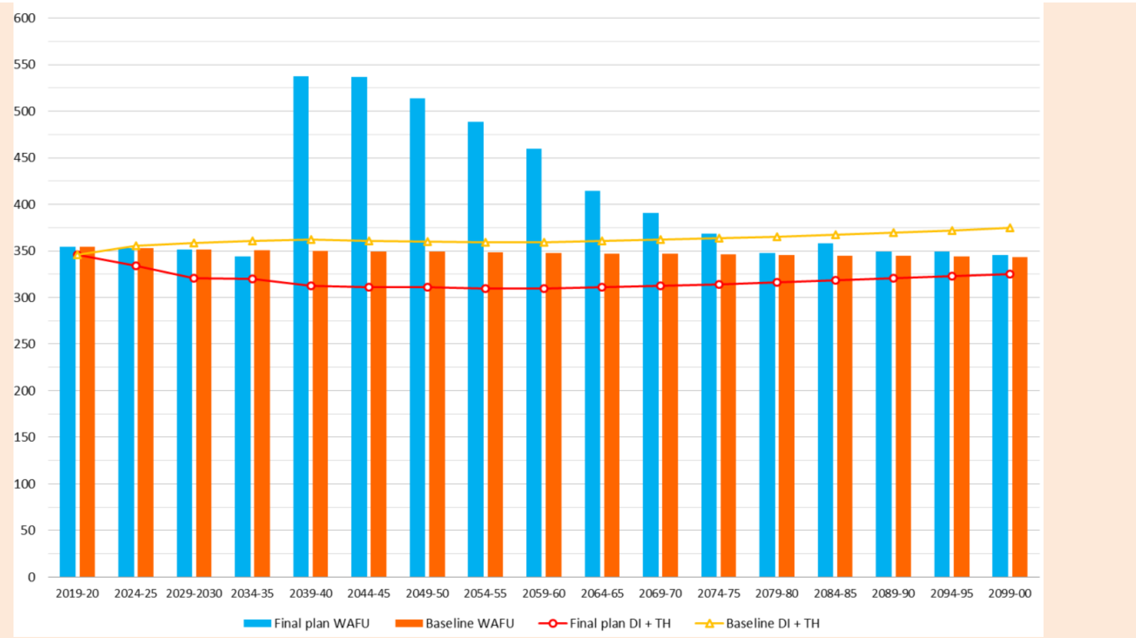
SWOX	End AMP6	End AMP7	End AMP8	End AMP9	End AMP10	End AMP11	End AMP22
	2019/20	2024/25	2029/30	2034/35	2039/40	2044/45	2099/2100
PCC (l/h/d)	136	128	121	118	112	110	99

Table 11-15: Programme appraisal metric scores[12]

Metrics / Programme	Cost (£bn NPV)	Resilience	Deliver-ability	Environ. benefit	Environ. adverse	Customer Preference	IGEQ
Least cost[13]	4.105	0.84	1.00	70	81	4.41	11.33
Preferred	4.628	0.88	0.95	81	77	4.42	11.19

[12] London, SWOX and SWA WRZ are modelled together, so these scores are for the combined zone
[13] For the preferred "Baseline + Drought + WRSE" baseline scenario.

Figure 11-3: SWOX supply-demand balance (DYCP) over 80-year planning horizon



Building the preferred plan

11.72 We followed the same stakeholder and governance process outlined above for London in developing our preferred plan for the SWOX WRZ.

11.73 In order to have a holistic view of the supply-demand balance, we undertook the programme appraisal of SWOX together with the London and SWA WRZs because SWOX is the main resource donor to serve these other zones. Furthermore, the same best-value plan for SWOX aligns with that for London and SWA. The synergies have been described in the programme appraisal process set out in Section 10: Programme appraisal and scenario testing.

11.74 We consider that a plan primarily based on demand management in the short and medium term period with the introduction of the SESRO in 2037 is the most appropriate, balanced plan. Water transfers and trades will be developed later in the planning horizon to meet any increase in local demand for water. Whilst this plan is not least cost, it has considerable benefits beyond pure monetary value. This is the best value long-term plan because:

- It provides sufficient resilience to respond to population growth, the impacts of climate change as well as regional water demands.
- It has balanced environmental impacts.
- It aligns with customer research preference on demand management and resource development schemes.

- It has close alignment to the achievement of Government policy objectives outlined in the WRPG and Defra's Guiding Principles and the 25 year Plan to improve the environment[14].

11.75 These factors are discussed in the programme appraisal process (Section 10: Programme appraisal and scenario analysis), reflecting the fact that the preferred plan is higher cost than the least cost plan but delivers better overall value for customers.

11.76 It has been noted that the impact of climate change is forecast to increase the intensity and frequency of extreme drought events. Without additional resource development, the SWOX WRZ will be potentially heavily reliant on environmentally damaging drought permit options in the event of a drought of greater severity than has been experienced in the historic record. Large-scale resource options provide important benefits to manage future climate uncertainty.

11.77 A further benefit of our preferred plan for SWOX is the importance of communicating a clear message of water stress and the need to use water wisely in the South East region. We want to maintain a consistent message to our customers and rolling out our PMP outside London will help us to extend and provide clarity on our demand management policy. Having consistent communication is significant for our long-term sustainable development if better use of water resources is to be achieved.

11.78 Delivering the SESRO in the mid-2030s helps to reserve groundwater schemes as contingency measures to help manage uncertainty.

Risks and uncertainties in the preferred plan

Risk: concern relating to the SESRO

11.79 We are very aware of the concerns expressed by members of the local community regarding construction of the SESRO, particularly concerning the change in land use and the adverse environmental impacts during construction. In describing the preferred plan for our London WRZ we have set out the advantages and disadvantages of the SESRO.

11.80 Our programme appraisal process has already reflected our position that we ranked adverse environmental impacts as a high priority during the decision making process. We determined through the programme appraisal process that the benefits brought about through implementing the reservoir as a sustainable water resource scheme for local supply as well as to supply the SWA and London WRZs and the wider South East region outweighed the temporary adverse impacts that would be caused during construction.

SWOX - preferred plan summary

11.81 The above section summarises the preferred plan for SWOX. From the work we have undertaken we consider the preferred plan has the right overall supply/demand balance, aligns to Government objectives, and has an optimum balance of metric scores when viewed from a holistic perspective of the overall plan.

[14] H M Government 2018 A Green Future: Our 25 Year Plan to Improve the Environment

11.82 We consider that the underlying strategy behind the plan to reduce the overall demand for water and to best secure the long term water supply with the introduction of a large-scale strategic reservoir resource the best value water management strategy for the plan period if we are to be able to accommodate future challenges created by growth, climate change and the need to protect the environment.

D. Slough, Wycombe and Aylesbury

The preferred plan for SWA

11.83 As illustrated in Figure 11-4 there is a baseline supply-demand deficit in DYCP.

11.84 However, there are no large scale local resource schemes within the SWA WRZ that can resolve the deficit and raw water imports into the zone are required.

11.85 For DYCP, a deficit is observed from 2033/34. If no action is taken, the deficit during peak time in SWA would reach 21 Ml/d at the end of the 80-year planning period.

11.86 Our PMP is the core demand management strategy implemented from 2025 together with a proactive water efficiency campaign and leakage reduction.

11.87 The preferred plan for the London-SWOX-SWA WRZs, as described earlier in Section 10: Programme appraisal and scenario testing, is to implement an inter-zonal raw water transfer from SWOX to SWA to meet the growing long-term deficit observed from 2066. This transfer is facilitated by the South East strategic reservoir. A local groundwater scheme is available from 2038, which is forecast to provide a benefit of 5 Ml/d.

11.88 The key feature of the preferred plan are:

Medium to long-term (2025 – 2099)

11.89 Demand management for SWA will start in 2025 (AMP8). Meter penetration of individual household customers of 92% will be delivered by 2040.

11.90 The Datchet groundwater scheme in 2038 will provide 5 Ml/d to maintain security of supply until an inter-zonal transfer from SWOX is required in 2066 at times of peak demand which provides a maximum benefit up to 24 Ml/d to meet the needs in SWA.

11.91 The plan is presented in Table 11-16 to Table 11-22.

Plan description

11.92 SWA WRZ is forecast to remain in surplus until a DYCP supply-demand deficit is observed from 2033/34, driven primarily by population growth, together with the loss of existing water resources through a 9.8 Ml/d abstraction licence reduction at Hawridge in 2024, where our groundwater abstractions are perceived to impact the River Chess.

11.93 We aim to install 56,882 household meters by 2039/40 alongside water efficiency to deliver 15.5 Ml/d reduction in usage. In addition with leakage reduction activities, the integrated demand management programme is expected to achieve circa 22 Ml/d benefits by the end of AMP10 (2040).

11.94 One small resource development scheme plus a large inter-zonal transfer are required to maintain the medium and long-term supply demand balance once savings from demand management are substantially taken up.

11.95 The delivery of the SESRO in 2037 provides an opportunity to stop any remaining abstraction at the Pann Mill groundwater source (9.5 Ml/d), following on from the imposition of an initial 7.3 Ml/d sustainability reduction in 2020. The source is perceived to have a detrimental environmental impact on the River Wye. Previous investigations concluded that it was not cost beneficial to stop abstraction at this site. The SESRO with its low annual opex costs will help to more cost effectively stop using the remaining licence at Pann Mill and thereby help to address concerns voiced by environmental groups.

11.96 To stop all abstraction at Pann Mill will require the imposition of new infrastructure earlier than currently included in the preferred plan. The Medmenham intake on the River Thames would need to be brought forward from its current planned date of 2066 to 2037 and a new main would also need to be constructed to allow for the water to replace that currently provided by Pann Mill.

11.97 Development of the Datchet groundwater source is currently planned in 2038 and this would no longer be required if the Medmenham intake scheme is brought forward. The overall total cost of the preferred programme would increase by approximately £20 million NPV, but environmental impacts associated with the Datchet scheme and its supporting infrastructure would not be incurred. We welcome regulator and stakeholder views on this suggested amendment to the preferred plan.

Performance of the preferred plan

11.98 Figure 11-4 illustrates the supply-demand balance for SWA. The preferred plan for SWA ensures that security of supply is maintained throughout the planning period.

Table 11-16: SWA preferred plan – Overall plan (DYCP) for demand management

SWA		Delivery date and ongoing supply demand benefit (Ml/d)			
		AMP8	AMP9	AMP10	AMP11-AMP22
		2025-2029	2030-2034	2035-2039	2040-2100
Total benefit from DMP		**12.2**	**3.2**	**6.6**	**Benefits maintained**
Leakage reduction	**Total leakage reduction**	**4.7**	**0.7**	**1.1**	**Benefits maintained**
	Household metering CSL	4.2	0.0	0.0	
	Bulk metering CSL				
	AMP8: 5,783 meters	0.5			
	AMP9: 0 meters		0.0		
	AMP10: 0 meters			0.0	
	Replacement metering CSL				
	Mains replacement		0.7	1.1	
	Pressure management				
	DMA enhancement				
Usage reduction	**Total usage reduction**	**7.5**	**2.5**	**5.5**	**Benefits maintained**
	Household metering				
	AMP8: 56,882 meters	6.00			
	AMP9: 0 meters		0.88		
	AMP10: 0 meters			0.00	
	Water efficiency	1.5	1.7	0.9	
	Incentive scheme				
	Non-potable water				
	Innovative tariffs			4.6	

Table 11-17: SWA preferred plan – Overall plan (DYCP) for resource management

SWA	Delivery date and ongoing supply demand benefit (Ml/d)							
	AMP7	AMP8	AMP9	AMP10	AMP11	AMP16	AMP17	AMP22
	2020-2024	2025-2029	2030-2034	2035-2039	2040-2044	2065-2069	2070-2074	2095-2099
Groundwater								
Datchet				5.4	5.4	5.4	5.4	5.4
Inter-zonal transfer								
River Thames to Medmenham						24	24	24
Total additional water resource				**5.4**	**5.4**	**29.4**	**29.4**	**29.4**
Baseline supply demand balance	3.6	0.9	-0.6	-2.9	-5.5	-9.9	-11.5	-21.3
Additional reduction in DO								
1:200 Drought resilience			**-3.3**	**-3.3**	**-3.3**	**-3.3**	**-3.3**	**-3.3**
Vulnerable chalk stream (Pann Mill)				**-9.8**	**-9.8**	**-9.8**	**-9.8**	**-9.8**

