Draft Water Resources Management Plan 2019

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Technical Report - Options appraisal

Draft WRMP19 Technical Report - Options appraisal

Contents

1. Introduction

This technical report sets out our approach to options appraisal to ensure our Water Resources Management Plan 2019 (WRMP19) represents the most cost effective and sustainable long-term solution, via a "best value" plan. Our approach has been informed by what customers, regulators and other stakeholders have told us, including during our pre-consultation activities. This document shows how we have utilised the UKWIR decision making framework[1] and:

- Assessed the requirements for each of our resource zones over the planning period[2];
- Applied existing[3] planning approaches, termed "core methods" across all resource zones (see Section 2.2); and
- Augmented the core planning approaches, in line with the outcomes of our problem characterisation exercise (see Section 2.2), with what we have termed "extended methods" to ensure we select a best value plan that protects customers and the environment, in the event that national water trading commences (see Section 3.3).

Our *Draft WRMP19 Technical Report - Options identification* documents our process of identifying options for WRMP19, including the development of option scopes[4] and the stages of primary and secondary screening. This ensures that the options appraisal process considers only those options that have passed through the screening process, having been assessed for:

- Benefit, in terms of water available for use (WAFU) or demand reduction;
- Cost, including capital and operational, as well as monetised environmental and social[5];
- Environmental impact, including a Strategic Environmental Assessment (SEA), Habitats Regulations Assessment (HRA), Water Framework Directive (WFD) assessment and Invasive Non Native Species (INNS) assessment; and
- Vulnerability to climate change.

Options appraisal takes these assessments further to understand the in-combination effects of any preferred plan and alternatives, including any effects on greenhouse gas emissions and water quality (see Section 5). Costs in the report have generally been presented as net present values[6] (NPV), or as maximum annual customer bill impacts, whether increases or reductions. At this stage of the water resources planning process costs should be considered as indicative and subject to change.

[1] From WRMP 2019 Methods – Decision Making Process: Guidance (UKWIR, 2016), this is an update to the framework in Water Resources Planning Tools (UKWIR, 2012) that we used for WRMP15 (we selected the "Intermediate Framework", based on a feasibility assessment), which was an update to The Economics of Balancing Supply and Demand (UKWIR, 2002)

[2] Over a minimum of 25 years, but for some aspects out to the 2080s

[3] Termed "Current (baseline) approaches" in WRMP 2019 Methods – Decision Making Process: Guidance (UKWIR, 2016)

[4] Including the estimated amount of time needed to investigate and implement each option, with an earliest start date based on that review. It's worth noting that, in this report, we have used a short name for each option, whereas our *Draft WRMP19 Technical Report - Options identification* will refer to the full option name. The "WR" reference is consistent between the two reports.

[5] Environmental and social costing (or "valuation") has been carried out for us by Amec Foster Wheeler. It helps us understand the value of the impact an option might have on the environment and local community, in terms of: accident risk; carbon; congestion; pedestrian delays; low pressure; supply interruptions; and noise pollution.

[6] Calculated by subtracting the present values (or the "current worth of a future sum of money") of cash outflows (including initial cost) from the present values of cash inflows over a period of time.

2. Approach

This section aims to provide some background and context, as well as describing the approach we've taken to determine the most applicable methods in line with the UKWIR decision making framework[7].

2.1 Resource zones

Following our WRMP19 Water Resource Zone Integrity review, as documented in our *Draft WRMP19 Technical Report - Supply forecasting*, we have four resource zones:

- The Strategic Resource Zone (SRZ), a combination of the Integrated Resource Zone and West Cumbria Resource Zone from 2022/23, covering over 98% of customers;
- The Barepot Resource Zone (BRZ), a newly created resource zone containing industrial customers on non-potable supplies;
- The Carlisle Resource Zone (CRZ); and
- The North Eden Resource Zone (NERZ).

2.2 Core methods

In previous WRMPs, we used two core methods to inform decisions:

- Average Incremental Cost (AIC) / Average Incremental Social Cost (AISC) ranking; and
- Economics of Balancing Supply and Demand (EBSD) modelling or, sometimes, "EBSD optimisation".

The results of these have previously been combined with quantitative customer research, as well as more qualitative environmental and resilience type assessments, to aid decision making. We referred to this method as a type of "manual multi-criteria analysis". A description of AIC and AISC is given in Table 1. Both AIC and AISC involve the calculation of the whole-life cost of each option over 80 years in pence per cubic metre (p/m^3). Whole-life costs[8] include treatment, pumping, network, storage, maintenance and operating costs. The AISC values for all our feasible options are shown in Appendix A.

Table 1 The definition AIC and AISC and how it is calculated for each option

Term	Acronym	Meaning	Calculation
Average Incremental Cost	AIC	A metric to present the unit cost of the extra water available for use or demand saving from a particular option	The net present value[9] of the capital (including maintenance and replacement costs, as well as the cost to finance the capital) and operating costs of the option, divided by the net present value of the extra water available for use or demand saving.
Average Incremental Social Cost	AISC	A metric to present the unit cost, accounting for environment (including carbon impacts) and social cost, of the extra water available for use or demand saving from a particular option	The net present value[9] of the capital (including maintenance and replacement costs, as well as the cost to finance the capital), operating, environment and social costs of the option, divided by the net present value of the extra water available for use or demand saving.

AIC / AISC ranking is one of the simplest, aggregated options appraisal techniques and, with expert judgement, allows the creation of a low cost, although not an optimised "lowest cost", investment programme[10] (or "schedule"). EBSD modelling was formulated in a key methodology document[11] published by UKWIR in 2002 to do this.

[7] From WRMP 2019 Methods – Decision Making Process: Guidance (UKWIR, 2016), this is an update to the framework in Water Resources Planning Tools (UKWIR, 2012) that we used for WRMP15 (we selected the "Intermediate Framework", based on a feasibility assessment), which was an update to The Economics of Balancing Supply and Demand (UKWIR, 2002)

[8] All prices are base dated at 2017/18, using the retail price index (RPI)

[9] Calculated by subtracting the present values (or the "current worth of a future sum of money") of cash outflows (including initial cost) from the present values of cash inflows over a period of time.

[10] There is a choice around including option utilisation, calculated by building the options into our Aquator™ water resources models and running the system at an average demand level, in AISC values when ranking options. We have presented AISC values at capacity, rather than at utilised capacity, in Appendix A, but have utilised both approaches when considering option ranking.

[11] The Economics of Balancing Supply and Demand (UKWIR, 2002)

EBSD modelling uses a similar whole-life costing approach to AIC and AISC, but can be used to solve any supply-demand deficits in the planning period by optimising[12] option start years. Once run, the optimiser displays the results of the optimum (lowest total NPV option set, while meeting the total deficit constraint) set of selected options, with the start year for each option. An optimisation summary, log of all simulations and log of progress steps are then reported. This process avoids indivisibilities[13] in the final solutions that can occur if the AISC approach is used to determine the optimal solutions.

However, EBSD modelling is still a relatively simplistic aggregated options appraisal technique and there are limitations when dealing with complex conjunctive use resource zones. The combined supply benefit of a group of resource management options is likely to differ from the sum of the individual options as they are typically to some extent mutually beneficial or exclusive (for example, two options might be situated upstream of the same critical network constraint). This is one of several reasons that we employed the use of extended methods.

2.2.1 Cost profile and discount rate for whole-life costs

The cost profile is the length of time option costs are considered over; it is longer than the planning period during which time options can be implemented. At WRMP15, we used a 25 year planning period and a 105 year cost profile. The Environment Agency questioned this approach, as we had not aligned to the 80 year cost profile in the 2013 Water Resources Planning Guideline[14]. Our reasoning was that, in EBSD modelling, an option can be chosen in any year of the 25 year planning period from 1 to 25. Therefore, options selected in year 25 need a further 80 years of cost profile to achieve a cost profile of a minimum of 80 years, hence 105 years. We engaged with the Environment Agency in 2016 and discussed the different potential cost profiles for WRMP19. Following this, we have adjusted the way we calculate option costs:

- Our AISC values are now calculated using an 80 year cost profile; and
- Our EBSD modelling allows an option start year to be at any point in the planning horizon (years 1 to 25) and, from that point, applies a minimum cost profile of 80 years.

In line with the 2017 Water Resources Planning Guideline[15], the net present value of all costs has been calculated using the Treasury Test Discount rate, as set out in the HM Treasury “Green Book”[16]. This is 3.5% for years 0 to 30 of the appraisal period, 3.0% for years 31 to 75, and 2.5% for years 76 to 125.

2.3 Problem characterisation and initial method review

An important step in the framework resulting from the UKWIR Decision Making Process project[1], “problem characterisation” allows us to evaluate “strategic needs” and complexity, to understand the level of concern required for each of our resource zones and tailor our approach.

In March 2016, we shared our initial problem characterisation[17] with the Environment Agency for feedback. We subsequently discussed this further with Ofwat and Natural Resources Wales, prior to our wider pre-consultation activities. This ultimately culminated in a methodology statement of our problem characterisation and approach selection, which was shared with the Environment Agency, Natural Resources Wales and Ofwat at pre-consultation in autumn 2016. A briefing note was also provided to stakeholders as part of pre-consultation to explain our intended approach to building the plan, supported by public events.

The rest of this section, and Section 2.4, explains briefing how our problem characterisation and approach selection was developed. A summary of our initial problem characterisation is shown in Figure 1.

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[12] For WRMP15 and WRMP19, we used software created by Palisade called Evolver. This uses innovative “mutations” and combinations of solutions, or “organisms,” and is well-suited to finding the best overall answer.
[13] An option is indivisible if it has a capacity below which it is unavailable, at least without significant qualitative change in scale and scope.
[14] Water Resources Planning Guideline (Environment Agency, 2013)
[15] Water Resources Planning Guideline (Environment Agency, 2017)
[16] The Green Book: Appraisal and Evaluation in Central Government (HM Treasury, 2003)
[17] The Barepot Resource Zone was not a resource zone at this stage, having only been created through the WRMP19 process. However, we have presented it in Figure 1 for completeness.

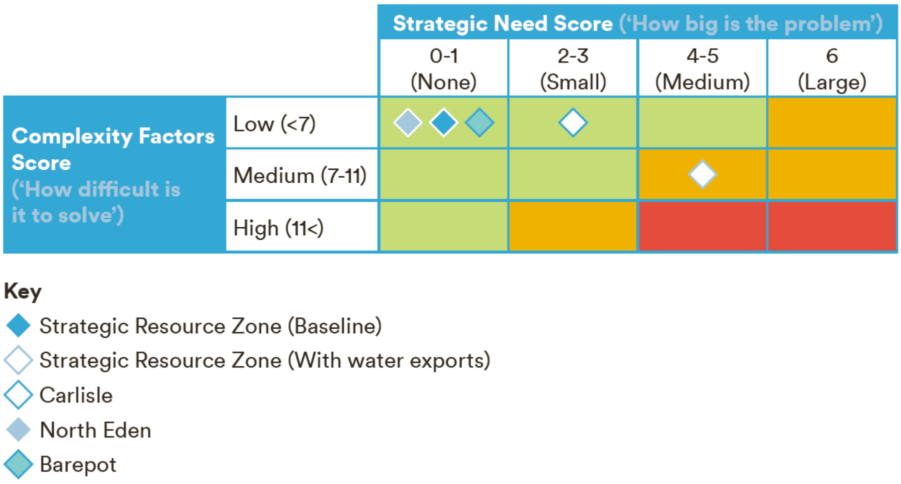

Figure 1 Summary of initial problem characterisation scores

Following the initial problem characterisation and following review by Atkins, the key outcomes were that:

- The baseline[18] view for all resource zones was of "low level concern", based on a low complexity factors score and a relatively low strategic needs score; and
- A "moderate" level of concern and added focus was required for the Strategic Resource Zone, due to a strategic need, now termed a "strategic choice", around national water trading. This was a key driver for the application of, the more sophisticated, extended methods in the Strategic Resource Zone, discussed further in Section 3.3.

Table 2 shows the chosen decision making approach/method type, based on our problem characterisation.

Table 2 Decision making approach/method by resource zone, with rationale

Resource Zone	Decision making approach/method type	Rationale
Strategic	Extended	Resource zone was of "moderate level concern", due to strategic choices
Barepot	Core	Resource zone was of "low level concern"
Carlisle	Core	Resource zone was of "low level concern"
North Eden	Core	Resource zone was of "low level concern"

Our problem characterisation triggered an initial method review to consider the different types of extended decision-making methods available[19]. We considered how best to add value to the core methods, taking into account proportionality in terms of the "strategic choices" and system complexity. When assessing the different decision-making methods, the UKWIR methodology[19] specifies four key elements for consideration, as shown in Figure 2.

[18] This is what would happen if we did not take any new supply or demand actions and did not implement any changes in our company policy or existing operations

[19] WRMP 2019 Methods – Decision Making Process: Guidance (UKWIR, 2016)

Figure 2 Four elements of decision making methods to be considered when selecting the appropriate method[20]

Each of these is taken in turn in Table 3 to assist with articulating our choice of approach, showing which methods were screened out as we progressed through each element. To reiterate, extended methods were explored to complement the core methods and aid development of the most cost effective, best value plan. Reference is made to the core methods where relevant and Figure 3 shows the different decision-making methods available.

