Appendix E – Decision making

Appendix E explains our investment modelling approach and how we use investment models as support tools to our decision making. The decision support tools used for our draft and final WRMP build on those developed for our previous water resource management plans and price reviews. We have used our Water Infrastructure Supply Demand Model (WiSDM) to derive a least whole life cost investment plan to meet our water infrastructure maintenance needs and supply demand balance over a 25 year planning horizon. This is discussed in section E1.

For this plan we have further enhanced our WiSDM model to create the Decision Making Upgrade (DMU) model, which explores the sensitivity of the investment plan under different future scenarios and considers the inherent uncertainty around delivery of solutions. Further information regarding our use of the DMU is provided in sections E2 and E3.

The outputs from these investment models have been used as part of our wider decision making framework which has considered the following aspects:

- Understanding regulators' expectations (described in Section E4)
- Understanding stakeholders' and customers' expectations (described in Section E4)
- Costs and benefits of options
- Supply / demand investment modelling
- Environmental impacts of our options
- Sensitivity testing of future scenarios
- Governance and assurance

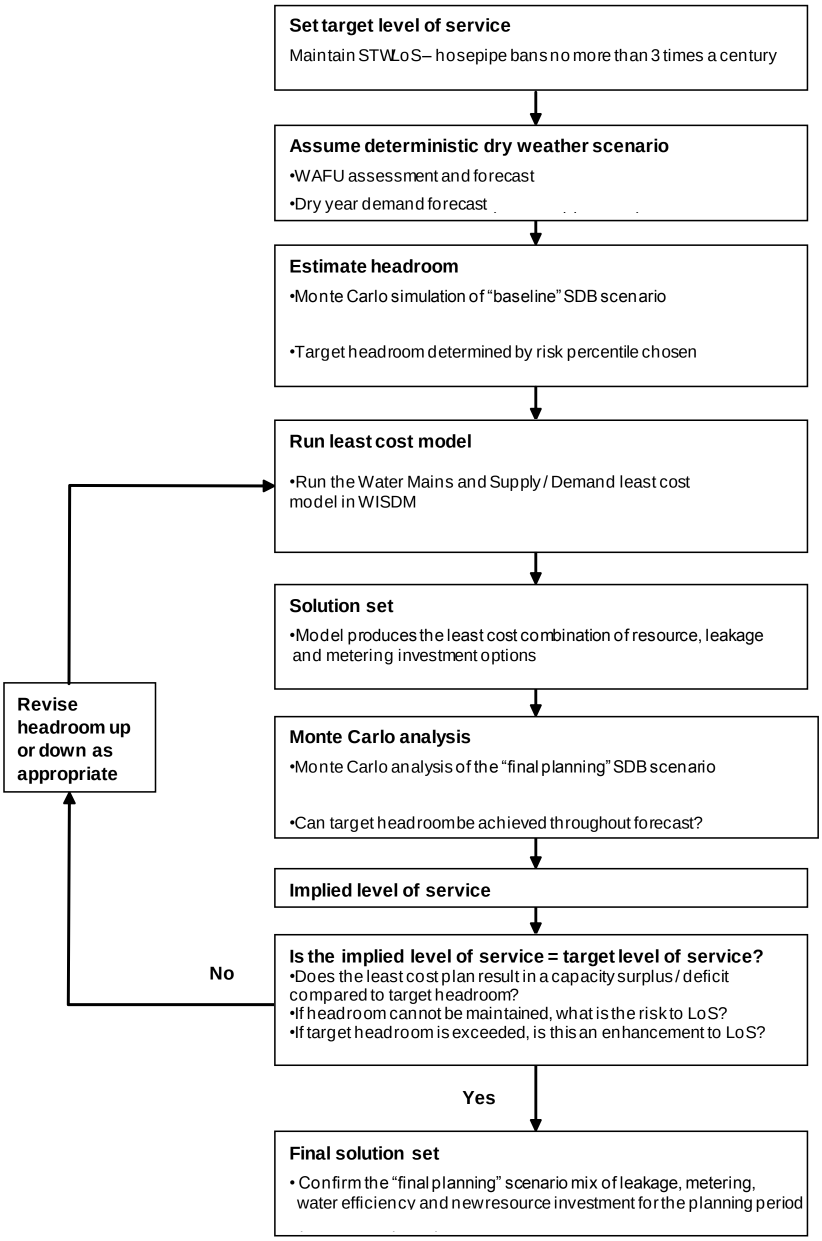
The supply / demand recommendations in our WRMP have tried to balance all of these factors to produce a flexible, sustainable and affordable plan.