Table 11-18: SWA preferred plan – Water resource schemes (delivery year in chronological order)

Resource schemes	DYCP yield (Ml/d)	Delivery year
Groundwater Datchet	5.4	2038
Inter-zonal transfer River Thames to Medmenham from SWOX	24	2066

Table 11-19: SWA preferred plan – Annual average leakage forecast

Slough Wycombe Aylesbury – DYAA	End AMP6	End AMP7	End AMP8	End AMP9	End AMP10	End AMP11
	2019/20	2024/25	2029/30	2034/35	2039/40	2044/45
Average leakage forecast (Ml/d)	37	37	33	32	31	31

Table 11-20: SWA preferred plan – Meter penetration

Slough Wycombe Aylesbury	End AMP6	End AMP7	End AMP8	End AMP9	End AMP10	End AMP11	End AMP22
	2019/20	2024/25	2029/30	2034/35	2039/40	2044/45	2099/2100
Household meter penetration (%) (incl. voids)	57	64	87	91	92	92	94

Table 11-21: SWA preferred plan – PCC (DYAA)

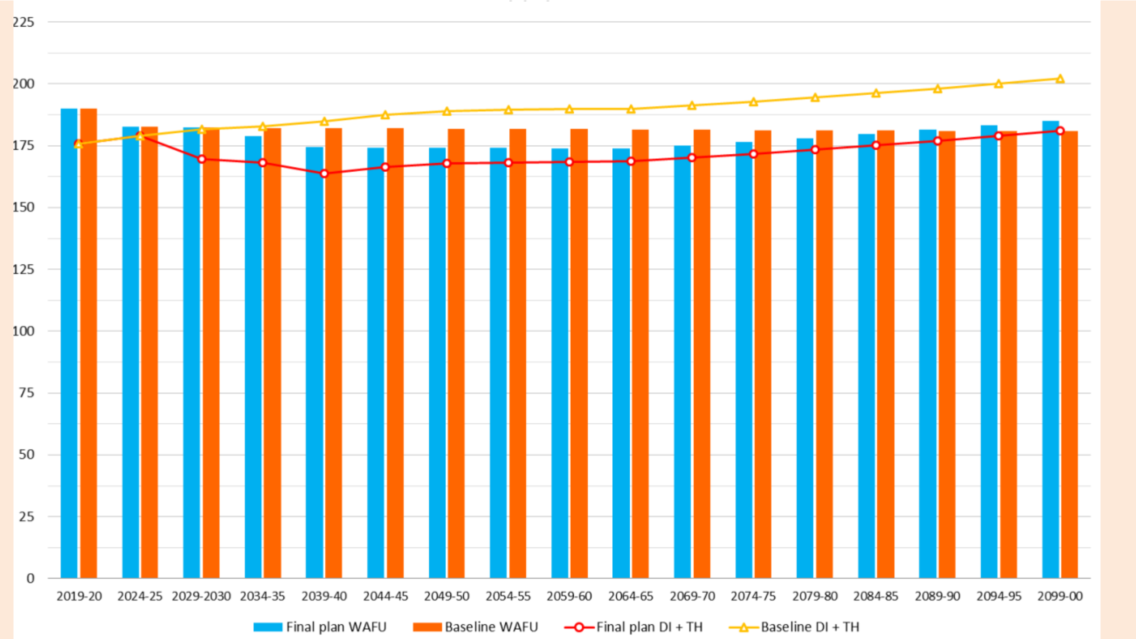
Slough Wycombe Aylesbury	End AMP6	End AMP7	End AMP8	End AMP9	End AMP10	End AMP11	End AMP22
	2019/20	2024/25	2029/30	2034/35	2039/40	2044/45	2099/2100
PCC (l/h/d)	138	136	126	122	114	113	102

Table 11-22: Programme appraisal metric scores[15]

Programme \ Metrics	Cost (£bn NPV)	Resilience	Deliver-ability	Environ. benefit	Environ. adverse	Customer Preference	IGEQ
Least cost[16]	4.105	0.84	1.00	70	81	4.41	11.33
Preferred	4.628	0.88	0.95	81	77	4.42	11.19

[15] London, SWOX and SWA WRZ are modelled together, so these scores are for the combined zone
[16] For the preferred "Baseline + Drought + WRSE" baseline scenario.

Figure 11-4: SWA supply-demand balance (DYCP)



Building the preferred plan

11.99 Due to the high complexity of the supply / demand deficit problem in the London, SWOX and SWA WRZs we have undertaken a combined WRZ programme appraisal. This provides a holistic view and facilitates an efficient, best value investment programme.

11.100 The preferred plan resulting from this combined programme appraisal process is the best value plan for the London-SWOX-SWA WRZs in total.

11.101 We consider the preferred plan aligns to the achievement of Government policies and aspirations, has reduced environment impact and allows us to respond flexibly to future uncertainties to deliver long term best value for customers and the wider water environment.

11.102 In-line with other Thames Valley WRZs, we have taken an integrated approach to demand management with our PMP being the core of our strategy.

SWA – preferred plan summary

11.103 The preferred programme for SWA ensures that security of supply is maintained throughout the planning period.

11.104 The approach of focusing on demand management and groundwater development in the medium-term and implementing a large inter-zonal transfer later in the planning period facilitates mitigation of long-term uncertainty.

11.105 The above section summarises the preferred plan for the SWA WRZ. From the work we have undertaken we consider the preferred plan provides the long term best value balance of relevant water management considerations, including securing sufficient resilience against growing demand and climate change, and has less environmental adverse impacts compared with alternative programmes.

11.106 Other uncertainties include likely increasing demand for water supply from the South East region (e.g. South East Water) and more frequent and intense drought events. As discussed earlier, the combined London, SWOX and SWA preferred plan addresses and enables mitigation of these risks. Our stress testing approach set out in Section 10: Programme appraisal and scenario testing is similar to an adaptive pathways approach.

E. Kennet Valley

The preferred plan for Kennet Valley

11.107 The Kennet Valley WRZ remains in surplus throughout the planning period in the baseline supply-demand balance forecast (Figure 11-5). However, the zone is not resilient to a 1 in 200 year severe drought event and as such requires investment to improve security of supply resilience. A deficit emerges at the end of the planning period in the 2090s.

11.108 The planning problem in Kennet Valley has been classified as being of low complexity and therefore Kennet Valley is following a least cost approach to close the deficit which emerges when resilience to a severe drought is included. This has been explained in Section 10: Programme appraisal and scenario analysis.

11.109 The preferred plan is centred on demand management starting from AMP9. The strategy on demand management is consistent with other WRZs. We continue to focus on our PMP and proactive water efficiency, in addition to the introduction of an incentive based financial tariff. We expect to receive circa 13.7 Ml/d benefits by the end of AMP10 (2035/40) associated with our demand management activities.

11.110 The key features of the preferred plan are:

Medium-term (2030-2040) demand management

11.111 Start roll-out of PMP and aim to achieve more than 95% household penetration by the end of AMP10 (2039/40).

11.112 The metering, an incentive based financial tariff scheme and a proactive water efficiency campaign will be implemented to promote reduction of usage and this approach is expected to deliver 10 Ml/d savings by 2039/40.

Plan description

11.113 Our preferred plan starts with an integrated demand management programme. Consistent with our other WRZs, Kennet Valley will roll out our PMP.

11.114 The demand management programme ensures resilience to a 1 in 200 year severe drought event.

11.115 Table 11-23 to Table 11-28 outline the details of the plan.

Table 11-23: Kennet Valley preferred plan – Overall plan (DYCP) for demand management

	Kennet Valley	Delivery date and ongoing supply demand benefit (Ml/d)			
		AMP9	AMP10	AMP11	AMP12-AMP22
		2030-2034	2035-2039	2040-2044	2045-2100
Total benefit from DMP		**8.6**	**5.2**	**Benefits maintained**	
Leakage reduction	**Total leakage reduction**	**3.8**	**Benefits maintained**		
	Household metering CSL	3.4	0.0	0	
	Bulk metering CSL				
	AMP9: 4,332 meters	0.3			
	AMP10: 0 meters				
	AMP11: 0 meters				
	Replacement metering CSL				
	Mains replacement				
	Pressure management				
	Innovation				
	DMA enhancement				
Usage reduction	**Total usage reduction**	**4.8**	**5.2**	**Benefits maintained**	
	Household metering				
	AMP9: 42,237 meters	3.31			
	AMP10: 0 meters		0.59		
	AMP11: 0 meters			0.00	
	Water efficiency	1.5	1.1	0.0	
	Incentive scheme				
	Non-potable water				
	Innovative tariffs		3.4		

Table 11-24: Kennet Valley preferred plan – Overall plan (DYCP) for resource management

Kennet Valley	Delivery date and ongoing supply demand benefit (Ml/d)							
	AMP7	AMP8	AMP9	AMP10	AMP12	AMP17	AMP19	AMP22
	2020-2024	2025-2029	2030-2034	2035-2039	2045-2049	2070-2074	2080-2084	2095-2099
Total additional water resource	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Baseline Supply Demand Balance	17.9	15.7	13.9	12.7	**11.7**	8.3	5.6	0.6
Additional reduction in DO								
1:200 Drought resilience			**-3.4**	**-3.4**	**-3.4**	**-3.4**	**-3.4**	**-3.4**

Table 11-25: Kennet Valley preferred plan – Annual average leakage forecast

Kennet Valley – DYAA	End AMP6	End AMP7	End AMP8	End AMP9	End AMP10	End AMP11
	2019/20	2024/25	2029/30	2034/35	2039/40	2044/45
Average leakage forecast (Ml/d)	26	26	26	22	22	22

Table 11-26: Kennet Valley preferred plan – Meter penetration

Kennet Valley	End AMP6	End AMP7	End AMP8	End AMP9	End AMP10	End AMP11	End AMP22
	2019/20	2024/25	2029/30	2034/35	2039/40	2044/45	2099/2100
Household meter penetration (%) (incl. void)	58	63	68	95	95	95	96

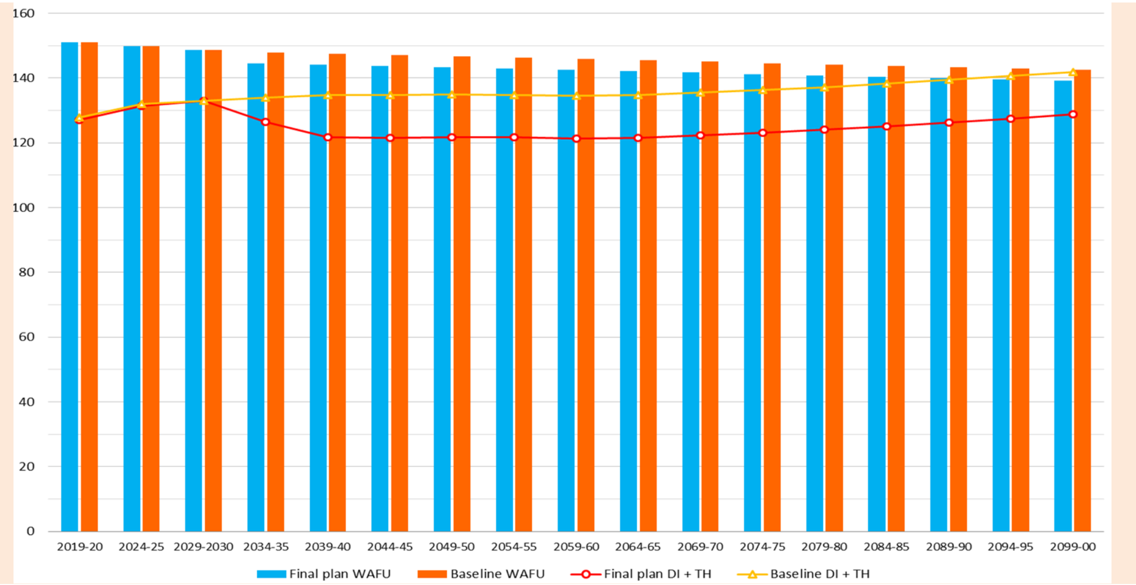
Table 11-27: Kennet Valley preferred plan – PCC (DYAA)

Kennet Valley	End AMP6	End AMP7	End AMP8	End AMP9	End AMP10	End AMP11	End AMP22
	2019/20	2024/25	2029/30	2034/35	2039/40	2044/45	2099/2100
PCC (l/h/d)	133	130	129	120	111	110	98

Table 11-28: Kennet Valley preferred plan – Programme appraisal metric scores

Metrics / Programme	Cost (£m NPV)	Resilience	Deliver-ability	Environ. benefit	Environ. adverse	IGEQ	Customer preference
Preferred	40.7	0.44	1	6	1	0.33	4.39

Figure 11-5: Kennet Valley supply-demand balance (DYCP)



Building the preferred plan

11.116 Our preferred plan is built from the outcomes of our programme appraisal process and we have followed the same governance process as outlined above for the London, SWOX and SWA WRZs.