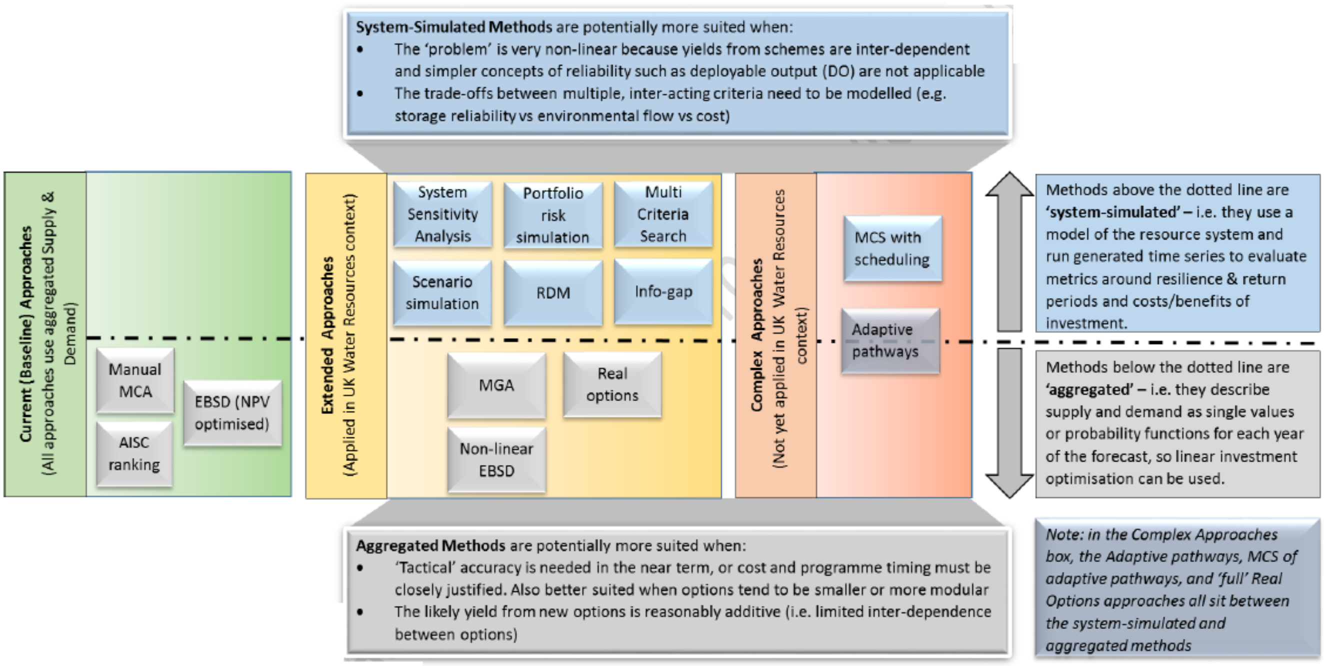

Figure 3 Decision-making methods, with a description of system-simulated and aggregated methods[20]

[20] From WRMP 2019 Methods – Decision Making Process: Guidance (UKWIR, 2016)

Table 3 Our consideration of the four elements of decision making methods from the methodological briefing of our initial problem characterisation and approach selection

Element	Consideration	Method(s) screened out
Objectives	Our Strategic Resource Zone is complex and non-linear and aspects such as deployable output may not fully capture all aspects of system performance, e.g. risk and resilience. Similarly, the scale of a supply-demand balance may not fully reflect the level of risk and resilience across the resource zone to different types or severities of future drought events, particularly under water trading scenarios. By examining multiple criteria, we can better appraise a wider range of considerations in future water resources management, and use these to help define a best value plan in a structured manner.	Single metric methods
Approach	At WRMP15, we utilised AISC ranking to complete a coarse screening of options, followed by EBSD optimisation to define the lowest cost and alternative plans. A “manual multi-criteria analysis” approach was then used to select between these plans. This is an ‘aggregated’ approach, dependent on the concept of the “supply-demand balance” over a pre-specified planning period. Aggregated methods describe supply capacity and demand as single values (e.g. as deployable output as the supply and “dry year” demand for a reference demand position). The orange zone in Figure 3 shows the range of methods that may be applied under an ‘extended approach’. We did not consider ‘complex approaches’ given the timescales involved for WRMP19 and the scale of vulnerability based on the outcomes of the ‘problem characterisation’ (multi-criteria search with scheduling and adaptive pathways have therefore effectively been ‘screened out’ at this stage). As shown in the grey box on the lower portion of Figure 3, aggregated approaches treat yield or deployable output as additive, and are best for ‘tactical’ decisions to define year on year programme accuracy (also portrayed in the next section) in the near term. For the Strategic Resource Zone, as described in the problem characterisation, individual option deployable output is not additive, given the interdependent nature and complexity of the system (in part, this is why for conjunctive use systems companies use water resources models like Aquator rather than simply add up individual source deployable output to estimate water available for use), but rather is highly non-linear. For a unit Ml of water added to the system, the benefit will depend on the type of source and its location in the supply system. Similarly, in considering water trading, the point in time that we may need to export water (and build options to implement this) will largely be determined by the receiving company WRMP as to when the water is required, so the decision-making method does not need to focus on timing of investment. The large uncertainties and key questions are long-term, not near-term. We have recognised the limitations of aggregated approaches to WRMPs, and in part used this to improve its appraisal of options appraisal outputs (e.g. iterative testing of EBSD option sets in Aquator models), however, significant additional understanding may be gained from a ‘system-simulated’ method. The blue box at the top of Figure 3 describes where simulated methods may be of greater value. As can be seen, this describes application on non-linear systems and where multiple-criteria need to be appraised (as in a complex appraisal to examine water trading against a background of planning uncertainty). For this reason, we explored extended methods in the upper half of the diagram, and others in the lower portion of the diagram have been discounted.	Multi-criteria search with scheduling Adaptive pathways

Element	Consideration	Method(s) screened out
Solution	Closely related to the consideration of approach, the plan solution should be considered. Of the three types listed in the UKWIR report[21], there is only one 'adaptive strategy' approach in the UKWIR methodology, that of 'adaptive pathways', so as an advanced approach that is unproven or tested in WRMPs this has not been considered. We have however developed a plan consistent with adaptive planning principles. This leaves two types of solution, portfolios or schedules. The existing WRMP supply-demand balance and EBSD approach is a good example of a schedule, as the outputs define both the options for the plan, and when on the horizon these should be developed over time. This is represented by different plan interventions, defined and appraised over time. This is 'tactical' accuracy. However, as described in the previous section, our choices for the Strategic Resource Zone relate to water trading in the context of future uncertainty, to ensure this represents 'best value' and is resilient to change in the long-term (as opposed to the minimum, least-cost solution defined using an EBSD approach). Therefore, it is more appropriate to pick key points in time (e.g. at 10 year, 25 year and potentially longer into the planning horizon), and test how a range of options (portfolios) perform at that discrete point in time to a wide range of uncertainties. Against, these long-term uncertainties, the year on year 'accuracy' of a schedule is of less interest. We, therefore, examined a 'portfolio' approach, given the long-term strategic nature of its considerations. Such an approach also enables better consideration of changes in levels of service against the background of longer-term uncertainty (e.g. climate change). Generally speaking, portfolio approaches are usually mapped to system-simulated approaches, as can be seen by the number of portfolio methods in the list. Portfolio Risk Simulation (PRS) has, therefore, been screened from the potential methods under consideration at this stage (it also requires a very high number of model runs, limiting the number of schedules that may be tested in the analysis).	Aggregated methods, other than those used as core methods Portfolio Risk Simulation (PRS)
Selection	Broadly speaking, there are two types of selection approach to defining the resulting solutions for consideration in the WRMP. 'Expert judgement' type approaches use the wealth of information from the options appraisal (i.e. performance metrics for different options sets) to select appropriate solutions. Those remaining use analytical approaches (e.g. optimisation or ranking) to identify potentially 'optimal' solutions. It should be noted that, as with the core methods, both of these realistically utilise 'expert judgement' or decision-making to define the solutions and WRMP. The decision-making methods are there to assist in decision-making, not to make the decisions, nor can all aspects of the planning process be fully quantified (e.g. qualitative stakeholder feedback from consultation, SEA outputs etc.). With reference to the UKWIR report[21], we screened out one more method at this stage of the process, System sensitivity analysis. This method has been developed almost entirely with climate change risks in mind. Although this represents one of our key uncertainties in the long-term, it is not the only consideration in the context of the Strategic Resource Zone and the strategic challenges faced, so has been discounted on this basis (rather than based on 'approach' criteria). We also considered screening out multi-criteria search on the grounds of complexity. This method requires Genetic Algorithm optimisation of portfolios and a high degree of modelling automation. The approach is stated as likely for use on plans with very significant concerns from 'problem characterisation', particularly where a company might face criticism from stakeholders over the range of portfolios that it chooses to analyse (for example, "very significant strategic investment needs"). Given that we are already relatively advanced in exploring Genetic Algorithm optimisers for control curve analysis, this may be a consideration in future planning rounds (WRMP24 and beyond) to build on the system-simulation approaches in WRMP19.	System sensitivity analysis

Following our consideration of the four elements of decision making methods in Table 3 and the screening out of several methods, as shown, there were four potential extended methods remaining:

- Scenario Simulation
- Robust Decision Making
- Info-gap Analysis
- Multi-criteria search

The next section describes our selection of the final approach from these four methods.

2.4 Detailed method review and method selection

As described in the previous selection, a screening approach was used to select four potential methods for implementation in support of EBSD at WRMP19. These choices were consistent with our view that a system-

[21] WRMP 2019 Methods – Decision Making Process: Guidance (UKWIR, 2016)

simulation, portfolio approach was most likely to add value to WRMP19 to supplement the core decision making methods. The potential choices, along with our findings and initial screening outcomes are shown in Table 4 below. As part of this process we also selected a risk composition for each resource zone in line with the UKWIR risk based planning framework[22]; this is outlined in our *Draft WRMP19 Technical Report - Supply forecasting.*

Table 4 Summary of more detailed method screening process carried out in 2016

Method[23]	Method screening findings	Method screening outcome
Scenario Simulation	Strong links to core approach and comes with the advantage of using established Aquator™ water resources models.	Continue to investigate
Robust Decision Making	Allows a much greater range of uncertainty to be explored. However, necessitates the use of a faster, simplified model, with associated trade-offs.	Continue to investigate
Info-gap Analysis	Similar approach to Robust Decision Making, but uncertainties perturbed from a central estimate. Simplified model requirements are identical.	Continue to investigate
Multi-criteria search	Lots of potential benefits. However, with the large range of future uncertainties to be explored, multi-criteria search was considered to be too intensive to facilitate this.	Cease investigation

We undertook a further, more detailed, review of the remaining three methods to establish the most suitable approach. Whilst Scenario Simulation and Robust Decision Making were both found to be applicable, the benefits of Info-gap Analysis were outweighed by the practicalities of implementation. The main issue in adopting an Info-gap Analysis approach was that many of the issues that needed to be explored were not readily quantified on the continuous basis that underpins Info-gap Analysis type approaches[24]. Therefore, the chosen extended methods approach was a combination of Scenario Simulation and Robust Decision Making, termed:

Scenario Simulation, with Robust Decision Making principles

This selection allowed us to utilise our existing Aquator™ water resources models and capabilities for an accurate simulation of the system, but also supplement this with a Robust Decision Making type assessment in a faster, simplified model built in Pywr[25] water resources software to explore a wide range of uncertainties. This process is described in Section 4.

2.5 Our baseline supply-demand position

The baseline supply-demand balance for each of our resource zones is shown in Section 4.6 of our *Draft WRMP19* main report. The overarching message is that all four of our resource zones are in surplus to 2044/45, negating the requirement for EBSD modelling to solve any baseline supply-demand deficits. However, there are several strategic choices to be taken which could impact all of our resource zones. These strategic choices are summarised in Section 3 below.

2.6 Customer support for each option type

This section describes two sets of customer research that gives us an understanding of the support for each option type. These are discussed in detail our *Draft WRMP19 Technical Report - Customer and stakeholder engagement*, and only summarised here. The first, completed in June 2017 used more traditional survey techniques (WRMP19 customer preferences: Phase 2 quantitative research – June 2017), whilst the second used new innovative techniques to engage with customers to ensure our investments and activities reflect customer priorities in an innovative interactive 'game' (Programme Choice Experiment – September 2017).

[22] WRMP 2019 Methods – Risk Based Planning (UKWIR, 2016)
[23] A full description of each method can be found in WRMP 2019 Methods – Decision Making Process: Guidance (UKWIR, 2016)
[24] Primarily geared towards identifying when choices of options 'switch' as future conditions are varied from the central estimate
[25] Pywr is a generalised network resource allocation model written in Python. It can be used for solving network resource allocation problems at discrete time steps using a linear programming approach, with a principal application in resource allocation in water supply networks. It was developed by Atkins and the University of Manchester.

Table 5 and Figure 4 show the customer support for each option type from the more traditional techniques, weighted against the base case of more frequent temporary use bans[26]. It's worth noting that cost was not shown in this research and, for example, all desalination options were screened out in secondary screening, based on cost.