Our draft WRMP focussed primarily on a planning horizon of 25 years. This horizon is the minimum required by the WRMP guidelines and we have selected this period due to the scale of the supply / demand challenge we face over the next ten years to achieve Water Framework Directive objectives and address the uncertainty around climate change impacts. Since our draft WRMP was published we have continued to explore the sensitivity of our investment planning decisions and we have extended our investment scenario modelling to cover an 80 year horizon. We have expanded Appendix E since the draft WRMP to describe our approach to longer term planning (section E1.8) and adaptation of our decision making approach.

E1 Decision making - Developing a best value plan

The schemes that make up our strategy for water resources, leakage and water efficiency investment for ensuring security of supply, have been derived by applying the principles of the UKWIR/Environment Agency report titled 'Economics of Balancing Supply and Demand (EBSD)'. However, our decision making approach in our WRMP has gone beyond a simple financial cost / benefit appraisal, and has explicitly considered customers' priorities, stakeholders' views, our environmental obligations and the environmental and social impacts of our supply and demand options. In addition, our Strategic Environmental Assessment has led us to make decisions that are not solely based on least cost appraisal and instead we consider wider environmental objectives. Our approach follows elements of the "intermediate" and "advanced" application of the EBSD methodology. The stages in the EBSD approach and how they relate to our WRMP are set out in Figure E1.1 below:

Figure E1.1: The stages in the "intermediate" EBSD approach



Using our investment modelling tools we have developed a best value, least regrets plan, taking into account environmental legislation and the needs of our customers and other stakeholders. Our investment scenario modelling and sensitivity analysis has helped us to identify water supply options that give us high confidence under a wide range of different future supply / demand scenarios. Our plan is adaptable so that we can adjust as we go to ensure that all investment is targeted effectively and efficiently. We have already worked collaboratively with the Environment Agency, and will continue to do so, to shape our plan and the required outcomes to meet the needs of the environment in the least cost way for our customers.

As explained in Appendix D, we have considered a wide range of potential options for balancing future supply and demand for water. We have considered the delivery risks and impacts of those options and have derived a final list of feasible options. Each of these feasible options has been taken forward for a more detailed assessment of long run financial, social and environmental costs and benefits. The costs and benefits associated with each of these schemes has then been used to determine the overall net least whole-life cost package of solutions to deliver the required security of supply over the long run to 2045 and beyond.

Our least cost investment plan has been derived using our Water Infrastructure Supply Demand Model (WiSDM). The model allows us to assess the costs and benefits of different levels of mains renewal, leakage reduction, demand management and metering alongside options to increase supply capability. The WiSDM model allows us to predict the future performance of our water distribution assets, the investment needed to achieve different levels of performance, and the scale of investment needed to make sure we have sufficient water supply to meet future demand. As a result, we can be confident that we are able to generate a truly optimised package of demand and supply investment measures needed to meet different planning scenarios, and we can fully explore the economics of different leakage decisions. Our approach means that the supply and demand solutions included in our WRMP are fully integrated into the broader PR19 investment plans.

As well as exploring the overall supply / demand investment programme options, we have conducted option level cost optimisation and feasibility assessments to make sure that option scope and costs are efficient. We have followed an option screening process to help us capture a wide range of these potential options early on, and that has helped us to screen out options that we don't consider feasible for consideration in our current WRMP. The screening process and screening criteria, described in Appendix D of our WRMP were shared with the Environment Agency, Natural Resource Wales and our wider stakeholders. The input of these parties helped us to refine our unconstrained list into a shorter list of feasible options. Using this approach, we were able to reduce the 200 possible options on our early unconstrained list to 111 viable options that we developed further to a stage where we could prepare initial cost and benefit estimates for each option.