11.117 We consider that a preferred plan based on demand management is appropriate.

Risks and uncertainties in the preferred plan

11.118 The preferred plan for Kennet Valley ensures that security of supply is maintained throughout the planning period.

11.119 The main risk to the supply demand balance of the zone is the potential reduction of output from the Environment Agency's West Berkshire Groundwater Scheme. This scheme, where in times of drought water is abstracted from underground aquifers in order to augment flows in the River Kennet, supports our abstraction at Fobney and further downstream in London.

11.120 The ownership, operation and long-term viability of these assets are unclear and the Environment Agency has requested we assess the potential impact of a reduction in outputs from the scheme on our plan.

11.121 The full scheme has a supply benefit of 43 Ml/d to the Kennet Valley WRZ. We believe that complete loss of the entire scheme benefit would be unlikely, so we have developed a scenario that reduces output by 27 Ml/d based on the contribution of sustainable drought sources in the confined chalk aquifer.

11.122 Currently there are insufficient options in the Kennet Valley to meet a reduction in supply of that scale and we would likely need to develop a new surface water intake on the River Thames near Reading in order to support Fobney. The additional abstraction from the River

Thames would be made viable through release of water from the South East strategic reservoir following its completion in 2037. An earlier requirement would necessitate bringing forward the demand management programme from the current planned start of 2030.

Kennet Valley - preferred plan summary

11.123 The above sections summarise the preferred plan for Kennet Valley. We consider the preferred plan has the right overall balance, aligns to customer research and provides sufficient long-term resilience. The plan is resilient to any uncertainties associated with the continuing availability of the West Berkshire Groundwater Scheme.

F. Guildford

The preferred plan for Guildford

11.124 As indicated in Figure 11-6, there is a baseline DYCP supply-demand deficit in Guildford, starting as early as 2025/26 and increasing over the rest of the planning period.

11.125 The problem characterisation of the Guildford WRZ has been classified as being of low complexity and we have followed a least cost approach for deriving Guildford's preferred plan because the supply-demand deficit can be balanced at this level of investment.

11.126 Similar to other WRZs, integrated demand management with focus on our PMP is applied in Guildford together with the removal of a network constraint at Ladymead which provides an additional 4.6 Ml/d supply to Guildford in 2024.

11.127 A new main is required to transfer water from sources in the west of the zone to the east, where resource availability is limited and demand management activity will be insufficient in itself to meet the forecast growth in demand associated with new housing development.

The key features of the preferred plan are:

Short to medium-term (2020-2030) demand management

11.128 Proactive promotion of water efficiency, implementing our PMP and an incentive based financial tariff scheme are the focus to help customers use water wisely.

11.129 Our PMP in Guildford will achieve over 90% individual household penetration by the end of 2035.

Short to long-term (2020 to 2099) water resource management

11.130 Removal of a network constraint at Ladymead allows an extra 4.6 Ml/d supply to Guildford from 2024.

11.131 A transfer main from Shalford water treatment works to Netley Mill in 2026 facilitates movement of water from the west of the resource zone to the east.

11.132 To maintain security of supply in the long-term requires removal of a network constraint at Dapdune in 2081 followed by development of a groundwater source at Dapdune in 2091.

Plan description

11.133 Our preferred plan includes a PMP with 9,259 household meters installed in AMP7, followed by 7,232 between 2025 and 2030.

11.134 A small resource scheme removing network constraints at Ladymeads is required as early as 2024 to support growth.

11.135 In the long-term, post 2080, another network constraint requires removal, together with further development of a small groundwater source.

11.136 Our preferred plan is listed in Table 11-29 to Table 11-35.

Performance of the preferred plan

11.137 The preferred plan for Guildford ensures that security of supply is maintained throughout the planning period. The WRZ is already resilient to a 1 in 200 year severe drought event.

Table 11-29: Guildford preferred plan – Overall plan (DYCP) for demand management

Category	GUI	AMP7 2020-2024	AMP8 2025-2029	AMP9 2030-2034	AMP10 2035-2039	AMP11-AMP22 2040-2100
		Delivery date and ongoing supply demand benefit (MP/d)				
	Total benefit from DMP	**3.3**	**2.6**	**0.9**	**1.5**	**Benefits maintained**
Leakage reduction	**Total leakage reduction**	**2.1**	**1.5**	**0.5**	**Benefits maintained**	
Leakage reduction	AMP6 Carry-over leakage	0.5				
Leakage reduction	Household metering CSL	0.8	0.6	0.00	0.00	
Leakage reduction	Bulk metering CSL	0.1				
Leakage reduction	AMP7: 1,194 meters					
Leakage reduction	AMP8: 1,194 meters		0.1			
Leakage reduction	AMP9: 0 meters					
Leakage reduction	Replacement metering CSL					
Leakage reduction	Mains replacement	0.0	0.3	0.49	0.00	
Leakage reduction	Pressure management					
Leakage reduction	Innovation					
Leakage reduction	DMA enhancement	0.7	0.5	0.0	0.0	
Usage reduction	**Total usage reduction**	**1.2**	**1.1**	**0.4**	**1.5**	**Benefits maintained**
Usage reduction	Household metering					
Usage reduction	AMP7: 9,259 meters	0.8				
Usage reduction	AMP8: 7,232 meters		0.9			
Usage reduction	AMP9: 0 meters			0.1		
Usage reduction	Water efficiency	0.5	0.3	0.3	0.0	
Usage reduction	Incentive scheme					
Usage reduction	Non-potable water					
Usage reduction	Innovative tariffs				1.5	

Table 11-30: Guildford preferred plan – Overall plan (DYCP) for resource management

Guildford	Delivery date and ongoing supply demand benefit (Ml/d)								
	AMP7	AMP8	AMP9	AMP10	AMP11	AMP17	AMP19	AMP21	AMP22
	2020-2024	2025-2029	2030-2034	2035-2039	2040-2044	2070-2074	2080-2084	2090-2094	2095-2099
Groundwater scheme									
Groundwater Dapdune								2.2	2.2
Removal of network constraint									
Ladymead	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6
Dapdune							1	1	1
Conveyance									
Shalford to Netley Mill									
Baseline deficit	0.3	-2.1	-6.5	-7.5	-8.1	-10.2	-11.3	-12.2	-12.6

Table 11-31: Guildford preferred plan – Water resource schemes (delivery year in chronological order)

Resource schemes	DYCP yield (Ml/d)	Delivery year
Ladymead removal of network constraint	4.6	2024
Dapdune removal of network constraint	1	2081
Groundwater Dapdune	2.2	2091

Table 11-32: Guildford preferred plan – Annual average leakage forecast

Guildford – DYAA	End AMP6	End AMP7	End AMP8	End AMP9	End AMP10	End AMP11
	2019/20	2024/25	2029/30	2034/35	2039/40	2044/45
Average leakage forecast (Ml/d)	13	11	10	9	9	9

Table 11-33: Guildford preferred plan – Meter penetration

Guildford	End AMP6	End AMP7	End AMP8	End AMP9	End AMP10	End AMP11	End AMP22
	2019/20	2024/25	2029/30	2034/35	2039/40	2044/45	2099/2100
Household meter penetration (%) (incl. void)	55	73	88	90	91	91	93

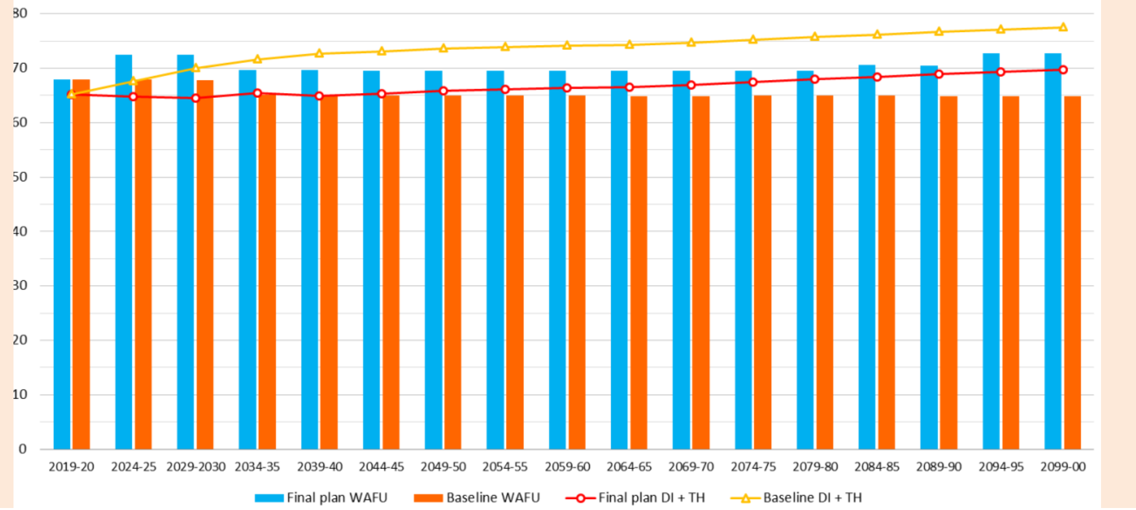
Table 11-34: Guildford preferred plan – PCC (DYAA)

Guildford	End AMP6	End AMP7	End AMP8	End AMP9	End AMP10	End AMP11	End AMP22
	2019/20	2024/25	2029/30	2034/35	2039/40	2044/45	2099/2100
PCC (l/h/d)	146	138	132	129	123	121	108

Table 11-35: Guildford preferred plan – Programme appraisal metric scores

Metrics / Programme	Cost (£m NPV)	Resilience	Deliver-ability	Environ. benefit	Environ. Adverse
Preferred	52.6	0.44	0.98	12	5

Figure 11-6: Guildford supply-demand balance (DYCP)



Building the preferred plan

11.138 Our preferred plan is built from the outcomes of our programme appraisal process and we have followed the same governance process outlined above for the London, SWOX and SWA WRZs in developing our preferred plan.

11.139 We consider that a plan based initially on integrated demand management from 2020 is appropriate having regard to relevant guidance. In addition, removal of a network constraint and a transfer main are also required to maintain security of supply until the 2080s.

11.140 The preferred plan for Guildford ensures that security of supply is maintained throughout the planning period and the resource zone is resilient to a 1 in 200 year drought event.

11.141 The problem characterisation of the WRZ is low.

Guildford - preferred plan summary

11.142 The above sections summarise the preferred plan for Guildford. We consider the preferred plan has the right overall balance, aligns to customer research and provides sufficient long-term resilience.

G. Henley

The preferred plan for Henley

11.143 As illustrated in Figure 11-7, Henley has no forecast supply-demand deficit over the planning period for either DYAA or DYCP. The resource zone is classified as low risk.