Table 5 Customer support for each option type, weighted against the base case of more frequent temporary use bans (i.e. more frequent temporary use bans is 1, with higher preference options having a higher ratio than 1) and not considering the cost of each type of option

Option type	Household customers	Non-household customers	Comments
More frequent temporary use bans	1	1	Base case
River abstraction	1	3	
Desalination	4	5	
New reservoir	3	2	
Increase existing reservoirs	3	2	
Transfer from outside our region	1	1	
Transfer within our region	2	1	
Metering	3	3	
Water efficiency	5	3	
Recycle water (directly)	2	2	
Recycle water (indirectly)	1	2	
Leakage reduction	10	6	Most favoured option type
Groundwater	1	1	
More frequent drought permits	0.4	0.6	Least favoured option type

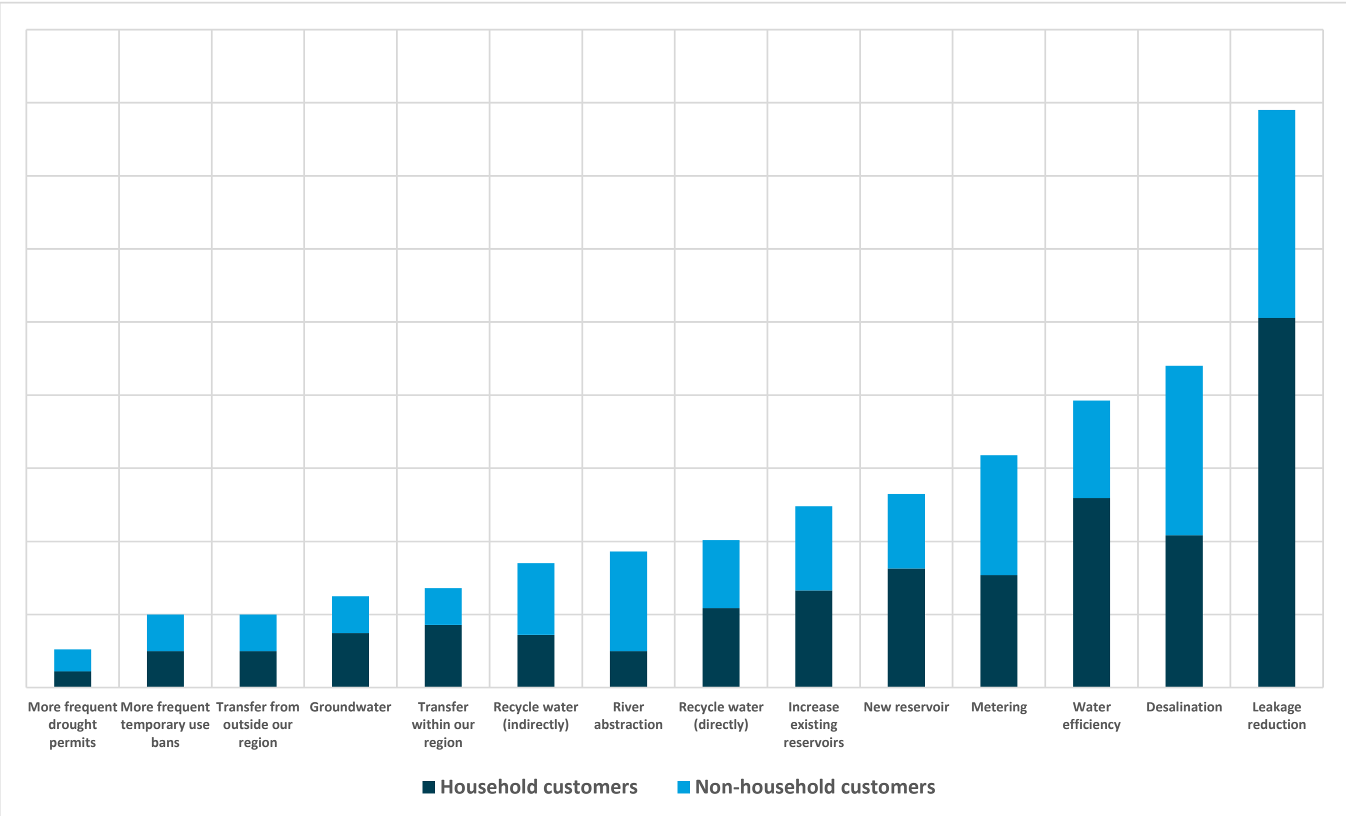

Figure 4 Customer support for each option type, weighted against the base case of more frequent temporary use bans and not considering the cost of each type of option

A clear preference can be seen for leakage reduction and water efficiency type options and we have used this, along with several other factors, in the appraisal of the different options.

Table 6 shows some key themes and outcomes from the second exercise, particularly useful in the context of some of our strategic choices, discussed in the next section.

[26] Via "odds ratios"

Table 6 Key themes and outcomes from our customer research (programme choice experiment)

Theme	Outcome
Leakage	• Willingness to pay for leakage reduction of 44 Ml/d, on average (based on preference over supply schemes); and • No preference for reducing visible leakage over non-visible.
Level of service: Temporary use bans (Hosepipe bans) & Drought Permits	• Only 14% of customers wanted less frequent temporary use (hosepipe) bans; • Average choice 1 in 13 years on average for temporary use bans; and • Slight preference for less frequent drought permits (1 in 24 years on average).
Water efficiency	• Most customers chose some water efficiency measures; and • No expensive schemes included so not possible to say whether it would be chosen over schemes to increase supply capacity.
Metering	• 75% metering chosen on average; and • 14% of customers chose no increase.
Resource management options	• Customers chose more water from reservoirs and boreholes, and less from rivers, despite higher costs.

3. Strategic choices for our region

When considering any strategic choice, we have several important overarching aims and these are:

- Selecting and defining choices on the basis of customer and stakeholder views;
- Ensuring we protect our customers, whether this be with regards to affordability, resilience or the quality of water being provided;
- Ensuring we protect and, where possible, enhance the environment, including meeting the objectives of environmental legislation[27] such as the Habitats Directive and Water Framework Directive; and
- Ensuring our plan can adapt to factors that are not within our control, i.e. water trading requires agreement from both parties, via plan "pathways".

The strategic choices, as outlined in our *Draft WRMP19* main report, are shown in Table 7. Our *Draft WRMP19 Technical Report - Customer and stakeholder engagement* documents the wide array of customer and stakeholder engagement and we have used this, as well as the option preferences in Section 2.6, to guide our decision making.

Table 7 Strategic choices for WRMP19

Strategic choice summary	Why has this become a strategic choice?	What is the choice?
Enhanced leakage reduction	Customers and stakeholders see this is as a clear priority area. Regulators and government have set out aspirations to reduce leakage further.	How far we go in terms of leakage reduction, balancing with customer affordability, and at what pace?
Improve the stated level of service for drought permits and drought orders to augment supply	Feedback from regulators and other stakeholders, as well as being a commitment in our WRMP15.	The reduction in stated frequency and timing of the change.
Increase the resilience of our supply system to non-drought hazards, such as asset failure	Through a full system-wide review of our resilience to different non-drought hazards, we have highlighted key risks that can be reduced through investment in our assets.	Should we invest to increase the resilience of our supply system to non-drought hazards, such as asset failure? What type of solutions should we develop?
Continue to explore national water trading from our Strategic Resource Zone	National need[28] and potential to reduce bills for customers, while protecting resilience and the environment.	Do we continue to explore national water trading from our Strategic Resource Zone?

This section aims to provide further detail and evidence for each of the strategic choices, with the main narrative being provided in Section 6 of our *Draft WRMP19* main report.

3.1 Enhanced leakage reduction

As discussed in Section 6.2 of our *Draft WRMP19* main report, we are proposing a total leakage reduction of 80 Ml/d by 2044/45 for consultation. It's worth noting that the costs to reduce leakage are likely to change in the future, due to factors like innovation in leakage detection and repair. Therefore, for this WRMP, we have sought to set out a programme that is innovative, cost effective and affordable in the long-term, but balance this with reliability in the shorter term. Our proposed leakage reduction programme is shown in Table 8; it will be subject to ongoing review in future business plans[29] and WRMPs, therefore the glide path may change in future plan reviews.

[27] This is also a key requirement in defining our baseline position, explained further in Section 7 of our *Draft WRMP19 Technical Report - Supply forecasting*

[28] In line with the outcomes of the Water resources long-term planning framework 2015-2065 (Water UK, September 2016)

[29] As part of the price review process, the next of which is the 2019 price review or "PR19"

Table 8 Proposed WRMP19 leakage reduction programme (the "WR" references refer to the specific options[30] used to deliver the leakage reduction)

Plan	AMP7	AMP8	AMP9	AMP10	AMP11
Proposed WRMP19 leakage reduction programme	**30 Ml/d further leakage reduction, delivered by:** WR500a to c (28 Ml/d) 3rd party pilot WR907e (2 Ml/d)	**~20 Ml/d further leakage reduction, delivered by:** WR500d (10 Ml/d) 3rd party WR907f (10.5 Ml/d)	**~10 Ml/d further leakage reduction, delivered by:** 3rd party WR914 (4 Ml/d), WR503 (4 Ml/d), WR515 (2 Ml/d)	**~10 Ml/d further leakage reduction, delivered by:** 3rd party WR907g (10.5 Ml/d)	**~10 Ml/d further leakage reduction, delivered by:** WR511 (8 Ml/d) and WR514 (1 Ml/d)

This leakage reduction programme was determined by considering views from customers, regulators and other stakeholders, including:

- Leakage reduction being a clear priority for the majority of stakeholders, as documented in our *Draft WRMP19 Technical Report - Customer and stakeholder engagement*, but customer affordability is a key factor in deciding the "pace" at which we deliver any leakage reductions;
- The results of our customer research[31], specifically our "leakage customer panel" and "programme choice experiment", showed that, on average, customers selected a total leakage reduction of 44 Ml/d, also providing willingness to pay values for the cost benefit below; and
- In "Delivering Water 2020: Consulting on our methodology for the 2019 price review", Ofwat have instructed companies to set stretching leakage performance commitment levels to achieve ambitious leakage reductions of at least a 15% reduction[32] or justify why not.

Figure 5 shows our proposed WRMP19 leakage reduction programme against the 15% leakage reduction in AMP7 (with reductions of 10 Ml/d in future AMPs) for context.

[30] See the AISC charts in Appendix A and our *Draft WRMP19 Technical Report - Options identification* for more detail on specific options
[31] As documented in our *Draft WRMP19 Technical Report - Customer and stakeholder engagement*
[32] One percentage point more than largest reduction commitment at PR14 (the 2014 price review)

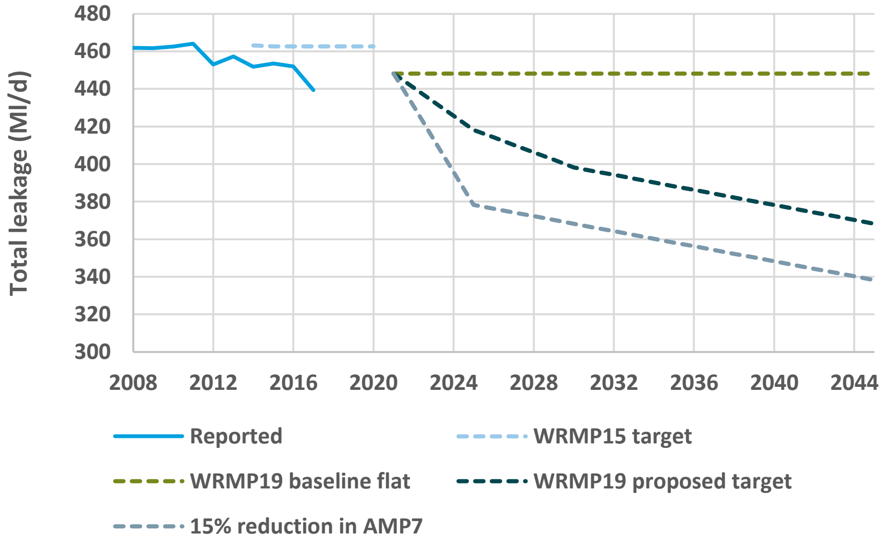

Figure 5 Reported total leakage and our WRMP19 proposed target, against our WRMP15 target (sometimes referred to as our "current commitment"), a flat target from the WRMP19 baseline[33] and the Ofwat 15% leakage reduction in AMP7 (reduces at 10 Ml/d in future AMPs)

Using the willingness to pay values from our customer research, Table 9 shows the costs and benefits of some of the different leakage reduction programmes we considered initially for AMP7 (covering 2020/21 to 2024/25 corresponding to the timescales of the requirements in the Ofwat methodology); (i) maintain current levels, (ii) the level selected for the preferred plan; and (iii) the 15% reduction stated by Ofwat.

Table 9 Costs and benefits of the different leakage reduction programmes we have considered for AMP7

AMP7 leakage reduction from WRMP19 baseline (three-year average 2014/15 to 2016/17)	Where total leakage would be at the end of AMP7 (2025) (Ml/d)	Maximum annual increase in bill to achieve (pence)	Willingness to pay from programme choice experiment (pence)	Cost beneficial in AMP7?
0 Ml/d	448.2	-	-	N/A
30 Ml/d	418.2	55p	50p	Finely balanced
70 Ml/d, in line with Ofwat 15% leakage reduction	378.2	Indicatively 260p*	96p	No

*Indicative bill impact created for stakeholder research. Derived directly from Economic Level of Leakage (ELL) model outputs. However, as this was the basis for the United Utilities "find and repair" options it is comparable to the 55p bill impact calculated later for 30 Ml/d (based on the actual leakage reduction programme included in the preferred plan).

As shown in Table 9, a 30 Ml/d leakage reduction in 2020-25 (AMP7) is finely balanced in terms of cost benefit. The 70 Ml/d (15%) reduction however was shown not to be cost beneficial if delivered with the type of leakage reduction options available for reliable deployment during 2020-2025. The difference between bill impacts highlights the non-linear relationship between the volume of leakage reduction and repair costs; the more leaks that we repair, the harder it becomes to find further leaks. Beyond 2025 we have more opportunity to start to introduce more innovative techniques; as explained in Section 6.2 of our *Draft WRMP19* main report. During this period 50% of our leakage options can be considered innovative. The costs and benefits of achieving a total of 50 Ml/d over the period 2020-2030 are shown below in Table 10 reflecting the increased level of innovation. Beyond this we apply another 10 Ml/d reduction in each 5-year AMP period from 2030-2045, taking the total to 80 Ml/d (an 18% reduction).

