Section 10

Programme appraisal and scenario testing

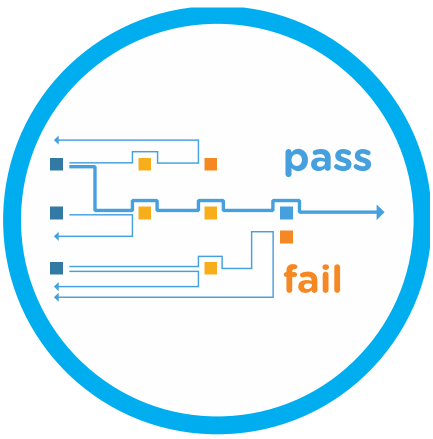


Table of contents

Figures

Tables

Section 10.

Programme appraisal and scenario testing

Changes since the revised draft WRMP19 (rdWRMP19):

We have further updated this section based on feedback from our consultation on the rdWRMP19 and the further information request received from Defra in December 2019.

We have added an Overview section (A) for those readers requiring only a summary of the key messages.

We have also added an additional methodological section (D) to clarify the methods and tools we've used in programme appraisal and how they fit together.

Our preferred programme of options remains unchanged. However, we have added further explanation where requested including:

- Adaptive planning
- Metric generation and interpretation
- How the metrics have informed decision making
- Identification of the alternative programmes
- Demand management programmes (DMPs)
- Option uncertainty
- The role of system simulation modelling (IRAS_MCS)
- Performance testing – Adaptability assessment
- Performance testing – What if analysis
- Impact of performance testing on the preferred plan
- Selecting the preferred programme
- The sensitivity of the preferred programme
- Reduction of abstraction from vulnerable chalk streams and water courses

We have clarified our selection of the preferred programme by putting our assessment in a wider adaptive planning context. We have taken the key delivery points identified over the planning period (2030, 2037/38 and 2080s) and included a decision tree approach to help explain the choice of options available at those times and why we have made a particular choice.

Over the planning period to 2100 it is likely that two or three strategic options will be required. One will not be enough, even after the completion of the DMP.

Importantly, we explain that the immediate investment decisions supported by this plan relate to the ramp up of leakage reduction and demand management activity and an increase in pre-planning investigations to better inform a decision in 2022/23 as to which strategic options (the South East Strategic Reservoir Option (SESRO), Severn-Thames Transfer (STT) and Indirect Potable Re-use (IPR)) should be delivered thereafter.

A. Overview

Changes since the rdWRMP19:

- This is a new section

10.1 In this section we set out our programme appraisal for each of our WRZs.

10.2 Programme appraisal is the process by which we seek to address and resolve the supply and demand problems identified in Section 6, by appraising combinations of water management options detailed in Sections 7-9.

10.3 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, their comments and feedback.

10.4 We have also sought peer review by sharing our analysis and decision making with a panel of industry experts.

10.5 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[1] and our customers[2], to develop best value[3] plans which take account of a wider range of factors over the longer-term. These factors include the environmental impacts of programmes, resilience to drought and other outage events, the needs of other water users and future generations, and customer water management preferences, in addition to cost.

10.6 Accordingly, we have worked with other water companies and industry regulators to develop a more advanced, risk-based decision making framework and have applied this in developing our revised rdWRMP19.

10.7 EBSD+[4] is now our primary programme development model. It is a multi-metric aggregated model that can optimise against a range of metrics to search for best value programmes of investment. It is a development of the least cost EBSD model used for WRMP14.

10.8 In parallel, we have developed a system simulation model (IRAS_MCS[5]) of the Thames and Severn catchments to help us solve the final supply-demand problem in relation to a wide range of potential drought scenarios developed from a stochastic drought library. This model is used as a support tool for performance testing EBSD+ programme outputs.

10.9 We have adopted a risk-based approach to programme appraisal consistent with industry guidance and used advanced modelling techniques in areas characterised as high risk.

10.10 Multiple potential programmes of options able to solve the baseline planning problem were identified and tested using our models. We have then repeated the analysis for two alternative

[1] Technical Stakeholder Meetings, March 2016 and November 2016
[2] Customer research, Britain Thinks, September 2016
[3] WRPG (July 2018) Section 6
[4] Economics of Balancing Supply and Demand
[5] Interactive River-Aquifer Simulation – Multiple Criteria Search

scenarios. Firstly, reflecting a greater resilience position to drought for our customers and secondly, providing greater resilience to drought and additionally, to support transfers to neighbouring companies in the south east of England.

10.11 It is the latter scenario, providing greater resilience to drought (to the Environment Agency's suggested reference level of 1:200 years (0.5% per annum) risk of failure to meet demand) and supporting best value planning for water supply/demand across the whole of south east England), that has been adopted as our preferred planning scenario.

10.12 A shortlist of six potential reasonable alternative programmes (RAPs), were identified based on cost, resilience and in order to maintain a mix of option types. These were then performance tested for their adaptability and robustness to future uncertainties. This exercise has included:

- Consideration of option uncertainty (as Final Planning headroom)
- Adaptability analysis
- 'What if' analysis
- System simulation modelling (drought resilience)
- Strategic Environmental Assessment (SEA)
- Local resilience and practicality checks

10.13 Having completed the performance testing we used an adaptive planning approach and expert judgement to propose a best value preferred programme of demand management and resource development interventions to solve the water supply demand planning problem identified.

10.14 In defining the preferred programme for our London, SWOX and SWA WRZs, we have identified a plan which facilitates synergies between them and also with other water suppliers in the south east of England.

10.15 We have also adopted this approach in defining the plans for the other WRZs, Henley, Guildford and Kennet Valley, thereby delivering a consistent messaging to all our customers.

10.16 Our overall preferred best value programme is (as previously) one that addresses and resolves the baseline supply demand problem expected to arise over the 80 year planning period from 2020-2100, allows for an enhancement in system resilience to a 1 in 200 year drought (by 2030) and enables sharing of water resources with neighbouring companies and other sectors to meet regional needs across the south east of England.

10.17 The proposed plan will also enable us to make changes to our abstractions to improve chalk stream ecosystems and other vulnerable water courses in our supply area, including the Wandle, Wye and Cray as well as the Lee (at Amwell Magna) and Thames (around Oxford).

10.18 Our first priority is to reduce waste of water resources. This being so, our preferred programme is demand management focussed in the short-medium-term, comprising an integrated package including significant reductions in leakage (15% in AMP7 (from our end of AMP6 target of 606 Ml/d) and 50% by 2050, in Ml/d terms), the metering of all water supply connections and an enhanced water efficiency programme to encourage reduced consumption by all, subject to affordability and the needs of vulnerable customers.

10.19 DMPs will be undertaken in all WRZs in the period from 2020 to 2050 with the goal of maintaining the savings to the end of the planning period.

10.20 Demand management on its own will not be enough to resolve all supply demand deficits, especially in the London WRZ. A twin track approach with resource development is required in order to maintain sufficient supplies to meet managed demand across the region, consistent with our general duty to develop and maintain an efficient and economical system of water supply.

10.21 We have planned accordingly, supplementing the proposed DMP with strategic water resource development at key points in the planning period to 2030 (driven by the need to increase drought resilience), to 2037 (driven by regional need for water resources) and the 2080s (to maintain security of supply in the long-term).

10.22 Our modelling has indicated that the leading strategic resource options best able to enable us to do so are:

- Indirect Potable Re-use (IPR) (at Deephams, Beckton or in West London)
- A strategic reservoir development (the South East Strategic Reservoir Option, SESRO)
- A Severn-Thames transfer (STT)

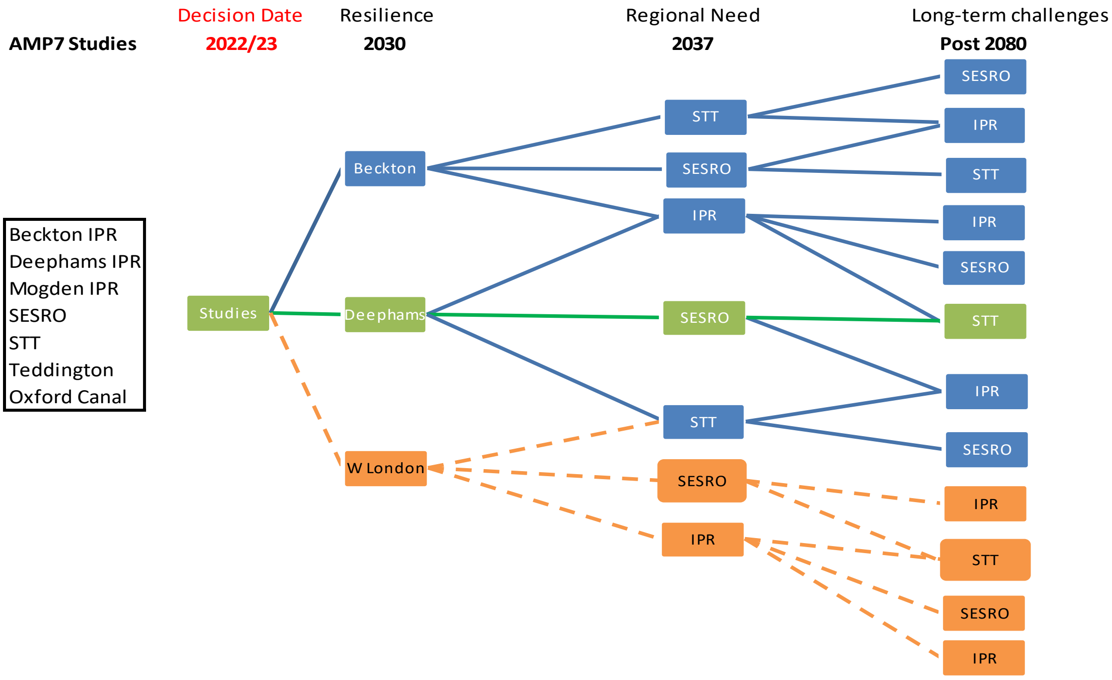
10.23 Desalination is discounted as inferior on cost and environmental grounds, compared with the available re-use options.

10.24 Re-use is the leading option type able to be constructed in time to meet the need to improve drought resilience by 2030, The decision is whether to build a single larger plant at Beckton, or a smaller plant at Deephams, supported by smaller innovative groundwater schemes, smaller regional trades and transfers.

10.25 Following the rejection of the Teddington Direct River Abstraction (DRA) option from our dWRMP19, in future plans we will also consider the feasibility of alternative options to use treated effluent from Mogden Wastewater Treatment Works in West London.

10.26 We have developed an option delivery tree (Figure 10-1), to help visualise the potential pathways. The preferred pathway will be informed by the ongoing investigation of the feasible options in AMP7, with a decision to confirm the timing and characteristics of the preferred investment programme in 2022/23.

Figure 10-1: Option delivery tree



Green = Preferred path; Blue = Alternative paths; Orange = Paths not currently feasible

10.27 Table 10-1 sets out the major scheme delivery points over the 80-year planning period from 2020 to 2100 and the drivers for determining the preferred investment programme.

Table 10-1: Major scheme delivery points over the planning period

From 2020	
Demand Management Focus	In the next five years, and continuing to 2050, we intend to undertake a substantial and ambitious DMP. We believe this is the right thing to do for future generations and aligns with the expectations of our customers, regulators and stakeholders.
2030	
Providing 1:200 year drought resilience (risk of insufficient supplies to meet demand of 0.5% per annum)	Providing 1:200 year drought resilience by 2030 will require new 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 wastewater reuse plant. We currently 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.

<table>
<tr><th colspan="2">2037/38</th></tr>
<tr><td>Regional need</td><td>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 needs and the management of uncertainty
The option is most regularly chosen across RAPs, adaptability, What if analysis and IRAS-MCS system simulation modelling
It maximises the capture and storage of water resources already available in the Thames Basin
Extra storage provides flexibility and resilience benefits
It is the option preferred by our customers and provides recreational and biodiversity benefits
Delivering this option will provide sufficient headroom to enable us to cost effectively deliver a series of environmental improvements to vulnerable chalk streams and watercourses through the reduction and re-location of abstraction sites. This responds to a number of stakeholder concerns raised during the consultation process.</td></tr>
<tr><th colspan="2">Long-term (beyond 2080)</th></tr>
<tr><td>Managing potential long-term changes</td><td>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:
Meeting the potential future need in the west of the Thames catchment, namely:
Greater need for regional transfers e.g. to meet Southern Water requirements in Hampshire
The uncertainty of the ongoing yield of the West Berkshire Groundwater Scheme
The possibility of further sustainability reductions being needed at environmentally sensitive sources
Increased demand for water supplies in the Cambridge, Milton Keynes Oxford growth corridor (CaMKOx)
SESRO and the Severn-Thames Transfer are regularly selected by system simulation modelling at higher drought return periods, e.g. in 1:500 year (0.2% per annum) extreme drought resilience.
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.
The timing of the need is determined by resilience and growth requirements. Enhancements in either would bring the scheme forwards. Adaptive planning enables appropriate decision making.</td></tr>
</table>

10.28 It is apparent that in order to meet the future supply demand challenges in the London, SWOX and SWA WRZs and to make our contribution to similar challenges at a regional level, multiple strategic options will be required. It is no longer a question of which single option is best; it's which option is needed when.

10.29 On the basis of current information, we favour IPR (at Deephams) and a set of smaller schemes to meet our needs by 2030; SESRO, to meet regional needs by 2037 and the STT by the 2080s, to maintain resilience in the longer-term.

10.30 Having an adaptive planning approach enables us to vary our plan as we proceed, taking account of changing circumstances, information and options. Further information on how our plan could change is provided in Section 11.

10.31 We recognise concerns raised by stakeholders regarding the likelihood of achieving our planned leakage reductions by 2020 and the ambitious further reductions from demand management built into the preferred programme in AMP7 and out to 2050.

10.32 We will be able to track our progress and report the impact of deviation from the forecast in our Annual Returns and our annual reviews to the Environment Agency. Our monitoring plan is set out in Section 11.

10.33 If the supply demand situation improves before 2030, we can defer or cancel construction of some of the smaller options in our preferred programme. If Deephams reuse or the Oxford Canal transfer was not available, or if the supply demand situation turns out to be worse than currently forecast, we would need to implement a larger re-use option at Beckton (or potentially in West London from the Mogden catchment). Our adaptive planning approach provides confidence that we will be able to plan and implement appropriate actions on a dynamic basis, with efficiency and reliability gains.

10.34 We intend to complete further studies and pre-planning on both reuse options (and similar options in West London) in AMP7, ready for implementation in 2030.

10.35 A preferred programme featuring the construction of the SESRO before a STT is supported by Affinity Water. The STT in isolation would not provide a resilient solution for Affinity Water and is more expensive. This position is supported by Water Resources in the South East Group (WRSE) too.

10.36 However, the final decision on which option is needed in 2037 need not be made now. We have a performance commitment to undertake further work on the SESRO, the STT and other strategic schemes in AMP7, to complete studies and to confirm option designs.

10.37 We have an adaptive plan that allows the **definitive decision on which strategic schemes to develop in 2030 and 2037 to be made in 2022/23,** in alignment with Affinity Water, Anglian Water, Southern Water, Severn Trent Water, United Utilities and regional-level WRMPs (including from WRSE) will also be available then, to better inform the decision making process by ourselves and others.

10.38 The immediate investment decisions (in the AMP7 period, from 2020-25) supported by this plan are therefore the ramp up of leakage reduction and demand management activity, and an increase in pre-planning activity on the key strategic options (on the SESRO, the Severn-Thames transfer and Re-use in London).

B. Introduction

Changes since the rdWRMP19:

- The introduction has been simplified to give details of the structure of the remainder of the section.

10.40 In this section we introduce our programme appraisal for each WRZ.

10.41 Programme appraisal is the process by which we seek to address and resolve the supply and demand problems identified in Section 6, by appraising combinations of water management options detailed in Sections 7-9.

10.42 We have followed a structured programme appraisal process to select our preferred programme, which has been reviewed and assessed by a panel of industry experts. The appraisal method, decision support tools (DSTs), results and conclusions are described in the following sections:

C. **Understanding the planning problem** describes how the most appropriate assessment methods and planning periods were identified for the problems faced by the different WRZs

D. **Developing assessment methods and metrics** describes which assessment methods were selected and developed into DSTs

E. **Identifying and assessing demand/supply programmes** describes how DSTs are used and outputs compared and assessed for programme appraisal for a single scenario.

F. **Programme appraisal: Section structure** describes the range of programme development and appraisal carried out for different scenarios for each WRZ.

G. **Programme appraisal: London, SWA, SWOX** describes the output programmes, appraisal, performance testing and selection for the three WRZs of higher concern.

H. **Programme appraisal: Kennet Valley** describes the output programmes, appraisal, performance testing and selection for Kennet Valley WRZ.

I. **Programme appraisal: Guildford** describes the output programmes, appraisal, performance testing and selection for Guildford WRZ

J. **Programme appraisal: Henley** describes the output programmes, appraisal, performance testing and selection for Henley WRZ

K. **Preferred programme summary** pulls together the conclusions from Sections F-J.

10.43 Further information on Methods can be found in Appendix W. Appendix X contains Outputs from the programme appraisal. The Expert Panel report is in Appendix Y.

C. Understanding the planning problem

Changes since the rdWRMP19:

The assessment methods sub-section has been updated to clarify:

- The development of our DSTs since WRMP14.
- Which DSTs we have used in programme appraisal.
- Where in the process each DST has been used.

Approach

10.44 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.

10.45 UKWIR's WRMP 2019 Methods – Decision Making Process: Guidance[6] 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.

10.46 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[7,8].

10.47 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[9] 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.

[6] UK Water Industry Research WRMP 2019 Methods – Decision Making Process: Guidance Report Ref. No. 16/WR/02/10
[7] Environment Agency and Natural Resources Wales, Water Resources Planning Guideline: Interim Update July 2018
[8] Defra, Guiding principles for water resources planning: For water companies operating wholly or mainly in England, May 2016
[9] NERA, What is the Appropriate Horizon for Integrated Water Resource Planning?, November 2016

Problem characterisation

10.48 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 10-2 to Table 10-5. Our detailed consideration of each question is provided in Appendix W.

10.49 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 10-2: Problem characterisation - strategic risk

How big is the problem?				
	Strategic WRMP Risks (Score 0-2 each)			
WRZ	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 10-3: Problem characterisation - supply complexity

How complex is it to solve? (1)					
WRZ	Supply Side Complexity (Score 0-2 each)				
	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 10-4: Problem characterisation - demand complexity

How complex is it to solve? (2)				
WRZ	Demand Side Complexity (Score 0-2 each)			
	Changes in current or near-term demand	Forecast uncertainty	Demand versus critical drought timing	**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 10-5: Problem characterisation - investment complexity

How complex is it to solve? (3)					
WRZ	Investment Programme Complexity (Score 0-2 each)				
	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**

10.50 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 10-6.

Table 10-6: 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

10.51 This analysis demonstrates that the London and SWOX WRZs have a water resource planning problem of high concern. The SWA WRZ has a moderate level of concern, while the remaining zones have planning problems of low concern.

Planning period

10.52 *"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).

10.53 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.

10.54 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 states 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.

10.55 In order to assess the correct planning period for a complex demand/supply problem, NERA advocates 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 10-7 from 25 to 100 years. The appropriate planning period can be selected from the range showing the highest score for each zone.

Table 10-7: Summary of scoring for extending planning period assessment

Is the current planning period appropriate?																	
WRZ	Potential planning period (years)																Appropriate period
	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	
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

10.56 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.

10.57 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.

10.58 We have demonstrated the impact of choosing an alternative, shorter planning period as a part of 'What if' testing, see Appendix X.

10.59 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

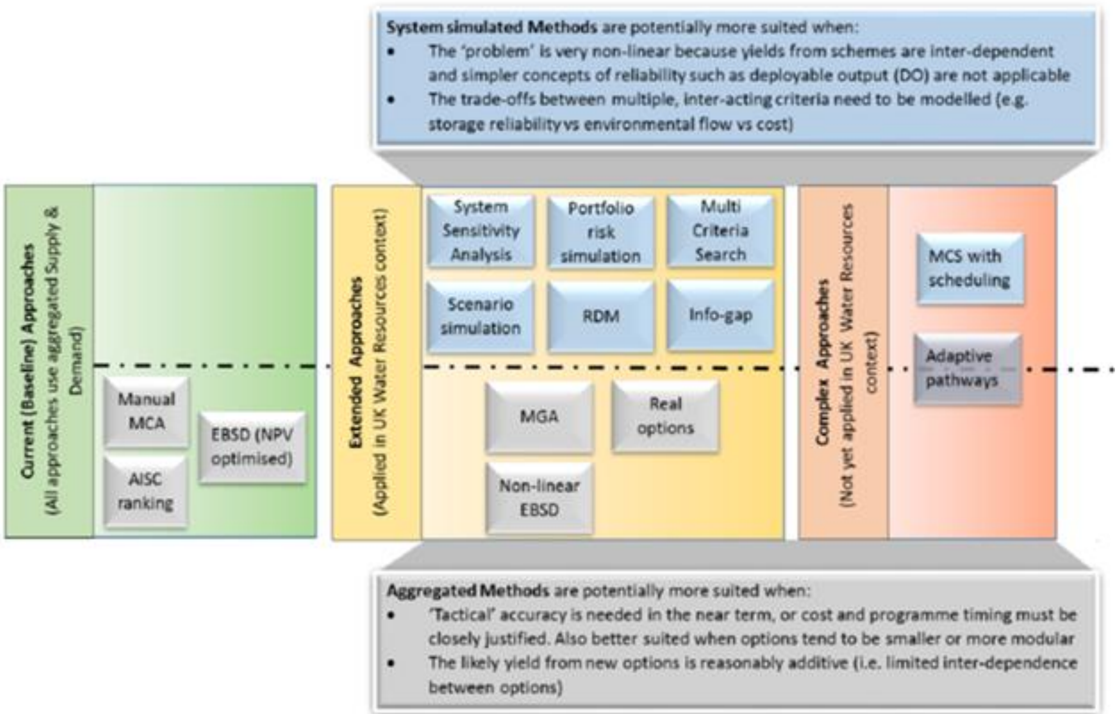
10.60 While problem characterisation should be carried out at WRZ level, the problems apparent in one zone may well be transferred to another and, accordingly, selected supply/demand planning methods for connected or potentially connected neighbouring zones should ideally be as closely aligned as possible 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 WRSE group, which also collaborates with Water Resources East (WRE) to tackle the demand/supply water resource issue across the whole south east region. Our WRMP19 is a fully integrated part of the WRSE regional plan for the south east.