11.144 To ensure an equitable policy for our customers across our WRZs, our PMP will be the core demand management strategy in the Henley WRZ. This is consistent with the policy set out in our WRMP14.

Plan description

11.145 Although we forecast that Henley will be in surplus throughout the planning period, integrated demand management is implemented from 2030-2040. This will ensure water usage reduction will continue by promoting water efficiency and our PMP.

11.146 The preferred plan reduces leakage by 0.35 Ml/d and total demand by 1.47Ml/d.

11.147 Total household meter penetration of 96% is achieved by 2039/40.

11.148 Table 11-36 to Table 11-40 outline the details of the preferred plan.

Performance of the plan

11.149 The preferred plan for Henley ensures that security of supply is maintained throughout the planning period and that the zone is resilient to a 1 in 200 year severe drought event.

Table 11-36: Henley preferred plan – Overall plan (DYCP)

	Henley	Delivery date and ongoing supply demand benefit (Ml/d)			
		AMP9	AMP10	AMP11	AMP12-AMP22
		2030-2034	2035-2039	2040-2044	2045-2100
Total benefit from DMP		**0.95**	**0.52**	**Benefits maintained**	
Leakage reduction	**Total leakage reduction**	**0.35**	**Benefits maintained**		
	Household metering CSL	0.32			
	Bulk metering CSL				
	AMP9: 346 meters	0.03			
	AMP10: 0 meters				
	AMP11: 0 meters				
	Replacement metering CSL				
	Mains replacement				
	Pressure management				
	Innovation				
	DMA enhancement				
Usage reduction	**Total usage reduction**	**0.61**	**0.52**	**Benefits maintained**	
	Household metering				
	AMP9: 3,852 meters	0.32			
	AMP10: 0 meters		0.06		
	AMP11: 0 meters				
	Water efficiency	0.29			
	Innovation				
	Incentive scheme				
	Non-potable water				
	Innovative tariffs		0.5		

Table 11-37: Henley preferred plan – Annual average leakage forecast

Henley – DYAA	End AMP6	End AMP7	End AMP8	End AMP9	End AMP10	End AMP11
	2019/20	2024/25	2029/30	2034/35	2039/40	2044/45
Average leakage forecast (Ml/d)	4	4	4	3	3	3

Table 11-38: Henley preferred plan – Meter penetration

Henley	End AMP6	End AMP7	End AMP8	End AMP9	End AMP10	End AMP11	End AMP22
	2019/20	2024/25	2029/30	2034/35	2039/40	2044/45	2099/2100
Household meter penetration (%) (incl. void)	68	72	75	92	96	96	96

Table 11-39: Henley preferred plan – PCC (DYAA)

Henley	End AMP6	End AMP7	End AMP8	End AMP9	End AMP10	End AMP11	End AMP22
	2019/20	2024/25	2029/30	2034/35	2039/40	2044/45	2099/2100
PCC (l/h/d)	141	138	138	129	122	120	111

Table 11-40: Henley preferred plan – Programme appraisal metric scores

Metrics / Programme	Cost (£m NPV)	Resilience	Deliver-ability	Environ. Benefit	Environ. Adverse
Preferred	4.089	0.44	1	3	1

Figure 11-7: Henley supply-demand balance (DYCP) over 80-year planning horizon

11.150 Our preferred plan is built from the outcomes of our programme appraisal process.

11.151 We consider that a plan based on demand management mid-way through the planning period is appropriate.

11.152 The problem characterisation of the WRZ is low.

Henley - preferred plan summary

11.153 The above sections summarise the preferred plan for Henley. We consider the preferred plan has the right overall balance, aligns to customer research and provides sufficient long-term resilience.

H. Summary supply-demand balance

11.154 The total supply-demand balance for all WRZs for our preferred plan is summarised in Table 11-41.

Table 11-41: Total supply-demand balance for all WRZs

WRZ	Item	Volume (Ml/d)															
		AMP7					AMP8	AMP9	AMP10	AMP11	AMP12	AMP14	AMP15	AMP16	AMP18	AMP20	AMP22
		2020/21	2021/22	2022/23	2023/24	2024/25	2029/30	2034/35	2039/40	2044/45	2049/50	2059/60	2064/65	2069/70	2079/80	2089/90	2099/2100
London (DYAA)	DI+TH	2129	2115	2113	2086	2069	2008	1988	1945	1965	1983	2019	2035	2049	2070	2089	2110
	WAFU	2152	2145	2138	2131	2130	2087	2007	1978	1969	1983	2019	2035	2049	2070	2089	2110
	SDB	**22.7**	**30.0**	**24.6**	**45.2**	**61.4**	**79.8**	**18.5**	**32.6**	**4.4**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
SWOX (DYCP)	DI+TH	344	344	341	338	335	321	321	313	312	311	309.9	311	313	316	320	325
	WAFU	355	354	354	354	353	352	344	537	537	514	459.8	415	391	348	341	345
	SDB	**10.4**	**10.7**	**12.7**	**16.0**	**18.7**	**30.3**	**23.2**	**224.5**	**225.1**	**203.0**	**149.8**	**103.3**	**77.8**	**31.9**	**28.7**	**19.9**
SWA (DYCP)	DI+TH	177	179	180	180	179	170	168	164	166	168	169	169	170	173	177	181
	WAFU	190	190	190	190	183	182	179	174	174	174	174	174	175	178	181	185
	SDB	**13.0**	**10.9**	**10.0**	**9.7**	**3.6**	**12.7**	**10.8**	**10.7**	**8.0**	**6.5**	**5.4**	**5.2**	**4.8**	**4.6**	**4.4**	**4.2**
Kennet Valley (DYCP)	DI+TH	129	130	131	131	131	133	126	122	122	122	121	122	122	124	126	129
	WAFU	151	151	150	150	150	149	145	144	144	143	142	142	142	141	140	139
	SDB	**21.8**	**20.4**	**19.4**	**19.0**	**17.9**	**15.7**	**18.7**	**22.5**	**22.2**	**21.6**	**21.1**	**20.5**	**19.4**	**16.9**	**13.8**	**10.5**
Guildford (DYCP)	DI+TH	65	65	65	65	65	65	65	65	65	66	66	66	67	68	69	70
	WAFU	68	68	68	68	73	72	70	70	70	70	70	70	69	70	71	73
	SDB	**2.8**	**3.1**	**3.1**	**3.2**	**7.8**	**7.9**	**4.3**	**4.8**	**4.2**	**3.8**	**3.2**	**3.0**	**2.5**	**1.6**	**1.6**	**2.9**
Henley (DYCP)	DI+TH	20	20	20	20	20	20	19	19	19	19	19	19	19	19	19	20
	WAFU	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26
	SDB	**5.4**	**5.3**	**5.3**	**5.3**	**5.3**	**5.3**	**6.2**	**6.9**	**6.8**	**6.8**	**6.7**	**6.7**	**6.6**	**6.4**	**6.2**	**6.0**

11.155 Figure 11-8 illustrates the surplus for London, SWOX and SWA. These three zones have been combined due to the complexity of water resource management between zones that are donors and receivers of raw water. The SESRO increases available water resources in the 2030s. This large-scale water resource scheme is expected to provide sufficient resilience to cover the demand of London, SWOX and SWA caused by population growth, climate change and regional demand from south east England. Supply resilience is improved to a 1 in 200 year severe drought event from 2030 onwards with the delivery of the combined groundwater, wastewater re-use and raw water transfer schemes which enhance resource availability in London.

11.156 From the 2080s, security of supply resilience is maintained through the supported Severn Thames transfer scheme. This scheme addresses long-term requirements of climate change and population growth.

11.157 For the rest of the three Thames Valley WRZs (Figure 11-9), Henley and Kennet Valley WRZs have a steady surplus across the 80-year span while stress in the supply-demand balance can be observed in Guildford WRZ from the mid-2020s.

Figure 11-8: Surplus for London (DYAA), SWOX and SWA (DYCP)