[33] Three year average total leakage, based on reported total leakage for 2014/15 to 2016/17

Table 10 Costs and benefits of two leakage reduction programmes we have considered for AMP7 (covering 2020/21 to 2024/25) and AMP8 (covering 2025/26 to 2029/30)

Total leakage target	Where total leakage would be at the end of AMP8 (Ml/d)	Where total leakage would be at 2044/45 (Ml/d)	Maximum annual increase in bill to achieve (pence)	Willingness to pay from programme choice experiment (pence)	Cost beneficial in AMP7 and AMP8?
WRMP19 baseline with flat target (three year average 2014/15 to 2016/17)	448.2	448.2	-	-	N/A
WRMP19 proposed target	398.2	368.2 (18% reduction against the WRMP19 baseline)	68p	78p	Yes, as willingness to pay is higher than the maximum annual bill increase

Our proposal offers a stretching leakage reduction target, requiring innovation in leakage detection and repair, but balances this with customer affordability. We have used a combination of AISC ranking and EBSD modelling (see Table 11) to define a cost effective leakage programme over the planning period from 2020/21 to 2044/45 planning period, for the purposes of consultation. To inform the revised draft Water Resources Management Plan we will conduct further research on our programme to reduce leakage, specifically with regards our programme and pace of delivery in the early part of the planning horizon

Table 11 Strategic Resource Zone leakage reduction options considered to deliver proposed WRMP19 leakage reduction (AMP7 covers 2020/21 to 2024/25, AMP8 covers 2025/26 to 2029/30, AMP9 covers 2030/31 to 2034/35, AMP10 covers 2035/36 to 2039/40 and AMP11 covers 2040/41 to 2044/45)

Focus	Option reference	Option short name	Leakage reduction (Ml/d)	AISC (pence per cubic metre)	Likely option start year	Rationale for programme choice
Reliability	**WR500a**	LEA_SRZ REDUCTION_1	10	8.5	2020/21	Selected for reliability to deliver AMP7 commitment
	WR500b	LEA_SRZ REDUCTION_2	10	10.5	2020/21	Selected for reliability to deliver AMP7 commitment
	WR500c	LEA_SRZ REDUCTION_3	8	12.9	2020/21	Selected for reliability to deliver AMP7 commitment
	WR907e	LEA_THIRD PARTY_SRZ_32	2	(1.4)	2020/21	AMP7 pilot to test reliability
Balanced	**WR500d**	LEA_SRZ REDUCTION_4	10	15.3	2025/26	Selected for reliability to deliver AMP8 commitment
	WR907f	LEA_THIRD PARTY_SRZ_33	10.5	(1.6)	2025/26	Will help deliver AMP8 commitment, if found to be reliable in AMP7 pilot
Innovation	**WR515**	LEA_SRZ_DMA SPLITTING	2	4.1	2030/31	High level of uncertainty
	WR503	LEA_HH_SUPPLY PIPE	4	(6.3)	2030/31	Potentially low reliability
	WR914	LEA_THIRD PARTY_SRZ_39	4	9.6	2030/31	High level of uncertainty
	WR907g	LEA_THIRD PARTY_SRZ_34	10.5	(1.6)	2035/36	Will help deliver AMP9 commitment, if found to be reliable in AMP7 pilot
	WR511	LEA_SRZ_LOGGER VERIFICATION	8	13.1	2040/41	High level of uncertainty
	WR514	LEA_SRZ_TEMPORARY LOGGING	1	(3.3)	2040/41	Small benefit, but combined with WR511 can help deliver AMP11 commitment

3.2 Improve the stated level of service for drought permits and orders to augment supplies

At WRMP15, we committed to undertake further work to understand how an improved level of service for implementing drought permits could be delivered beyond 2020. Since then we have carried out further customer research and consultation on specific proposals for WRMP19. As documented in our *Draft WRMP19* main report, moving to an improved level of service for drought permits and orders to augment supplies is supported by stakeholders, and customers have shown some willingness to pay, albeit not as a priority area in its own right[34].

Section 6.1.7 of our *Draft WRMP19 Technical Report - Supply forecasting* covers our assessment of different levels of service for drought permits, as well as those for temporary use bans[35]. Section 3.4 of our *Draft WRMP19 Technical Report - Customer and stakeholder engagement* shows the value customers placed on the frequency of drought permits and this value is presented in Table 12. From this same research, there was insufficient willingness to pay to improve the stated level of service for temporary use bans. This was consistent with customer views from our more qualitative research and, therefore, improving the level of service for temporary use bans was not considered as a strategic choice.

Table 12 The value customers placed on the frequency of drought permits

Activity	Willingness to pay from WRMP19 programme choice experiment (pence)
1 year change in frequency of drought permits	3p

Table 13 uses the value from Table 12 to show the costs and benefits of different levels of service for drought permits and drought orders to augment supply.

[34] There was a slight preference for less frequent drought permits (1 in 24 years on average)
[35] Previously "hosepipe bans"

Table 13 Costs and benefits of different levels of service for drought permits and drought orders to augment supply

Level of service for the implementation of drought permits	Water available for use impact	Maximum annual increase in bill (pence)	Willingness to pay from WRMP19 programme choice experiment (pence)	Cost beneficial
1 in 10 or a 10% chance in any year	Not considered as no customer or stakeholder support to deteriorate			
1 in 20 or a 5% chance in any year (current level)	0 Ml/d	0p	0p	N/A
1 in 40 or a 2.5% chance in any year	10 Ml/d[36]	0p (can be delivered by our proposed leakage reduction programme, discussed in Section 3.1)	60p	Yes

Although this is not a key priority for customers in its own right, based on the cost benefit and accounting for our proposed leakage reduction programme, we are proposing to improve the stated level of service for drought permits and orders to augment supplies to 1 in 40 (or a 2.5% chance in any year) from 2025.

For non-essential use bans we are able to improve the stated expected frequency from no more than 1 in 35 years on average to more than 1 in 80 years (moving from 2.9% to 1.25% annual average risk), reflecting the point at which we would expect these to be implemented from our analysis. For emergency droughts orders we are able to state a frequency of no more than 1 in 200 years on average (0.5% annual average risk); this corresponds to Defra's new reference level of service, and is expanded upon in the next section. This does not constitute an improvement in the level of service statement as such, but adds context to our existing position that they are unacceptable, even in extreme droughts. These changes will apply from 2025 along with the changes to drought permits and orders as explained in Section 6.3 of our *Draft WRMP19* main report.

In addition we propose an improvement to the stated level of service for non-essential use bans. This is simply due to gaining a much better understanding of our actual drought resilience from our sophisticated new tools and techniques. This will not result in an improvement to the actual level of service experienced by customers. We also confirmed that our expected frequency of implementing emergency drought orders is better than Defra's reference level of 1 in 200 years (0.5% annual risk). We explored further improving our drought resilience but ultimately it is already at a high level and there is no customer appetite to further improve this. All of this analysis is described in Section 6.3 of our *Draft WRMP19* main report.

3.3 Continue to explore national water trading from our Strategic Resource Zone

This strategic choice was the key reason for us using extended methods and is in part driven by a national need to explore water trading. A key role of the extended methods is to ensure that customers and the environment are protected. As explained in Section 7.6 of our *Draft WRMP19* main report, this strategic choice relates to national water trading[37] and Section 4 covers our assessment of national water trading using extended methods.

[36] This is not water available for use in a conventional sense, but an estimate of lost water to preserve stable resilience

[37] As we were finalising this draft plan, Thames Water advised us that in the current Water Resources South East regional strategy the water would instead be needed from the late 2040s onwards. We also understand that other companies may be considering export options from our region for their draft WRMP. The outputs of these draft WRMP were not available in time to incorporate into this plan, but we will consider this further at the revised draft stage, based on the options selected and the timescale required for implementation.

4. Extended methods and assessing national water trading

As discussed in Section 7.2 of our *Draft WRMP19* main report, to aid in decisions around national water trading, we have used a sophisticated options appraisal process (known as "extended methods"). The key aim of which is to ensure that customers and the environment are protected under any potential water trade.

The extended methods process, created in conjunction with one of our service providers, Atkins, has allowed us to understand the performance of the Strategic Resource Zone, via certain metrics (documented further in Section 4.4), and assess the impact of a national water trade on those metrics. Figure 6 shows the key stages in the extended methods process and these are explained further below.

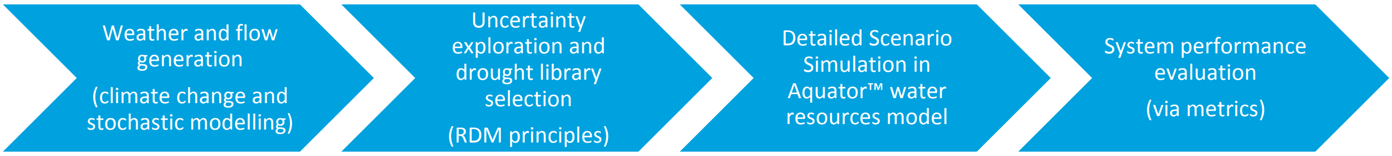

Figure 6 Key stages in the extended methods process

4.1 Weather and flow generation (climate change and stochastic modelling)

As explained in Appendix B of our *Draft WRMP19 Technical Report - Supply forecasting*, Atkins has created 17,400 years of stochastic[38] inflows for the Strategic Resource Zone. Stochastic inflows represent statistically plausible versions of historic conditions, as they are based on historical weather patterns, but contain more extreme events due to the volume of data (i.e. we can sample the tails of the distribution).

As part of the climate change assessment for WRMP19, HR Wallingford created 100 sets of climate change factors, which were a sub-sample of the 10,000 UKCP09 climate projections[39] for the 2080s, under medium emissions. A sub-set of 20 of these factors were selected for the climate change assessment by testing with a simplified model of the Strategic Resource Zone, built by Atkins in Pywr water resources software. This work is described in our *Draft WRMP19 Technical Report - Supply forecasting*.

For extended methods, three of these 20 climate change scenarios were selected to represent the circa. 50th (referred to as "CCA"), 75th (referred to as "CCB") and 90th (referred to as "CCC") percentiles of climate change impact, and the factors were used to perturb the stochastic flows. This enabled the assessment to take place with a broad range of climate change impacts, but allowed the assessment of system performance in droughts more severe than those in the historic record.

As part of a joint project with Thames Water, Atkins also carried out a piece of work to match the stochastic sequences for the South East of England, with those for our region. This was used to create utilisation sequences for water trading that matched our stochastic inflow record, allowing us to thoroughly test our system in a water trading scenario.

4.2 Uncertainty exploration and drought library selection (Robust Decision Making principles)

As the Strategic Resource Zone Aquator™ model is large and complex, it would have been practically infeasible to run full stochastic sequences through on multiple occasions[40]. To assess the severity of events in the perturbed stochastic sequence, a simplified model of the Strategic Resource Zone was created in Pywr. This system uses cloud

[38] Synthetically generated hydrology used to explore a wide range of droughts; explained in our *Draft WRMP19 Technical Report - supply forecasting*

[39] http://ukclimateprojections.metoffice.gov.uk/

[40] Each 17,400 year model run would take about a week.

computing[41] and can run enormous data sets in a short period of time. Each of the 20 sets of climate change perturbed stochastic flows[42] was run through the model at 26 demand steps. The system response in each run was assessed by emergency storage failures (see Figure 7 for an example of this). By counting the number of failure years at each demand a return period could be placed on each failure year (e.g. if there was a single failure in the whole run, then that event would have a return period of 17,400 years). By allocating a return period to each year it was possible to select the required number of droughts with the specified severity.

2080s	Demand																									
UKCP09_ID	1600	1625	1650	1675	1700	1725	1750	1775	1800	1825	1850	1875	1900	1925	1950	1975	2000	2025	2050	2075	2100	2125	2150	2175	2200	2225
3413	644	446	285	205	146	99	71	48	33	24	15	10	7	6	4	3	3	2	2	2	2	1	1	1	1	1
1952	870	644	512	370	232	163	128	94	70	56	41	31	24	18	14	12	9	7	6	5	4	4	3	3	2	2
6035	669	527	405	268	191	133	95	66	43	32	22	16	11	8	6	5	4	3	3	2	2	2	2	2	1	1
7916	2486	1933	1582	1450	1024	696	378	245	147	86	54	36	25	17	13	10	8	6	5	4	4	3	3	2	2	2
6050	3480	2900	1243	791	644	527	341	249	145	91	64	45	33	24	19	15	11	9	7	6	5	4	4	3	3	2
9942	1933	1582	1450	1088	725	580	395	252	166	121	87	65	50	38	30	23	18	15	12	9	7	6	5	4	4	3
8937	2900	2175	1933	1243	1088	696	470	290	198	119	83	61	45	34	25	19	15	12	9	8	6	5	4	4	3	3
6923	5800	3480	2900	2175	1933	1160	791	405	300	166	107	67	47	33	23	17	13	10	8	6	5	4	4	3	3	2
864	2900	1933	1740	1450	1024	669	458	355	238	146	98	68	52	39	30	23	18	14	11	9	7	6	5	4	3	3
8026	4350	2900	1933	1582	1160	967	621	483	378	235	158	116	85	65	49	38	30	24	18	15	12	9	7	6	5	4
6252	3480	2900	1933	1338	1160	967	644	414	295	183	123	84	60	46	36	28	21	17	13	11	8	7	6	5	4	3
6341	5800	4350	4350	3480	2486	1450	1024	757	483	268	178	125	81	57	43	34	25	19	15	12	9	8	6	5	4	4
9474	4350	4350	3480	2486	2175	1338	1024	644	544	300	196	137	93	67	49	38	29	22	17	14	11	9	7	6	5	4
6622	17400	8700	8700	8700	5800	2900	2900	1160	916	696	378	295	207	139	98	70	53	40	30	24	19	15	11	9	7	6
941	17400	17400	8700	8700	8700	5800	4350	1933	1024	870	600	370	229	166	117	88	66	48	37	29	22	17	14	11	8	7
9543	17400	17400	8700	8700	8700	5800	5800	2900	1243	791	580	355	268	193	139	104	75	60	46	34	25	20	16	13	10	8
6962	17400	8700	8700	8700	8700	8700	5800	2486	1450	967	512	285	196	132	102	76	56	42	33	25	19	15	12	9	7	6
9985	17400	17400	17400	8700	8700	8700	8700	4350	2175	1740	829	644	370	295	215	144	110	83	61	45	33	25	20	16	13	10
3372	inf	17400	17400	17400	8700	8700	8700	5800	2900	1450	1243	967	696	497	290	205	146	108	77	60	43	32	24	19	15	12
5231	inf	inf	inf	inf	17400	17400	17400	17400	17400	17400	8700	5800	2900	2486	1933	1450	967	621	424	281	187	139	97	69	51	38

Figure 7 Baseline breaches of reservoir emergency storage simulated with a range of demands (shown across the top) and 2080 climate change scenarios (shown down the left hand side)

Drought libraries containing a fixed number of events of varying severity (see Table 14) were created, to limit the run time and allow multiple configurations and portfolios of options to be tested. Each drought was given a two year "warm up" period and a one year "cool down" period. The selected hydrology was then spliced together with other randomly selected periods to create a carefully constructed dataset for Scenario Simulation in Aquator™. This was a very innovative approach and, to our knowledge, has not been done elsewhere as part of WRMP19.