Assessment methods

10.61 There are a wide range of DSTs available to facilitate programme appraisal, from simple to more advanced tools which support a more detailed analysis of the supply demand planning problem and solutions to it.

10.62 The problem characterisation matrices (Table 10-2 to Table 10-6) demonstrate that both size of the supply demand imbalance and the controversial nature of some of the solutions available in the London, SWOX and SWA WRZs mean that least cost optimisation alone is no longer appropriate. 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 10-2, which is colour coded to match the problem characterisation matrix (Table 10-6).

Figure 10-2: Decision making methods and tools for problems of different complexity



Source: UKWIR WRMP 2019 Methods

10.63 Rather than rely solely on one method and model output, we have developed two DSTs, EBSD[10] and IRAS_MCS[11], that use aggregated and system simulation methods respectively to develop a range of potential solutions to the planning problem (see Table 10-8 below).

[10] **EBSD** - Economics of Balancing Supply and Demand

[11] **IRAS_MCS** - Interactive River-Aquifer Simulation – Multiple criteria search**.**

Table 10-8: Our DSTs and modelling approaches

<table>
<tr><th colspan="2">Model</th><th colspan="2">Method</th><th>Approach</th><th>Used for</th></tr>
<tr><td rowspan="3">EBSD</td><td>EBSD</td><td>Current</td><td rowspan="3">Aggregated</td><td>NPV[12] optimised</td><td>Low risk WRZs</td></tr>
<tr><td>EBSD+</td><td>Extended</td><td>Multi-metric optimisation</td><td>Med & High risk WRZs</td></tr>
<tr><td>EBSD+ with Adaptability</td><td>Complex</td><td>Adaptability</td><td rowspan="3">Performance testing</td></tr>
<tr><td rowspan="2">IRAS_MCS</td><td>Portfolio_MCS</td><td>Extended</td><td rowspan="2">System-simulated</td><td>Multi-Criteria Search (MCS)</td></tr>
<tr><td>Scheduling_MCS</td><td>Complex</td><td>MCS with scheduling</td></tr>
</table>

10.64 The WRMP14 EBSD model was re-developed to form the EBSD+ model, allowing analysis and optimisation using additional parameters besides cost. This extended approach, aggregated method is suited to providing better understanding of programme timing, especially in the near-term which was necessary for London WRZ. The solver was coupled to an MGA (Modelling to Generate Alternatives) optimiser to enable multiple near-optimal solutions to be generated, providing a range of best value rather than only least-cost programmes for comparative appraisal (See ***Aggregate model*** in Section 10.D below).

10.65 EBSD+ outputs include single least-cost optimisation, the results of which are assessed for continuity from WRMP14 and validation of the programmes developed, as the current EBSD method is established and understood.

10.66 Assessing the resilience of a potential investment programme to several different futures is difficult using aggregated methods alone, which typically solve only a single supply-demand problem at a time. Although EBSD+ can be run several times to find solution programmes to different supply-demand problems (i.e. Other scenarios or for What-if analysis), the programmes developed are limited by pre-selection of the problem, for example the 'most likely' DO required to remain resilient to a 1:200 drought, based on prior WARMS2 simulation of multiple droughts of different duration and intensity.

10.67 One solution was to develop in addition, a complex approach extension to the EBSD+ model to batch run EBSD+ least-cost optimisation across multiple different predetermined futures and assess how a selected programme would adapt should the 'most likely' forecast change in future AMPs (See ***Complex approaches: Adaptability*** in Section 10.D below).

10.68 Further, we developed a system simulation model, IRAS_MCS to optimise for the impact of various weather scenarios, including multiple droughts of different types, and demonstrate the consequences for each potential investment portfolio (See ***Simulation model*** in Section 10.D below).

10.69 The first model, Portfolio_MCS, uses an extended level system simulation approach to identify a range of good value investment portfolios[13]. The portfolios allow assessment of the

[12] **NPV** – Net Present Value

trade-off between cost and resilience when judging solutions to the final planning problem. However, in order to ensure full assessment of cost and resilience, a programme of investment over the planning horizon is required. IRAS_MCS has been enhanced to include a second, complex level model (Scheduling_MCS) to allow scheduling of a pre-selected portfolio (See ***Complex approaches: Scheduling*** in section 10.D below).

10.70 The other WRZs have low complexity problems. The analysis of Guildford, Henley and Kennet Valley WRZs has therefore been carried out using a current level approach, least-cost EBSD optimisation across the 80-year time period.

10.71 These methods and the metrics that they evaluate are described in Section 10.D and Appendix W.

10.72 In all cases, it should be appreciated that the techniques detailed in the UKWIR WRMP 2019 Methods guidance are DSTs and that they are 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.

Summary

10.73 The London and 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 planning period and used advanced DSTs to enable a thorough analysis of the supply demand planning problem and to develop multiple feasible programmes of investment to address it.

10.74 The remaining three WRZs (Kennet Valley, Guildford and Henley) have planning problems of comparatively lesser complexity. Relatively low-cost options are available and are relatively quickly implemented. As such, current EBSD approaches to the identification of supply/demand options have been used to develop the preferred programmes in these zones.

[13] A portfolio lists the options that together could solve the final year supply-demand scenario, without commissioning dates or construction cost profiles dates across the planning period.

D. Developing assessment methods

Changes since the rdWRMP19:

- This is a new section that sets out further detail on our assessment methods and the metrics that have been developed in each DST

Approach

10.75 In this section we provide an overview of our DSTs selected and developed following the problem characterisation process in Section 10.C. Further details of the methods and metrics used are available in Appendix W: Programme appraisal methods. How the DSTs interact and how they are used to develop and test potential programmes is described in Section 10.E.

10.76 The models detailed in this section are decision support tools and are used as such. The outputs have been carefully appraised by knowledgeable experts and the information used to inform the decision making process.

10.77 There are two main types of model recommended for use in water resource planning in the UKWIR Guidance. Firstly, aggregate or spreadsheet models; these are less complex, established tools based on solving deficits due to supply and demand forecasts determined externally to the model, such as EBSD. Secondly, system simulation models; these are more complex tools which allow direct simulation of supply and/ or demand based on ranges of forecast weather, and then solve any simulated deficit.

10.78 In brief, aggregate models solve a pre-selected 'most likely' supply-demand problem. Simulation models provide a solution together with its performance against a range of possible futures.

Aggregate model (EBSD)

10.79 The EBSD method for single objective least-cost optimisation has remained sufficient for Kennet Valley, Guildford and Henley zones, the only key change being expansion to the 80-year time horizon and evaluation (not optimisation) of additional metrics (below).

10.80 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 revised dWRMP19 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 dWRMP19 programme appraisal please refer to Appendix W: Programme appraisal methods.

Least-cost assessment

10.81 The first programme generated for any scenario for any WRZ is the least-cost programme. The objective for least-cost optimisation 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.

10.82 The model will select a feasible schedule of 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.

10.83 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.

10.84 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 licence 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.

10.85 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

10.86 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+.

10.87 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.

10.88 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

10.89 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 are not readily capable of monetisation). These have been evaluated on a qualitative basis in our options assessment, as discussed in Section 9: Environmental appraisal.

10.90 The NPV of whole life costs for a programme has been calculated over a fixed 80-year period, April 2020 to 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.

10.91 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 costed at different times still have the same cost.

Multi-objective assessment and optimisation

10.92 For the more complex problems in London, SWOX and SWA zones, our EBSD model was re-developed to form the EBSD+ model which allowed assessment of programmes using seven[14] different metrics, to reflect parameters of value beyond just cost. These metrics are listed in Table 10-9 below and described in Step 2 of Section 10.E – Programme Development.

10.93 Optimisation methods have also expanded in EBSD+, from optimisation of a single metric alone, to search within a constrained space (SCS), and modelling to generate alternatives (MGA).

10.94 Each metric can be optimised separately (except Preference which is not suited to linear regression so optimisations are carried out on each of the two Preference components separately). SCS can be carried out on any metric except cost, as cost is the constraint defining the search space. In SCS optimisation runs the cost constraint is 120% of the least cost NPV. MGA is run on a user-selected output from a previous run, to find a solution which differs by either a) at least one option is completely different or b) the commissioning year of at least one option has changed by at least one AMP.

[14] Seven development metrics were described in stakeholder engagement and the dWRMP19, which includes the two different components of the Preference metric: preferred level of service and preferred type of option. These proved computational challenging to combine or optimise as a single metric and so have been calculated and optimised separately as PREF_FP and PREF_TP.

10.95 EBSD+ can search for as many SCS and MGA solutions as required by the user; the range of optimisations available in EBSD+ is listed in Table 10-9 below.

Table 10-9: EBSD+ optimisation types and output programmes

Metric Optimised	Optimisation Type and *Run name*		
	Single Objective	SCS (≤ 120% LC)	MGA
	(1 output)	(User defined number of outputs)	
Net Present Value	*Phased_LC*		
Adverse Environmental	*Min_ENVC*	*MultiObj_EnvC*	*NearO_EnvC*
Positive Environmental	*Max_ENVB*	*MultiObj_EnvB*	*NearO_EnvB*
Deliverability	*Max_DEL*	*MultiObj_Del*	*NearO_Del*
Resilience	*Max_RES*	*MultiObj_Res*	*NearO_Res*
Intergenerational Equity	*Min_IGEQ*	*MultiObj_IGEQ*	*NearO_IGEQ*
Preference: level of service	*Max_FP*	*MultiObj_FP*	*NearO_FP*
Preference: type of option	*Max_TP*	*MultiObj_TP*	*NearO_TP*

10.96 A full optimisation batch in EBSD+ can therefore produce any number of outputs from a minimum of twenty-two to a maximum limited by the time available. The equations for each type of calculation optimised are described with each metric in Section 10-E Step 2.

Complex approaches: Adaptability

10.97 Adaptability analysis is an extension of the EBSD+ model, used to performance test the robustness of programmes selected in programme appraisal. It allows re-assessment of a potential RAP against a range of different futures to see how the investment programmes would change, using least-cost optimisation. The inputs are:

- alternative future supply and demand forecasts for testing
- decision points, when the selected investment programme must be retested

Alternative future supply and demand forecasts

10.98 Key uncertainties affecting the baseline supply and demand forecasts (Section 6) are:

- Climate change
- Population
- Per capita consumption
- Leakage level
- Regional water needs, i.e. requirement from other WRSE companies
- Legislation, e.g. WINEP

10.99 The baseline supply and demand forecasts are developed using the most likely forecasts for each driver; however, where plausible alternative forecasts may cause significant change, adaptability scenarios should include them.

10.100 The final demand forecast includes reduction due to the selected DMP and is subject to additional uncertainty over achievement of the reduction of leakage and/or per capita consumption. The DMP policy is fixed, and hence for adaptability testing of an existing programme, alternative leakage and PCC forecasts are based on the final demand uncertainty rather than baseline alone, to incorporate DMP uncertainty.

10.101 Preliminary assessment has shown that even without including WINEP no deterioration as a driver, the combined scenarios would require EBSD+ to develop programmes that include a combined volume of reuse and desalination in London which may be detrimental to the lower Thames[15]. Adding WINEP no deterioration to exacerbate this environmental risk would not make sense, so legislative change has not been included as a separate driver for Adaptability.

Table 10-10: Adaptability datasets

Uncertainty	Alternative dataset
Population	ONS 2016 Trend based forecast High and Low variations
PCC	No demand savings from Policy DMP, Future PCC scenarios of 105 and 86 l/head/d by 2065
Leakage uncertainty	Assume 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 2037-38)[16]
Climate change	Taking the Medium emissions 5% and 95% percentile impact on deployable output. Also that the impact occurs by 2050 instead of 2080

10.102 These alternative datasets (charted in Appendix W), both individually and in combination form 726 variations to the baseline supply-demand forecast in each WRZ. Several of the combinations create very similar deficits; rather than assess each alternative future scenario individually, the range of futures in each WRZ was examined to determine when alternative scenarios would require significant changes to a plan, i.e. when a key decision must be reviewed.

Decision points

10.103 London WRZ has a relatively low volume of smaller quick-to-implement supply options available in relation to the size of the most likely deficit; in the future, large options will be required to meet most deficits, which will require selection in advance to allow for planning and construction lead time. The decision points, therefore, will be based on when a new large option may be required.

10.104 Water resource management planning is typically updated in five year AMP cycles, and so the common decision point is at the start of each AMP. The London baseline 'most likely' DYCP forecast averages an increase of over 100 Ml/d deficit per AMP cycle, for the first twenty-five years. When necessary, a large option of 150 Ml/d capacity is therefore required to ensure

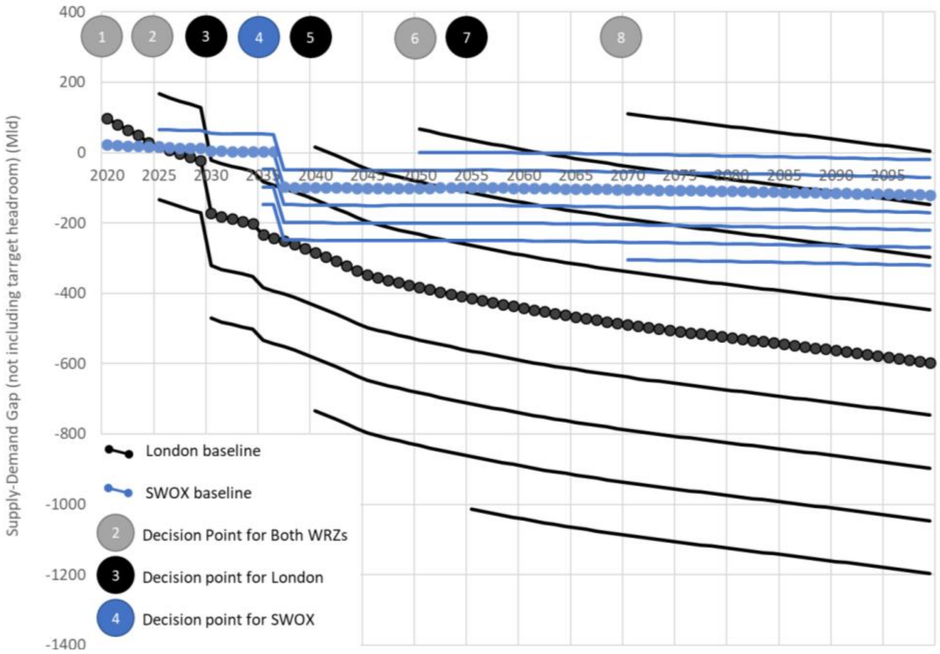
[15] Please see SEA in Part E, Step 4: Performance Testing.
[16] e.g. requirement from Southern Water, SES and South East Water.

there would be sufficient water until the next planning cycle, for the baseline including the DMP uncertainty.

10.105 For analysis of futures that diverge from the baseline, a decision point for London WRZ was generated at the start of any AMP when the potential future scenarios deficits diverged from the current maximum or minimum by a figure greater than 150 Ml/d ±10 Ml/d, starting from the baseline deficit in 2020.

10.106 Seven decision points were determined from the widening of the gap between different potential futures in London. A similar method was used for SWOX and SWA WRZs, to test whether additional decision points would be required due to deficit divergence in the other two zones. The final eight decision points selected were based on the London and SWOX future scenarios as shown in Figure 10-3, where the dotted black line shows the London baseline supply-demand balance (SDB), the dotted blue line shows the SWOX baseline SDB, and the black and blue lines show the London and SWOX alternative forecasts respectively.

Figure 10-3: London and SWOX future forecasts and decision points



10.107 A useful note from this decision point analysis is that with the current size of the majority of options (phased or stand-alone) planned for London WRZ (100-150 Ml/d), a decision as to whether or not to build a new large option may be required each AMP for four out of the next five.

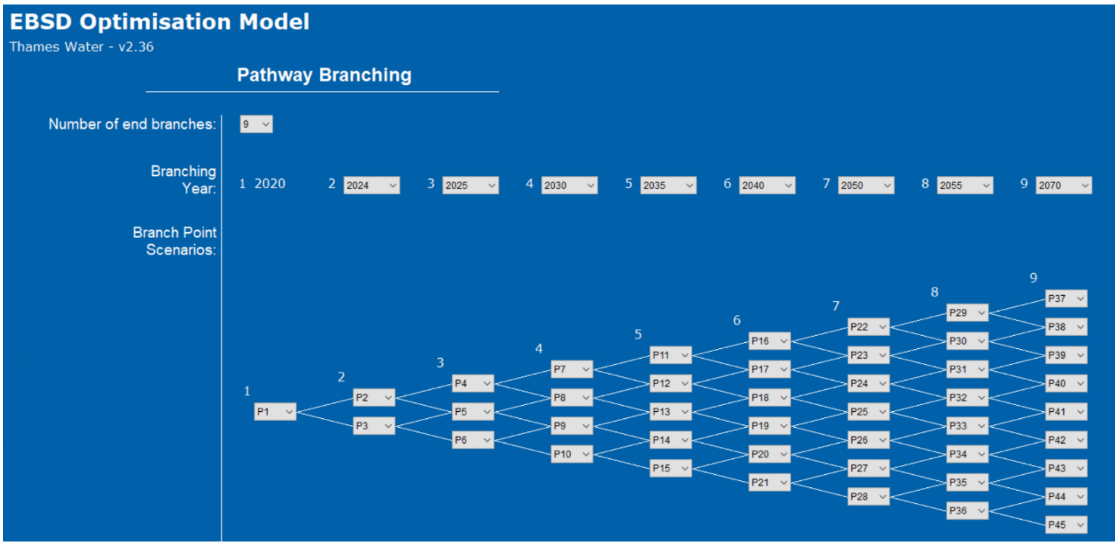
Pathways assessment

10.108 To streamline the analysis, the 726 scenarios were replaced at each decision point by new forecasts that follow the same trend as the baseline forecast to the end of the planning horizon. The spread of the eight adaptability forecasts within each WRZ represents the spread of the adaptability scenarios.

10.109 At each future decision point, options for which construction has already begun are fixed for completion, and least-cost optimisation is carried out for the new forecast supply-demand deficit from that decision point. The baseline target headroom balance is included, with year 0 of the forecast reset to each decision point.

10.110 Pathways are therefore created by linking these forecasts as each pathway moves forward in time. At each decision point, the pathway under consideration can move to either the path immediately above or below. There are 45 different forecasts leading to nine different endpoints (Figure 10-4) making a total of 256 pathways, across which each RAP is analysed (Appendix W, Annex 5).

Figure 10-4: Adaptability: Pathway links and endpoints



10.111 For example: Pathway_N1 fixes the investment options in the pre-selected programme for which construction has started before 2024-25, then re-optimises selection of the remaining options using supply and demand forecasts P3 with the target headroom year 0 reset to 2024-25. The options for which construction begins in 2024-25 are then added to the fixed option list, and a third optimisation run for the remaining 75 years using forecasts P6, with the target headroom year 0 reset to 2025-26. Options for which construction begins before 2030-31 are added to the fixed options, and the optimisation is repeated using supply demand forecasts P10 with the target headroom year 0 reset to 2030, etc. By 2100, each Pathway has undergone nine optimisations as shown in Table 10-11.

Table 10-11: Adaptability pathway N1

Supply forecast	Demand forecast	Target headroom forecast year 0	Optimisation horizon (years)
P1	P1	2020-21	80
P3	P3	2024-25	76
P6	P6	2025-26	75
P10	P10	2030-31	70
P15	P15	2035-36	65
P21	P21	2040-41	60
P28	P28	2050-51	50
P36	P36	2055-56	45
P45	P45	2070-71	30

10.112 For further information on how the pathways were constructed by repeated optimisation, see Appendix W. The full list of Pathways is given in Appendix W, Annex 4.

10.113 There are three main concerns when making long-term investment decision under deep uncertainty, which are represented by the consolidated outputs from each of the 256 optimisation runs per RAP:

- Costs for all programme adaptations and the potential for initial under or over-investment
- Failures (number and magnitude) in all programme adaptations brought about by delayed investment
- Standby costs of each adaptive programme

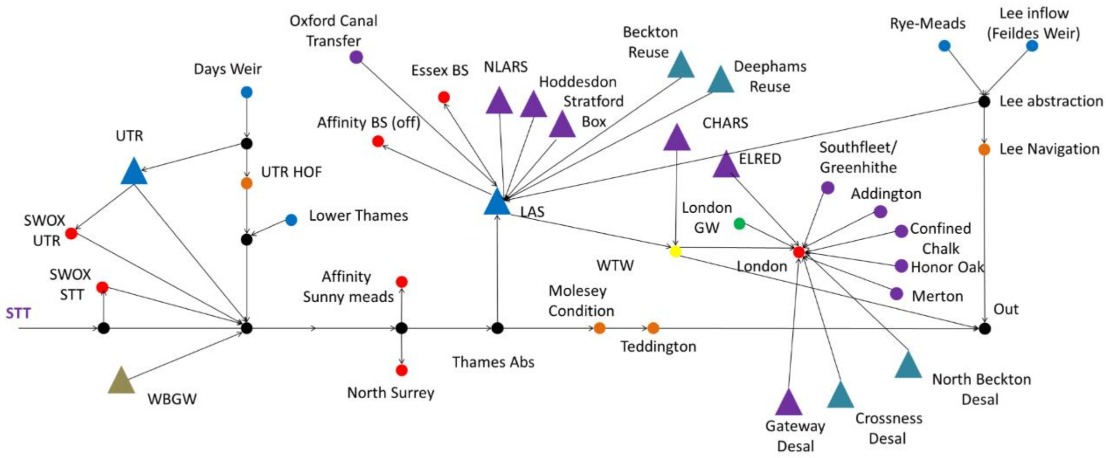
10.114 These outputs, together with how adaptability analysis is utilised, are described in Section 10-E Step 4 and in more detail in Appendix W.

Simulation model (IRAS)

10.115 A simulation model representing the Thames catchment using the Interactive River-Aquifer Simulation software (IRAS) has been expanded to also simulate the Severn catchment and hence allow full analysis of a potential Severn-Thames transfer under different weather configurations. The model tracks system flows, abstractions, consumption, storage and multiple metrics of performance in weekly timesteps across any input time series within the river catchments.