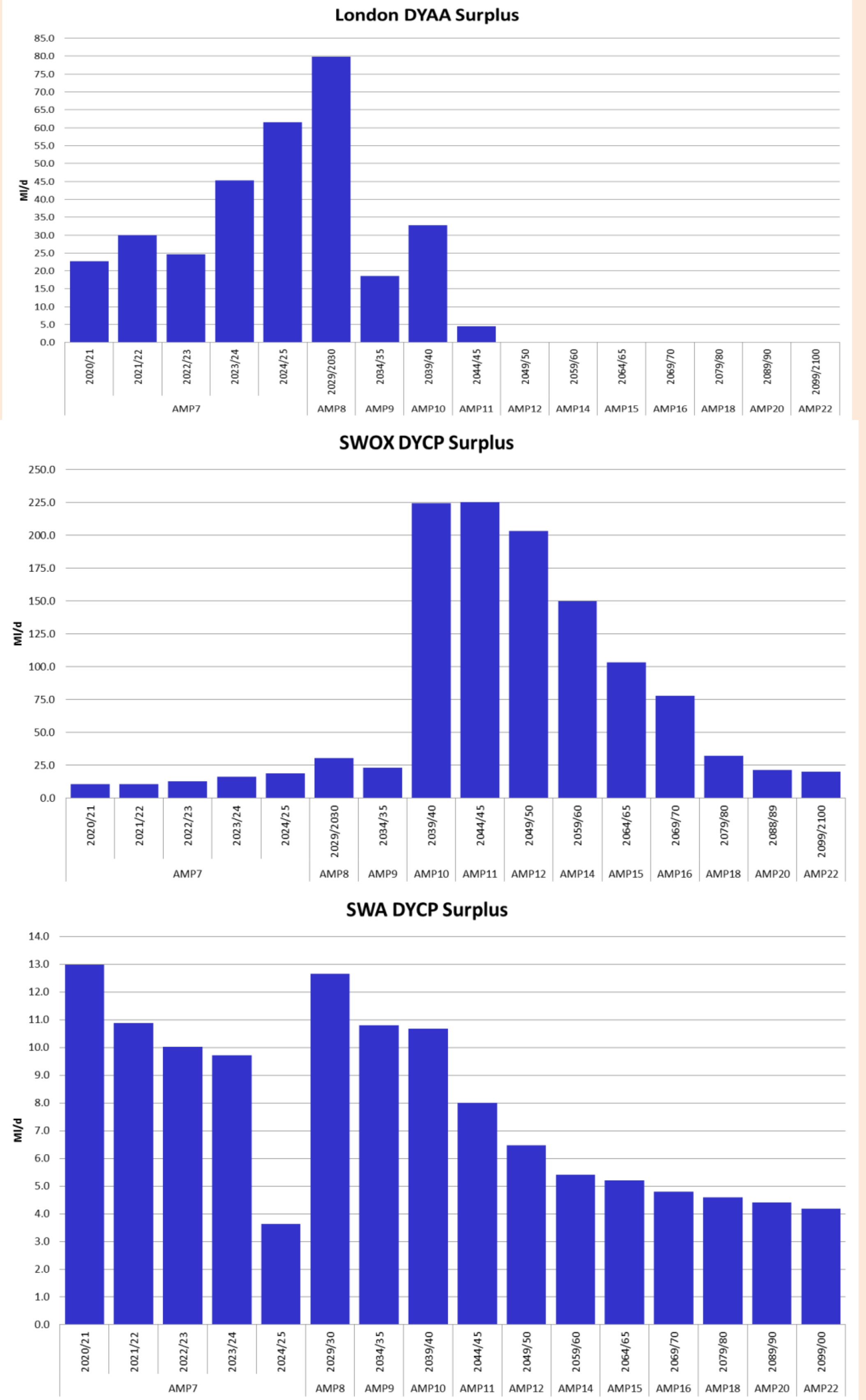
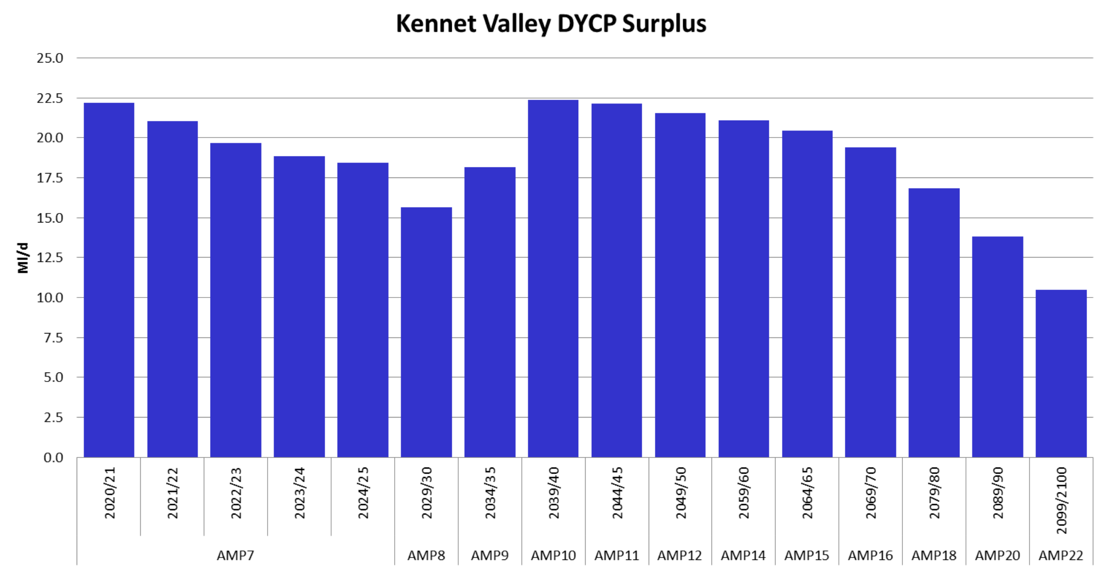
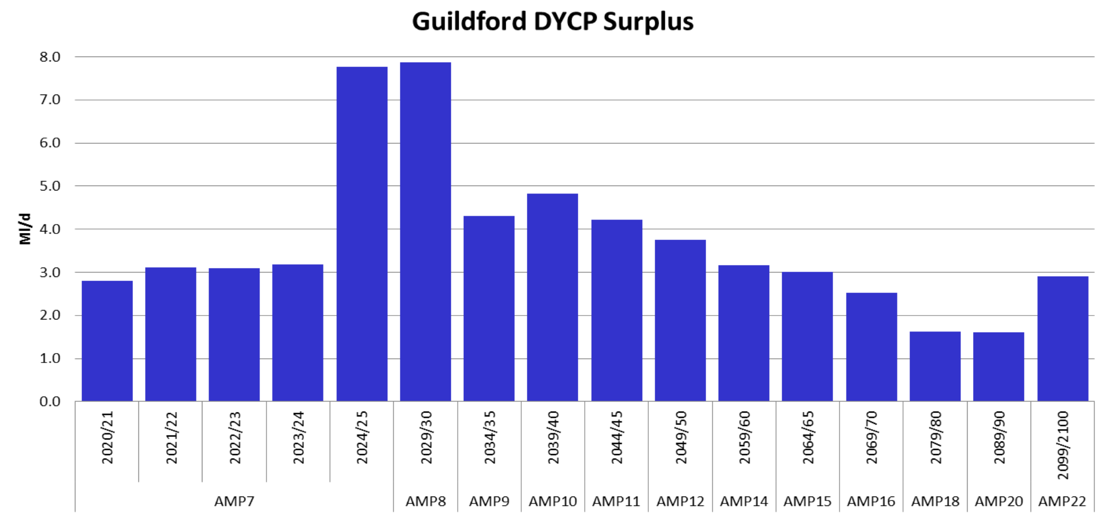
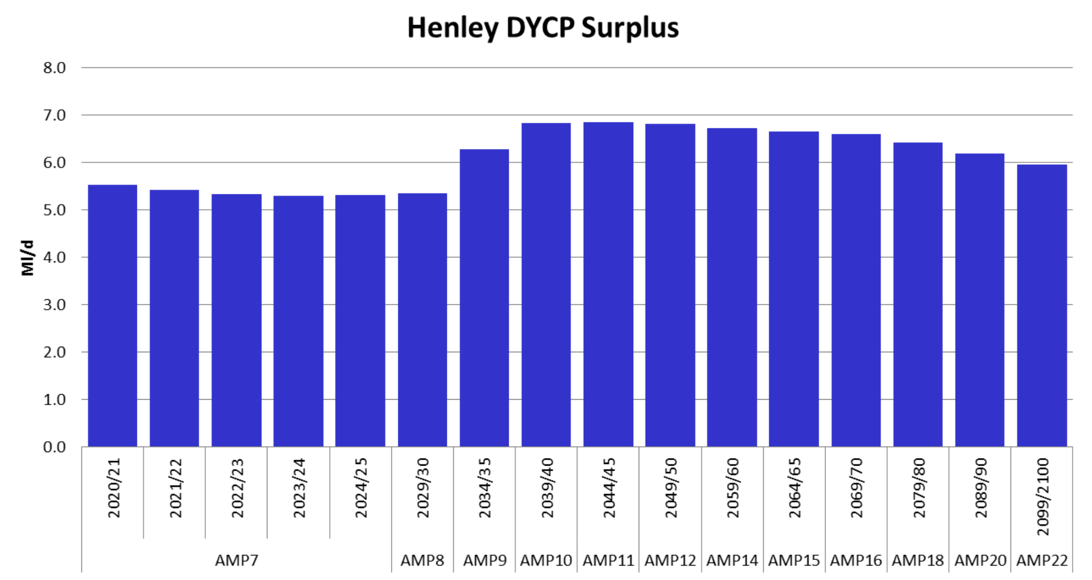


Figure 11-9: Surplus for Kennet Valley, Guildford and Henley (DYCP)







I. Preferred plan – overview of demand management outputs

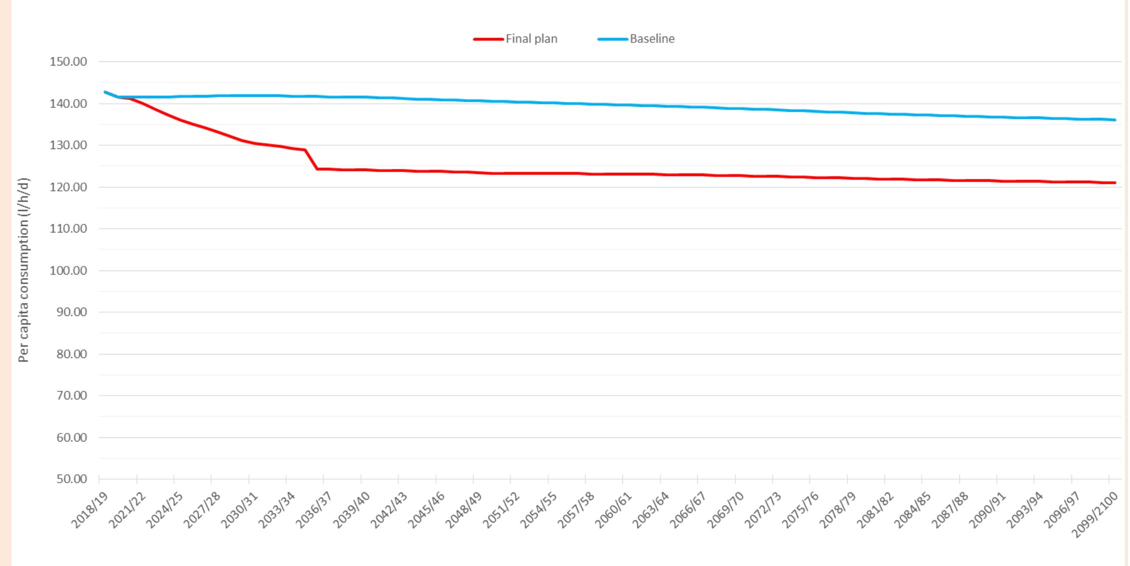
Per capita consumption forecasts

11.158 Our preferred plan follows the Government's objective which sets a clear target for water companies, who are either designated as being in a water stressed area or where their PCC is above the national average, to significantly reduce demand[17].

11.159 Continuing the integrated demand management approach that we set out in our WRMP14 allows us to achieve this important objective. The combined effect of our PMP, together with a reward based incentive scheme in the London WRZ and widespread financial incentive based tariffs throughout our supply area, proactive industry leading water efficiency activities and innovative non potable supplies to new developments facilitates a significant reduction in PCC throughout our supply area. The preferred plan PCC profiles are shown in Figure 11-10 for London and Figure 11-11 for Thames Valley.

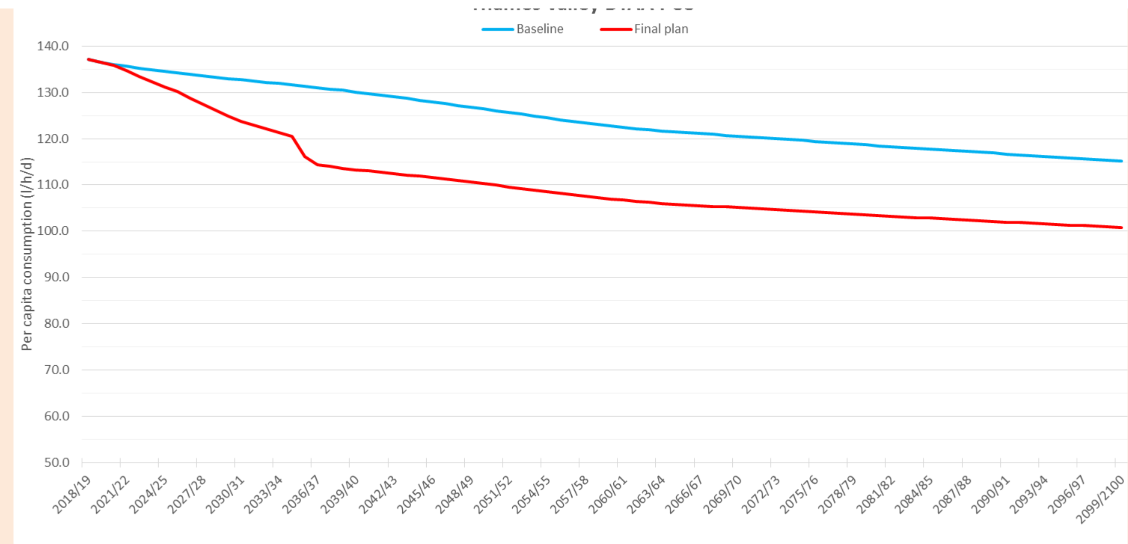
11.160 These graphs clearly show the reduction in PCC of water across our entire water supply area and demonstrate the potential effectiveness of our integrated demand management approach in reducing usage. In Section 8: Appraisal of demand options we have set out the savings assumptions that we have included in our demand management options; namely a 17% reduction in household demand in response to movement to a measured tariff, with further additional water efficiency savings of up to 6% usage reduction. These reductions are higher than those quoted by other water companies in the south east region. We have included smart meter technology and believe this will assist in achieving our ambitious water usage reduction forecast.