Table 14 Severity and number of events in each drought library[43]

Return period (1 in X years)	Number of events in drought library
1000	3
500	3
250	9
100	9
50	9
30	9
20	12
10	12

[41] Cloud computing the practice of using a network of remote servers to store, manage, and process data, rather than a local server or a personal computer.

[42] In line with the findings of the climate change vulnerability and modelling, described in our *Draft WRMP19 Technical Report - supply forecasting*, groundwater sources have a low vulnerability to climate change and, therefore, source yields have not been adjusted for climate change impacts

[43] As the number of droughts in the library exceeded the naturally occurring frequency, operational weighting factors were used to prevent the skewing of the statistical results produced by the over representation of severe events. This methodology allowed statistics to be calculated that represented the results of testing with a longer record that would have contained the severities of droughts described, but in a much more efficient way.

4.3 Detailed Scenario Simulation in Aquator™ water resources model

As documented in our *Draft WRMP19 Technical Report - Supply forecasting*, the Strategic Resource Zone Aquator™ model is complex, but provides the best way to assess system response, as it contains all of the key constraints in the real system. It was used to test system response under the conditions represented by the drought libraries, in scenarios representing different strategic choices (e.g. with water trading taking place) and with different portfolios of options.

A number of changes were made to the Strategic Resource Zone base model to make it suitable for portfolio testing in extended methods. These changes included:

- Allowing the use of emergency storage[44], as we would expect to use emergency storage in droughts more severe than those experienced historically; and
- Annual demand variation, depending whether it was a selected "dry year" (1 in 20 year frequency or less) or not. Dry years had "dry year" demand and other years has "normal year" demand (Table 15).

4.3.1 Portfolio creation and selection

As discussed in Section 2.3 and 2.4, portfolios (abbreviated below to "PF", e.g. PF1 would be portfolio 1) are sets of options designed to address a strategic choice or more typically a combination of strategic choices in an alternative plan. The options appraisal process aims to deliver the best value set of options for each case tested.

A key element in creating a portfolio is cost effectiveness and the core methods of AISC ranking and EBSD modelling, described in Section 2.2, were utilised to help ensure that any options being considered in portfolios for testing in extended methods were cost effective. EBSD modelling was used initially to understand which options were being chosen at varying supply-demand deficit levels, but as extended methods became more about protecting system performance (via the metrics shown in 4.4), and was not defined by a supply-demand balance need, AISC ranking became a direct input to the options appraisal process. The 50 options with the lowest AISC were built into the Scenario Simulation model in Aquator™ and, through the modelling process, we discovered how the locations and size of the different options influenced the system performance, via the metrics (Table 16).

EBSD modelling was also used to help schedule the options in a portfolio from extended methods, based on the earliest start year (using the estimated amount of time needed to investigate and implement each option).

It's worth noting that cost effective leakage options already formed part of the proposed leakage reduction programme (see Section 3.1) and, therefore, were pre-selected in extended methods and reflected via reduced demand for water. Cost effective water efficiency options were reflected in extended methods in the same way. However, as the benefit of water efficiency options decays over time[45], we used the average benefit over the planning period.

[44] As described in our *Draft WRMP19 Technical Report - Supply forecasting*, this is a "reserve water storage capacity aimed at accommodating the operational uncertainty for the duration of a particular drought".
[45] As discussed in *Draft WRMP19 Technical Report - Demand for water*, we apply a decay rate or half-life of two and a half years to represent factors, such as the deterioration in water efficiency products over time.

4.3.2 Extended methods time slices

In terms of temporal coherence, two key "time slices" have been used for the modelling of national water trading for extended methods:

- 2034/35 was selected as the potential timing for a national water trade[46], a key strategic choice[47], with any options being developed in the period from 2024/25 onwards; and
- The 2080s was selected to align to our furthest reaching calculated climate change impacts. This view helps to ensure best value for customers over the longer term, helping us to understand the impact of uncertainty on our plans, useful when considering the time it takes to develop major infrastructure.

Table 15 shows the demand for water to be used to represent the two time slices. As different percentiles of climate change are being tested explicitly in extended methods, climate change headroom has not been included to ensure there is no double counting of uncertainty. There is significant uncertainty in our demand forecast for the 2080s.

Table 15 Demands for extended methods modelling

Resource Zone	Demand Adjustment Applied	Demand at 2034/35 (Ml/d)	Demand in the 2080s (Ml/d)	Raw water and process losses (Ml/d)	Outage allowance (Ml/d)	Target headroom not inc. climate change at 2034/35 (Ml/d)	Target headroom not inc. climate change in the 2080s (Ml/d)	Demand at 2034/35 for extended methods (Ml/d)	Demand in the 2080s for extended methods (Ml/d)
Strategic (baseline)	"Average year"	1,633	1,693	42	101	57	61	1,833	1,897
Strategic (baseline)	"Dry year"	1,652	1,724	42	101	57	61	1,852	1,928
Strategic (with leakage reduction[48])	"Average year"	1,573	1,518	42	101	57	61	1,773	1,722
Strategic (with leakage reduction[48])	"Dry year"	1,592	1,549	42	101	57	61	1,792	1,753

Table 25 in Appendix B shows a full list of the scenarios tested in extended methods, representing the leakage reduction at the different time slices, the different demand levels and the different setups of national water trading that have been explored.

[46] Our assessment is based on 2034/35, however, it may be considered as representative of a trade occurring at any point in the 2030s; this was the agreed working assumption during draft WRMP19 development. It is unlikely that any trade will be required before this date based on discussions. If the trade is at a later date, defined by other draft Water Resources Management Plans and/or subsequent work, we will reassess our plans accordingly in future.

[47] In line with the outcomes of the Water resources long-term planning framework 2015-2065 (Water UK, September 2016)

[48] Based on the draft WRMP19 proposed leakage reduction, this would be a 60 Ml/d leakage reduction at 2034/35 and, continuing the 10 M/d reduction in future AMPs, this would be a 175 Ml/d reduction by 2079/80

4.4 System performance evaluation (via metrics)

Metrics help us to ensure that we are achieving the overarching aims set out at the start of Section 3. Table 16 documents our WRMP19 metrics, developed with input from customers[49], regulators[50] and other stakeholders[51]. The statistical results from our extended methods modelling were simplified by placing them into performance bands, allowing an easy visual comparison.

[49] Through key priorities from our customer research

[50] Through early engagement with the Environment Agency, Natural Resources Wales (NRW), Ofwat and the Drinking Water Inspectorate (DWI).

[51] Via our WRMP19 Technical Stakeholder Group (TSG)

Table 16 Metrics for WRMP19

Metric type	Initial metric category	Metric	Why is this a metric?	Calculation of metric	Banding used to present metric
Primary	Customer	Change in the likelihood of temporary use bans	This is measure of the frequency of the implementation of temporary use bans, previously "hosepipe bans", the impact of which directly affects customers.	Calculate the total number of temporary use ban events expected in a 25 year period and measure the percentage change in these.	<2% change equates to no impact 2% to 6% = +/- 6% to 10% = ++/-- >10% = +++/---
Primary	Customer	Change in drought resilience	This is a measure of the risk of drought that customers are under, the impact of which directly affects customers	Calculate storage remaining at annual minima. Convert this into a 'number of days remaining' based on emergency storage equating to 20 days of supply. Take first percentile of results (roughly equivalent to a 1:100 year event or 1% annual chance).	<2 days = no impact 2 to 5 days = +/- 5 to 10 days = ++/-- > 10 days = +++/---
Primary	Environment	Change in river flows and implementation length of drought permits	This is a measure of the length of time drought permits are implemented for, the impact of which directly affects the environment.	Calculate both as a value per annum and calculate the weighted average percentage change.	River flows below prescribed flow: <1% = no impact 1 to 5% = +/- 5 to 10% = ++/-- > 10% = +++/--- Drought permits: <5% change equates to no impact 5% to 10% = +/- 10% to 20% = ++/-- >20% = +++/---
Contributory	Environment	Change in abstraction from environmentally sensitive groundwater sources	This is a measure of the potential impact on the amount of water abstracted from several Water Framework Directive (WFD) sensitive groundwater sources.	Total abstraction divided by number of days, expressed as a percentage change.	<1% change equates to no impact 1% to 5% = +/- 5% to 10% = ++/-- >10% = +++/---
Contributory	Customer	Change in spill from reservoirs	A key concern for our customers and stakeholders, while a full flooding impact assessment is being carried out separately as part of our resilience review, this spill metric allows us to understand if our actions are likely to lead to an increase (or decrease) in spill from reservoirs. Conversely, greater spill, and spill variability, can benefit downstream habitats.	Generate annual maximum for each year, then use percentile calculator to estimate 99th percentile. Change expressed as a percentage.	<1% change equates to no impact 1% to 5% = +/- 5% to 10% = ++/-- >10% = +++/---
Contributory	Customer	Climate change resilience – change in the likelihood of temporary use bans	Helps us understand if our primary metric of "change in the likelihood of temporary use bans" is impacted under different potential climate change scenarios.	As main metric, but compare CCA to CCA, CCB to CCB and CCC to CCC for baseline and with options scenarios.	Highlight if there is a change in band as a result of climate change. The worst impact will be shown.
Contributory	Customer	Climate change resilience – change in drought resilience	Helps us understand if our primary metric of "change in drought resilience" is impacted under different potential climate change scenarios.	As main metric, but compare CCA to CCA, CCB to CCB and CCC to CCC for baseline and with options scenarios.	Highlight if there is a change in band as a result of climate change. The worst impact will be shown.

5. Preferred plan and alternatives

The section sets out our preferred plan for WRMP19, as the most cost effective and sustainable long-term solution, as well as some alternatives we've considered. It also shows how we'll deal with national water trading, via a trading and non-trading pathway, and how we've assessed the benefits of leakage reduction and investment in resilience. The full narrative can be found in Section 7 of the draft Water Resource Management Plan.

5.1 Overview of alternative plans

The strategic choices, as documented in Section 3, have been combined into four alternative plans, as shown in Table 17.

Table 17 Our alternative plans for WRMP19

Alternative plan	Pathway	What is the plan?	Why is this an alternative plan?
AP1	Non-trading	Continued demand management	This plan requires no extra investment, which helps with the affordability challenge. However, it does not offer the enhanced leakage reduction and improvement in the stated level of service for drought permits (and drought orders to augment supply), supported by customers, regulators and other stakeholders.
AP2	Non-trading	AP1 with 80 Ml/d leakage reduction by 2044/45 and an improvement in the stated level of service for drought permits and orders to augment supply	This plan requires investment in leakage reduction, but also enables us to improve in the stated level of service for drought permits and orders to augment supply.
AP3	Non-trading	AP2 with an increase in the resilience of our supply system	This plan requires investment in leakage reduction, but also further investment in resilience, specifically Manchester and Pennines Resilience, which as discussed in our *Draft WRMP19 Technical Report - Water supply resilience*, has been highlighted as a risk in our supply system.
AP4	Trading	AP3 with further exploration of national water trading	This plan requires the investment in leakage reduction and resilience, as well as potential future investment to support national water trading.

5.2 Deciding on a preferred plan

The section uses information from Section 3 and the findings from extended methods, documented in Section 4 to show why AP4 is our preferred plan.

5.2.1 Benefits of leakage reduction

Extended methods was also used to understand the wider benefits of leakage reduction. The impact on system performance, demonstrated by the metrics shown in Section 4.4, is shown in Table 18.

Table 18 Benefits of the 60 Ml/d leakage reduction by 2034/35 compared to the baseline (Alternative Plan 1), as assessed in extended methods

	Baseline	Leakage reduction
Scenario (see Appendix B for explanation)	2035_Base	2035_L60
Cost (NPV in £m with environmental and social costs)	0	46.7
Change in the likelihood of temporary use bans	NSC	+++
Change in drought resilience	NSC	+
Change in river flows and implementation length of drought permits	NSC	++
Climate change resilience – change in the likelihood of temporary use bans	NSC	NSC
Climate change resilience – change in drought resilience	NSC	NSC
Change in abstraction from environmentally sensitive groundwater sources	NSC	+
Change in spill from reservoirs	NSC	-

The benefits in the customer and environment metrics are clearly shown, with a positive impact on the likelihood of temporary use bans and drought resilience, as well as the implementation length of drought permits and the reduction in abstraction from environmentally sensitive groundwater sources. The change in spill could be viewed as positive in terms of increasing flow and flow variability to downstream habitats, or negative (as displayed in Table 18) in terms of increasing the potential for flooding. It should be noted, however, that there is unlikely to be any flood risk associated with many of the reservoirs. Where there is a risk, detailed assessment including hydraulic modelling would be required to determine if there was any actual change in risk; i.e. this is just an indicative metric view.