10.116 Several of the system components have been aggregated to allow rapid simulation which can be used for investment optimisation. For example, the London and Lee Valley reservoirs have been combined into a single node 'London Aggregated Storage' (LAS, Figure 10-5). IRAS has been calibrated and validated against WARMS2, demonstrating similar performance outputs[17].

Figure 10-5: IRAS representation of Thames catchment



10.117 The IRAS model is coupled with a multi-criteria search (MCS) optimiser (the Epsilon Non-dominated Sorting Genetic Algorithm II[18]), which searches for the optimal investment portfolios to balance supply demand across the range of potential future forecasts.

10.118 IRAS-MCS is able to examine system performance across a wide range of drought return periods in a single optimisation. Specific metrics have been developed to show how each run performs against Level 3 and Level 4 service failure and also recovery times. The metrics used in IRAS_MCS are summarised in Table 10-9 below and described in the Step 4 of Section 10-E.

10.119 IRAS_MCS has two modules:

- Portfolio_MCS optimises by simulating water available from a range of flow sequences based on weather patterns perturbed by the climate change impact of 2099/2100, in order to find portfolios of options that meet demand in that final year of the planning period
- Scheduling_MCS takes a portfolio of options identified using Portfolio_MCS and optimises their commissioning dates by simulating water available from weather patterns perturbed by the full profile of climate change to 2099/2100, to meet the full demand profile to the same final planning year.

10.120 Portfolio_MCS takes dry year annual average water demand, demand headroom and outage allowance for the year 2099-2100, profiled into weekly timesteps to ensure it reaches critical peak. Supply available to meet this demand profile is simulated from 153 different hydrological scenarios, generated from the *Future Flows* database, containing 78-year weather patterns of varying severity perturbed by the climate change impact of 2099/2100. Hands-off flow constraints on the Thames and Severn are also simulated to ensure minimum

[17] Atkins 2018; Thames Water Stochastic Resource Modelling Stage 2&3 Report, Atkins DG04, 16 July 2018.
[18] Kollat, J.B., Reed, P.M. (2006) *Comparing state-of-the-art evolutionary multi-objective algorithms for long-term groundwater monitoring design*. Advances in Water Resources 29, 792-807.

flow is maintained for the environment and shipping, or to report river levels where drought conditions make this impossible.

Complex Approaches: Scheduling

10.121 The ***scheduling*** extension of the IRAS_MCS model, Scheduling_MCS, takes a pre-selected portfolio from the Portfolio_MCS outputs and determines the optimal commissioning AMP periods for the options contained within it, optimising against the same metrics as for portfolio development.

10.122 For scheduling, DOs are simulated using 176 resampled 78-year flow time series which are perturbed by the climate change impact profile to 2099/ 2100. Local block bootstrapping (LBB)[19] was used to build a sample distribution for droughts across the planning horizon and limit scheduling bias. LBB ensures that the severe drought that had been sampled (three consecutive dry winters) appears in each 5-year planning cycle across the scheduling period, while preserving the original trend in each re-sampled timeseries.

10.123 A Scheduling_MCS run outputs a series of investment programmes, all using the same options but with different commissioning dates and hence varying NPVs and levels of service.

Summary

10.124 Two DSTs have been built, EBSD+ and IRAS_MCS, which use the aggregated and simulation approaches for supply demand planning respectively.

10.125 Both DSTs can optimise against the range of metrics listed in Table 10-12, to produce a range of potential programmes.

[19] Paparoditis, E., Politis, D.N. (2002) *Local block bootstrap*. Comptes Rendus Mathematique 335, 959-962.

Table 10-12: WRMP19 Metrics assessed within each DST

Category	Metric	EBSD+	EBSD+ with Adaptability	IRAS_MCS (Portfolio and Scheduling)
Cost	Cost (80 yr NPV)	√	√	√
	Intergenerational Equity	√		
	Standby cost		√	
Env	Environmental Cost	√		√
	Environmental Benefit	√		√
Del	Deliverability	√		
Cust Pref	Frequency of Restrictions	√		
	Type of Options	√		
Resilience	Resilience	√		
	Risk of Failure		√	
	Level 4 Return Period			√
	Level 4 Recovery Time			√
	Level 3 Return Period			√
	Level 3 Recovery Time			√

10.126 Both DSTs also have an extension whereby a preselected good-value programme or portfolio can be tested further using complex approaches: EBSD+ uses adaptability to assess a programme across multiple futures; IRAS_MCS schedules a potential investment portfolio using a range of 178 hydrological timeseries.

10.127 The models have been developed in conjunction so that outputs from both can be compared, to see whether any identified trends hold whether using aggregated or simulation models.

10.128 However, IRAS_MCS is not as mature as EBSD+ as a water resources management planning DST. EBSD+ has therefore been used as the primary tool for programme development and appraisal, while IRAS_MCS outputs are used for verification, both to validate trends from the aggregate model and to further our understanding of the simulation model so that it may be used in a more prominent role in future.

E. Programme identification and assessment

Changes since the rdWRMP19:

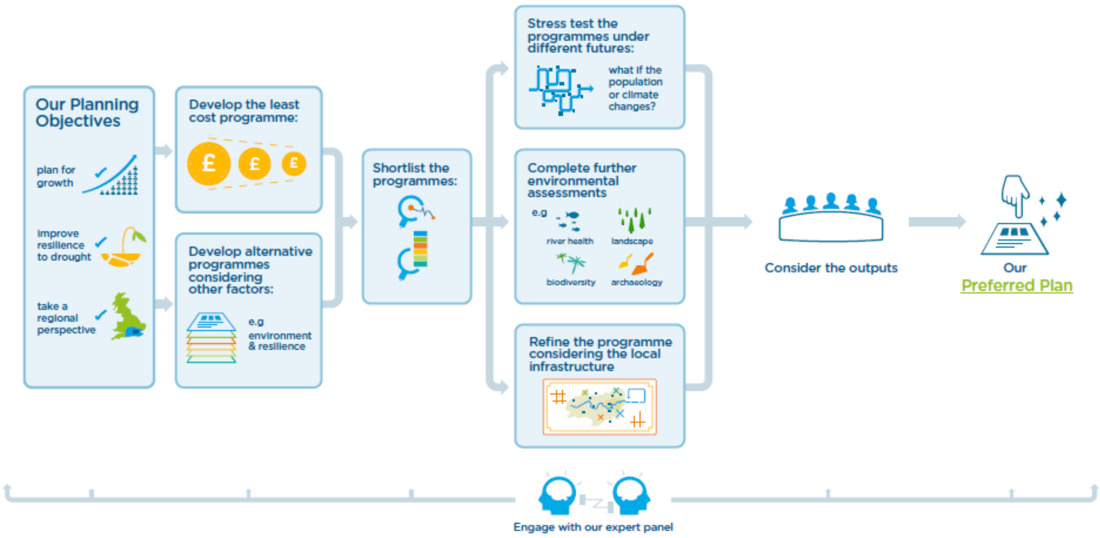
- Added Step 0 to the programme appraisal process to acknowledge the pre-modelling decisions around which DSTs to develop and which metrics to use.
- Simplified section structure so that each Step of the process is described once.
- Discussion of the metrics has been moved and into the Step of the process they are directly relevant to. i.e. EBSD+ metrics in Step 3 and IRAS_MCS metrics in Step 4.
- Metric descriptions have been reviewed and expanded.
- The Adaptability performance testing elements have been added.

Approach

10.130 In this section we provide an overview of our programme appraisal method and metrics. Full details are available in Appendix W: Programme appraisal methods.

10.131 As in our previous WRMPs, we have developed an approach to plan making (Figure 10-6) 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 10-6: Approach to programme appraisal



10.132 Our programme modelling approach for the rdWRMP19 is as set out in Figure 10-7. The steps are described below. The key decision points in the programme appraisal process are shown in Table 10-13.

Figure 10-7: Modelling the programme appraisal

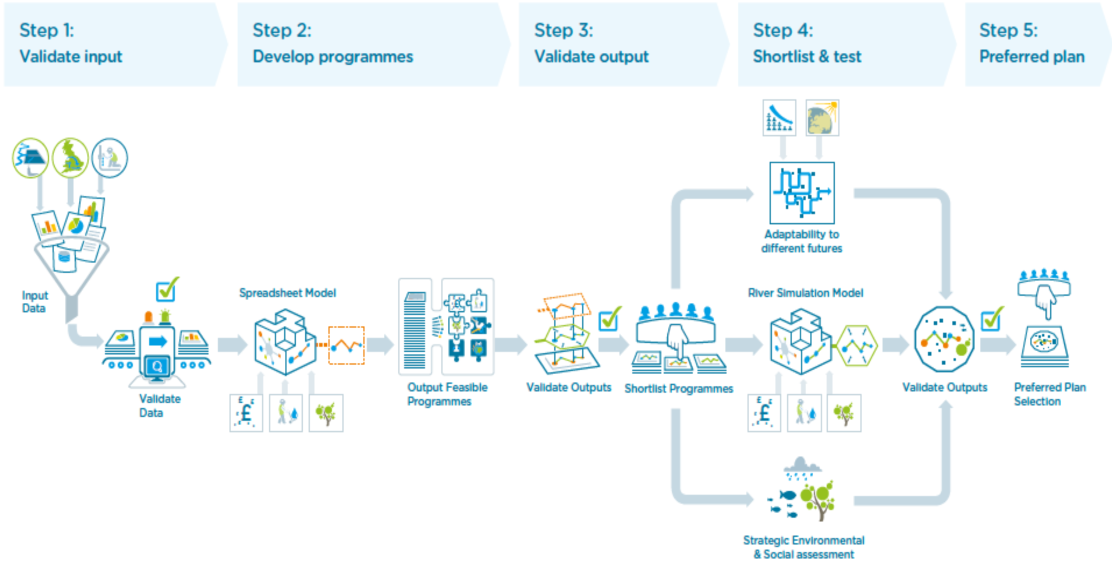


Table 10-13: Key decision points within the programme appraisal process

Decision Point	When?	What?	Who?	Reviewed by	Signed off
DP0	Step 0: Pre-modelling	- selection of modelling approach from Problem characterisation - Number and type of metrics	Thames Water	Thames Water Expert Panel and Stakeholders	
DP1	Step 1: Model run selection	- Number and type of optimisations - Number of scenarios - Establishing a demand management policy	Thames Water	Thames Water Expert Panel	
DP2	Step 3[20]: After initial optimisation runs	Identifying RAPs (for the preferred scenario)	Thames Water Ricardo[21]	Thames Water Expert Panel	
DP3	Step 4: After uncertainty testing	Identifying themes emerging from the following performance 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

[20] NB. Step 2: Develop programmes has no specific decision points, it just requires the model to be run to produce programmes.
[21] Ricardo-AEA, our consultant environmental specialists.

Step 0: Selection and development of models and metrics

10.133 The models were selected and developed as described in Sections 10-C and 10-D. Table 10-11 listed earlier the metrics used in each DST, which are further defined in Step 3 or Step 4, below, depending on whether they were used for programme development and RAP shortlisting or for performance testing of a RAP.

Step 1: Collation and validation of input data

10.134 The EBSD+ model (for Step 2) and IRAS-MCS model (for Step 4) were given as inputs:

- The baseline supply demand balances for annual average and critical period, including headroom (rdWRMP19 Section 6).
- The range of water resource and transfer options (rdWRMP19 Section 7).
- DMPs optimised in the Integrated Demand Management (IDM) model (rdWRMP19 Section 8).
- Information supporting the efficacy of the metrics (see below) used by each model, e.g. environmental performance data (rdWRMP19 Section 9).

10.135 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.

10.136 A large number of iterations of the models were produced in the programme appraisal exercise so the stability of the input data was tested using trial runs before the full batch runs commenced.

Step 2: Develop programmes

10.137 Sets of programmes are developed using the EBSD+ model for the following purposes:

- Least cost assessment
- Multi-metric assessment – To identify programmes using the full range of metrics and optimisation methods
- DMP 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

10.138 Least cost optimisation is run twice for each WRZ. Firstly with free choice of options and secondly with the company's preferred demand management policy (resulting from the DMP assessment).

Multi-metric assessment

10.139 In London, SWA and SWOX WRZs multiple further runs are carried out to develop programmes using the full range of metrics and optimisation methods, as listed in Table 10-9.

Demand management programme assessment

10.140 A range of DMPs are developed by the IDM model (as discussed in Section 8), to provide options for balancing supply and demand in programme appraisal.

10.141 Least-cost optimisation is used to develop investment programmes utilising each of the available DMPs in order to enable examination of the trade-off between total programme cost and demand management investment.

10.142 We have carried out a Sustainable Level of Demand Management (SELDM) assessment to examine the impact of varying the size of DMP in our London WRZ.

10.143 We have then tested this against our policy drivers and known customer and stakeholder priorities to select a preferred policy demand management option. The policy position DMP is then used in all future optimisations.

10.144 Our assessment is set out in Section G below.

Alternative baseline assessment

10.145 The following baseline 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 facilitate strategic water transfers to neighbouring companies in the south east

Step 3: Validate output - comparison of programmes

10.146 The EBSD+ model can generate hundreds of feasible programmes, each with seven metrics to be evaluated in parallel.

10.147 Comparison requires understanding of each of the metrics, discussed below and covered in further detail in Appendix W: Programme appraisal methods.

EBSD+ Metrics

10.148 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.

10.149 Metrics have been selected and developed to provide understanding of the wider value of any potential programme of investment, enabling those appraising the programmes to shortlist

RAPs. The selection of metrics is therefore determined by what we, our customers, regulators, government and key stakeholders 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).

10.150 Following consultation and stakeholder engagement we selected seven metrics for development and evaluation of the WRMP19 programmes (Table 10-14). They are described briefly in the following sub-sections, with further detail provided in Appendix W: Programme Appraisal Methods.

Table 10-14: WRMP19 Metrics (EBSD+)

Performance metric	Description	What is better?	Observed Range[22]		Interpretation
			Best	Worst	
Cost	NPV of the total cost of a proposed programme using the declining STPR.	Lower value is better	2,014	9,205	£m NPV over 80 years[23]
Intergenerational equity (IGEQ)	Indicator of preference for investment sooner over deferring to later	Lower value is better	5,340	13,970	£m NPV at 1% flat rate over 80 years (multiplied by demand saving significance)
Adverse environmental impact	Total SEA score of all the options chosen in the programme. Each option is scored 1-10.	Lower negative score is better[24]	-11	-165	Worse score could mean either more options are chosen in the programme, or that the options are worse performing environmentally.
Environmental benefit		Higher positive score is better	+147	+22	Better score could mean either more options are chosen in the programme, or that the options are better performing environmentally.
Deliverability	Probability that the programme will deliver the volume of water within the timescale	Higher score is better	1	0.89	A score of 1 = No deliverability concerns. A score of 0 = Programme will not deliver. Ranges from probability of 0 to 9 years of failure to meet target headroom across 80 years
Resilience	Resilience of the proposed investment to more severe droughts than in the historical record	Higher score is better	0.952	0.44	A score of 1 = resilience in all years to a 1:500 drought A score of 0 = no enhanced resilience to more severe drought.
Customer preference	Evaluation of the programme in relation to customers' preferences and priorities	Higher score is better	4.55	4.22	A score of 10 would indicate a programme containing only customers' preferred option type and frequency of restrictions. A score of 0, the opposite. No material difference in the observed best to worst range.

[22] From model runs 2(LC), 2a, 2b and 2c for the combined London, SWOX and SWA WRZ.
[23] Social Time Preference Rate, 3.5% to 2.5% declining discount rate
[24] i.e. closer to zero

10.151 The multi-objective optimisation methods have been developed to provide the experts undertaking programme appraisal with a broad range of potential investment programmes that offer good value across each of these metrics. While each metric has been quantified and calculated to enable the solution development DSTs to search and optimise using different constraints, the metrics cannot quantify all elements of concern. Although they are used to develop programmes and inform the programme appraisal process, expert judgement takes precedence over the comparative metric values.

Cost [Phased_LC]

10.152 The cost metric in EBSD+ is the NPV of the total cost of a proposed programme across the 80-year planning period. Capex, fixed opex, variable opex and carbon cost profiles for all options selected and utilised are combined, indexed and discounted using the Treasury Green Book declining discount rate. This method is described in detail in least-cost optimisation in Section 10-D.

Intergenerational Equity [IGEQ]

10.153 Sustainability in water resource planning requires 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 reduction) and the social impact (e.g. bill increase).

10.154 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.

10.155 Supporting enhanced demand management is a key policy in the rdWRMP19. The DMP is determined by company policy with the progressive metering programme (PMP) continuing, alongside leakage reduction and water efficiency enhanced through household metering. After DMP assessment the DMP is fixed and therefore a flat rate is included in the IGEQ optimisation or assessment.

10.156 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 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.

10.157 The affordability element therefore shows the cost impact of any proposed plan using an Intergenerationally Equitable discount rate (IEDR) of 1.0%. It can then be appraised in comparison with the NPV cost developed using the 3.5% declining STPR.

10.158 A chart showing cumulative total capex and opex of the preferred plan using both discount rates is provided in Appendix W, together with details of this calculation and how it translates to the IGEQ score.

Environmental benefit and adverse environmental impact [ENVB, ENVC]

10.159 Environmental metrics are only required for options that pass screening to meet Water Framework Directive (WFD) and Habitats Regulation Assessment (HRA) requirements. Those which passed screening were subject to an SEA to qualify the environmental impact of construction and operation.

10.160 Two environmental grades were developed from the SEA of each option. They represent a guide to the overall environmental impacts, both adverse and beneficial, of the development and operation of that option.

10.161 For each SEA objective, an effects assessment was made against a significance matrix (Figure 10-8) 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 10-8: 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 adverse / Major beneficial	Major adverse / Major beneficial	Moderate adverse / Moderate beneficial
	Medium	Major adverse / Major beneficial	Moderate adverse / Moderate beneficial	Minor adverse / Minor beneficial
	Low		Minor adverse / Minor beneficial	Negligible

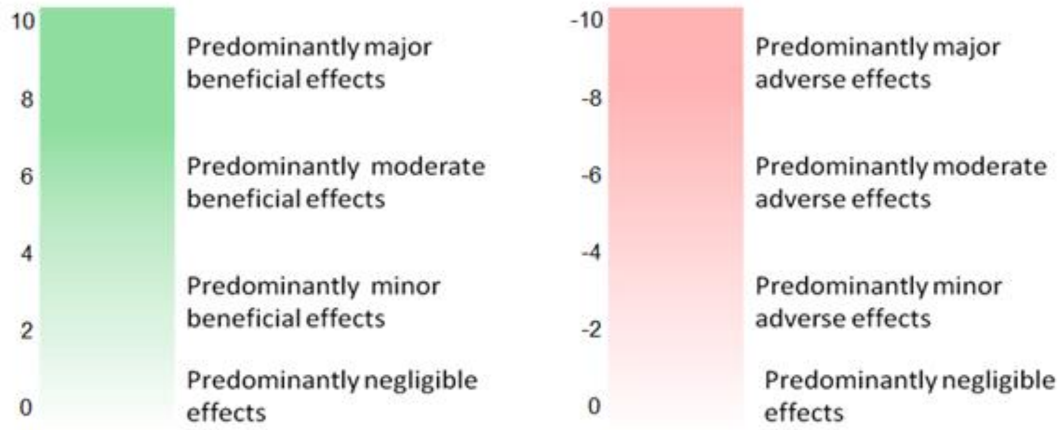
Key

Significance of effect is dependent on vale/sensitivity of receptor

10.162 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.

10.163 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 10-9). 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 10-9: Qualitative grading to reflect environmental and social effects of each option



10.164 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.

10.165 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.

10.166 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 play an influential part in the derivation of alternative programmes.

10.167 A full SEA was carried out for all the shortlisted RAPs 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 [DEL]

10.168 Programme deliverability is the probability that the programme will deliver sufficient water on time across the planning period.

10.169 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.

10.170 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.

10.171 The total programme deliverability is 1 minus the maximum probability of failure to satisfy the supply-demand gap across the 80-year planning horizon, where 1 means no probability of failure to meet target headroom. With outputs ranging from 1 to 0.89, each 0.01 decrease in Deliverability is an additional 0.8 years of failure.

10.172 Please see Appendix W for details of this calculation.

Resilience [RES]

10.173 In order to enable better understanding of relative programme resilience values, the resilience metric was cut down after consultation on the dWRMP19 and now evaluates only the ability of a proposed investment programme to maintain supply during drought more severe than 1:100 return period.

10.174 The WARMS2 model has evaluated the probable reduction in DO during a range of drought events of different duration and severity for each WRZ[25]. Probable reduction in DO of new option types to the same droughts has also been evaluated. The EBSD+ model then calculates the probability that each proposed investment programme will continue to deliver the required yield across the planning period in event of a 1:200 or 1:500 year drought. The probable consequence in each year is adjusted by the probability of either drought occurring across the planning period, in order to give a programme resilience score between 1 (no risk of failure during a 1:500 drought in any year), and 0.44 (failure in all years). As the probabilities of 1:200 or 1:500 droughts occurring across the 80-year planning horizon are 0.4 and 0.16 respectively, it is impossible to reach a resilience score of 0.

10.175 For example in most scenarios we plan to increase drought resilience to 1:200 year droughts by 2030 (see Section E). For each programme developed for this drought resilience, the 'enhanced' resilience output therefore is the risk of insufficient supply should a 1:200 drought occur before 2030, plus the risk should a 1:500 drought occur in any year, and the lowest possible resilience value is 0.79.

10.176 To understand the output values for the preferred scenario programmes, we can assume that very few programmes for London could be resilient to a 1:200 drought before 2030 when the first large options may be commissioned. So the resilience range for the main scenario reduces to between 0.79 and 0.93, with 0.93 meaning that a programme would also be resilient to 1:500 droughts for all 70 years from 2030. Each 0.01 decrease in resilience score indicates reduction of that enhanced 1:500 resilience for five years of the 70.

[25] Atkins 2018; Thames Water Stochastic Resource Modelling Stage 2&3 Report, Atkins DG04, 16 July 2018

10.177 In practice, the maximum resilience score is 0.952, the programme optimised to maximise resilience achieves 1:200 resilience at the earliest possible date (2026) and 1:500 resilience in 2029, both of which are maintained to 2100. However, the programme costs £9.2 billion.

10.178 Please see Appendix W for details of this calculation.

Customer preference

10.179 Customer research has been carried out as part of a wider analysis of Business Planning for Thames Water.

10.180 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.