Figure 11-10: PCC for London (DYAA)



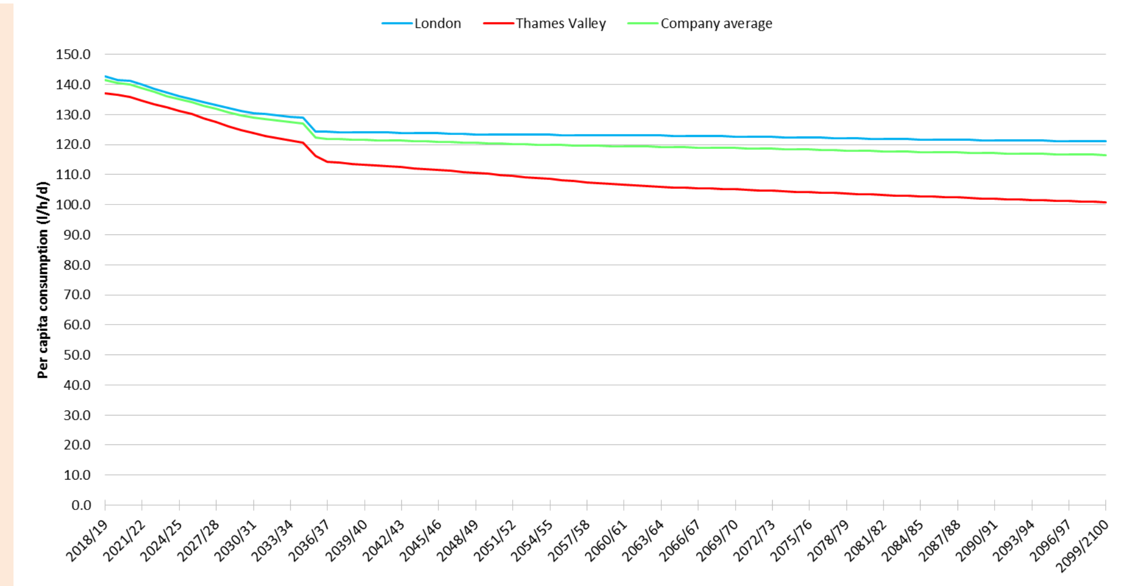
[17] H M Government 2018 A Green Future: Our 25 Year Plan to Improve the Environment

Figure 11-11: PCC for Thames Valley (DYAA)



11.161 The demand management programme in our revised draft plan brings about a reduction in DYAA per capita water use in London to 124 l/h/d at 2044/45, with further ongoing reductions thereafter to the end of the planning period, such that average household consumption is approximately 121 l/h/d. In Thames Valley, where consumption is more typical of that found elsewhere in England the equivalent figures are 112 l/h/d and 101 l/h/d, respectively. Average household consumption across our supply area is shown in Figure 11-12 with forecast regional consumption of 121 l/h/d in 2045 and 117 l/h/d at 2099. The figures shown are dry year consumption figures and consumption would be lower during a normal year.

Figure 11-12: DYAA household PCC – revised draft WRMP19 preferred plan



11.162 In Section 3: Current and future demand for water, we have explained that household PCC in London is higher than in the rest of our supply area due to the following four factors:

- The high proportion of rented properties with relatively fast turn over in tenancy means that households do not have the same incentive to invest in water efficient fixtures and fittings and associated reductions in water use
- The higher proportion of properties with complex supply arrangements means that inevitably there is a lower proportion of individual households paying for their water usage on a measured tariff
- The higher proportion of flats means that the opportunities for discretionary water use savings are lower in London than in the Thames Valley area, and in other parts of England and Wales
- There is a higher ethnic population in London whose cultural and religious beliefs result in higher water usage than in other sectors of the population

11.163 A higher PCC in London in comparison with the Thames Valley and other areas in the UK is therefore not unexpected. The extent of the London WRZ population as a proportion of the total Thames Water supply population is very significant. London's population comprises 77% of the total Thames Water population. This is much more significant than in any other water company.

11.164 Although the forecast reduction in water usage goes beyond the economic levels of demand reductions (SELDM), further potential reductions in PCC have been brought about through the implementation of punitive financial tariffs from 2035. This is in response to concerns raised by Ofwat that PCC in our draft WRMP19 was above the national average. However, our research to date has shown that customers do not consider that rising block tariffs are equitable, potentially unfairly penalising large households for what might be considered essential water use, and impacting adversely on water affordability for the poorest.

11.165 In WRMP14 we included an assumption in our plan that punitive financial tariffs could reduce consumption by 5%. This option has been included in our revised draft WRMP19 to address the concern voiced by Ofwat. A study by Reynaud (2015) has shown the estimated price elasticity of household water demand in 28 EU countries is negative[18]. The price elasticities typically vary between -0.5 and -0.1 across countries. Facing a price increase of 10%, Reynaud suggests it is expected that the household water consumption will be reduced by 1 to 5%. The elasticity in demand for water is shown to be narrow, such that very large changes in price would be required to secure a significant reduction in demand. The price that companies can charge for water is controlled by Ofwat and as such it is not a measure that is directly within our control to further reduce consumption. To impose such a tariff is therefore dependent on agreement with Ofwat. We welcome customers and stakeholders' views on the inclusion of such tariff types in our revised draft WRMP19.

11.166 Changes in the regulations applying to new appliances and buildings could also help to further reduce household consumption but again this is not something that is directly within a water company's control and requires legislative changes in Building Regulations.

11.167 If there is a concerted desire to see household consumption significantly reduced beyond the ambitious levels set out in our draft plan this will require proactive joint activity with regulators and Government to deliver such aspirations.

[18] Joint Research Centre Technical Reports Modelling Household Water Demand in Europe. Insights from a cross-country econometric analysis of EU-28 countries. Arnaud Reynaud 2015 EUR 27310 EN

11.168 We consider that it would be high risk to plan on these reductions being achieved without appropriate changes in legislation, in light of the significant uncertainty associated with timing of the impacts of climate change and the potential for earlier onset.

Leakage forecasts

11.169 In our preferred plan, we expect that leakage reductions are delivered across all our WRZs.

11.170 In London this is achieved through a combination of customer supply pipe leakage savings associated with roll out of our PMP, pressure management, mains replacement and mains rehabilitation. In addition, we have introduced a range of new tools in AMP6 to improve analysis of the supply-demand balance and thereby improve the efficiency and effectiveness of our leakage detection and repair activity. This includes tools for targeting mains replacement which we will continue to develop and enhance.

11.171 In Thames Valley the leakage reduction is exclusively achieved through customer supply pipe leakage savings associated with the roll out of our PMP. There is no leakage reduction planned to be achieved by mains replacement and pressure management in Thames Valley.

11.172 The difference between the baseline and final plan leakage forecast is shown in Figure 11-13 for London and Figure 11-14 for Thames Valley WRZs.

Figure 11-13: DYAA leakage forecast for London

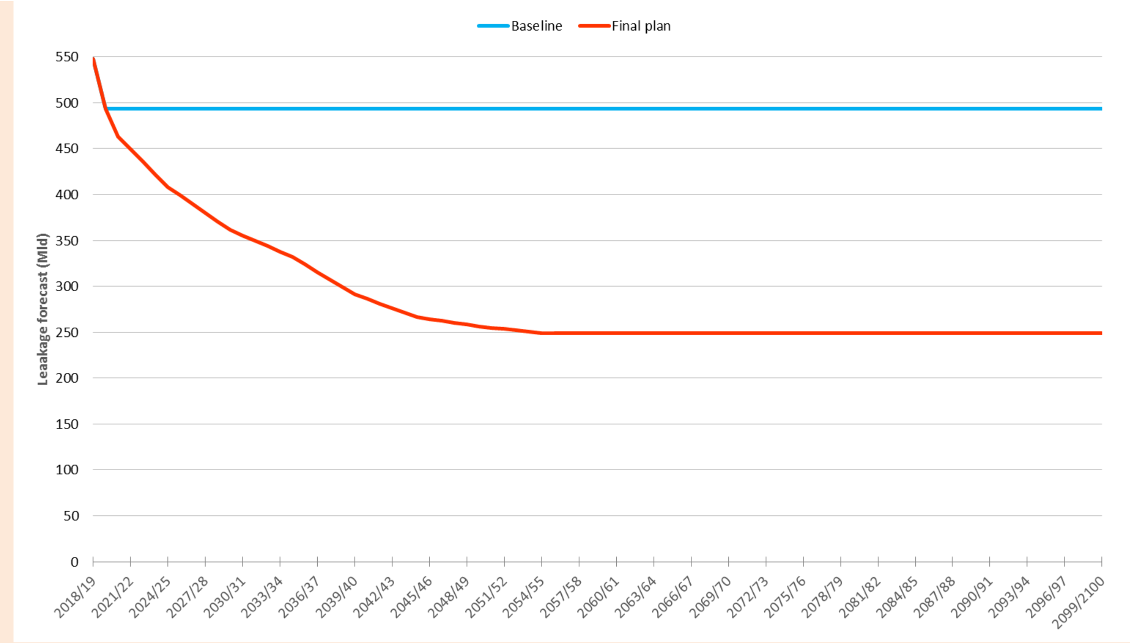
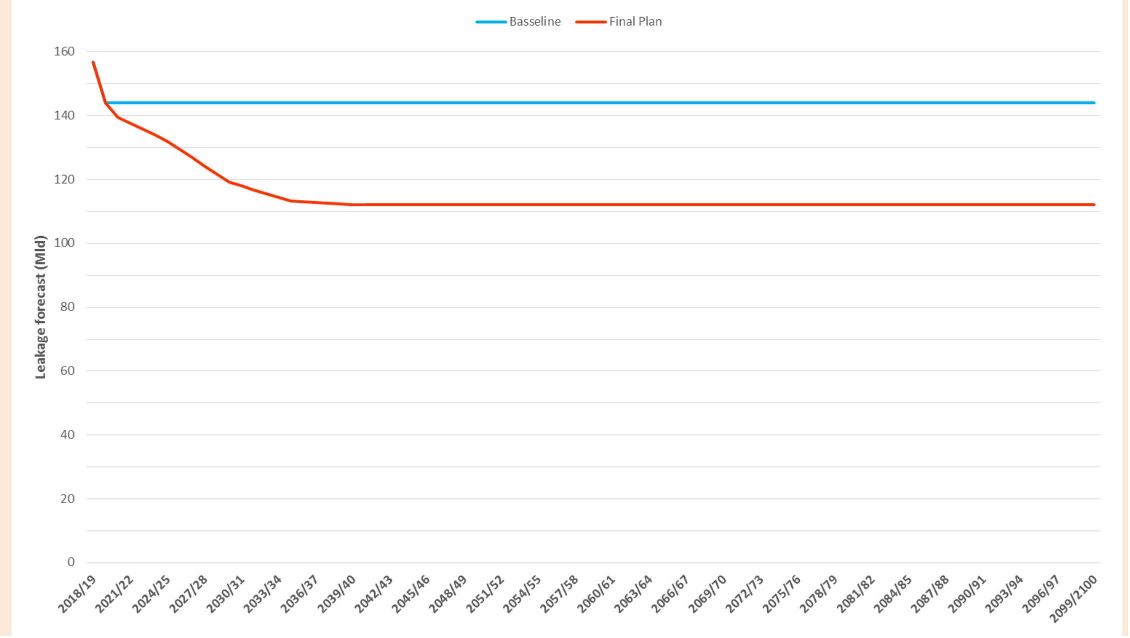


Figure 11-14: DYAA leakage forecast for Thames Valley WRZs



11.173 WRMP14 set out our ambition to reduce reported leakage by 108 Ml/d in the period to 2035, including 59 Ml/d of reduction by 2020. Our revised draft WRMP19 goes beyond this, with a reduction of 192.6 Ml/d by 2035, in addition to the 59 Ml/d already being delivered in AMP6, i.e. a total reduction of 252 Ml/d by 2035 in comparison to the target set in WRMP14. This reduction in leakage goes significantly beyond the sustainable economic level of leakage (SELL)[19].

11.174 The forecast leakage reduction in London at 2050 is 237 Ml/d, and 269 Ml/d for the Thames Water region as a whole. This represents a halving of leakage and aligns with the recommendations of the NIC, April 2018. It is also equates to the views expressed by our customers who considered a long-term leakage level of approximately 15% of water put into supply is appropriate.

11.175 Opportunities for large scale pressure management and leakage reduction due to find and fix activity have mostly been exhausted in our London WRZ and further leakage reduction will only be delivered through wholescale mains replacement. This has been demonstrated in the AMP4 period 2005-2010 when the company replaced approximately 2000km of distribution mains in London and secured a sustainable leakage reduction of 200 Ml/d. Mains replacement is, however, a very expensive option and inevitably causes disruption and inconvenience to customers while the work is undertaken. There is therefore a compromise to be drawn between continuing to reduce leakage in line with customer preference and the impact on customer bills and affordability and day-to-day inconvenience that the activity will create.