5.2.2 National water trading

When considering national water trading, system performance (captured via the metrics in Section 4.4) was always determined by comparison against a baseline. In the 2034/35 model runs, performance was compared against the scenario in which 60 Ml/d of leakage reduction had taken place (see Appendix B for a list of all scenarios). When selecting the preferred portfolio it was necessary to match the performance in this scenario, so that customers and the environment would not suffer any detriment through the strategic choices being considered (noting that customers would previously have paid for this investment to reduce demand, with the resultant benefits this provides).

In selecting the preferred portfolio the lowest cost set of options that would provide the desired performance were sought. However, some options that were not necessarily the cheapest were selected to serve specific purposes, such as protecting sensitive groundwater sources and reducing abstraction, i.e. they provided “best value” to meet our objectives.

A selection of some of the portfolios tested is shown below in Table 19. PF23 is used for the preferred plan. PF15 has a lower cost, but does not meet our objective to protect customers and the environment. PF18 offers similar performance to PF23, but has a higher cost, i.e. it is a sub-optimal solution. PF19 and PF20 offer further benefits over PF23, however they have a higher cost, therefore we do not consider them to be a cost effective way to meet our objective.

Table 19 Portfolio performance comparing to baseline with 60 Ml/d leakage reduction (trading pathway)

Portfolio and capacity of options	PF15 - 104.7 Ml/d	PF23 - 110.7 Ml/d	PF18 - 123.7 Ml/d	PF19 - 133.7 Ml/d	PF20 - 159.7 Ml/d
Scenario	2035_L60_T300_Plus	2035_L60_T300_Plus	2035_L60_T300_Plus	2035_L60_T300_Plus	2035_L60_T300_Plus
Cost (NPV in £m with environmental and social costs)	159.1	169.5	184.1	202.4	254.9
Change in the likelihood of temporary use bans	+++	+++	+++	+++	+++
Change in drought resilience	NSC	NSC	NSC	NSC	NSC
Change in river flows and implementation length of drought permits	NSC	NSC	+	+	++
Climate change resilience – change in the likelihood of temporary use bans	-	NSC	NSC	NSC	NSC
Climate change resilience – change in drought resilience	NSC	NSC	NSC	+	+
Change in abstraction from environmentally sensitive groundwater sources	+	+	+	+	++
Change in spill from reservoirs	++	++	++	++	++

The preferred portfolio for water trading, based on the costs and metrics shown in Table 19, is PF23.

5.3 Our preferred plan

As outlined in this technical report and the *Draft WRMP19* main report, we have chosen the preferred plan using standard industry methods that include consideration of technical feasibility, financial costs and benefits, and quantified impacts on the environment and community, taking into account the findings of the SEA, HRA and WFD Assessment (Section 5.3.4), as well as input from key stakeholders.

We considered four alternative plans as outlined above and in Section 7 of the draft WRMP. In simple terms, Alternative Plan 4 was selected as the preferred plan because it contains all of the strategic choices we proposed to address customer and stakeholder views. Selecting Alternative Plan 3 would not allow us to continue to explore national water trading, thereby failing to meet a potential future national need, and missing the opportunity to provide the associated bill saving to customers. Alternative Plan 2, whilst much cheaper than Alternative Plan 3 (cost to be confirmed), would not allow us to address pressing supply system resilience needs. Alternative Plan 2 has an additional estimated cost of £46.7M (net present value including environmental and social costs) compared to Alternative Plan 1 (Section 7.5 of the draft WRMP), but will help to meet customer and regulatory aspirations on leakage reduction, and at the same time provide environmental benefits and allow us to improve our level of service for drought permits in 2025. Alternative Plan 1 has the lowest cost of all plans, but it does not deliver any of these strategic choices.

In order to select options for water trading we developed a sophisticated “extended methods” approach, as outlined in this technical report and in Section 7.2 of the *Draft WRMP19* main report. Its principal objective is to help ensure that customers and the environment are protected in the event of water trading. In summary, portfolios of options are generated and optimised on the basis of a range of performance metrics relating to cost, customers (including resilience) and the environment; the preferred plan includes the most optimal set of options. Those portfolios rejected as part of the process either did not meet the objective to protect customers and the environment, or did not represent the lowest cost way to achieve this.

Overall, our comprehensive option identification and appraisal process means that, from a very large pool of options, only the most applicable ones have been selected in the preferred plan. This is critical to ensuring that the plan represents the most cost effective and sustainable solution in the long-term. Figure 8 shows our preferred plan pictorially, with the specific options to deliver the plan shown in Table 20.

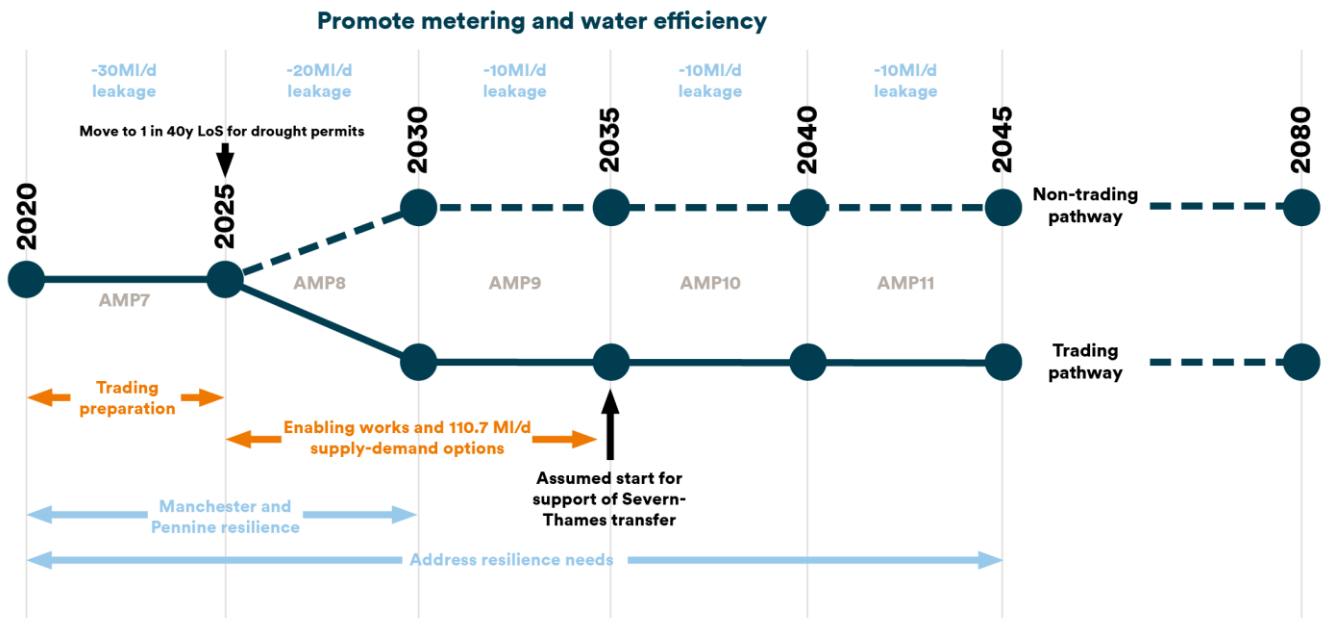

Figure 8 Our preferred plan timeline

Table 20 Preferred plan options

Pathway	AMP7	AMP8	AMP9	AMP10	AMP11
Non-trading	**30 Ml/d further leakage reduction** WR500a to c (28 Ml/d) 3rd party pilot WR907e (2 Ml/d) **Manchester and Pennines Resilience** Solution will be submitted in our Revised Draft WRMP19	**~20 Ml/d further leakage reduction** WR500d (10 Ml/d) 3rd party WR907f (10.5 Ml/d) **Manchester and Pennines Resilience** Solution will be submitted in our Revised Draft WRMP19	**~10 Ml/d further leakage reduction** 3rd party WR914 (4 Ml/d), WR503 (4 Ml/d), WR515 (2 Ml/d)	**~10 Ml/d further leakage reduction** 3rd party WR907g (10.5 Ml/d)	**~10 Ml/d further leakage reduction** WR511 (8 Ml/d) and WR514 (1 Ml/d)
Trading (in addition to non-trading)	Preparation for trading	Preparation for trading	**Trading enabling works will be brought online, as will several WRMP options, including:** **Water efficiency** WR610b education programme (1 Ml/d), WR620b goods and advice on metering (5 Ml/d), WR623b home checks on metering (4 Ml/d) **Improved reservoir compensation release control** WR159 regional reservoirs (13 Ml/d), WR160 local reservoirs (9 Ml/d) **Further develop existing groundwater sources** WR113 Tytherington (3 Ml/d), WR099b Worsthorne (4 Ml/d) , WR102e Bold Heath (9 Ml/d), WR114 Python Mill (3 Ml/d), WR101 Franklaw (30 Ml/d) **3rd party supply** WR821 Shropshire Union (30 Ml/d)		

For more detail on each specific option, including high level scope, please refer to our *Draft WRMP19 Technical Report - Options identification* and Section 7.7.2 of the *Draft WRMP19* main report.

5.3.1 Our plan using core methods

As discussed in Section 2.5, there was no requirement for any EBSD modelling to solve any baseline supply-demand deficits. However, we've used a mock supply-demand balance need, based on the water available for use of the extended methods preferred portfolio, in EBSD modelling to allow a cost comparison and to generate information to submit in the Water Resources Planning Tables submitted alongside the *Draft WRMP19* main report.

Method	Portfolio cost (NPV in £m with environmental and social costs)
Core	99.5
Extended	169.5

The core methods portfolio provides the same overall benefit in water available for use terms (i.e. the sum benefit of individual options) as extended methods portfolio, however it:

- Doesn't meet the extended methods objectives to protect customers and the environment;
- Has had no detailed assessment through SEA, HRA and WFD; and
- Does not properly account for the conjunctive water available for use under the trading configuration or option location, which is much more critical under trading and a reason for us selecting certain options.

5.3.2 Greenhouse gas emissions

Environmental (including carbon) and social costs have been considered throughout the options appraisal process. This section aims to report the greenhouse gas emissions that could arise from our preferred and alternative plans, in line with The Water Resources Management Plan (England) Direction 2017. Table 21 summarises the greenhouse gas emissions from our preferred and alternative plans in carbon dioxide equivalent (CO_2e).

Table 21 Greenhouse gas emissions from our preferred and alternative plans

Alternative plan	Pathway	Construction or implementation related carbon, including embedded carbon (total tonnes CO_2e)	Operation related carbon (average tonnes CO_2e per year over 80 years)
AP1	Non-trading	0	0
AP2	Non-trading	7,119	0
AP3	Non-trading	Solution will be submitted in our Revised Draft WRMP19	Solution will be submitted in our Revised Draft WRMP19
AP4 (preferred plan)	Trading	156,733	75

5.3.3 Drinking water quality

Our preferred plan needs to ensure that we continue to meet drinking water quality standards, minimise water quality risks and that the water we supply remains acceptable to customers; there should be no deterioration. This is in line with the latest Drinking Water Inspectorate guidance to water companies including its Long Term Planning guidance published in 2017. Our assessment of the impact of the preferred plan on drinking water quality is outlined in Section 8.5 of the *Draft WRMP19* main report.

5.3.4 Environmental appraisal

As discussed in Section 1, at the start of the options appraisal process, options have already been screened to ensure they have no environmental impact, including a Strategic Environmental Assessment (SEA), Habitats Regulations Assessment (HRA) and Water Framework Directive (WFD) assessment. The section documents the in-combination effects of any preferred plan and alternatives.

For the full SEA, HRA and WFD assessment of the impacts of our feasible options, and alternative and preferred plans, please refer to:

- Section 7.7.1 of our *Draft WRMP19* main report
- *Strategic Environmental Assessment of the Draft Water Resources Management Plan 2019: Environmental Report*
- *Draft Water Resources Management Plan 2019: Habitats Regulations Assessment*
- *Draft Water Resources Management Plan 2019: Water Framework Directive Assessment*

Following the publication of the Environment Agency's position statement 'Managing the risk of spread of Invasive Non-Native Species through raw water transfers' (January 2017), we have also considered whether the options included in the preferred plan could pose a risk to the spread of invasive non-native species (INNS). The pathway created by the implementation of each of the options has been considered, rather than current occurrence of INNS. Where there is a transfer of raw water proposed, we have considered whether options will link isolated catchments or link catchments which are already connected. This initial assessment will inform whether mitigation measures need to be included in designing the new transfer, or, where already connected catchments are linked, an assessment of the increased risk that the option poses needs to be carried out. Further risk assessments and identification of mitigation measures will be carried out if the plan is adopted. Table 22 covers our approach in assessing the risks of spreading of INNS.

Table 22 INNS risk assessment of preferred plan

Strategic choice	Options required to address strategic choice	INNS risk assessment
Leakage reduction	Leakage reduction WR500, WR914, WR503, WR515, WR907e, WR907f, WR907g, WR511 and WR514	Leakage reduction options will not need INNS risk assessments as there is no transfer of raw water
National water trading	Water efficiency WR610b, WR620b and WR623b	Water efficiency options will not need INNS risk assessments as there is no transfer of raw water
	Improved reservoir compensation release control WR160 and WR159	Reservoir compensation release options will not need INNS risk assessments as there is no new transfer of raw water
	Develop existing groundwater sources WR113, WR099b, WR102e, WR114, WR101	Development of groundwater source options will not need INNS risk assessments as there is no new transfer of raw water
	Trading enabling works	Trading enabling works will not need INNS risk assessments as water being transferred will have been treated
	3rd party supplier WR821	This option will require INNS risk assessment as it considers both water transfers for navigations and water company raw water transfers. INNS risk assessment will be required as the transfer creates a pathway included in the Environment Agency Position Statement: 'water transfers for navigations, including canals' and 'water Company raw water transfers'. The aim of any risk assessment will be to identify points of greatest risk within the transfer network and within individual transfer options.