10.181 The second phase focused on quantitative assessment of customer preferences for specific options or boundary conditions used for dWRMP19 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 (_TP)
- customer preference for level of service (_FP)

10.182 Preference for one type of water resource option over another is shown in Table 10-15**Error! Reference source not found.**.

Table 10-15: 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

10.183 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.

10.184 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.

10.185 We have sought customer views on how desirable it is to plan for these more extreme droughts. The research findings (Table 10-16) are used as a Preference metric to promote an acceptable level of drought resilience within the WRMP19.

Table 10-16: 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	154	201	295

10.186 A third element, affordability, was considered, but because the bill impact calculation cannot easily be embedded in the programme development models (as it depends on additional factors outside the remit of the WRMP19), it has been assessed for the PR19 Business Plan as a whole and not included in this metric.

10.187 The Preference score reported for any programme is the sum of both the components (option type and frequency of restrictions). However, optimisation of a summation of two independent components is computationally challenging and so EBSD+ optimises both components separately, increasing the number of programmes available for programme appraisal.

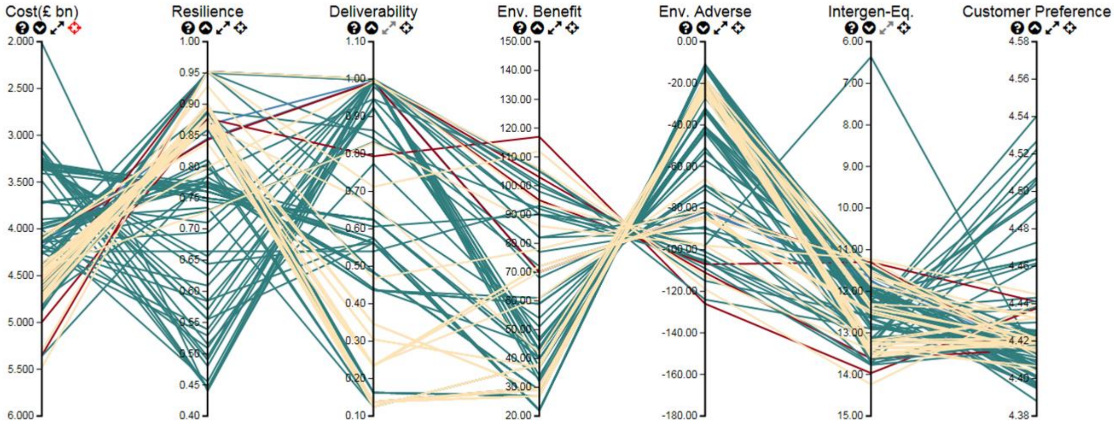
10.188 The range of preference values if very narrow: 4.22 to 4.55, and due to the fact that a similar mix of options is available in most programmes and a similar level of resilience this is difficult to interpret the precise meaning of the intervals. Lower scores indicate a more resilient programme with a greater proportion of desalination, groundwater or transfer capacity (which is often what makes up more resilient schemes). Higher scores indicate lower resilience with more reuse instead of transfers or desalination.

Programme visualisation

10.189 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.

10.190 An illustrative output of PolyVis is shown in Figure 10-10. 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 10-10: Illustrative output from PolyVis



Reasonable alternative programmes

10.191 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.

10.192 The outputs of all the runs are provided in Appendix X: Programme appraisal outputs.

Step 4: Performance testing

Expert Panel

10.193 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.

10.194 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 16 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 1 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.

10.195 The Panel has been represented at Water Resources Stakeholder Forums and Technical Meetings.

10.196 The members provided a provisional report[26] with their comments on the dWRMP19.

10.197 They have produced a further report for the rdWRMP19 which forms Appendix Y of this submission.

Performance testing

10.198 We have performance tested the RAPs 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

10.199 How these tests and additional elements have influenced the development of the preferred programme is discussed later in Step 4 of Sections G-J below.

Option uncertainty (Final planning target headroom)

10.200 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.

[26] Expert Panel’s Report, dWRMP19, November 2017

Adaptability

10.201 An adaptability analysis method (explained in S10.D and in detail in Appendix W) was developed for use as part of the WRMP19 planning to supplement our 'What if' analysis.

10.202 We were not able to finalise this approach for use in the dWRMP19. however we were able to include it in the revised draft for the London, SWOX and SWA WRZs.

10.203 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[27])
- 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%)

10.204 These inputs were chosen to be included in the adaptability analysis as they represent key drivers for future uncertainty.

10.205 We have produced decision points and links covering the range of futures and established 256 potential future pathways over the planning period.

10.206 We have given the EBSD+ model each RAP and then re-optimised it at each decision point to see how robust the programme is.

10.207 The metrics examined following adaptability analysis are cost, standby cost, and risk of failure:

Cost

10.208 The 80-year NPV cost calculation in EBSD+ is used for both programme development in Step 2 and Adaptability analysis.

Standby cost

10.209 One of the concerns when planning for uncertainty is the possibility of building assets which are rarely if ever required, so-called 'White elephants'. In the futures in Adaptability analysis the deficit can reduce as well as increase, so EBSD+ calculates the annual maintenance capex and fixed opex for any commissioned asset which is not utilised in that year, 'Standby cost'. The NPV of all standby costs across the 80-year horizon is calculated for each pathway.

10.210 Please see Appendix W for details of this calculation.

Risk of failure

10.211 Adaptability pathways include sudden changes in forecast when they are recast at 5 year periods and at times there are not sufficient rapid-response options available to meet the corresponding deficit. EBSD+ records the magnitude of such S/D failures for all pathways.

[27] Taken from Artesia Consulting (for Ofwat) (2018) The long-term potential for deep reductions in household water demand AR1206

These are analysed in programme appraisal in comparison with the standby cost of over-engineering for potential futures that may not occur.

What if analysis

10.212 '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.

10.213 This method has the benefit of providing a specific output for a specific challenge.

10.214 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 10-17.

Table 10-17: 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

10.215 As discussed in S10.D, 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.

10.216 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.

10.217 The metrics used both for portfolio optimisation and scheduling are:

- cost
- adverse and beneficial environmental effect
- Level 3 and 4 restrictions return period
- Levels 3 and 4 recovery time

10.218 Further metrics were developed but not used for the rdWRMP19 programme appraisal:

Cost

10.219 IRAS_MCS uses the same capex, fixed opex, variable opex and carbon cost profiles per option as EBSD+; the capex and carbon profiles are annuitized to provide an average annual cost.

Environmental benefit and adverse environmental impact [ENVB, ENVC]

10.220 IRAS_MCS uses the same environmental cost and benefit calculations, using the same option gradings as were developed and used in EBSD+.

Level 4 Return Period [L4RP]

10.221 IRAS calculates the minimum return period for Level 4 drought restrictions in the Thames when evaluating the stochastic drought library utilised. A value of 2000 signifies that no level 4 restrictions were required for all droughts under analysis.

Level 4 Recovery Time [L4RC]

10.222 When level 4 drought restrictions are required during the IRAS analysis, the model records the number of weeks for which the restrictions are required, and reports the maximum.

Level 3 Return Period [L3RP]

10.223 IRAS also calculates the minimum return period for Level 3 drought restrictions in the Thames. A value of 2000 signifies that no level 3 restrictions were required for all droughts under analysis.

Level 3 Recovery Time [L3RC]

10.224 When level 3 drought restrictions are required during the IRAS analysis, the model also records the number of weeks for which the restrictions are required, and reports the maximum.

10.225 Full descriptions of the IRAS_MCS metrics can be found in Appendix W.

SEA (and HRA and WFD compliance)

10.226 Each of the RAPs 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.

10.227 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.

10.228 These assessments have been used to compare the environmental performance of each of the RAPs to help inform decision-making alongside other key criteria.

10.229 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

10.230 The RAPs 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

10.231 Having assessed the outcomes of Step 4, the overall best value preferred programme is identified and reported in overview in Part K, below. A full description of the preferred programme is provided in Section 11: Preferred plan.

F. Programme appraisal: Section structure

Changes since the rdWRMP19:

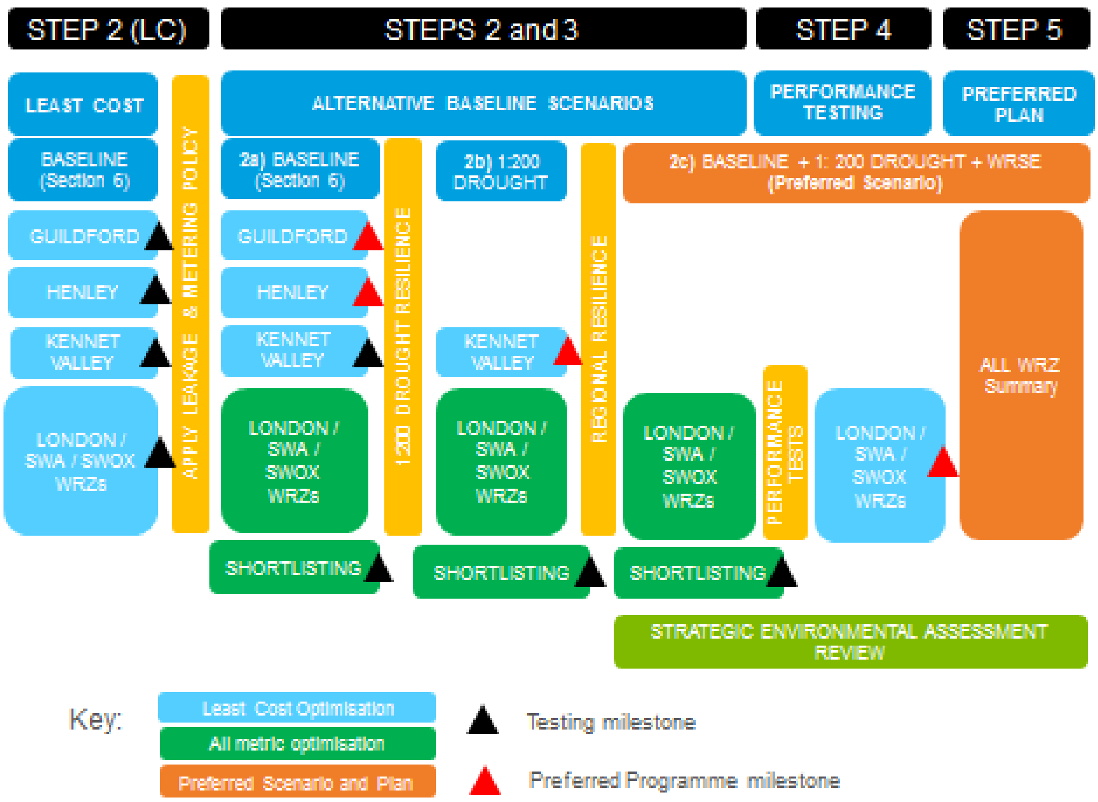
- No material changes have been made to the section structure of the programme appraisal.

Section structure

10.232 We have followed a step-wise approach to programme appraisal. These are shown in Figure 10-11, which builds on Figure 10-7 shown earlier in sub-section C. Step 1 – Collation of data is omitted as it represents preparatory work.

10.233 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 10-11 below), to the selection of an overall best value plan and the testing of 'What if' scenarios.

Figure 10-11: Programme appraisal – step-wise development



10.234 The remainder of this section is structured as follows:

Programme appraisal: London, SWOX and SWA WRZs (Heading G)

- 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 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 RAPs that can ‘solve’ the deficits.
- Step 4 - We then performance test the RAPs against a variety of alternative futures, incorporating SEA.
- Step 5 - Lastly we set out our preferred best value programme.

Programme appraisal - Kennet Valley, Guildford, Henley WRZs (Headings H, I, J)

- 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.

G. Programme appraisal: London, SWOX, SWA

Changes since the rdWRMP19:

We have further updated this section based on feedback from our consultation on the rdWRMP19.

Our preferred programme of options remains unchanged. However, we have added further explanation where requested including:

- Adaptive planning
- Metric generation and interpretation
- How the metrics have informed decision making
- Identification of the alternative programmes
- DMPs
- Option uncertainty
- The role of system simulation modelling (IRAS_MCS)
- Performance testing – Adaptability assessment
- Performance testing – What if analysis
- Impact of performance testing on the preferred plan
- Selecting the preferred programme
- The sensitivity of the preferred programme
- Reduction of abstraction from vulnerable chalk streams and water courses

We have clarified our selection of a preferred programme by putting our assessment in a wider adaptive planning context. We have taken the key delivery points identified over the planning period (2030, 2037-38 and 2080s) and included a decision tree approach to help explain the choice of options available at those times and why we have made a particular choice.

Over the planning period to 2100 it is likely that two or three strategic options will be required. One will not be enough, even after the completion of the DMP.

Importantly, we explain that the immediate investment decisions supported by this plan relate to the ramp up of leakage reduction and demand management activity and an increase in pre-planning activity so a decision on which key strategic options (Reservoir, Severn-Thames Transfer and Re-use) should be delivered, can be made in 2022/23.

10.235 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.

10.236 As set out in our dWRMP19 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.

10.237 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 DMP to identify the preferred DMP. We then assess RAPs produced based on metrics additional to cost. Having done this we shortlist and identify an initial preferred programme (Step 2/3a).

10.238 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).

10.239 Having identified a preferred scenario and the RAPs able to solve that scenario, we subject them to further performance 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

10.240 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 dWRMP19. Raw outputs are shown in Table 10-18.

10.241 In the short and medium-term period the model selects a minimal least-cost DMP 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).

10.242 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.

10.243 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 10-18: 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[28]	Benefit (Ml/d)	Implementation date		
DMP_LON-110-70-7[29]	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	
NTC_Ashton 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		

10.244 Whilst the investment programme set out in Table 10-18 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 DMP which takes into account other factors than just financial cost. Whilst there is a phased development of wastewater reuse,

[28] Resource development and demand management only.
[29] 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.

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.

10.245 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.

10.246 It is the latter requirement on which we focus our attention first.

Step 2 SELDM

10.247 One of the key decisions in developing a WRMP is the balance of demand management and resource development measures in a preferred programme.

10.248 Leakage has been 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.

10.249 The delivery of leakage reduction and demand management activities can be combined 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 SELDM.

10.250 We believe our approach to SELDM analysis represents good practice and is consistent with guidance for SELL analysis[30]. 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.

10.251 We have ensured that our approach to environmental and social impacts is consistent for both our demand and supply options so that there is no bias in our scheme selection. As with the supply schemes, the SELDM analysis incorporates monetised carbon costs, but other

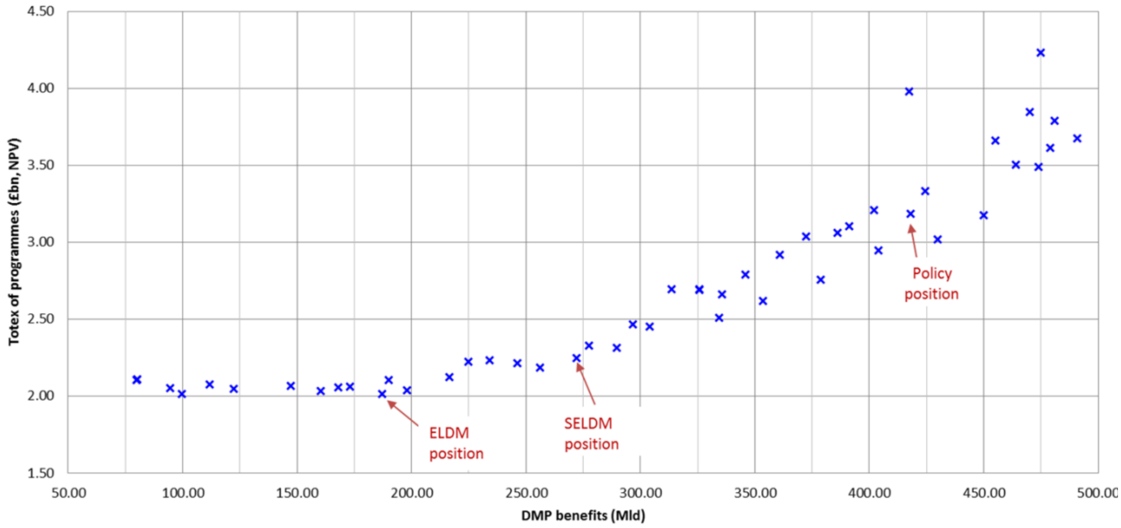
[30] Environment Agency (August 2017) Leakage in WRMPs, revised guidance note.

economic and social costs are excluded to ensure consistency. These elements are dealt with by our use of environmental metrics as described in Section 10 G and the SEA.

10.252 We have produced 50 DMPs for London, SWOX and SWA WRZs combined (LSS) from our IDM model. We have run each one through the EBSD+ model to identify a least-cost programme featuring each of them that resolves the baseline deficit as described in rdWRMP19 Section 6.

10.253 Figure 10-12 shows the results plotting total demand savings in London over the planning period against 80-year NPV of cost.

Figure 10-12: SELDM analysis – London



10.254 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.

10.255 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.

10.256 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.

10.257 The Policy Position is a balance of ambition and practicality and the priorities of our customers and stakeholders. Its position was chosen to meet the leakage reduction target of 50% by 2050 (in Ml/d terms, from current levels).

10.258 We discuss going beyond SELDM and establishing the policy position below, after an explanation of why repeating the analysis above is not a meaningful exercise in our other WRZs.

Other Thames Valley WRZs

10.259 In the other Thames Valley WRZs there are insufficient options available to undertake an EBSD-type analysis to determine the SELDM.

10.260 Our DMPs for the Thames Valley WRZs are focussed on the continued delivery of the PMP and associated leakage and water efficiency activity, and the timing thereof. This is expected to represent a SELDM position.

10.261 Going beyond this position, post metering, would require mains replacement activity.

10.262 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.

Going beyond SELDM

10.263 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.

10.264 The ELDM position does not align with our own ambition to reduce the demand for water in our supply area.

10.265 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.

10.266 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.

10.267 We have, through an extensive and continuing programme of customer and stakeholder engagement, found that:

- Customers generally support demand management activity[31], 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.

[31] Thames Water (September 2018) What customers want.

- 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.

10.268 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.

Our policy position

10.269 Our policy position seeks to strike a balance between practicality and ambition.

10.270 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.

10.271 Ofwat has set out a leakage reduction challenge for companies of 15% from 2020 to 2025[32]. The NIC expand on this recommending a reduction from current levels of 50% by 2050[33].

10.272 We have made achieving both suggested goals our policy position for leakage reduction.

10.273 When modelled in IDM alongside metering and water efficiency this equates to an overall DMP of 420Ml/d. 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.

10.274 We have examined whether we could go beyond 420Ml/d of demand reduction; there are other points around the policy position indicated on the SELDM graph that appear cheaper for greater benefit. This will be explored further as we start to deliver the programme and learn from it.

10.275 Importantly, the overall reduction in the longer-term does not impact the demand management activity that would be delivered in AMP7 (2020-25).

10.276 We have considered if the ELDM/SELDM position changes under different supply demand scenarios (e.g. moving to 1:200 resilience). We have done this by comparing the costs of leakage reduction techniques against the costs of other options. This analysis of costs shows that under those different scenarios our long-term policy still includes greater leakage reductions than the economic level of leakage. This is because the mains replacement options that drive long-term demand reductions get incrementally more expensive the bigger the programme, whereas the unit cost for strategic resource development options shows economies of scale. As such resource development will be cheaper in the longer-term and the SELDM position is not sensitive to the planning scenario.

10.277 We note that beyond the SELDM point, as the level of demand management increases the spread of the points on the graph widens. This reflects the differing make up of demand management options being selected by IDM to meet the desired demand reduction. Whether

[32] Ofwat, Delivering water 2020: Consulting on our methodology for the 2019 Price Review, July 2017.
[33] NIC (2018) Preparing for a drier future: England's water infrastructure needs.

the programme is towards the lower or higher end of the spread is broadly linked to the balance of active leakage control interventions and mains replacement in the programme.

10.278 Mains replacement options are higher cost, but lower risk (because it physically replaces the asset). Active leakage control focusses on improving our ability to find and fix the leaks but is higher risk as it does not renew the assets.

10.279 Our preference is to use active leakage control techniques in the first instance to drive leakage down but then follow it up with mains replacement to balance the overall cost and risk, hence why the policy position may not appear on the bottom edge of the SELDM curve.

10.280 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.

10.281 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%.

10.282 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 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.

10.283 The DMP that matches our policy position is used in all subsequent runs of the EBSD+ and IRAS_MCS model.

Step 2/3a: Scenario assessment: Baseline

10.284 Having established the policy position on demand management, further batches of EBSD+ runs were completed. Up to this point we have only optimised based on cost (Phased_LC). We now complete our database of runs by optimising against the other seven metrics:

- Environmental Benefit (_EnvB)
- Adverse Environmental Impact (_EnvC)
- Resilience (_RES)
- Deliverability (_DEL)
- Intergenerational Equity (_IGEQ)
- Customer preference
    - For option type (_TP)

— For frequency of demand restrictions (_FP)

10.285 For each metric we complete 3 types of optimisation run:

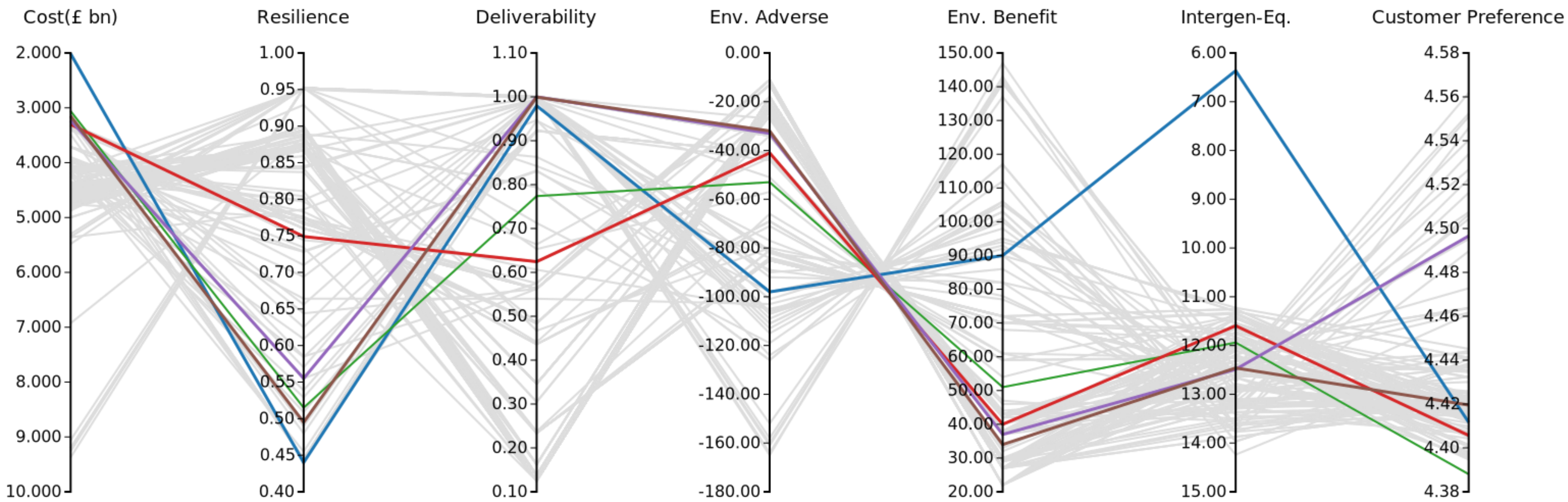
- Min/Max – Seeking to minimise or maximise the result for that metric (whichever is better)
- Multi-objective (Multi-obj) – Seeking to optimise each metric with cost
- Near-optimal (NearO) – Seeking to optimise each metric to within 120% of the least cost.