[19] Definition can be found on Ofwat's website at https://www.ofwat.gov.uk/households/supply-and-standards/leakage/

11.176 Ofwat and Government[20] have set out requirements for companies to deliver reductions in leakage of 15% by 2025, which for Thames Water equates to a reduction of almost 100 Ml/d in this period. This is a very ambitious target and has a high degree of risk associated with its delivery. We have set out our commitment to such a reduction.

11.177 In 2012 Thames Water and Ofwat jointly commissioned an independent review of the cost effectiveness of the mains replacement activity that the company had undertaken[21]. The findings of this review noted that there were benefits in linking mains replacement activity with the availability of household metering infrastructure to facilitate effective targeting of the activity. This is why we aim to deliver more than the 15% leakage reduction target over a longer time period which is aligned to the roll-out of our PMP.

11.178 We have no doubt that there will be further innovations in leakage detection activity and mains rehabilitation techniques which will facilitate further cost effective reductions in leakage beyond the levels set out in our WRMP19, but at this stage we have used the best information available to us to set out what we consider is a deliverable and best value programme. Furthermore, as we roll out our PMP we expect to find water currently reported as leakage is actually usage or wastage within customer properties, and consequently our leakage is likely to be lower than currently reported.

11.179 We consider that, currently, this approach is the optimum approach given the high cost of mains replacement and the uncertainties in reported leakage levels.

Metering forecasts

11.180 The household metering penetration for London and Thames Valley is shown in Figure 11-15 and Figure 11-16, respectively. In both graphs the effects of our PMP are evident.

11.181 In London the programme is expected to be completed by 2030 and 73% of individual households will have had a meter installed and be charged for their water use on a measured tariff. All property connections will be metered but given the large proportion of blocks of flats with complex plumbing arrangements it will not be economic or practical to meter all households on an individual basis. Metering these properties at the boundary will however enable detection and targeting of supply pipe leakage. Furthermore, measured consumption details at the total property level together with knowledge of the number of individual households will facilitate understanding of whether very high water usage is occurring and thereby facilitate targeting of water efficiency activity, including smart household water audits.

11.182 For London over 78% of household meter penetration (including voids) is subsequently achieved in the early 2050s and for the Thames Valley over 90% of individual household meter penetration (including voids) is achieved by 2040, together with the metering of all property connections. The ongoing increase in the percentage of meter penetration thereafter is due to all new properties being metered.

[20] H M Government 2018 A Green Future: Our 25 Year Plan to Improve the Environment
[21] Black & Veatch, ChandlerKBS, GL Water Thames Water Mains Replacement Programme Independent Review Findings and Recommendations Report July 2012

11.183 We expect the steady increase of household meter penetration will contribute to behavioural change and associated reductions in leakage and water usage. It will also facilitate the introduction of reward based incentive schemes and potentially punitive high usage tariffs, if required.

Figure 11-15: Household meter penetration for London WRZ

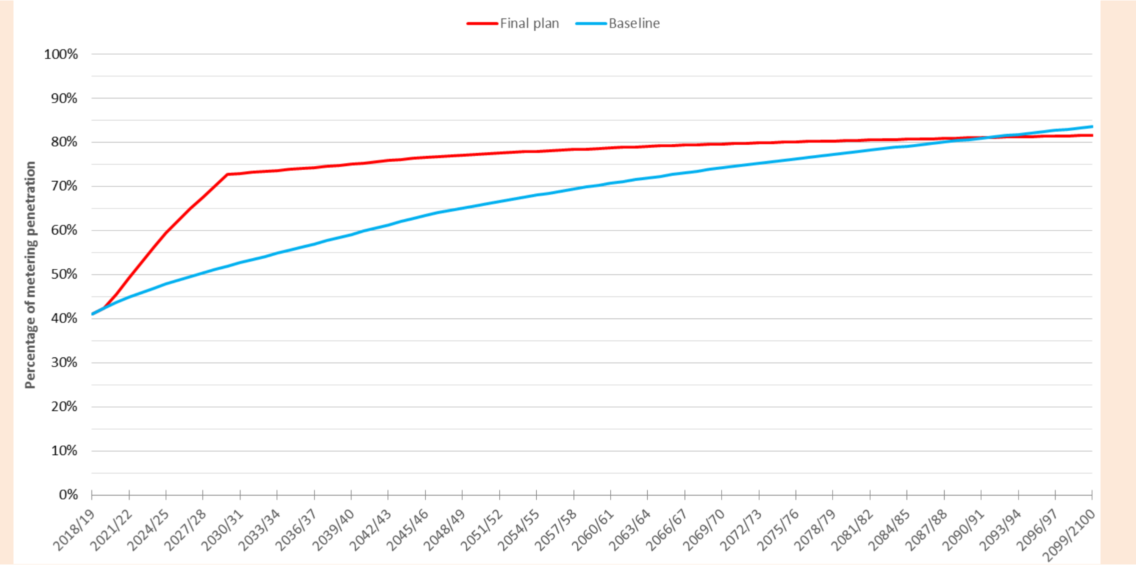
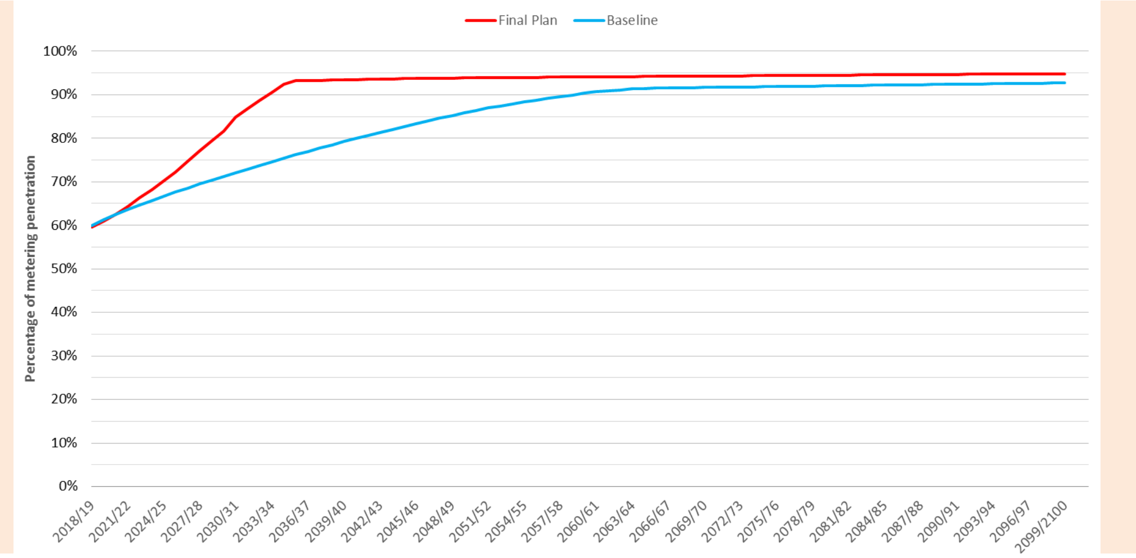


Figure 11-16: Household meter penetration for Thames Valley WRZs



Water efficiency forecasts

11.184 Water efficiency is a core component of the sustainable management of water resources. There are five categories of activity that make up our enhanced Water Efficiency Programme;

Smarter Home Visits, Smarter Business Visits, Wastage Fix ('leaky loos'), Housing Association Fix and Innovation.

11.185 The total water efficiency savings per AMP have been optimised based on our current water efficiency demand management options. However, we also recognised there was opportunity to be more ambitious with our customer usage reductions. Consequently, to enhance customer usage reductions, specifically in AMP7, we included further water efficiency activity in the form of innovation. This innovation is based on our work with other water companies through the Water Efficiency Network, our role within the UK Water Efficiency Strategy Steering and Leadership Groups, and our efforts during the 2018 ''heatwave'. Potential areas of demand reduction innovation to be considered could include; alternative water supply options for large irrigation users, innovative engagement through partner digital platforms, and working closely with Defra on water labelling.

11.186 Table 11-42 details the breakdown of our Water Efficiency programme activities and the associated usage savings expected each AMP. This shows that by the end of AMP12 a 99.5 Ml/d usage reduction will have been achieved. Beyond AMP12, we will continue to undertake water efficiency activity to maintain these benefits to 80 years.

Table 11-42: Water efficiency activity savings Ml/d (end of AMP)

Total water efficiency saving per year	AMP7	AMP8	AMP9	AMP10	AMP11	AMP12	AMP13 - AMP22
	2024/ 25	2029/ 30	2034/ 35	2039/ 40	2044/ 45	2045/49	2049 - 2099
London							**Benefit maintained**
Smarter Home Visits (Ml/d)	6.3	6.0	0.1	0.0	0.0	0.0	
Smarter Business Visit (Ml/d)	10.0	2.0	0.8	0.0	0.0	0.0	
Wastage Fix ('leaky loos') (Ml/d)	8.0	1.4	3.3	0.0	0.0	0.0	
Housing Association (Ml/d)	0.1	0.6	0.0	0.0	0.0	0.0	
Innovation (Ml/d)	0.5	8.1	12.7	5.0	5.0	5.0	
Total London Benefits (Ml/d)	**24.8**	**18.1**	**16.9**	**5.0**	**5.0**	**5.0**	
Thames Valley					**Benefit maintained**		
Smarter Home Visits (Ml/d)	1.3	1.7	1.1	0.2	0.0	0.0	
Smarter Business Visit (Ml/d)	2.2	1.4	0.0	0.0	0.0	0.0	
Wastage Fix ('leaky loos') (Ml/d)	1.4	2.0	3.4	1.9	0.0	0.0	
Housing Association (Ml/d)	0.0	0.0	0.0	0.0	0.0	0.0	
Innovation (Ml/d)	4.4	2.5	1.2	0.0	0.0	0.0	
Total Thames Valley Benefits (Ml/d)	**9.3**	**7.6**	**5.7**	**2.1**	**0.0**	**0.0**	
Total Company Benefits (Ml/d)	**34.1**	**25.7**	**22.6**	**7.1**	**5.0**	**5.0**	**Benefit maintained**

J. Environmental assessment of the preferred plan

11.187 We have carried out extensive and comprehensive environmental assessment of all of the Constrained List option elements and of the alternative options and programmes considered in the subsequent programme appraisal process. We have developed scheme design, mitigation measures and investigated environmental effects at an unprecedented level of detail for a strategic plan, recognising the scale of the investment necessary to address a very substantial supply deficit over the next 80 years. For the larger schemes, we have carried out detailed strategic level investigations of environmental effects which we have used to develop mitigation packages to minimise adverse effects on the environment.

11.188 As we have increased our level of investigation and consulted widely with regulators and stakeholders, we have, inevitably, identified issues that were not foreseen at the initial option screening stage. In the majority of cases, we have addressed identified substantive concerns through further iteration of the scheme design and/or mitigation measures such that the residual adverse effects are reduced to acceptable levels. Through this detailed approach to addressing environmental effects, our SEA, HRA and WFD assessments indicate that, despite the scale of new resource schemes required, our revised draft WRMP19 has overall minor to moderate adverse effects and minor to moderate beneficial effects on the environment and society. Details of these assessments can be found in Appendix B: SEA environmental report, Appendix C: HRA – stage 1 screening and Appendix BB: WFD.

11.189 Our preferred plan is compliant with the Habitats Directive and associated Habitats Regulations with the application of appropriate mitigation measures. We will continue to work with Natural England to ensure we protect, and where possible enhance, European sites as we implement our plan.

11.190 We have also considered the cumulative effects of the preferred plan, including effects with our revised draft Drought Plan 2018, other water companies, Thames river basin management, land use and development, and other infrastructure plans. Both beneficial and adverse effects have been found arising from temporary construction and operational activity. These have been described in Appendix B: SEA environmental report.