We are also currently assessing the INNS risk relating to transfers in our existing supply system; this is outlined in our *Draft WRMP19 Technical Report - Supply forecasting*.

6. Supply-demand scenarios and stress testing

As discussed in Section 8 of our *Draft WRMP19* main report, our preferred plan must be resilient to a wide range of uncertainties, such as the impacts of climate change, population growth and future customer demand for water. Whilst our extended methods process reflects uncertainties critical to the nature of our supply system and problem characterisation, discussed in Section 2.2, we have also created further supply-demand scenarios, in a similar manner to that in WRMP15, to "stress test" the preferred plan.

This approach enables a clear understanding of the 'tipping points' in EBSD, whereby different types of solutions (e.g. larger options) may be triggered and thus whether this is appropriate to consider in the context of longer term best value (e.g. could be tested in the extended methods framework). Primarily, as mentioned, we see the supply-demand scenarios as a method of stress testing the preferred plan. Table 23 shows the key uncertainties that could impact our plan and how we have created scenarios to stress test our plan.

Table 23 The key uncertainties that could impact our plan and how we have created scenarios to stress test our plan

Uncertainty	Creation of high impact[52] scenario or stress test	Resource zones impacted
Sustainability changes	As described in our *Draft WRMP19 Technical Report - Supply forecasting*, this scenario works on the possibility of further sustainability changes being applied, due to the Habitats Directive and Water Framework Directive.	Strategic
Demand forecast[53]	In line with the uncertainties highlighted in Section 10 of our *Draft WRMP19 Technical Report - Demand for water*, this scenario shows what would happen if all of our demand forecasting uncertainties materialised, known as the "high demand" or "upper" scenario.	Strategic, Carlisle and North Eden[54]
Climate change	As described in *Draft WRMP19 Technical Report - Supply forecasting*, we have included the 50th percentile climate change impact in our baseline supply forecast. This scenario shows what would happen if climate change was worse than we anticipate, with the 95th percentile climate change impact being applied to the supply forecast.	Strategic (although, tested in extended methods) and Carlisle[55]
Water trading	To deal with the uncertainty around the size and utilisation of any national water trade, we have included a scenario that assumes the trade will be utilised more often. The key assumption here is that the 300 Ml/d abstraction from the River Severn, being supplemented by releases up to 180 Ml/d from Lake Vyrnwy is actually sized at 500 Ml/d, requiring releases from Lake Vyrnwy more often.	Strategic
Leakage convergence	As discussed in Section 4.8 of our *Draft WRMP19 Technical Report - Demand for water*, we have assessed several scenarios for leakage convergence. This scenario relates to leakage convergence scenario 1 and is the current view of the potential impacts of leakage convergence on our forecast of demand for water.	Strategic, Carlisle and North Eden[56]

To ensure there is no double counting of uncertainties, demand related target headroom has not been included in "high demand" type scenarios. This is similar to how climate change uncertainty is treated in extended methods, as discussed in Section 4.3.2, headroom percentile testing was completed as part of the baseline supply-demand balance assessment and is documented in our *Draft WRMP19 Technical Report - Target headroom.*

Table 24 shows the scenarios used to test the plan, with supply-demand impacts and cost implications.

[52] We have also created low impact scenarios to understand the variability in some of these uncertainties, e.g. climate change and our demand forecast. However, as the baseline position for all our resource zones is a surplus to 2044/45 (see Section 2.5), these low impact scenarios only lead to an increase in that surplus and have not been used to stress test our plan. Although, they have informed our target headroom assessment, as documented in our *Draft WRMP19 Technical Report - Target headroom*.

[53] Scenarios for demand management have also been created, e.g. a "no demand management" scenario. However, these were purely to understand the benefits of demand management and have not been used to stress test our plan.

[54] Demand in the Barepot Resource Zone is constrained by the operating agreement

[55] We worked with Atkins to understand the vulnerability of each of our resources zone to climate change. This assessment showed that the Barepot and North Eden Resource Zones have a very low vulnerability to climate change and, following further assessment, a low risk of being impacted by it. Therefore, we have not included climate change scenarios for those resource zones.

[56] The Barepot Resource Zone constitutes a non-potable supply and will not be impacted by leakage convergence

Table 24 Supply-demand scenarios used to test the plan, with supply-demand impacts and cost implications

Scenario	Uncertainty					Supply-demand balance impact in 2044/45 under the scenario (Ml/d)	Surplus or deficit in 2044/45 under the scenario (Ml/d)	Cost implication (NPV in £m with environmental and social costs)	Options selected
	Sustainability changes	Demand forecast	Climate change	Water trading	Leakage convergence				
Strategic Resource Zone (Preferred plan)									
Further sustainability changes	H	B	B	B	B	-14	89 (surplus)	N/A	N/A
High demand (inc. Northern Powerhouse)	B	H	B	B	B	-158	-55 (deficit)	96.5	Two options to make use of existing reservoirs, four further groundwater options and an option to increase the capacity of an existing water treatment works
Climate change is worse than anticipated	B	B	H	B	B	Tested using Extended Methods – preferred plan portfolio is robust across a range of climate change scenarios			
Higher utilisation of national water trading	B	B	B	H	B	N/A	103 (surplus)	7.8	Higher utilisation of preferred portfolio (trading pathway)
Leakage convergence	B	B	B	B	H	-7	96 (surplus)	N/A	N/A
Strategic Resource Zone (Non-trading Pathway)									
Further sustainability changes	H	B	B	N/A	B	-14	85 (surplus)	N/A	N/A
High demand (inc. Northern Powerhouse)	B	H	B	N/A	B	-158	-60 (deficit)	68.9	Two groundwater options, two options to control the compensation from reservoirs and an option to make use of an existing reservoir
Climate change is worse than anticipated	B	B	H	N/A	B	Tested using Extended Methods - preferred plan portfolio (leakage reduction programme) is robust			
Leakage convergence	B	B	B	N/A	H	-7	91 (surplus)	N/A	N/A
Barepot Resource Zone									
Further sustainability reductions	H	N/A	N/A	N/A	N/A	-4.1	1.7 (surplus)	N/A	N/A

Scenario	Uncertainty					Supply-demand balance impact in 2044/45 under the scenario (Ml/d)	Surplus or deficit in 2044/45 under the scenario (Ml/d)	Cost implication (NPV in £m with environmental and social costs)	Options selected
	Sustainability changes	Demand forecast	Climate change	Water trading	Leakage convergence				
Carlisle Resource Zone (Critical Period)									
High demand	N/A	H	B	N/A	B	-2.5	0.9 (surplus)	N/A	N/A
Climate change is worse than anticipated	N/A	B	H	N/A	B	-2.7	0.5 (surplus)	N/A	N/A
Leakage convergence	N/A	B	B	N/A	H	0.1	3.1 (surplus)	N/A	N/A
North Eden Resource Zone									
High demand	N/A	H	N/A	N/A	B	-0.3	3.5 (surplus)	N/A	N/A
Leakage convergence	N/A	B	N/A	N/A	H	0.0	3.6 (surplus)	N/A	N/A

As shown in Table 24, over all scenarios/stress tests, only two lead to a supply-demand deficit, potentially requiring further investment in the future[57], and both of these relate to demand forecast uncertainty[58]. However, as well as these two scenarios/stress tests, there is potentially a cost implication of higher utilisation of national water trading.

[57] As shown in the cost implication column
[58] As highlighted in Section 10 of our *Draft WRMP19 Technical Report - Demand for water*

Appendix A: AISC values and ranking in pence per cubic metre for our options

The charts in this section show the Average Incremental Social Cost (AISC) values and ranking for the feasible options in each of our resource zones. The calculation of these values is described in Section 2.2. For these charts, we have used a short name for each option, whereas our *Draft WRMP19 Technical Report - Options identification* will refer to the full option name. The "WR" reference is consistent between the two reports. It's worth nothing that options with a negative AISC[59] have formed part of our proposed leakage reduction programme (see Section 3.1).

Strategic Resource Zone

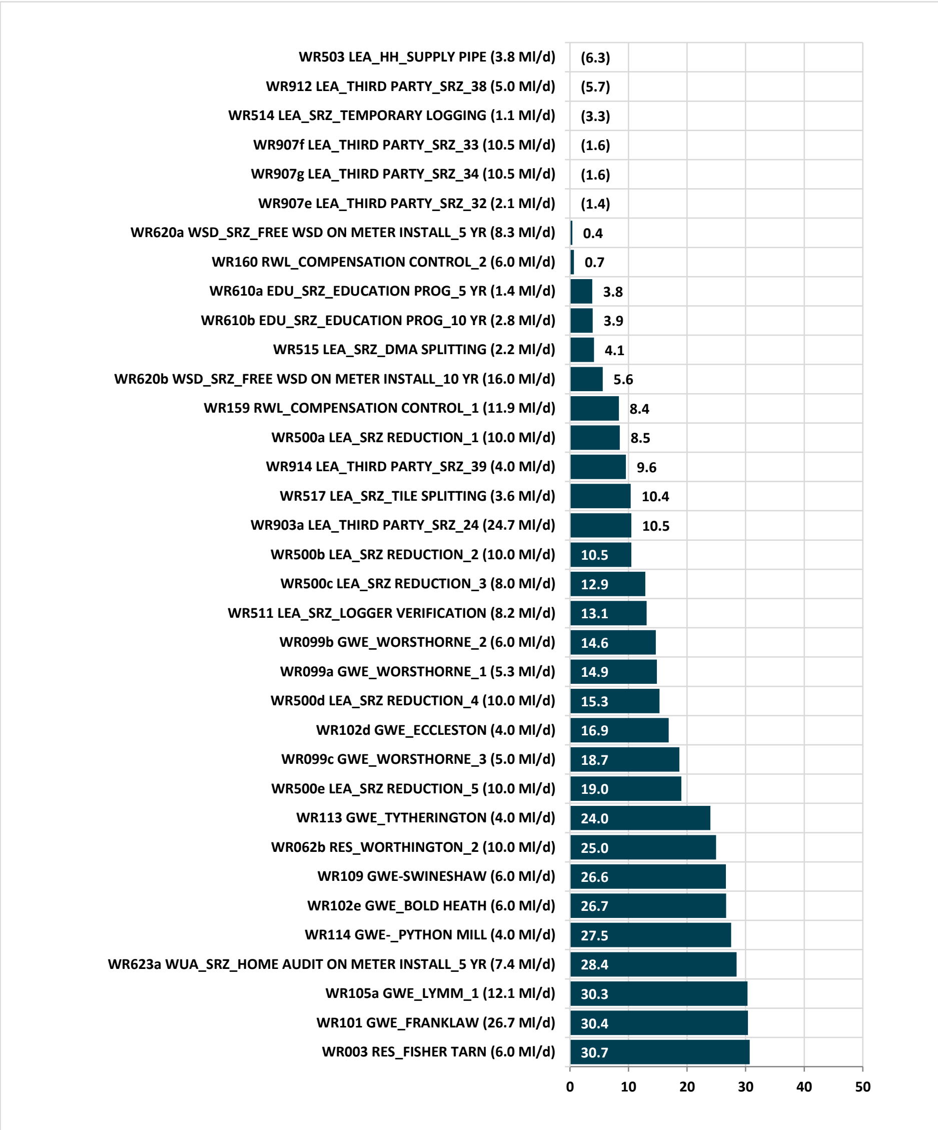

Figure 9 AISC values and ranking for options in the Strategic Resource Zone (1 of 3) (pence per cubic metre)

[59] A negative AISC value indicates that an option is cost beneficial to implement irrespective of there being a supply-demand deficit to address

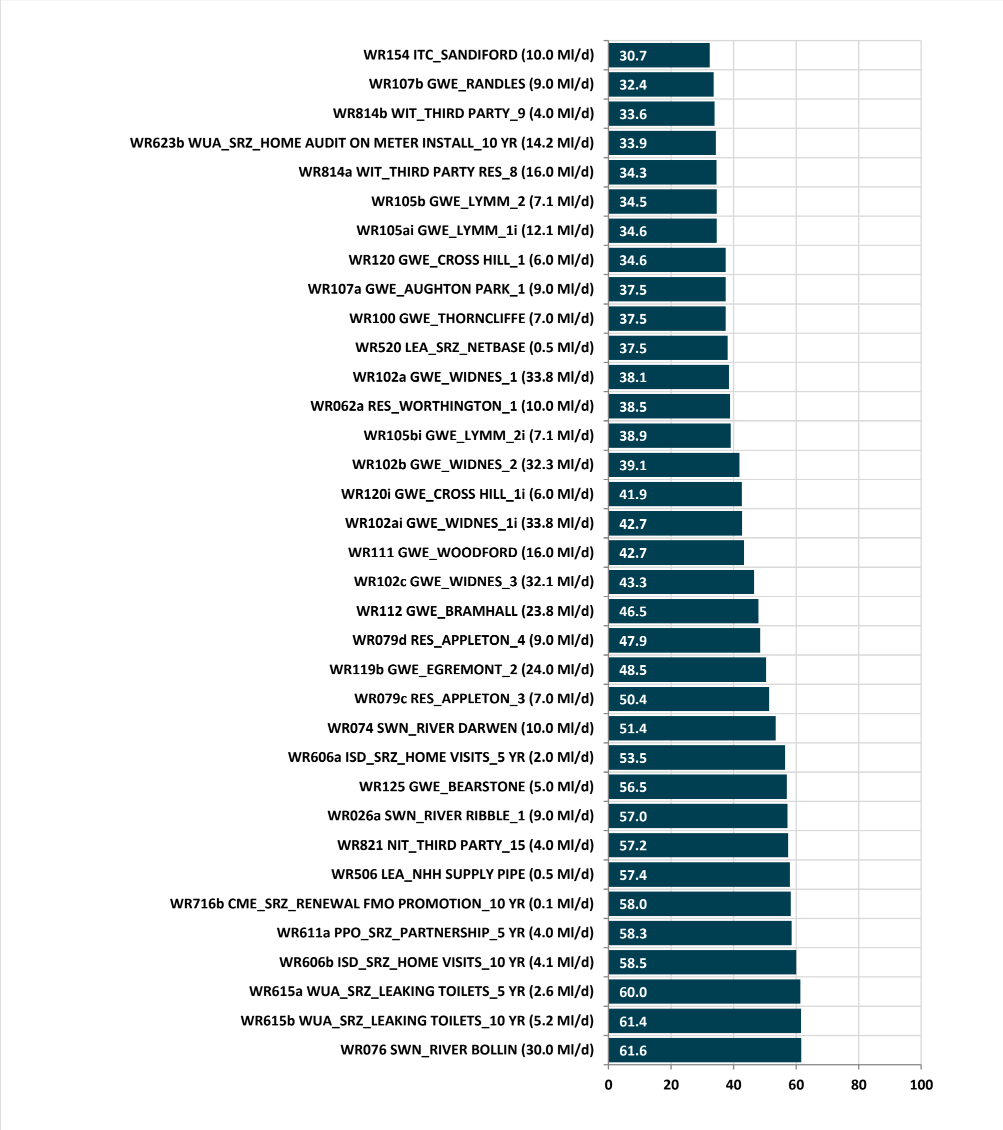

Figure 10 AISC values and ranking for options in the Strategic Resource Zone (2 of 3) (pence per cubic metre)