10.286 In total that generates a database of 22 optimisation outputs (3 types x 7 metrics, plus least cost).

10.287 The outputs were uploaded to PolyVis for analysis as shown in Figure 10-13.They are also available in tabular form, including option implementation dates in Appendix X, Part B.

10.288 The coloured lines represent the shortlisted runs (discussed later) and the Step 2 (LC) run, for reference. [NB. All outputs for all runs in Steps 2a, 2b and 2c are shown greyed out in the background, i.e. there are more than just the 22 Step 2a runs shown.]

Figure 10-13: Step 2a PolyVis output - Baseline scenario runs



Key:

- Step 2 (LC): Least-cost position (for reference)
- Step 2a: Least-cost (including policy DMP) (Phased_LC)
- Step 2a: Favouring intergenerational equity (Min_IGEQ)
- Step 2a: Favouring customers’ preference for option type within 120% of least cost (NearO_TP)
- Step 2a: Favouring customers’ preference for frequency of restrictions within 120% of least cost (NearO_FP)

10.289 We observe the following based on the PolyVis plot (above) and the supporting database of metric scores and option selection. [It is recommended to have the Appendix X Part B tables open for reference]:

- The introduction of the policy DMP increases the cost of the solution to the baseline supply demand problem by £1,045m NPV (52%). i.e. the Step 2a least cost optimisation compared with Step 2 (LC).
- 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 run that maximises resilience (Max_Res) seeks to build as much as it can as soon as it can, irrespective of cost, 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 £9.2bn to £4.4bn NPV in the case of the _RES runs and from £4.1bn to £3.1bn NPV in the _FP runs.
- The remaining optimisations all produce programmes that are between £3.1-3.4bn NPV. This is a reduced range of cost compared with the assessment in the dWRMP19. This is due to change in the baseline deficit (particularly the reduction in the long-term population forecast) and the increased amount of the deficit which is being met through the revised dWRMP19 policy DMP.
- The Intergenerational equity metric (_IGEQ) uses a different discount rate to the Least cost (Phased_LC) optimisation. As such, optimisations using IGEQ result in higher programme costs, because it is less favourable to defer investment to future generations. This change does enable the model to select different options, which is a useful outcome.
- The customer preference metrics produce outputs with a restricted range (4.3 to 4.6). This reflects that to meet the deficit a wide range of option types are required in all optimisations. As such differences in the output values are not material.
- The PolyVis plot confirms some common sense trade-offs across the metrics:
    - Lower the cost, lower the resilience (because fewer options are chosen)
    - Lower the cost and resilience, the higher the deliverability (because is it simpler to build fewer options)
- With respect to the Environmental metrics, programmes with low adverse scores also have low benefit scores and vice versa. This is linked to the number of options that form the programmes. As each option selected contributes to the total score, the more options selected, the higher the score. Therefore care is needed when examining these parameters as a programme with several groundwater schemes may appear worse that one with a single large strategic scheme, yet in reality the combination of the groundwater schemes may have lower overall impacts than the single large scheme.
- 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

10.290 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.

10.291 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.

10.292 We have not set specific thresholds for the metrics at which potential programmes would be discounted. It is useful to examine trade-offs in the round especially as some of the metrics are indicative rather than absolute.

10.293 We have, however, discounted clear outliers, notably on cost.

10.294 What weight is given to each of the metrics when shortlisting is also a preference choice. We discussed this at length with the Expert Panel when developing our appraisal process. Our tools enable us to look at the analysis from a number of perspectives.

10.295 In general it was felt that cost and resilience were of greater importance but within environmental boundaries as identified through the SEA, rather than the environmental metric scoring.

10.296 With the outlier cost programmes removed as being unaffordable, the remainder were then tested against other key metrics:

- the programmes where investment costs are 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.

10.297 Other programmes offered either no improvement compared with 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.

10.298 Because the reduced cost variance in the rdWRMP19 outputs has not restricted the range of option types selected by the EBSD+ model, we also decided that the shortlisting process should be mindful to maintain as wide range of option types in the shortlisted programmes as possible. Excluding specific option types through the shortlisting process and before performance testing (Step 4) would be inappropriate.

10.299 We have shortlisted three RAPs, 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.

10.300 The RAPs identified for comparison with the least-cost are listed below, with their characteristics shown in Table 10-19:

- Favouring intergenerational equity (Min_IGEQ[34])
- Favouring customers' preference for option type (NearO_TP[35])
- Favouring customers' preference for frequency of restrictions (NearO_FP[36])

Table 10-19: Step 2a Reasonable Alternative Programmes

BASELINE SCENARIO (Combined LSS)		Least-cost (Step 2a)	Min _IGEQ	NearO _TP	NearO _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[37]	**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		

[34] Min_IGEQ = (Minimise intergenerational equity score) 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.
[35] NearO_TP = (Near optimal type preference) An optimisation run that meets customer preferences for option type, constrained to within 120% of the Least-cost
[36] 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.
[37] Resource development and demand management only.

GW_Addington	1	2063	2062		
IPR_Deephams 45	45	2064			2060
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

10.301 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 desalination plant) would be a concern for the environment of the Thames Tideway. Consequently we would not favour these programmes.

Step 2a: Preferred programme (Baseline)

10.302 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 least cost of £3.061bn NPV (a 52% increase).

10.303 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.

10.304 After the completion of the DMP, 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.

10.305 If solving the baseline planning problem was our preferred scenario, we would probably choose a modified least-cost plan which would also bring forward some of the small scheme investment to balance the risk of delivery of the DMP and to maintain both strands of the twin track approach of resource development alongside demand management. We would also consider re-use over desalination in the longer-term to limit brine impacts on the Tideway and because treated effluent provides a more stable inflow than brackish tidal water.

10.306 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 additional needs of the wider south east region. As such we have tested two further baseline scenarios.

Explaining the additional baseline scenarios

10.307 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

10.308 Our customers have also expressed a preference for improved resilience to drought, where affordable, as our climate changes[38]. Increasing resilience of water supply systems to drought is a key company policy objective. We have also received guidance from Defra, the Environment Agency and Ofwat to increase our resilience.

10.309 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

[38] Thames Water, Draft WRMP19 Appendix T - Our customer priorities and preferences; Section D; Levels of Water Service – Water Use Restrictions.

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[39].

10.310 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[40] as shown in Table 10-20:

Table 10-20: 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

10.311 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 and desalination options to be available, allowing the optimiser a choice of how to respond to this requirement.

10.312 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 from environmentally sensitive waters in drought conditions.

Increased resilience and regional transfers

10.313 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.

10.314 Affinity Water has requested that we allow 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 10-21 below.

Table 10-21: 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)	2037-38	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*

[39] '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.
[40] Thames Water, Draft WRMP19 Section 04 - Current and Future Water Supply; Section D; Drought and Risk.

10.315 Southern Water has requested that we run 'What if' scenarios with transfers to its supply area. This is a potential need, but not yet confirmed (see Step 4) and Southern Water has advised that its revised draft WRMP preferred plan does not include use of the transfer.

Scenario assessment: Impact on least-cost solutions

10.316 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.

10.317 Table 10-22 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[41] (104% higher than Step 2 (LC)).
- As the deficit in supply and demand is increased, the DMP is then supported by a number of smaller resource development schemes that are regularly chosen. This suggests that there are a number of 'low 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).

[41] This includes the full cost of the options delivered to meet that need. No adjustments are made to account for the proportion of the costs that would eventually be borne by Affinity Water's customers.

Table 10-22: 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[42]	**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_Ashton Keynes	2	2089			2082
GW_London confined chalk	2	2069	2074	2051	2083
NTC_Britwell	1	2096			2083
GW_Addington	1	2041	2063	2052	2085

[42] Resource development and demand management only.

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

10.318 In the dWRMP19 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 rdWRMP19.

10.319 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.

10.320 **As such our preferred planning scenario is as set out in Step 2c, baseline plus increased drought resilience plus regional (WRSE) transfers.**

10.321 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.

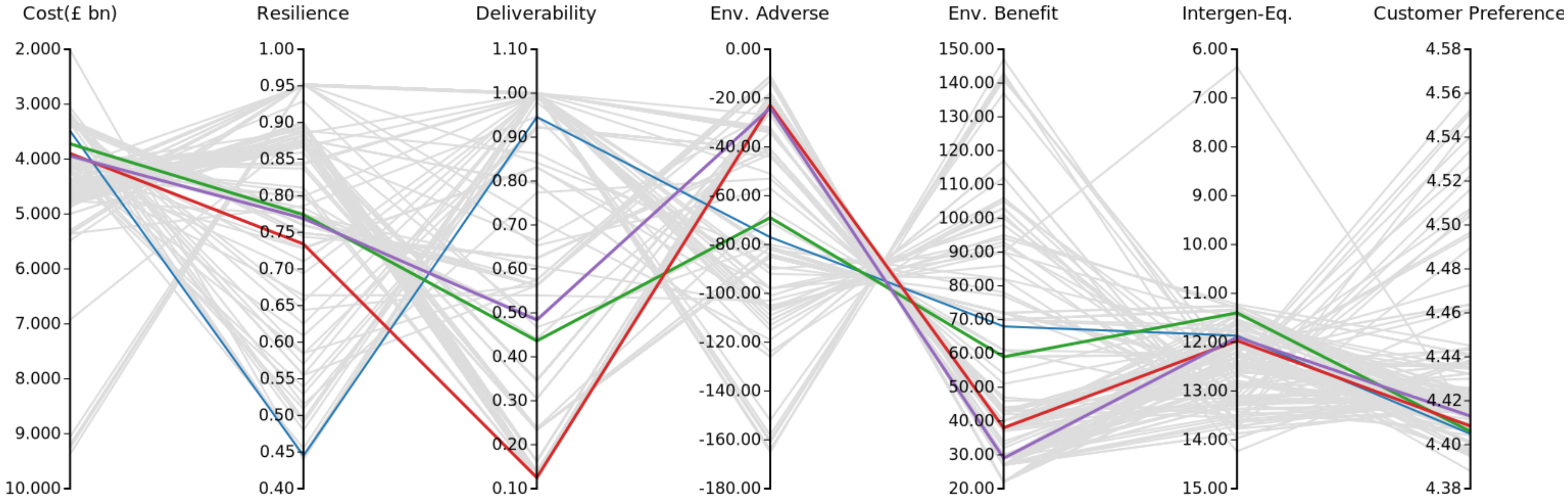
Step 2/3b: Scenario assessment: Baseline + increased resilience

10.322 Repeating the process in Step 2a, as well as the least-cost run shown above, further batches of EBSD+ optimisation runs, 22 in total, were produced to solve the Baseline + increased resilience planning problem for each of the assessment metrics.

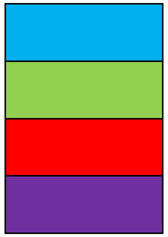
10.323 The outputs are uploaded to PolyVis for analysis as shown in Figure 10-14. They are also available in tabular form in Appendix X, Part B. Shortlisted runs are highlighted and discussed below. Note the shortlisting process for Step 2b does not have a presumption of favour towards programmes shortlisted in Step 2a. The selections are independent.

10.324 The coloured lines represent the shortlisted runs (discussed later). [NB. All outputs for all runs in Steps 2a, 2b and 2c are shown greyed out in the background, i.e. there are more than just the Step 2b runs shown.]

Figure 10-14: Step 2b PolyVis output - Baseline + Increased Resilience scenario



Key:



Step 2b: Least-cost (including policy demand management)

Step 2b: Favouring intergenerational equity (Min_IGEQ)

Step 2b: Favouring environmental benefit (options only) alongside cost (Multi-obj_ENVB)

Step 2b: Favouring deliverability alongside cost (Multi-obj_DEL)

10.325 As noted similarly in Step 2a, we make the following observations based on the PolyVis plot (above) and the supporting database of metric scores and option selection. [It is recommended to have the Appendix X part B tables open for reference]:

- The introduction of moving to 1:200 resilience in 2030 has increased the cost of the solution by £426m NPV (16%), compared with Step 2a.
- 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.
- 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 with the dWRMP19.
- 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.

Shortlisting

10.326 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.

10.327 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.

10.328 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.

10.329 Other programmes offered either no benefit improvement compared with 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.

10.330 Because the reduced cost variance in the rdWRMP19 outputs has not restricted the range of option types selected by the EBSD+ model, we also decided that the shortlisting process should be mindful to maintain as wide range of option types in the shortlisted programmes as possible. Excluding specific option types through the shortlisting process and before performance testing (Step 4) would be inappropriate.

10.331 We have shortlisted three RAPs, 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.

10.332 The RAPs identified for comparison with the least-cost are listed below, with their characteristics shown in Table 10-23 below:

- Favouring intergenerational equity (Min_IGEQ)
- Favouring environmental benefit (options only) alongside cost (Multi-obj_ENVB[43])
- Favouring deliverability alongside cost (Multi-obj_DEL[44])

Table 10-23: Step 2b Reasonable Alternative Programmes

BASELINE + DRO SCENARIO (Combined LSS)		LEAST-COST (Step 2b)	Min _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[45]	**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		

[43] Multi-obj_ENVB = (Multiple objective Environmental Benefit) An optimisation run optimises the environmental benefits of the options and cost simultaneously.
[44] Multi-obj_DEL = (Multiple objective Deliverability) An optimisation run optimises the deliverability and cost simultaneously.
[45] Resource development and demand management only.

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			
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

10.333 The Least-cost programme chooses multiple re-use schemes, which as we stated in Step 2a would place cumulative stresses on the Thames Tideway and be a concern for compliance with environmental legislation.

10.334 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.

10.335 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 Step 2c in the assessment of adaptability.

Step 2b: Preferred programme (Baseline + 1:200 drought resilience)

10.336 The Min_IGEQ programme would likely form the basis of our preferred programme for this scenario as it provides a useful balance of small and large schemes for a reasonable increment in cost compared with the least-cost run.

10.337 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.

10.338 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

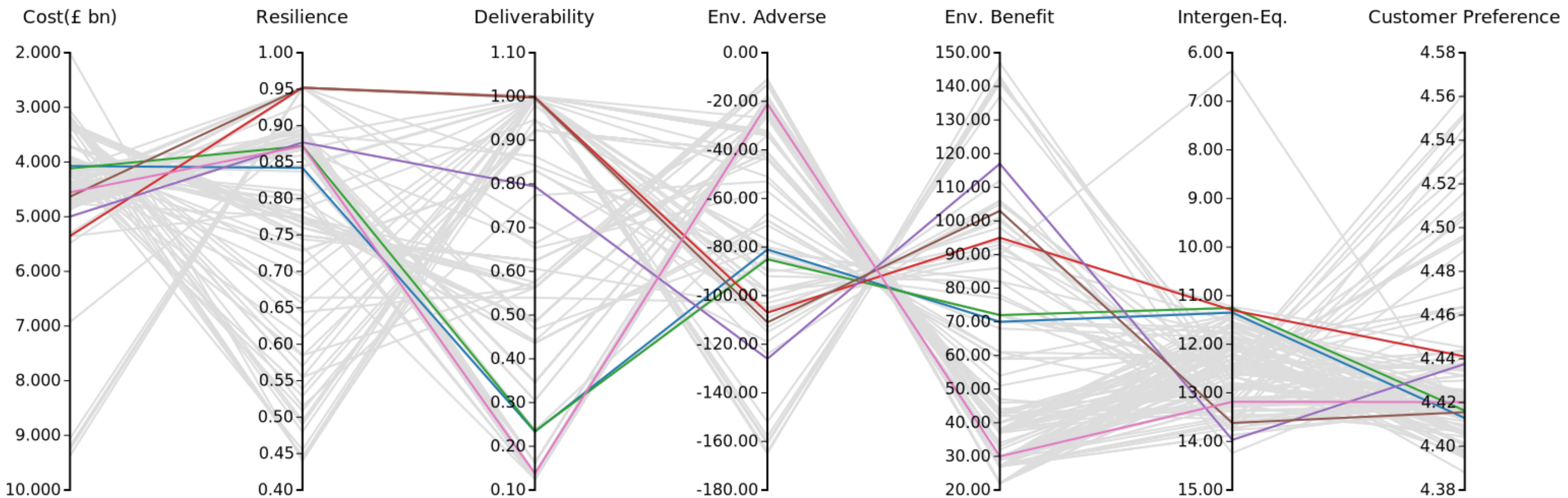
10.339 In Step 2c we introduce a need to provide a further 100 Ml/d to Affinity Water from 2037-38. The same batch of EBSD+ optimisation runs have been produced to resolve the additional supply demand deficit resulting from this scenario.

10.340 The outputs are uploaded to PolyVis for analysis as shown in Figure 10-15. The coloured lines represent the shortlisted runs (discussed later). [NB. All outputs for all runs in Steps 2a, 2b and 2c are shown greyed out in the background, i.e. there are more than just the Step 2b runs shown]. The outputs are shown in full in tabular form in Appendix X, Part B.

10.341 In Figure 10-16 we also show the relative proportion of each option type selected in each output run, against cost, £bn NPV.

10.342 RAPs are highlighted in both figures. The reasons for their selection are discussed in the shortlisting section below.

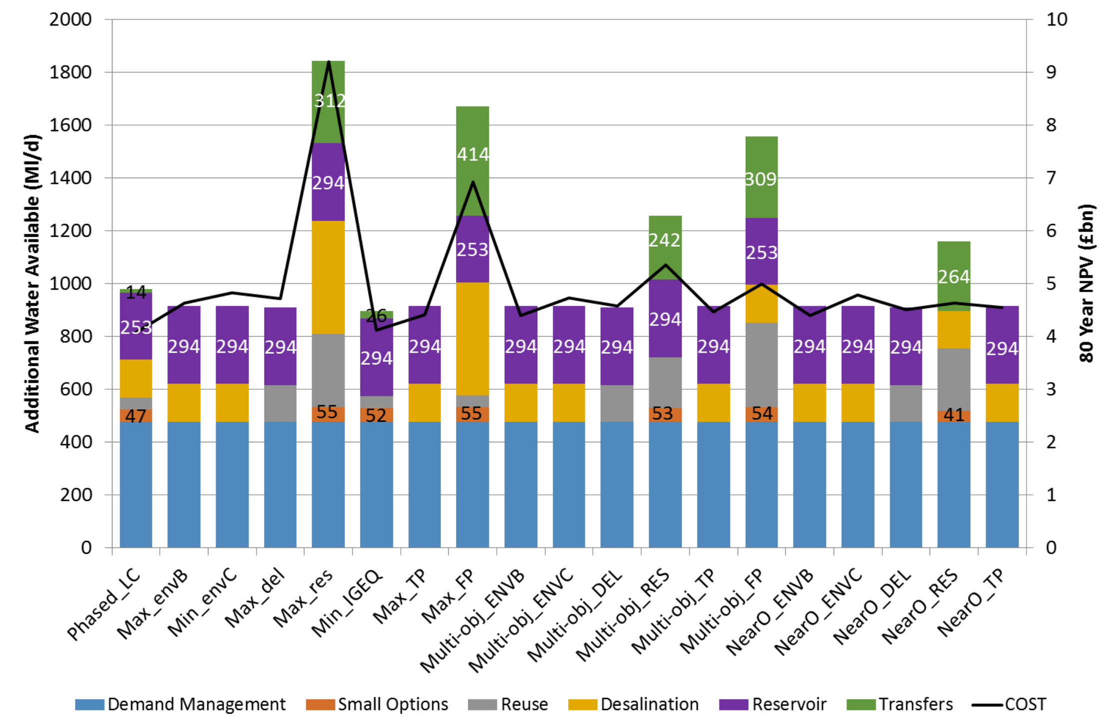
Figure 10-15: Step 2c: PolyVis output - Baseline + DRO + WRSE scenario



Key

	Step 2c: Least-cost (including policy position)
	Step 2c: Favouring intergenerational equity (Min_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 10-16: Step 2c: Optimisation outputs by option type



**Values are Ml/d; used as a guide to which/how many options are selected*

10.343 We observe similar patterns as seen in Steps 2a and b based on the PolyVis plot (above) and the supporting database of metric scores and option selection. [It is recommended to have the Appendix X part B tables open for reference]:

- 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 with the dWRMP19 due to the reduction in the long-term population forecast and the increased amount of the deficit which is being met through the policy DMP.
- Despite the reduced cost variance there is considerable variety in the choices of options made by the model to meet the deficit.

Shortlisting

10.344 When looking across all the metrics it appears that there are alternative programmes that could provide a better overall solution than the straight least-cost programme.

10.345 We shortlisted programmes using the following process, which is expanded upon in the paragraphs below:

- Exclude unaffordable programmes
- Exclude poorly performing programmes
- Review internally and with the Expert Panel
- Identify the RAPs

10.346 We initially 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.

10.347 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.

10.348 Other programmes offered either no benefit improvement compared with 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.

10.349 We noted that there was broad similarity in outputs produced across a number of the optimisation runs. This included small changes like the inclusion of smaller groundwater schemes, or switching re-use and desalination options. This was different to the situation for the dWRMP19 where it was much clearer to pick out leading RAPs. We discussed this with the Expert Panel and decided that we should select RAPs not only on metric performance, but also to ensure that we retained a sufficient breadth of option types to take forward to performance testing (Step 4). We felt it important to preserve the wide range of option types and assess whether performance testing could help tease out those types (or combinations of types) with the overall best value performance.