11.191 Consideration of potential environmental impacts at an early stage and, where necessary, development of suitable mitigation packages has resulted in the schemes in our preferred plan being considered compliant with the objectives of the WFD. Mitigation measures may be necessary to be implemented in the form of additional flow augmentation support and/or abstraction licence controls to avoid WFD deterioration risks in respect of the Epsom groundwater option once more detailed investigations of the effects of increasing abstraction within existing licence limits are completed in dialogue with the Environment Agency.

11.192 We have examined reasonable alternative programmes to the preferred plan as described in Section 10: Programme appraisal and scenario analysis.

11.193 The water management schemes within the preferred plans for Kennet Valley, Guildford and Henley WRZs have been subject to the same environmental and social assessment process as set out for the preferred programme for London, SWA and SWOX.

11.194 The environmental and social adverse and beneficial effects are broadly negligible and minor in nature for the additional demand management options for each of the three WRZs. Beneficial effects are mainly of a minor magnitude.

11.195 The groundwater schemes at Dapdune and Ladymeads water treatment works (removal of constraints), has mostly negligible to minor beneficial effects. Adverse effects of these groundwater options are mainly negligible or minor in magnitude.

11.196 There are cumulative major beneficial effects for the Demand Management Programmes in relation to these measures acting in combination achieving a major scale of demand savings across the Thames Water supply area and, thereby, contributing to sustainable water management. The cumulative benefits will help reduce growth in demand for water and growth in energy use for water pumping and treatment.

11.197 In conclusion, the schemes forming the preferred plan for Kennet Valley, Guildford and Henley WRZs are compliant with Habitats Regulations and with WFD objectives. Overall, the environmental and social effects of this plan for Kennet Valley, Guildford and Henley WRZs are predominately of a minor to moderate significance (both adverse and beneficial effects). .

11.198 Overall, through detailed environmental investigations we have developed a comprehensive plan that delivers reliable, resilient water supplies to our customers over the long term. Overall, the environmental and social effects of the preferred plan are predominately of minor to moderate significance (both adverse and beneficial effects). Whilst some major adverse effects have been identified, which is to be expected given the scale of the schemes necessary to address a very large supply deficit, many of these major effects are temporary in nature and largely unavoidable while construction works take place. Where some of the major effects are related to extended construction periods over a number of years we would consider whether further additional mitigation measures can be applied to reduce the identified effects in dialogue with regulators, planners, stakeholders and any local communities affected. Opportunities have also been identified for beneficial effects and we will look to see where we can further enhance these benefits as we implement our plan over the coming years.

K. Greenhouse gas emissions and carbon accounting

11.199 As a part of the Annual Return process, we produce an estimate for the emission of greenhouse gases from our water supply activity. The operational carbon calculation for the year 2016/17 uses the revised UKWIR (2016/17) Carbon Accounting Workbook version 11 and the associated guidance document. This is the methodology supported by Ofwat for reporting operational greenhouse gases. The 2016/17 reported emissions per Ml/d of water supplied are 0.230 tonnes of CO_2e/Ml/d.

11.200 By applying the resultant 0.230 tonnes of CO_2e/Ml/d to the baseline and final planning forecasts, a long-term trend can be produced, Figure 11-17.

11.201 For the DYAA scenario in the base year, 2016/17, our estimate is 226,001 tCO_2e. Under the baseline scenario demand continues to increase across the forecast period, primarily due to population growth, resulting in an emissions estimate of 248,479 tCO_2e in the final year of the plan, 2099/100, 22,477 tCO_2e higher than in the base year.

11.202 The reductions in demand, forecast as a result of the integrated demand management programme, contained within the final plan gives a final emissions figure of 207,622 tCO2e which is a reduction of 40,857 tCO2e compared to the forecast baseline in 2099/100.

11.203 The greenhouse gas impact of supply options has been incorporated into option appraisal (see Section 10: Programme appraisal) and has formed part of the consideration of delivering a balanced plan. The cost associated with the carbon equivalent greenhouse gas impact (tCO2e), across the planning period has been presented in Table 11-43. The carbon costs associated with other feasible options and preferred options can also be found in Table 5 of each WRZ, see Appendix A: dWRMP19 planning tables.

Figure 11-17: Greenhouse gas emissions tCO2e – 2016 to 2100

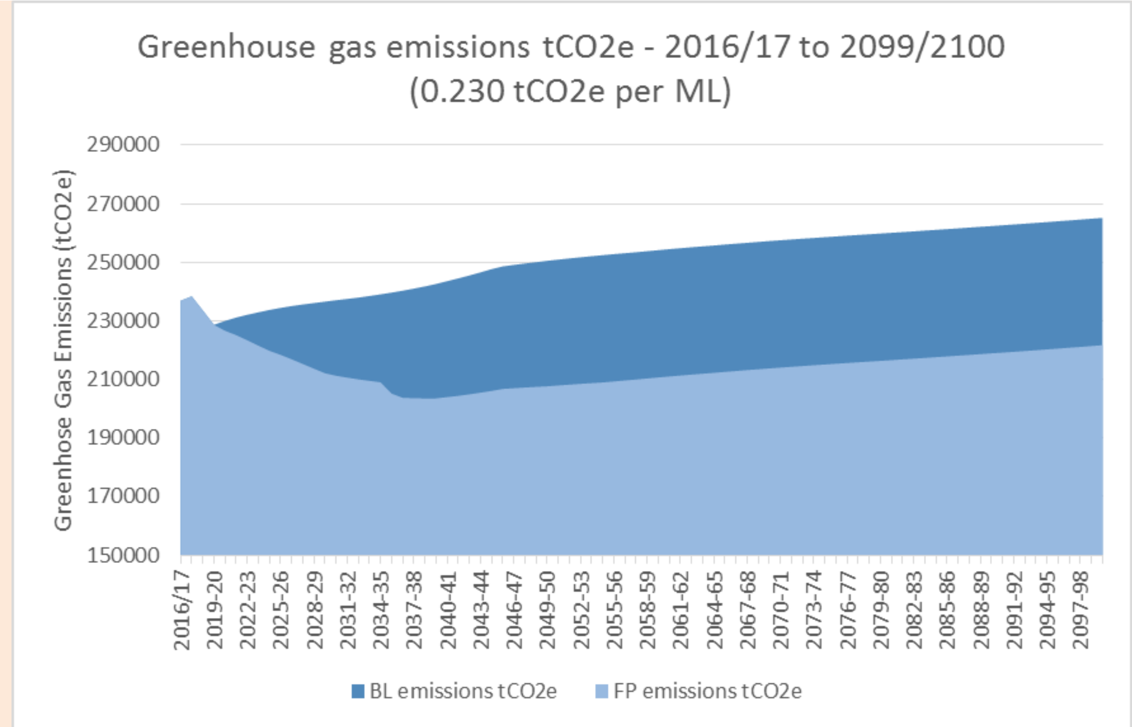


Table 11-43: GHG Impact of Supply and Demand Options tCO2e across planning period

Options	Carbon Impact Across Planning Period (tCO2e)
AR_Kidbrooke (SLARS1)	15,837
AR_Merton (SLARS3)	5,020
ASR_Horton Kirby	8,429
ASR_South East London (Addington)	9,372
DMP_GUI_Sprint4a	96,345
DMP_HEN_Sprint4a	2,770
DMP_KEN_Sprint4a	90,501
DMP_LON_S4a	1,781,416
DMP_SWA_S4a	81,935
DMP_SWX_S4a	113,235
GW_Addington	326
GW_Dapdune	1,862
GW_Datchet	7,905
GW_Merton	16,520
GW_Southfleet/Greenhithe	2,615
IPR_Deephams 45	132,111
IZT_R Thames to Medmenham	6,997
NTC_Dapdune	1,981
NTC_Epsom	646
NTC_Ladymead	1,686
NTC_New River Head	7,395
RES_Abingdon 150 Mm3	30,164
RWP_Chingford (E&S)	Included within DMP
RWP_Didcot	Included within DMP
RWP_Oxford Canal to Cropredy	21,970
RWP_STT Mythe	-*
RWP_STT Netheridge	-*
RWP_STT UU/ST Opt B	-*
RWP_STT Vyrnwy 60	-*
CON_Deerhurst to Culham 300	214,539
IZT_R Thames to Medmenham	26,862

** GHG data was not provided by donor companies*

11.204 The values in Table 11-43 have been taken from EBSD+ modelling outputs. These values provide total carbon impacts of each of the supply and demand options, including operational carbon at expected utilisation across the 80 year planning period.

L. Summary

11.205 This section has presented our preferred plan for the period of 2020 to 2100.

11.206 We have conducted a sophisticated programme appraisal process in Section 10: Programme appraisal, which has led to the identification of the preferred plan following a step-by-step iterative approach taking account of and applying relevant water supply/demand metrics whilst maintaining a holistic view of the efficient and economical system of water supply in our area that we are required to provide.

Our preferred plan for London, SWOX and SWA

11.207 During programme appraisal we have derived our preferred plan for London, SWOX and SWA as a combined zone due to the complexity of the supply demand challenge in these three zones.

11.208 Our strategy, as provided for in the preferred plan, is to combine demand management with resource scheme development to secure long-term resilience to drought based on best-value delivery of water services to our customers. The plan elements are listed below:

- Start implementing a reward based incentive scheme, accompanied by our PMP and enhanced water efficiency activity to reduce customer usage. With widespread household meter penetration, implement an incentive based financial tariff in 2035 to further reduce household consumption.
- Undertake significant mains replacement and other leakage control activity to reduce leakage.
- Implement a combination of groundwater development, wastewater reuse and raw water transfer schemes in 2030 to facilitate increased resilience to severe drought events, followed by the SESRO in 2037 and the supported Severn Thames Transfer from 2083 to provide sufficient resilience against increasing demand and forecast reductions in water available for use. There are also third party water trading schemes in London WRZ and the development of small scale groundwater schemes in the London and SWA WRZs.

11.209 A growing deficit is observed in the SWA WRZ from the mid-2030s but there are insufficient local resource schemes to resolve the issue within the zone itself. Additional raw water is required to be transported into the WRZ from a strategic water supply scheme located in the west of the River Thames catchment.

11.210 Likewise, London is facing significant challenges from population growth, decreasing water availability due to the impacts climate change, increasing south east regional demand and potential environmental requirements linked to the achievement of WFD objectives. There is no single large-scale resource scheme that can provide sufficient resilience for London and the south east in the long-term and our preferred programme is a combination of demand management measures and new water resource schemes.

11.211 The preferred plan delivers the WRSE water resource requirements of Affinity Water.

Our preferred plan for Guildford, Kennet Valley and Henley

11.212 Continue to focus on demand management through roll out of our PMP to deliver benefit of increased resilience against population growth and reductions in water availability due to climate change.

11.213 Start implementing an incentive based financial tariff scheme together with enhanced water efficiency activity to reduce customer usage.

11.214 Removal of the network constraint at Ladymeads allows an extra 4.6 Ml/d supply to Guildford WRZ as early as 2024 to resolve the increasing short-term deficit due to population growth.

11.215 In the Kennet Valley WRZ, implement our progressive metering policy from 2030 to maintain security of supply resilience in the long-term.

11.216 Investment in Henley WRZ is minimal due to the supply surplus observed. However, the roll out of our PMP is extended to this zone to ensure that there is a consistent and equitable policy across Thames Water's supply area that customers pay for their water usage on a measured tariff. Furthermore, the demand management programme promotes water usage reduction which helps to improve resilience against extreme weather events such as drought.

11.217 In conclusion, we have selected our preferred plan by examining a wide-range of factors, including financial, environmental and social impacts, resilience to drought, customer preference and deliverability. A series of scenario tests and performance stress testing have been undertaken to demonstrate that the plan is robust and adaptable and that the proposed investment represents no regrets, best value investment that is consistently selected under a wide variety of different and uncertain futures. By these means we consider that our revised draft WRMP19 preferred plan is consistent with an adaptive pathways approach to long term best value water resource management decision making.