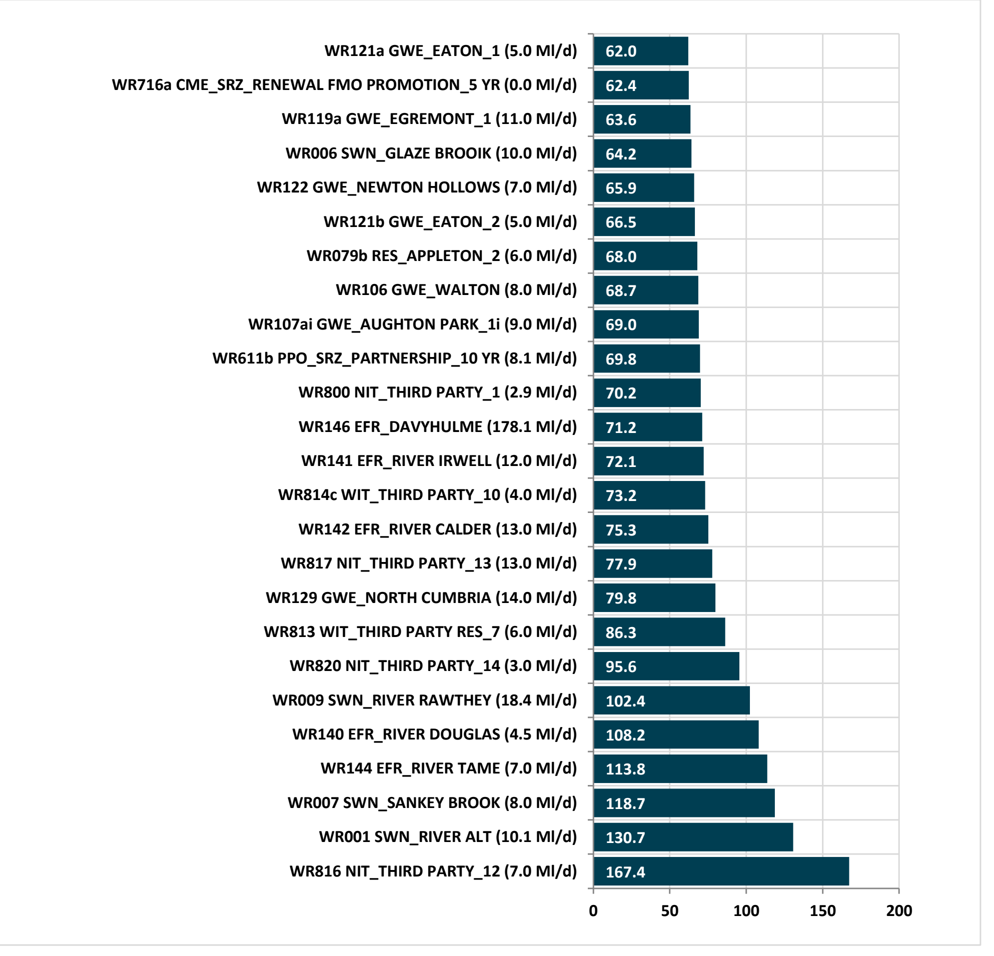

Figure 11 AISC values and ranking for options in the Strategic Resource Zone (3 of 3) (pence per cubic metre)

Carlisle Resource Zone

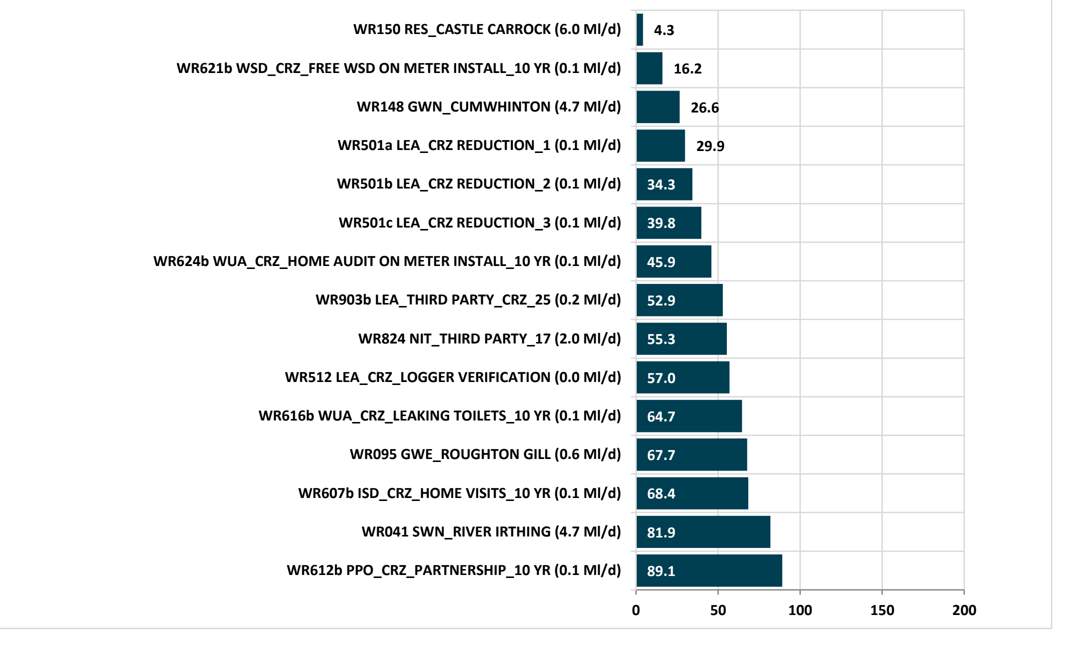

Figure 12 AISC values and ranking for options in the Carlisle Resource Zone (pence per cubic metre)

North Eden Resource Zone

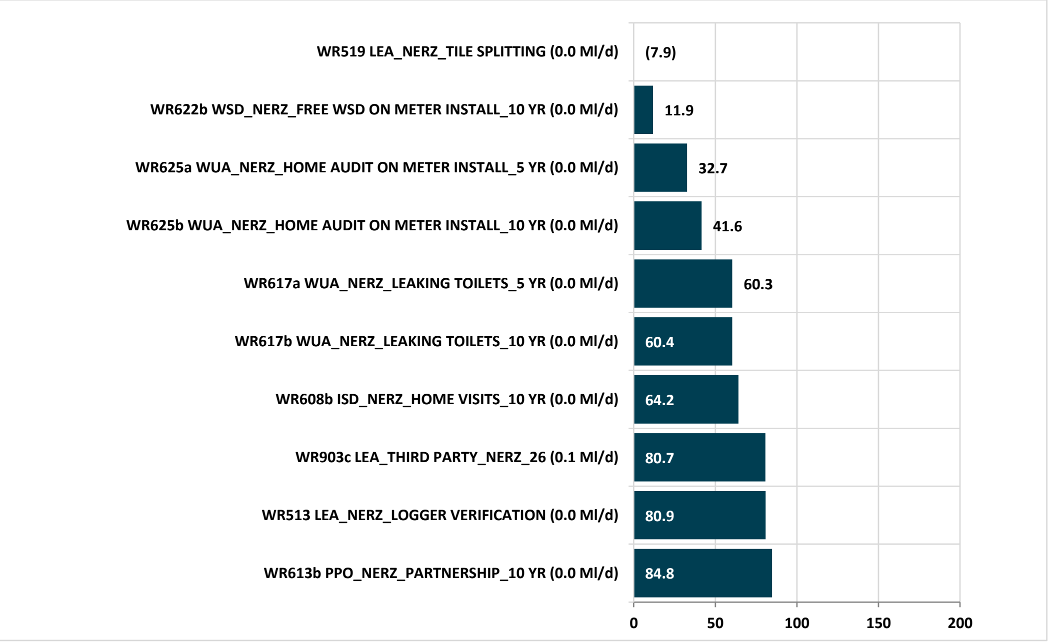

Figure 13 AISC values and ranking for options in the North Eden Resource Zone (pence per cubic metre)

Appendix B: Extended methods model run scenarios and nomenclature

Our supply-demand scenarios cover a wider range of uncertainties. These are illustrated in Section 0, where our extended methods process reflects those critical to the nature of our supply system and planning problem characterisation. Whilst the latter mainly focusses on supply-side uncertainty, as part of 'smart' evolution of our process we have been developing the plan, we have also now included demand within the framework. Table 25 shows the table of extended methods scenarios tested, with the relevant nomenclature used in the presentation of results.

Table 25 Table of extended methods scenarios tested

Run name	Run ID	Climate change setup	Demand for water setup	National water trading setup	Portfolio of options setup	Rationale
2035_Base	1	Circa. 50th percentile climate change impact at 2035 (referred to as "CCA")	Demand for water at 2034/35 plus target headroom (excluding the climate change component) plus outage and losses	N/A	N/A	Indicates expected system performance in 2035, with no leakage reduction and no options.
2035_L60	2	As **2035_Base**	As **2035_Base**, but includes 60 Ml/d of demand reduction through leakage	N/A	N/A	Indicates the change in system performance in 2035, with the proposed leakage reduction programme.
2035_L60_T300	3	As **2035_L60**	As **2035_L60**	Trade sized at 180 Ml/d, utilised in line with a 300 Ml/d abstraction from the River Severn	N/A	Indicates the change in system performance in 2035, if national water trading is added in without options.
2035_L60_T300_Plus	4	As **2035_L60_T300**	As **2035_L60_T300**	As **2035_L60_T300**	Includes options designed to return the customer and environment metrics back to the level indicated under **2035_L60**	Indicates the portfolio of options required to return the system performance to that with the proposed leakage reduction programme and no national water trading.
2035_L60_T300_CC resilient	5	As **2035_L60_T300_Plus**	As **2035_L60_T300_Plus**	As **2035_L60_T300_Plus**	As **2035_L60_T300_Plus**, but if the secondary climate change metrics show a negative impact the portfolio of options is changed to address this	Examine the extra options to make the system performance, under national water trading, resilient to climate change.
2035_L60_T300_Dem resilient	6	As **2035_L60_T300_Plus**	As **2035_L60_T300_Plus** with demand increased in case of demand forecast uncertainty	As **2035_L60_T300_Plus**	As **2035_L60_T300_Plus**, but if the metrics show a negative impact the portfolio of options is changed to address this	Sensitivity run to examine the impact of increased demand on our system.
2035_L60_T500_Plus	7	As **2035_L60_T300_Plus**	As **2035_L60_T300_Plus**	Trade sized at 180 Ml/d, utilised in line with a 500 Ml/d abstraction from the River Severn	As **2035_L60_T300_Plus**, but if the metrics show a negative impact the portfolio of options is changed to address this	Sensitivity run to examine impact of a higher utilisation of national water trading on our system.

Run name	Run ID	Climate change setup	Demand for water setup	National water trading setup	Portfolio of options setup	Rationale
2080_L175	8	Circa. 50th percentile climate change impact at 2080s	Demand for water in the 2080s plus target headroom minus climate change plus outage with 175 Ml/d leakage reduction	N/A	N/A	Indicates the expected system performance in the 2080s.
2080_L175_T300_CC resilient	9	As **2080_L175**	As **2080_L175**	Trade sized at 180 Ml/d, utilised in line with a 300 Ml/d abstraction from the River Severn	Includes options designed to return the customer and environment metrics back to the level indicated under **2035_L60**	Examine whether the portfolio of options assigned to support national water trading changes in the longer term.

Appendix C: Key references and data sources

Table 26 List of key UK Water Industry Research (UKWIR) projects

Year	Manual/report name	Manual/report reference	Key components/elements that are informed/impacted
2002	The Economics of Balancing Supply and Demand	02/WR/27/4	Early framework for making supply-demand decisions and informs the core methods for options appraisal and selection
2012	Water Resources Planning Tools	12/WR/27/6	An extension to "The Economics of Balancing Supply and Demand" and informed the thinking for "WRMP19 Methods – Decision Making Methods"
2016	WRMP 2019 Methods – Decision Making Process: Guidance	16/WR/02/10	A key change for WRMP19, this project provided a framework for the consideration and application of advanced/enhanced decision making methods
2016	WRMP 2019 Methods – Risk Based Planning	16/WR/02/11	A key change for WRMP19, this project provided guidance and a methodology to aid in the understanding of risk through the WRMP19 planning process