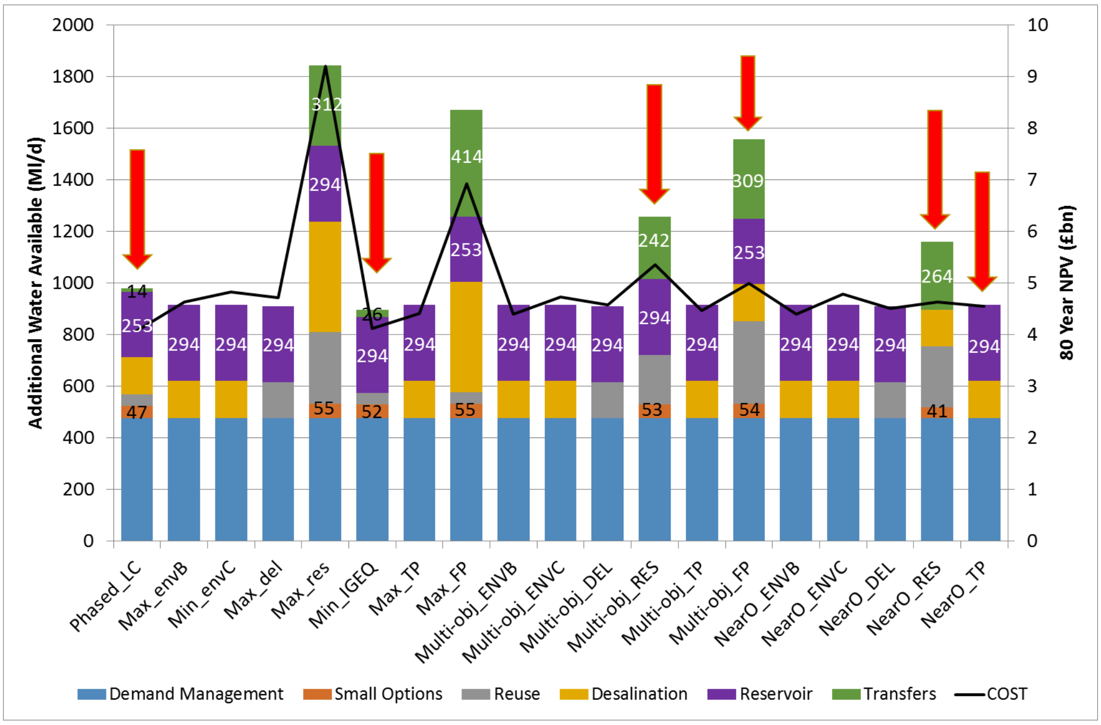
10.350 As with the other scenarios, we have shortlisted a number of RAPs, alongside least-cost. We have done so on the basis of their performance across all the metrics and to provide choices in terms of options types used in the solutions to resolve the supply demand problem in this scenario.

10.351 The RAPs identified for comparison with the least-cost are listed below, highlighted in Figure 10-17, with their characteristics shown in Table 10-24:

- Favouring intergenerational equity (Min_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)

Figure 10-17: Step 2c: Selected RAPs



10.352 The Min_IGEQ run was chosen as it is close to least cost and develops a lower volume of additional water available in total.

10.353 The NearO_TP run was chosen as it contains the simplest programme of options and it enables us to examine how flexible such a programme would be during performance testing.

10.354 The three _RES and _FP runs were chosen because they develop a much larger overall volume of resources for a relatively small increase in cost. As such it is interesting to examine the trade-off of cost and resilience and the combination of options chosen to achieve it.

10.355 For example, the NearO_Res run is the only run that doesn't pick a reservoir. However it does assume that the Severn Thames Transfer option would be available from 2030. The Environment Agency in its representation on our rdWRMP19 considers that the 10 year lead time could be an underestimation[46].

10.356 The _FP run develops a large total volume of resource, with all the strategic option types but is cheaper overall than Multi-obj_RES, which does not include desalination.

10.357 We discussed the outputs and shortlisting of Step 2c programmes with the Expert Panel.

10.358 The characteristics of each these programmes are summarised in Table 10-24 below:

[46] Environment Agency (Nov, 2018) Representation on Thames Water's revised draft WRMP Evidence Report, Annex 1 R4.8

Table 10-24: Step 2c Reasonable Alternative Programmes

BASELINE+DRO+WRSE (Combined LSS)		Least-cost (Step 2c)	Min _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[47]	**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	

[47] Resource development and demand management only.

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	
RWP_STT Netheridge	18			2030	2055	2030	
GW_Moulsford	4	2082	2051	2026	2039	2026	
NTC_Ashton 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		

10.359 In addition to the DMP, 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 option (SESRO).

10.360 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.

10.361 In these six RAPs we have selected the full range of option types for more detailed evaluation through the SEA and performance testing in Step 4 of our programme appraisal process.

Step 2c: SEA review of shortlisted programmes

10.362 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.

10.363 For each shortlisted programme shown in Table 10-24 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 SEA of each shortlisted programme is provided in Appendix B: SEA – Environmental Report.

Figure 10-18: Summary SEA findings of the reasonable alternative programmes

Multi_Obj RES	Phased_LC	Multi_Obj_FP	NearO_ RES	NearO_TP	Min_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"	

10.364 Three of the six RAPs are assessed as having cumulative major adverse effects, with the MultiObj_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.

10.365 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).

10.366 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 10-18. 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.

10.367 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.

10.368 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.

10.369 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.

10.370 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 discussed in Step 4.

Step 4: Performance testing

10.371 The RAPs identified in Steps 2 and 3 are modelled outputs. As modelled outputs they are unlikely to be immediately suitable as a preferred programme. Performance testing is required to examine how practical and sensitive to change the RAPs are.

10.372 Once complete, this information enables us to consider if changes are required to form the overall preferred best value programme. These changes are discussion further in Step 5.

10.373 We have conducted a substantial programme of performance testing, which has included six elements (as shown in Figure 10-19, below):

Figure 10-19: The elements of performance testing

Option uncertainty (Final planning target headroom)

10.374 The uncertainty around the baseline supply demand balance and the target headroom values included in the assessment were discussed in Section 5: Risk and Uncertainty.

10.375 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.

10.376 This section discusses the application of final planning 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.

10.377 The six reasonable alternative plans contain options that each have their own additional uncertainties associated with them. The uncertainty in these options should also be taken account of when developing a preferred programme.

10.378 Because the additional uncertainty component for new options is relatively small compared with the uncertainty in baseline forecasts and because the demand management programme provides significant surpluses in AMP7, we found that when we followed the UKWIR methodology (set out in the planning guidance) this lead to the final plan target headroom being lower than the baseline target headroom, which is counter intuitive. Therefore, we have used an alternative approach. This approach adds 5% of the benefit of the schemes selected up to 2045 to the baseline headroom allowance to account for option uncertainty. We are continuing to develop a more complex approach for future iterations of the plan.

10.379 We have tested our plan to make sure that our alternative approach to calculating final planning target headroom does not result in inefficient investment or put levels of service at risk. We are confident that our approaches (reviewing the strategic options available to us and developing adaptive pathways) means that our alternative approach does not cause either inefficient investment or affect levels of service. The explanation is provided in the following paragraphs.

10.380 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.

10.381 Company-wide the maximum impact is approximately 28 Ml/d by 2045, which is relatively small compared with the total uncertainty range assessed (+/-600 Ml/d) via adaptability analysis and what-if testing in the next sections.

10.382 Having added the additional option uncertainty to baseline headroom values and repeated the least cost optimisation in EBSD+, it was noted that the four RAPs that are optimised including elements other than cost are unaffected. This is because they favour retaining surplus and thus can absorb the minor changes in the forecast supply demand balance.

10.383 The Phased_LC and Min_IGEQ programmes, which are optimised including cost, are more sensitive and a few small schemes come forward in time and others are added to meet the additional need.

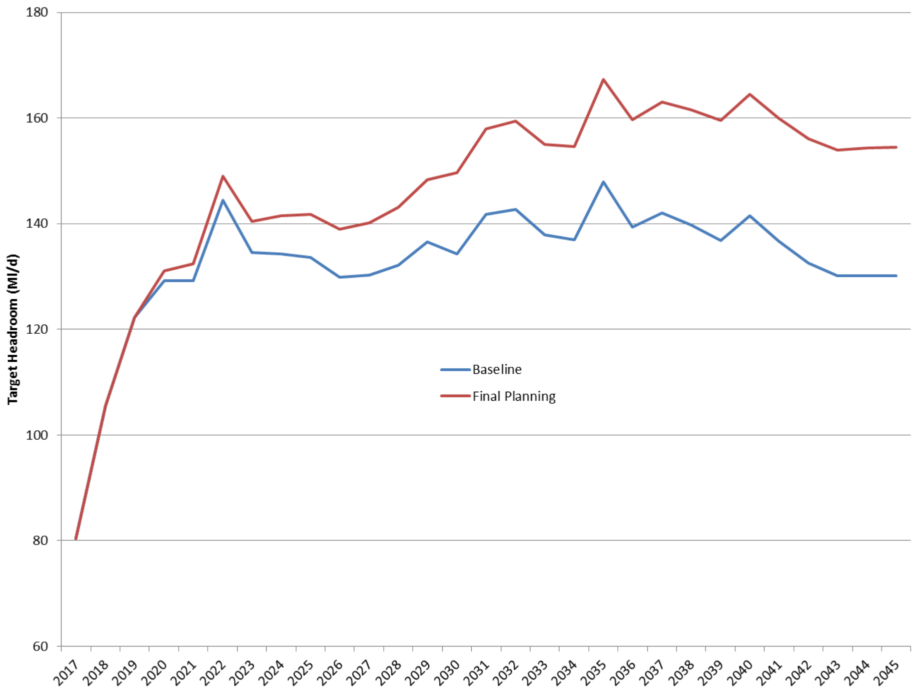
10.384 The results of target headroom for London WRZ are shown in Figure 10-20 below, where the variance between baseline and final lines represents the uncertainty around options in the plan.

10.385 The impact on the other WRZs is discussed in Appendix X and also shown in Appendix A: rdWRMP19 planning tables (Table 9).

Summary

10.386 The additional risk related to option uncertainty can be managed through changes in the timing and number of smaller resource development options delivered. It does not materially impact the selection and timing of the strategic supply schemes.

Figure 10-20: London target headroom



Adaptability testing

10.387 One way of analysing multiple futures simultaneously is through the use of adaptability testing of the RAPs.

10.388 We have developed a method, using the Adaptability extension in the EBSD+ DST (as described in S10.D), 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.

10.389 The uncertainties used in adaptability testing are:

Table 10-25: 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 2037-38)
Climate change	Taking the Medium emissions 5% and 95% percentile impact on deployable output. Also that the impact occurs by 2050 instead of 2080

10.390 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.

10.391 For further information on how the pathways were constructed see Appendix W.

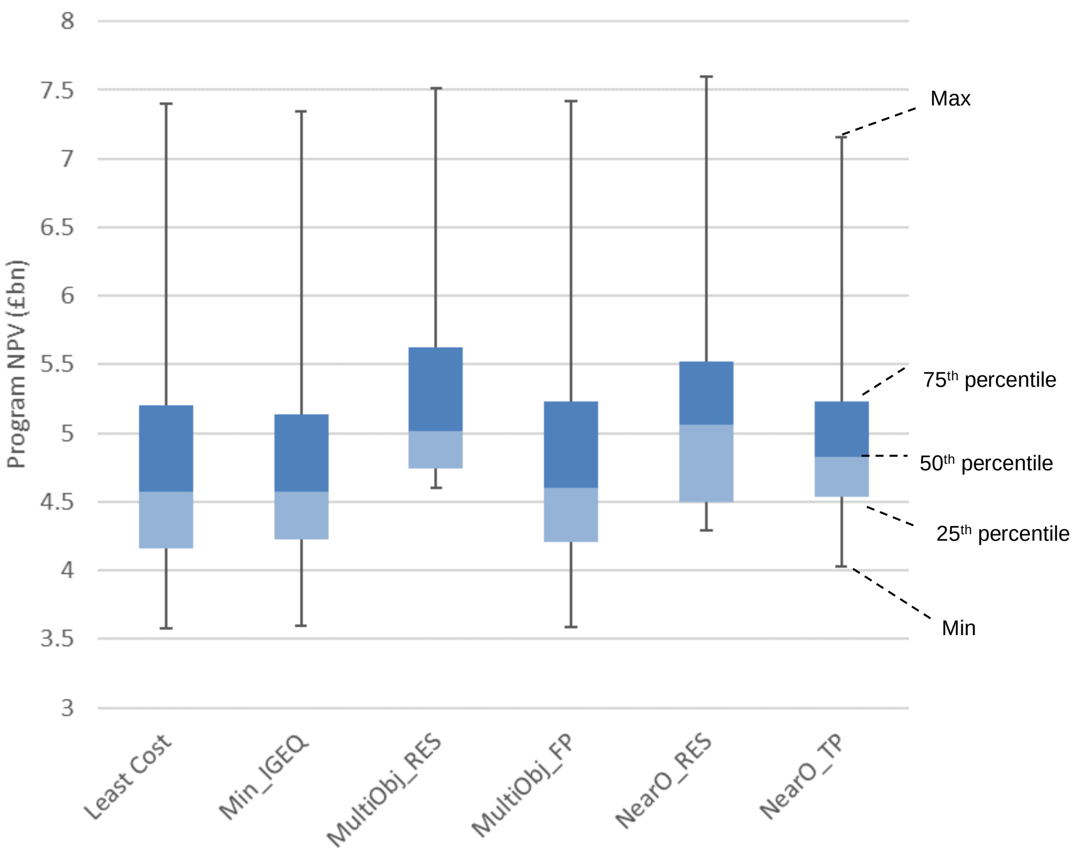
10.392 Three outputs are generated:

- Overall cost ranges
- Risk variability (Failures, risk and magnitude, in each programme)
- Standby costs

Overall cost range

10.393 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, 25th, 50th and 75th percentiles) (Figure 10-21).

Figure 10-21: Adaptability Outputs: Cost ranges



10.394 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.

10.395 The Least Cost, Min_IGEQ and MultiObj_FP programmes have the lowest mean cost across the different futures at ~£4.6bn. The Min_IGEQ programme has the narrower cost range about the mean, both from minimum to maximum and across the central 25th-75th percentiles, which makes it the more attractive programme. Investment in a programme with a higher mean cost reduces the cost range (MultiObj_RES, NearO_Res and NearO_TP).

Risk variability

10.396 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.

10.397 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.

10.398 Up to the mid-2030s 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.

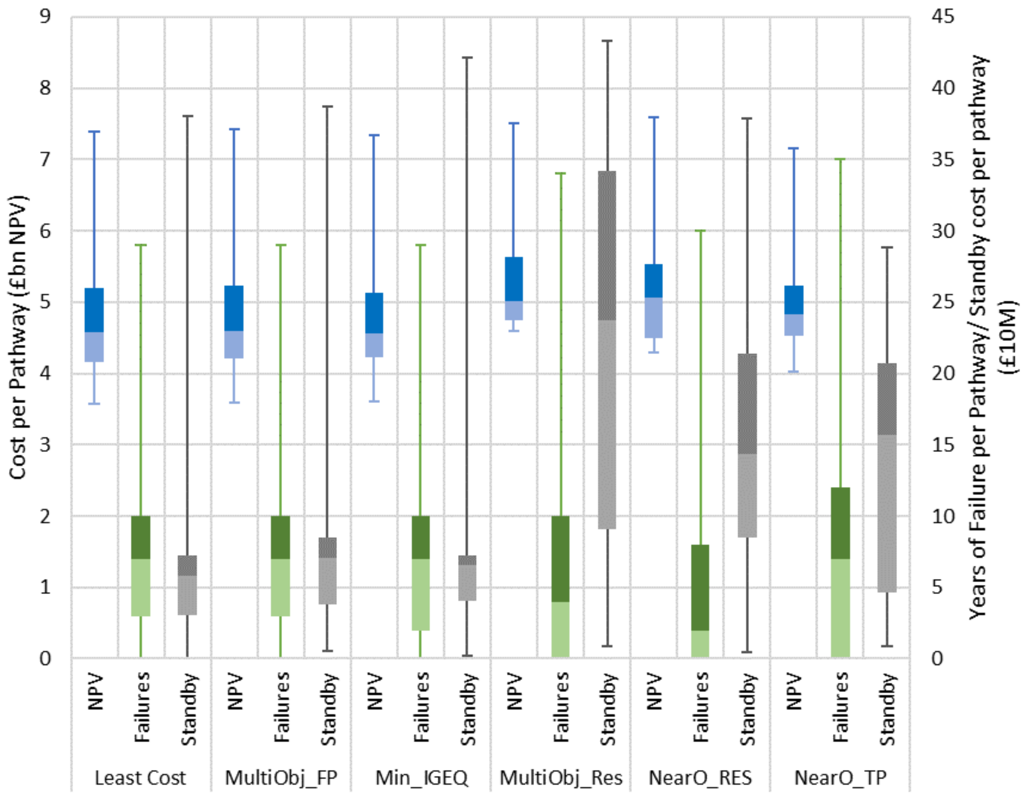
10.399 The flip-side to being able to cover this risk is the extra cost of having built assets that may not be used, i.e. the cost of standby.

Standby costs

10.400 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 10-22). 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.

10.401 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 10-22 to allow analysis of the trade-offs between them.

Figure 10-22: Adaptability Outputs: Trade-offs



10.402 Least Cost and MultiObj_FP both begin investment in Deephams reuse and the 125Mm³ 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 programme has slightly higher standby costs due to the additional capacity.

10.403 Min_IGEQ builds Deephams reuse in conjunction with the 150Mm³ 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.

10.404 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 programme because desalination, unlike reuse, is not a modular option whereby the plant capacity can be increased at a later date. The NearO_RES-based programme therefore develops the reservoir for approximately half of the pathways as they become more challenging, while the MultiObj_RES programme 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 programmes.

10.405 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

10.406 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.

10.407 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.

10.408 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.

Analysing specific pathways

10.409 It is possible to pull out specific pathways from the Adaptability analysis to assess how the different RAPs would adapt for that future. For example, Path N-180 is within 20 Ml/d of the most likely volume required to be resilient to a 1:500 drought in London, SWA and SWOX combined (see Appendix W, Annex 5).

What If testing

10.410 As well as testing multiple uncertainties at once, we have also carried out a set of simpler, single, What if tests to investigate what would change if one aspect of the supporting information or input data were to change.

10.411 Only the least-cost metric is run as the intention is to examine the impact of a change.

10.412 We carried out a limited selection of What if testing in the dWRMP19. We then had a significant number of requests for consideration of alternative What Ifs in our consultation responses and expanded the analysis accordingly.

10.413 Clearly there are a very large number of potential scenarios that could be assessed but we have chosen a set that covers the key future uncertainties and to respond to the requests we have received.

10.414 Table 10-26 lists the topics covered in the tests we have performed for this rdWRMP19. The comments in the table relate to the impact on the supply demand balance both in terms of increasing the gap (+) or reducing it (-).

10.415 There are 37 individual runs. Full details on how each run was configured (i.e. the changes we made to the input data) and the associated outputs is reported in full in Appendix X.

10.416 For reasons of brevity an abridged set of outputs is included in Table 10-27 below, alongside a comparator programme for ease of reference. This programme reflects the Step 2c least cost programme before the inclusion of final planning target headroom.

Table 10-26: 'What if' analysis scenarios

Topic	Scenario	No.	Impact (Ml/d)	Comment
Resilience	Timing of 1:200 drought resilience	2	N/A	Timing only, 2027 and 2035
Resilience	1:500 drought resilience in 2040	1	+130	Testing impact of greater resilience to drought from 2040.
Resilience	Reservoir Outage/Replacement	2	+108	Temporary (2 year impact) in 2030-31 or 2040-41, reflecting the need to take a reservoir out of service.
Supply change	Remove outages >90 days from record	1	-19	Response to a technical query from the Environment Agency regarding outage
Supply change	Change to West Berks Groundwater Scheme (WBGWS)	2	+40 (LON) +27 (SWOX)	Impact of an estimated partial revocation of WBGWS licences in 2031 or 2040
Economics	Shortened planning periods	3	N/A	50, 55, 60 years
Supply change/WRSE	Alternative use of existing bulk supply	1	+15 to-10	Impact of alternative transfer volumes to Affinity Water at Fortis Green
WRSE	Alternative new WRSE transfers (Affinity, Timing and Volume)	3		2027, 2035 @ 100Ml/d; phased 50Ml/d 2038 and 2053
WRSE	Potential new WRSE transfers (Other companies)	4	+50 to -185	Combination of estimates of potential need from SWS, SEW and SES.
Supply option change	No Reservoir options	1	N/A	No reservoir options available for selection
Environmental	WINEP – WFD No Deterioration	4	a) +32 b) +107	Company view of potential future sustainability reductions for WFD no deterioration by 2027 & 2035
Environmental	Reduction in abstraction from Chalk Streams	2	a) +34 b) +77	Company view of potential reductions to chalk stream abstraction. 34Ml/d at 2030, up to 77Ml/d by 2040
Demand forecast	Population Uncertainty	3	+100 to -250	Trend based growth; ONS High and ONS Low
Demand forecast	PCC Uncertainty	6	+210 to -380	Assuming no usage savings DMP; or using future deep reductions in PCC from Ofwat/Artesia work.
Demand forecast	Leakage uncertainty	1	+125	Assuming leakage reduces by 33% instead of 50% by 2050
Climate change	Climate change (2050s instead of 2080s)	1	N/A	Timing only. Impact moved to 2050.

Table 10-27: 'What if' scenarios: Example outputs

What If Test	BASE COMPARATOR	Resilience			No Res Options	WRSE Transfers					Environmental						Demand Forecast				
		1:200 DRO Timing		1:500 DRO		Timing Affinity 100Ml/d	Affinity Phased 50/50	Potential new WRSE transfer			WINEP - No deterioration				Reduction in abstraction chalk streams		Population		PCC		Leakage
		2027	2035	2040		2035	2038/ 2053	Run 1 SWS 50Ml/d	Run 2 SWS 125M/d	Run 4 Max 185Ml/d	Most likely 2027	Most likely 2035	Potential 2027	Potential 2035	34Ml/d by 2030	77Ml/d by 2040	ONS16 High	ONS16 Low	No Usage savings	PCC -105	33% reduction instead of 50%
Metrics																					
Financial (£m NPV)	4,073	4,123	4,055	4,229	4,089	4,228	4,201	4,301	4,387	4,468	4,174	4,125	4,409	4,327	4,450	4,513	4,242	3,501	4,759	3,713	4,450
Environmental +	70	79	82	77	103	79	73	81	75	86	79	79	71	79	79	77	113	72	66	59	75
Environmental -	81	83	86	80	102	79	70	86	77	94	83	83	72	79	83	80	115	56	93	68	77
Deliverability	0.96	0.99	1	0.99	0.99	0.99	0.99	1	0.99	0.99	0.99	0.99	1	0.99	0.99	0.99	1	1	0.97	1	1
Resilience	0.98	0.84	0.9	0.87	0.67	0.88	0.87	0.9	0.9	0.9	0.85	0.85	0.83	0.9	0.85	0.87	0.75	0.48	0.87	0.64	0.87
IGEQ	11.35	12.58	12.42	11.24	11.79	11.27	11.90	11.19	12.64	12.71	11.31	12.52	12.85	11.19	11.29	11.2	13.41	12.05			11.63
Customer preference	4.41	4.41	4.42	4.42	4.39	4.42	4.42	4.42	4.42	4.43	4.41	4.41	4.41	4.42	4.41	4.41	4.41	4.38	4.24	4.39	4.41
Options																					
AR_Kidbrooke (SLARS1)			2098				2082			2098				2080							
AR_Merton (SLARS3)	2083	2086	2095	2066	2055	2031	2081	2082	2066	2096	2031	2081		2076	2031	2031			2031		2089
AR_Streatham (SLARS)	2087	2088	2097	2099				2084		2097	2083	2083		2079	2030	2030			2035		
ASR_Horton Kirkby	2080	2027	2075	2062	2050	2030	2030	2080	2063	2070	2030	2035	2080	2073	2030	2030	2031	2030	2022	2083	2080
ASR_South East London	2084	2084	2096	2065	2056	2031		2083	2065	2072	2031	2035	2089	2075	2031	2031	2040	2031	2035		2087
ASR_Thames Central	2086	2087		2064	2066	2079		2086			2030	2035		2077	2030	2030	2040	2031	2035		
DMP_LON	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020
DMP_SWA	2025	2025	2025	2025	2025	2025	2025	2025	2025	2025	2025	2025	2025	2025	2025	2025	2025	2025	2025	2025	2025
DMP_SWX	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020
DSL_Beckton 150	2088	2089		2067	2067	2081		2087	2067		2084	2084	2029	2082	2082	2081			2029		2029
DSL_Crossness 100																					
GW_Addington	2086	2027	2083	2064	2055	2030	2032	2081	2064	2071	2030	2034	2088	2074	2030	2030	2032	2030	2023	2084	2086
GW_Datchet	2082	2082	2082	2079	2082	2080	2051	2082	2082	2082	2082	2082	2082	2082	2042	2042	2075		2030	2098	2068
GW_Honor Oak								2086					2099						2021		
GW_London confined chalk		2027	2096		2066	2080		2085	2064	2072	2031	2035	2088	2078	2031	2031	2035	2031	2032		2088
GW_Merton		2085	2094	2065	2099	2030		2081	2065	2095	2030	2080		2075	2030	2030	2099		2022		2088
GW_Moulsford	2082	2083	2076	2061	2045	2078		2079	2062	2069	2081	2079	2084	2072	2080	2080	2039	2039	2072	2039	2081
GW_Southfleet/Greenhithe	2031	2027	2081	2031	2031	2030	2079	2031	2031	2031	2030	2031	2086	2031	2030	2030	2031	2030	2024	2031	2082
IPR_Beckton 100										2060							2060		2084		
IPR_Beckton 100										2073							2071				
IPR_Beckton 100																	2086				
IPR_Beckton 150																					
IPR_Deephams 45	2030	2027	2084	2030	2030	2030	2030	2030	2030	2030	2030	2030	2090	2030	2030	2030	2055		2073	2030	2090
IZT_North SWX to SWA 72																					
IZT_R Thames to Medmenham	2095	2095	2095	2092	2095	2093	2078	2095	2095	2095	2095	2095	2095	2095	2069	2069	2085		2066		2084

What If Test	BASE COMPARATOR	Resilience			No Res Options	WRSE Transfers					Environmental						Demand Forecast				
		1:200 DRO Timing		1:500 DRO		Timing Affinity 100Ml/d	Affinity Phased 50/50	Potential new WRSE transfer			WINEP - No deterioration				Reduction in abstraction chalk streams		Population		PCC		Leakage
		2027	2035	2040		2035	2038/ 2053	Run 1 SWS 50Ml/d	Run 2 SWS 125Ml/d	Run 4 Max 185Ml/d	Most likely 2027	Most likely 2035	Potential 2027	Potential 2035	34Ml/d by 2030	77Ml/d by 2040	ONS16 High	ONS16 Low	No Usage savings	PCC -105	33% reduction instead of 50%
NTC_Ashton Keynes	2082	2082	2074	2063	2049	2079		2078	2064	2071	2081	2080	2087	2074	2080	2079	2039	2039	2032	2039	2079
NTC_Britwell	2085	2083	2083	2064	2049	2080		2078	2064	2071	2082	2082	2089		2081	2080	2039		2083	2039	2087
NTC_Epsom	2030	2027	2082	2030	2030	2030	2031	2030	2030	2030	2030	2030	2085	2030	2030	2030	2030	2030	2024	2030	2086
NTC_New River Head	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020
RES_Abingdon 100 Mm3																					
RES_Abingdon 125 Mm3	2039	2039				2035					2039	2039	2039		2039						
RES_Abingdon 150 Mm3			2035	2039			2038	2035	2035	2035				2035		2039			2039		2039
RWP_Chingford (E&S)	2035	2035	2035	2035	2035	2035	2035	2035	2035	2035	2035	2035	2035	2035	2035	2035	2035	2035	2035	2035	2035
RWP_Didcot							2020														
RWP_Oxford Canal to Cropredy	2030	2027	2077	2030	2030	2030	2030	2030	2030	2030	2030	2030	2027	2030	2030	2030	2030	2030	2030	2030	2084
RWP_Oxford Canal to Dukes			2077																		
RWP_STT Minworth					2057												2045			2085	
RWP_STT Mythe					2039		2090										2039	2075		2039	
RWP_STT Netheridge					2039		2096										2030	2091		2039	
RWP_STT UU/ST Opt A					2039												2030	2071		2071	
RWP_STT UU/ST Opt B					2051		2093										2030	2082		2079	
RWP_STT Vyrnwy 180																					
RWP_STT Vyrnwy 60					2039		2084										2030	2039		2039	
RWP_STT Welsh 60																					
RWP_Wessex to SWOX	2085	2085	2099	2063	2056		2064	2085	2099	2099	2082	2082		2078	2081		2040		2083		2099

Summary

10.417 Our approach to What-if testing has been to produce a large number runs across a range of topics. The intention is to provide the reader an indication of the potential movements in the options selected should the future be different. Rather than discuss the outputs of individual runs, we summarise general impacts below.

10.418 If the predicted deficits are higher than anticipated then the outputs tend to favour the construction of a larger desalination or re-use plant instead of smaller options (Deephams re-use, Oxford Canal and groundwater) before 2030.

10.419 In the medium to long-term, a reservoir is regularly selected (of varying sizes from 100-150Mm^3). 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.

10.420 If the deficit eases then fewer small options would be delivered and phased options are preferred including a smaller reservoir, the Severn-Thames Transfer or re-use.

10.421 With respect to the timing of 1:200 drought resilience, it could be brought forward from 2030 to 2027 without significant changes to the options selected (other than bringing them forward). However this would front end load the investment programme, put pressure on the delivery of savings through the DMP and leave little flexibility.

10.422 If it was pushed back to 2035 (or later), nearly all of the resource development required in 2030 could be deferred and the reservoir would become the first strategic option delivered, (brought forward from 2037/38). This would however run counter to the customer, stakeholder and company priority to increase drought resilience and is unlikely to be acceptable.

10.423 With respect to earlier availability of water for regional transfers, they could be brought forward to 2035, the earliest reservoir start date. Providing significant transfers before 2035 would be unlikely and would require identification of new alternative options that could be delivered more quickly.

IRAS-MCS (System simulation modelling)

10.424 IRAS-MCS is a system simulation model that is able to examine system performance across a wide range of drought return periods in a single optimisation. Specific metrics have been developed to show how each run performs against Level 3 and Level 4 service failure and also recovery times.

10.425 It has two modules:

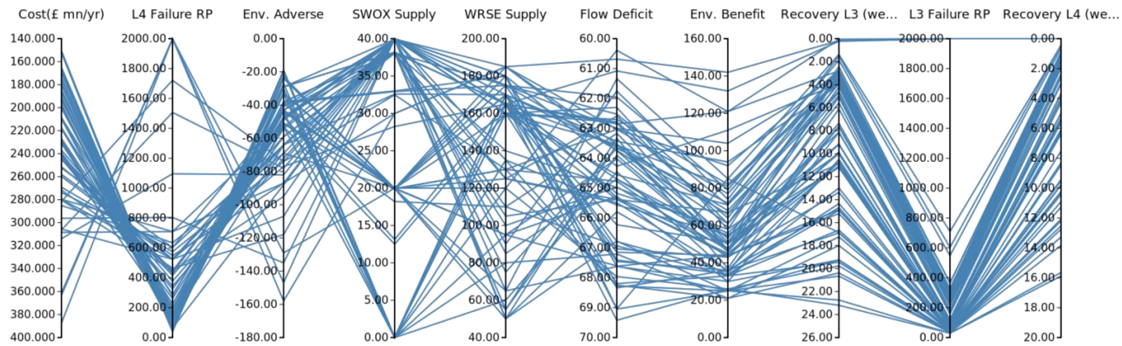
- Portfolio_MCS optimises using a range of single year weather patterns which perturb the simulated river flow and therefore water available, in order to find portfolios of options that meet the deficit in the final year of the planning period
- Scheduling_MCS which takes a portfolio of options identified using Portfolio_MCS and then uses a range of 80-year weather patterns to schedule the options across the planning horizon.

10.426 Portfolio_MCS was given 153 different single year weather patterns of varying return periods, generated from the Future Flows dataset for use in the model. 66 portfolios were developed that could meet the deficits in for the final year of the planning period in the BL+DRO+WRSE scenario.

10.427 These were uploaded to PolyVis (Figure 10-23).

10.428 The policy DMP is fixed in the model, as it is in EBSD.

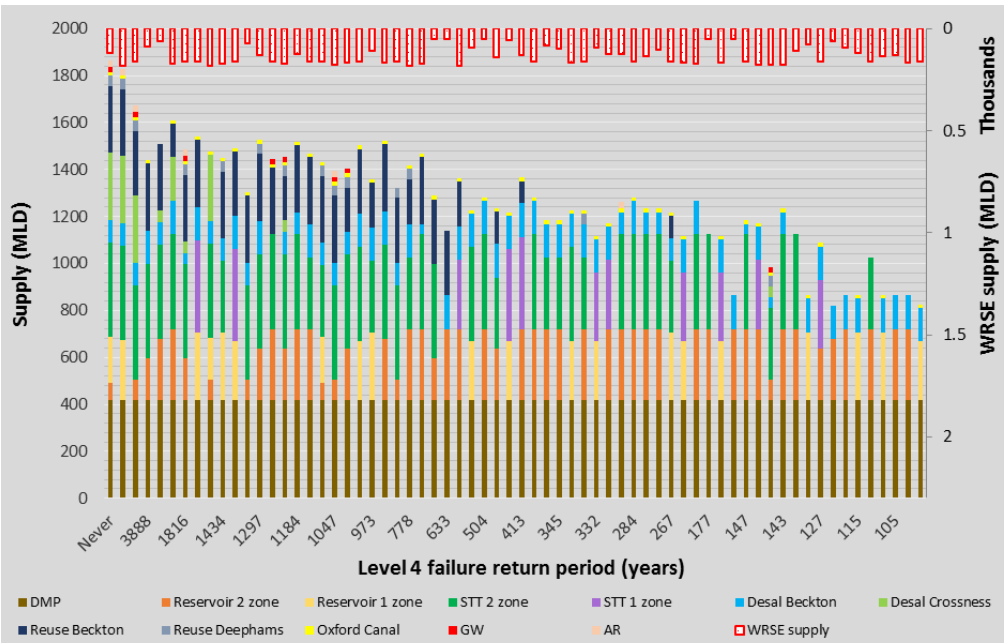
Figure 10-23: IRAS-MCS Programmes



10.429 The 'L4 Failure RP' axis (second left) shows the return period for L4 restrictions, the most severe drought restrictions, from <1:100 to never (graphed as1:2000). 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).

10.430 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 10-24).

Figure 10-24: IRAS-MCS Programmes ranked by L4 return period



10.431 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%).

10.432 We have compared the outputs from the EBSD+ model with the IRAS-MCS model and noted alignment in the options selected to meet the supply demand deficits.

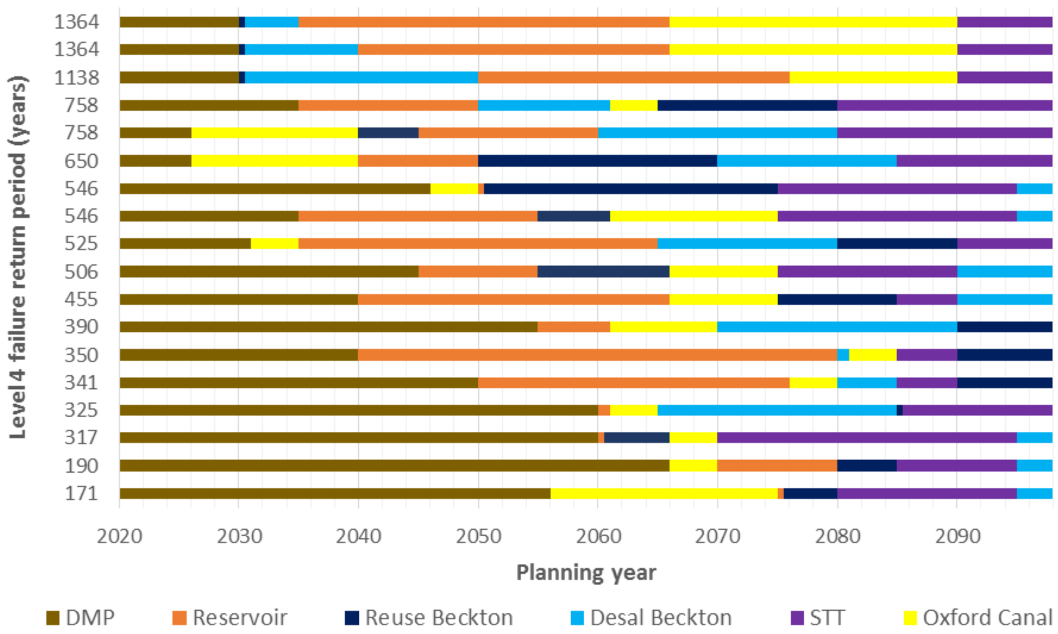
10.433 The smaller options that feature in the EBSD+ runs are not chosen individually as they have been aggregated in IRAS-MCS to reduce model run times (One optimisation takes 3 days).

10.434 We then selected four of the 66 programmes to see how Scheduling_MCS would schedule the schemes in each portfolio across the planning period and how the timing and usage of the schemes would vary with increasing drought severity.

10.435 A different set of 176, 80-year weather patterns including a severe drought from three dry winters was optimised against across the planning period with a bootstrapping method used to ensure all patterns could occur in any AMP so that timing and usage of option was not influenced by drought timing, only potential drought severity. The four portfolios were selected by scrutiny of the options within each, to enable scheduling of portfolios which most closely match the RAPs selected from EBSD+ outputs. This allows comparison of the programmes of options output from Scheduling_MCS with the RAP programmes, to better inform the appraisal process and further understanding of response to varied weather conditions including severe drought. Details of the 4 portfolios are in Appendix W, Annex 6, and further explanation of the selection in Appendix W.

10.436 An example run (No.14655) is provided in Figure 10-25 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 10-25: Portfolio 14655 with options scheduled and ranked by L4 return period



10.437 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 until 2090.

10.438 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.

10.439 For the lowest return periods the activation of all supply resources of all supply schemes is deferred until ~2060.

10.440 Severn-Thames Transfer is generally active towards the end of the planning period (from ~2080).

Summary

10.441 Simulation modelling demonstrates that a large reservoir is a consistently robust option across the full range of weather patterns investigated for portfolio development.

10.442 For the scheduled portfolio, the reservoir is the first large supply option commissioned for all Level 4 return periods between 200 and 1000 years, not counting the 11 Ml/d available from the Oxford Canal. The reservoir is commissioned between 2035 and 2060.

10.443 To supplement supply from the reservoir, commissioning of the Severn-Thames transfer is often delayed until after desalination or reuse has first been employed. This may change if increased resilience were required for neighbouring water companies, which for Southern or Affinity Water would require abstraction points upstream of London

SEA (in development of preferred programme)

10.444 We demonstrated in Step 2/3c how we have applied SEA to the options selected in the six RAPs and to the potential cumulative effects of each of these programmes.

10.445 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:

- DMPs 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[48] policy objectives, the policies included in the revised National Planning Policy Framework 2018[49] and stakeholder feedback on the dWRMP19. 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 SESRO option
- 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:
  - SESRO with Severn-Thames Transfer conveyance pipeline
  - Beckton reuse and Beckton desalination schemes
  - Pipeline to Southern Water (if required) and SESRO
- 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 has a lower level of adverse environmental effects compared With the STT option. Additionally, since there is little material environmental differences between the 125Mm^3 and 150Mm^3 reservoir capacity options, it may be beneficial to construct the larger capacity since

[48] H M Government 2018 A Green Future: Our 25 Year Plan to Improve the Environment.
[49] Ministry of Housing, Communities & Local Government July 2018 National Planning Policy Framework.

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 SESRO.

Local resilience and practicality

10.446 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.

10.447 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.

10.448 This knowledge can be used to reasonably justify changes to modelled output to provide a better overall solution.

10.449 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.

10.450 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

10.451 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.

10.452 The outputs from the DSTs 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.

10.453 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.

10.454 The number and range of alternative views and data analysis available to us to inform our decision is significantly greater than in the dWRMP19. 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.

10.455 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.

10.456 Our first priority is to reduce waste of water resources. As such the preferred programme is demand management focussed in the short-medium-term, comprising an integrated package including significant reductions in leakage (15% in AMP7 (from our end of AMP6 target of 606 Ml/d) and 50% by 2050, in Ml/d terms), the metering of all water supply connections and an enhanced water efficiency programme.

10.457 DMPs will be undertaken in all WRZs in the period to 2050 with savings maintained to the end of the planning horizon.

10.458 Demand management on its own will not be enough to resolve all supply demand deficits, especially in the London WRZ. A twin track approach with resource development is required in order to be consistent with our general duty to develop and maintain an efficient and economical system of water supply.

10.459 We have planned accordingly, supplementing the proposed DMP with strategic water resource development at key points in the planning period to 2030 (driven by the need to increase drought resilience), 2037/38 (driven by regional need for water resources) and the 2080s (to maintain security of supply in the long-term).

10.460 Our modelling has indicated that the leading strategic resource options are:

- (IPR (at Deephams, Beckton or West London)
- Severn-Thames transfer (STT)
- Reservoir development (SESRO)

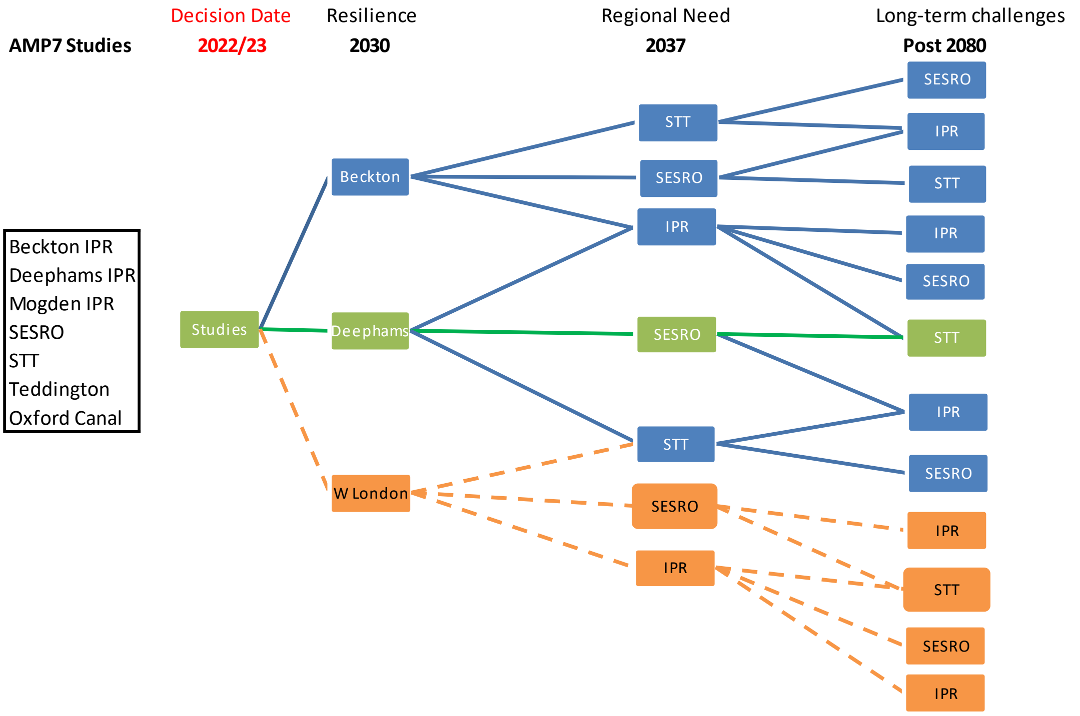
10.461 Desalination is discounted as inferior on cost and environmental grounds, compared with the available re-use options.

10.462 Re-use is the leading option type able to be constructed in time to meet the need to improve drought resilience by 2030, The decision is whether to build a single larger plant at Beckton, or a smaller plant at Deephams, supported by smaller innovative groundwater schemes, smaller regional trades and transfers.

10.463 Following the rejection of the Teddington DRA option from our dWRMP19, we will also need to consider if there are alternative feasible West London based options utilising the Mogden Sewage Treatment catchment.

10.464 We have put these major scheme development dates into an option delivery tree (below) to be informed by further pre-planning work in AMP7.

Figure 10-26: Option delivery tree



Green = Preferred path; Blue = Alternative paths; Orange = Paths not currently feasible

10.465 We have demonstrated that our rdWRMP19 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 10-28.

Table 10-28: Major scheme delivery points over the planning period

From 2020	
Demand Management Focus	In the next five years and continuing to 2050 we intend to undertake a substantial and ambitious DMP. We believe this is the right thing to do and aligns with the expectations of our customers, regulators and stakeholders.
2030	
Providing 1:200 year drought resilience (risk of insufficient supplies to meet demand of 0.5% p.a.)	Providing 1:200 year drought resilience from 2030 onwards will require new 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 wastewater reuse plant. We currently 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.
2037/38	
Regional need	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 and the management of uncertainty • The option is most regularly chosen across RAPs, adaptability, What if analysis and IRAS-MCS system simulation modelling • It maximises the capture and storage of water resources already available in the Thames Basin • Extra storage provides flexibility and resilience benefits • It is the option preferred by our customers and provides recreational and biodiversity benefits. Delivering this option will provide an additional benefit through using available headroom, although chalk streams has not driven this programme, 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 currently favour the Severn-Thames Transfer on the basis of: • Meeting the potential future need in the west of the Thames catchment, namely: — Greater need for regional transfer e.g. for Southern Water requirements in Hampshire — The uncertainty of the yield of the West Berkshire

	Groundwater Scheme — The possibility of further sustainability reductions being required at environmentally sensitive sources — Increased demand for water supplies in the Cambridge, Milton Keynes and Oxford growth corridor (CaMKOx) • SESRO and the Severn-Thames Transfer are regularly selected by system simulation modelling at higher drought return periods. eg. 1 in 500 year (0.2% per annum) extreme drought resilience • 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 • The timing of the need is determined by resilience and growth requirements. Enhancements in either would bring the scheme forwards. Adaptive planning enables appropriate decision making.

10.466 Our overall preferred programme for the LSS combined zone, covering London, SWA and SWOX WRZs, is shown below in Table 10-29, including for chalk stream abstraction reductions from 2037-38.

Table 10-29: 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[50]	**Benefit (Ml/d)**	**Implementation date**	
DMP_LON_S4b	421	2020	
DMP_SWX_S4b	51	2020	
DMP_SWA_S4b	22	2025	
RWP_Didcot	18	2020-25	See Note 1
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	

[50] Resource development and demand management only

10.467 The following notes (as indicated in the table above) refer to where changes have been made to the RAPs following performance testing, in selecting the preferred programme.

Note 1 – Licence trade agreement with RWE Npower (Didcot)

10.468 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 – Bringing forward schemes in SE London

10.469 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 environmental impacts on chalk streams and vulnerable 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 shortfall in the DMP.

Note 3 – Maximising SESRO benefit

10.470 We have included the largest (150 Mm^3) SESRO in 2037/38, 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.

10.471 The delivery of the 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 chalk streams and other vulnerable water courses, although this surplus is not driven by the chalk streams reductions (Table 10-30). 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 10-30: Changes to abstraction on vulnerable chalk streams and watercourses

Source	Waterbody	WRZ	Reduction (Ml/d)		Scheme (2037)
			Average	Peak	
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	

10.472 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.

10.473 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.

10.474 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.

10.475 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 – Severn-Thames Transfer in the long-term

10.476 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.

10.477 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.

10.478 The delivery date for the Severn-Thames Transfer would be brought forward if key future challenges are greater than currently envisaged or if greater resilience to extreme drought is desired.

10.479 For example, delivery of SESRO provides sufficient surplus to be resilient to a 1:500 drought for a time. If we wanted to sustain that level of resilience (instead of 1:200) it would require 142 Ml/d of additional resource to be available for London, SWA, SWOX and Kennet Valley zones. To meet this need the Severn-Thames transfer would be brought forward to 2060.

10.480 If housing and population growth rates were higher than anticipated for example due to the potential Cambridge-Milton Keynes-Oxford (CaMKOx) growth corridor, we have estimated an impact of 85 Ml/d for SWOX and 28 Ml/d for neighbouring Affinity zones by 2050 (linearly projected from a start in 2030).

10.481 Timing of the growth would be critical. If CaMKOx growth was forecast to increase demand in early in the 2030s, this may suggest earlier commissioning of SESRO or require the delivery of intervening small groundwater developments. Once the SESRO is available, CaMKOx demand would be satisfied for a number of years for both companies. However it would likely bring commissioning of the Severn-Thames Transfer (STT) forward to 2065 for SWOX demand only or 2060 for SWOX and Affinity.

10.482 If both CaMKOx growth follows this preliminary forecast and 1:500 drought resilience are required, then the Severn-Thames transfer could be commissioned in the mid-2040s, less than ten years after completion of SESRO. A re-use plant would also be required ~2080.

Impact of potential changes in water availability from the Severn Thames Transfer

10.483 The Environment Agency has raised concerns about the water available from the transfer if alterative assumptions were used regarding a) the level of losses in the Severn catchment en-route to the proposed abstraction point and b) the Hands off Flow (HoF) condition at Deerhurst.

10.484 These issues will be examined further in the period to 2022/23, in conjuction with United Utilities, Severn Trent Water and other interested stakeholders. However we have the following initial observations on the potential impact.

- Increasing the losses assumption from 10% to 20% or 30% have a relatively minor impact on the deployable output available from the transfer, in the region of 15Ml/d for the largest single option through the largest pipe size.
- A change to the HoF (Increased to 2600 Ml/d from 1800Ml/d from 31/03/19) has a much more significant impact, reducing deployable output by approximately a third.

10.485 Clearly, reducing the water available for transfer would make the option less attractive but if water continues to be required in the west of the region, there are currently few strategic alternatives.

10.486 In the first instance we would likely look to compensate for the reduction by increasing the size and number of supporting elements e.g. selecting a larger Vyrnwy option.

10.487 Such risks would also support the need to develop the largest 150Mm^3 SESRO option. The opportunities to upsize a smaller reservoir once built would be limited and disruptive.

Impact of lower than expected leakage savings between 2020-25

10.488 We recognise that leakage reduction is a large and potentially challenging component in the first five years of our preferred plan.

10.489 Further developing the understanding gained from the range of alternative supply and demand scenarios assessed as part of the performance testing step of programme appraisal (Step 4), in this sub-section we consider how the preferred programme would change if the leakage reduction component of our integrated demand management programme is less effective than forecast over the first five years of the plan.

10.490 We are not able to define a single, realistic worst case for leakage reduction as this is dependent on a whole range of factors that are outside of the company's control, e.g. the severity and extent of an extreme weather event. However, we can take the leakage reduction component of the preferred plan and reduce its impact. We have considered the following scenarios:

- 25% underperformance, 2020-25
- 50% underperformance, 2020-25
- 75% underperformance, 2020-25

10.491 In each case we have assumed that the deficit is not recovered in later years. Also, all other components of the supply demand balance remain unchanged, including the 5% target headroom allowance.

10.492 Note that the preferred plan includes providing an increasing surplus over 2020-25, to mitigate some of the risk associated with underperformance. By 2025 this is equivalent to nearly half of the size of the forecast leakage reduction.

10.493 Table 10-31 below sets out how the supply demand balance in the London WRZ is impacted by the three alternative leakage reduction scenarios.

Table 10-31 Impact on the London WRZ supply demand balance of alternative leakage scenarios

	AMP7					AMP8					AMP9				
Leakage Under-Perf.	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**
Pref. Plan	2	14	15	43	61	51	62	70	76	80	9	7	9	16	19
25%	-8	-1	-6	14	31	21	32	39	46	49	-21	-23	-21	-14	-12
50%	-20	-18	-28	-12	0	-10	1	9	15	19	-52	-54	-52	-45	-43
75%	-33	-34	-49	-38	-30	-41	-30	-22	-16	-12	-83	-84	-83	-76	-73

10.494 Observations:

- A 25% underperformance would put Years 1-3 into deficit (an underperformance >5% would be enough for a deficit in Year 1). Deficits also appear in AMP9 as the schemes chosen to deliver 1:200 resilience would not also cover underperformance.
- A 50% underperformance brings further deficits in year 4 and 6 and increases the AMP9 deficit.
- A 75% underperformance would see deficits throughout AMPs 7-9.

10.495 Plan response:

- There are limited options to manage deficits that appear in Years 1-3 because of the lead times to deliver resource options. For the 25% underperformance scenario, we may be able to re-profile some the demand management to bring forward savings from later in the programme, however this would be unlikely to be enough to balance the 50% and 75% scenarios. As part of WRSE's development of a regional resilience plan for the South East we are examining opportunities for further conjunctive use of water resources between Thames Water and Affinity Water and it may be that this work delivers additional water resources from the enhanced conjunctive use of existing available water resources. WRSE's development of a regional water resources simulation model is not sufficiently advanced at this stage to indicate the potential magnitude of such a gain, but it offers further opportunities to mitigate any short-term underperformance in leakage control.

- Deficits in AMP8 could be mitigated by bringing forward groundwater (GW) options or the Oxford Canal from 2030. We could also seek to extend the RWE Didcot raw water bulk supply agreement.
- All underperformance can be mitigated in full in 2030 by building different and/or larger schemes than those currently selected in the preferred plan.
    - 25% underperformance – additional GW options and Didcot
    - 50% underperformance – replace Deephams with Beckton 100
    - 75% underperformance – replace Deephams with Beckton 150 (or Deephams + Beckton 100)
- Because of the ability to change the options developed for 2030 at the 2022/23 decision point, the remainder of the programme, such as the SESRO development in 2037/38, would remain unchanged.
- The Severn Thames Transfer would likely remain in the 2080s, the precise date depending on which set of options are developed in 2030 and 2037.
- In the event of a significant drought occurring under any of the three scenarios in AMP7 Thames Water would ensure early enactment of its Drought Plan measures in order to ensure maintenance of security of supply at all times. Customer water use restrictions would be implemented (e.g. TUBs), in addition to enhanced demand management measures undertaken by the company, followed by the implementation of drought permits, if appropriate.

10.496 Summary:

- Leakage underperformance would put pressure on the supply demand balance particularly in the early years of AMP7. Supply demand deficits could be expected although it should be noted that our plan already includes a headroom allowance to allow for such uncertainty.
- AMP8 deficits can be mitigated by bringing forward options from 2030 once deficits are identified by the monitoring plan in AMP7. As these are likely to be smaller non-strategic options, they are not bound to the 2022/23 decision point.
- AMP9 deficits would be mitigated by selecting different/larger reuse options for delivery in the early 2030s at the 2022/23 decision point.
- We consider that the 2022/23 decision point would not need to be brought forward due to leakage underperformance alone.

SEA of preferred programme for London, SWOX and SWA WRZs

10.497 SEA has been carried out of the preferred programme for the London, SWOX and SWA WRZs. The key findings are summarised below.

10.498 Further details are available in Section 11: Preferred plan and Appendix B: SEA – Environmental Report.

10.499 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 "chalk stream" pipelines.

10.500 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.

10.501 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 SESRO) 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.

10.502 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).

10.503 The environmental performance of this programme is characterised by moderate adverse effects but has the advantage over the RAPs 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 SESRO 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 as a co-benefit of the additional supply headroom and developing additional water supply transfer

infrastructure from 2037/38. This measure materially improves the overall environmental performance of the rdWRMP19.

H. Programme appraisal: Kennet Valley

Changes since the rdWRMP19:

- The programme appraisal for Kennet Valley WRZ is unchanged.

10.505 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)
- Performance testing (West Berks Groundwater Scheme)
- Preferred programme

Step 2 (LC): Least-cost

10.506 The starting point is a least-cost solution to the baseline planning problem.

10.507 The zone is in surplus throughout the planning horizon, so no intervention is required.

Step 2/3: Scenario assessment

10.508 Increasing drought resilience to a 1:200 return period in 2030 has a 3.36 Ml/d impact on supply.

10.509 The impact of increasing resilience is shown in Table 10-32. A requirement for removal of network constraints and a small groundwater scheme is triggered in the 2090s.

10.510 There are no requirements for exports to neighbouring zones.

10.511 The results of our programme appraisal set out in Table 10-32 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

10.512 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.

10.513 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.

10.514 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.

10.515 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. This would not be available until the late 2030s and is associated with delivery if the SESRO in 2037-38.

Step 5: Preferred programme

10.516 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.

10.517 Options are therefore required to provide surplus to the end of the planning horizon.

10.518 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.

10.519 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.

10.520 It is our intention to continue to promote a 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.

10.521 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.

10.522 We believe this to be an equitable solution, in keeping with the needs of the wider Thames catchment and the wider South East region.

10.523 We will continue to work with the Environment Agency to clarify the potential risks associated with the WBGWS.

Table 10-32: 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		

10.524 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

10.525 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.

10.526 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).

10.527 Further details are available in Section 11: Preferred plan and Appendix B: SEA – environmental report.

I. Programme appraisal: Guildford

Changes since the rdWRMP19 consultation:

- The programme appraisal for Guildford WRZ is unchanged.

10.528 As a low risk zone, a simple programme appraisal approach can be used for Guildford WRZ.

Step 2 (LC): Least-cost

10.529 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 10-33 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.

10.530 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.

10.531 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

10.532 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).

10.533 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

10.534 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 WRMP19. We will continue to assess potential threats using business as usual processes.

Step 5: Preferred programme

10.535 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.

10.536 Our preferred programme for the Guildford WRZ modifies the least-cost programme through the inclusion of a DMP. We propose to fully meter the zone as part of our wider PMP from 2020-2030.

10.537 Although not needed to be started until 2025, it is our intention to start the programme from 2020, recognising that early delivery will help to reduce the operational risk in the first year of the next business plan.

10.538 Delivering this programme enables the deferral of most of the resource development to the 2080s.

10.539 We believe this to be an equitable solution, in keeping with the needs of the wider Thames catchment.

10.540 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.

10.541 A breakdown of the supply and demand components for the preferred plan is available in Appendix A: dWRMP19 planning tables.

Table 10-33: 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	

SEA of preferred programme for Guildford WRZ

10.542 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.

10.543 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).

10.544 Further details are available in Section 11: Preferred plan and Appendix B: SEA – environmental report.

J. Programme appraisal: Henley

Changes since the rdWRMP19 consultation:

- The programme appraisal for Henley WRZ is unchanged.

10.545 As a low risk zone, a simple programme appraisal approach can be used for Henley WRZ.

Step 2 (LC): Least-cost

10.546 There is no supply demand deficit in Henley WRZ, so the least-cost option requires no intervention.

Step 2/3: Scenario assessment

10.547 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

10.548 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 WRMP19. We will continue to assess potential threats using business as usual processes.

Step 5: Preferred programme

10.549 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 PMP. See Table 10-34.

10.550 In our WRMP14 we set out the case for metering across our entire supply area. This was supported by stakeholders and customers.

10.551 It is our intention to continue to promote a PMP in this plan, which drives further water efficiency and leakage reduction activity as part of delivering IDM.

10.552 We believe this to be an equitable solution, in keeping with the needs of the wider Thames catchment.

10.553 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 10-34: 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**

10.554 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

10.555 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).

10.556 Further details are available in Section 11: Preferred plan and Appendix B: SEA – environmental report.

K. Preferred programme summary

Changes since the rdWRMP19:

- The preferred programme is unchanged from the rdWRMP19.
- We have placed the preferred programme in an adaptive context, demonstrating alternative options available at the key decision points across the planning period horizon.
- A new key decision date of 2022/23 has been highlighted. This is the point at which we will need to decide which strategic options to develop for 2030 and 2037.
- Until 2022/23 we propose the continued study and pre-planning assessment of all the strategic option types, in conjunction with other parties.
- The decisions to be made now based on this plan, other than the need for continued strategic option investigation, are related to support for the enhanced DMP and the local resilience resource development options (in SE London and Guildford).

Our programme appraisal journey

10.557 Our programme appraisal journey to identify the preferred programme can be summarised in five steps, (Table 10-35 sets out the programmes developed at each stage):

- **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 RAPs 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 RAPs 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 RAPs 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 SESRO Option at Abingdon is selected in 2037/38 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 expert judgement. It includes the identification of key decision points across the planning horizon where strategic resource development will be required. Our preferred programme also allows for reduction of abstraction from vulnerable chalk streams and other water courses.

Table 10-35: 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[51]
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[52]	**Benefit (Ml/d)**	**Implementation date**				
LONDON						
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**

[51] Including £0.097bn for the preferred programme in Kennet Valley, Guildford and Henley WRZs.
[52] Resource development and demand management only.

AR_Kidbrooke (SLARS1)	7	2070	2079			**2030**
AR_Merton (SLARS3)	5	2098	2075	2050	2030	**2031**
ASR_South East London	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		
IPR_Beckton 100	95	2072		2093		
GW_London confined chalk	2	2069	2074	2051	2083	
GW_Honor Oak	1	2071		2092		
ASR_TV/TC	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_Ashton Keynes	2	2089			2082	
NTC_Britwell	1	2096			2083	
RWP_Wessex Water to SWX	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**

The preferred programme

10.558 We consider that the overall best value plan for our customers only is one that delivers more demand management and greater resilience to drought.

10.559 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 supply resilience to the region.

10.560 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 five 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.

10.561 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.

10.562 Customers strongly favour demand management before resource development. However demand management alone will not be enough and resource development will be necessary in addition.

10.563 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.
- 2037/38 – 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.

10.564 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.

10.565 For the most part, the programme for the next five to 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.

10.566 An intra-zonal transfer and associated constraint release work (in Guildford WRZ) is also proposed to meet local resilience issues.

10.567 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 SESRO Option is delivered in 2037/38.

10.568 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 10-27).

Figure 10-27: SESRO as a regional resource

10.569 In the long-term we propose supporting the SESRO and existing sources in the Thames Basin with a transfer from the River Severn.

10.570 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.

Decision date 2022/23

10.571 However, the decision on which strategic option is needed in 2030 and 2037/38 need not be made now. The lead in times for the schemes involved are such that the key date at which the strategic options to be delivered will need to be decided is 2022/23.

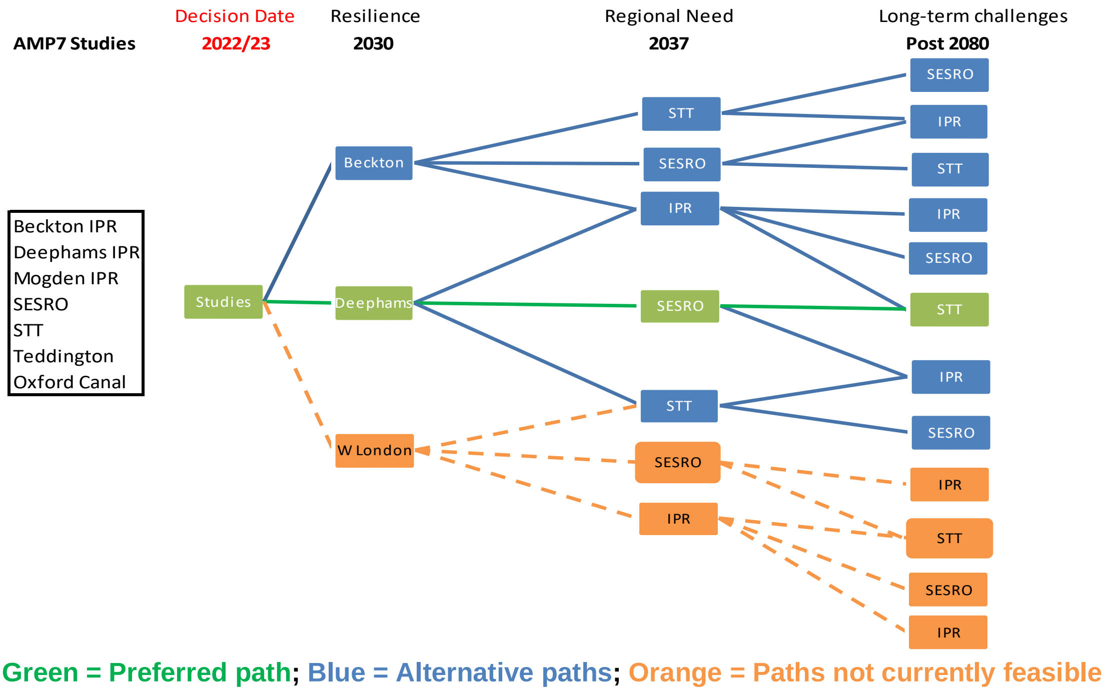
10.572 We have developed an option delivery tree (Figure 10-28), to help visualise the potential pathways. The preferred pathway will be informed by the ongoing investigation of the feasible options in AMP7, with a decision to confirm the timing and characteristics of the preferred investment programme in 2022/23.

10.573 Re-use is the leading option type to meet the need to improve drought resilience by 2030, The decision is whether to build a single larger plant at Beckton, or a smaller plant at Deephams, supported by smaller innovative groundwater schemes, smaller regional trades and transfers.

10.574 Following the rejection of the Teddington DRA option from our dWRMP19, we will also need to consider if there are alternative feasible West London based options utilising the Mogden Sewage Treatment catchment.

10.575 We have a performance commitment to undertake further work on SESRO, STT and other options in AMP7 to complete studies and confirm option design. We will work jointly with other companies to progress this work.

Figure 10-28: Option delivery tree



10.576 By making the decision in 2022/23 we can ensure alignment with our neighbouring companies involved in strategic option development. Affinity Water, Anglian Water, Southern Water, Severn Trent Water and United Utilities will be updating their WRMPs and we'll be jointly engaged in pre-planning works.

10.577 Regional WRMPs will also be available by that point to help inform the decision making process.

10.578 The immediate investment decisions (in the AMP7 period, 2020-25) supported by this plan are therefore the ramp up of leakage reduction and demand management activity and an increase in pre-planning activity on the key strategic options (Reservoir, Severn-Thames Transfer and Re-use).

10.579 Further details on the content of the preferred plan, particularly with respect to the DMP, the programme of studies to be undertaken in AMP7 (2020-25) and the environmental assessment of the preferred programme, are provided in the following section, Section 11: Preferred programme.