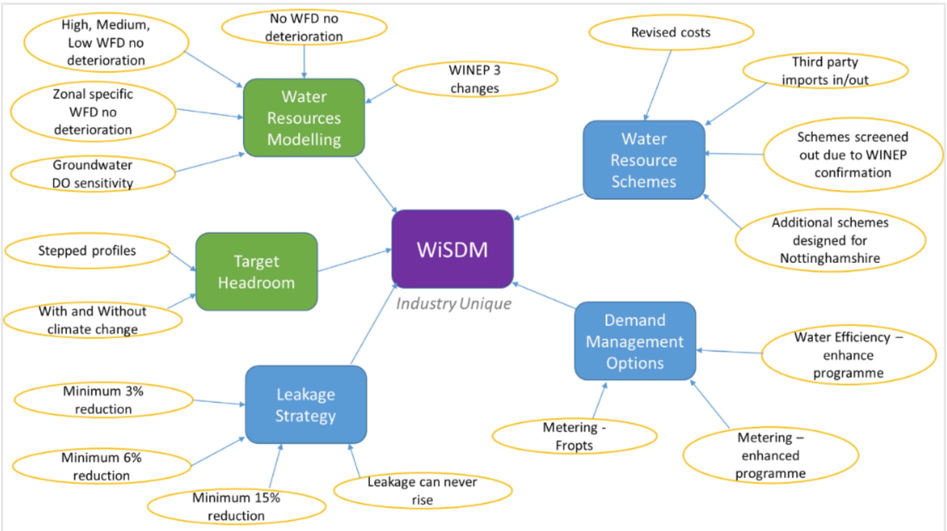
The feasible options were subsequently developed further in terms of engineering design, cost estimation and environmental appraisal to ensure a robust understanding of the options. For these feasible options we assessed deliverability, the likely construction and operating costs, the potential volume of supply or demand benefit they might deliver, the likely time it would take to plan, build and commission the option, and the environmental impacts. These cost and benefit values were then used in our investment modelling to give us an understanding of the optimised balance of leakage reduction, demand management and new supply investment needs.

Our approach to option-level and programme-level investment modelling has allowed us to generate a number of potential long term investment programmes which represent different ways of securing our long term supply and demand objectives. Additionally we have used our WiSDM model to understand variations to the optimum investment needs as a result of changes to our approach to our company-wide strategies. These strategies, such as leakage reduction, metering and the pace at which we adapt to abstraction licence changes needed to achieve Water Framework Directive objectives affect our approach to future investment and it is important to us that we establish the most cost and environmentally beneficial portfolio of investment for our customers.

We have explored how trading water with neighbouring water companies could impact on our long term investment needs, and what investment would be required to achieve the strategic objectives of Water UK's Water Resources Long Term Planning Framework. As a result, we have been able to generate a range of different feasible investment programmes and use these to assess the cost implications of maintaining our supply / demand balance whilst continuing to meet or exceed the expectations of our customers and other stakeholders. We have also used complex scenario and uncertainty modelling to understand the sensitivity of our investment decisions to the parameters we have used to estimate our projected future supply and demand data.

We considered numerous future supply / demand scenarios when developing our WRMP. From our water resources modelling we were able to create a number of different supply scenarios to help us understand the range of potential supply demand deficits we could face in the future, as a result of abstraction licence changes as part of WINEP3 and uncertainty around the potential impacts of climate change. Figure E1.2 shows an overview of the input variables that we include in our WiSDM modelling. As well as varying supply and demand data, we used WiSDM to test the cost implications of applying different strategies, such as enforcing a minimum leakage requirement and use of third party bulk imports.

Figure E1.2: WiSDM model inputs and scenario testing



We have carried out a large number of different assessments using our WiSDM model. These have included variations to the following parameters:

- Supply side options data:
  - Option benefits (deployable outputs)
  - Option costs (financial and monetised environmental costs)

- Future deployable output capability data:
  - Baseline deployable outputs and revisions during the course of developing our WRMP
  - Water Framework Directive impacts
  - Restoring Sustainable Abstraction impacts
  - Water trading impacts
  - Different level of climate change impacts
  - WINEP implications

- Customer-side and Distribution-side option data:
    - Varying leakage reduction levels
    - Varying meter optant uptake/profiles
    - Varying water efficiency implementation and benefit realisation

By assessing different permutations of the above data we were able to assess the implications of using, for example, enhanced leakage, metering and water efficiency programmes, in line with what our customers and other stakeholders told us they wanted.

Finally, the preferred programme of options output by our WiSDM model was subject to an expert engineering overview prior to inclusion in our draft WRMP. This final step and the resulting impact on our preferred programme are described in Appendix E1.6. As noted by Ofwat's response to our draft WRMP consultation, this review resulted in a variation of the least cost plan. For example, in our North Staffs WRZ the WiSDM output for our draft WRMP selected options UNK01 (New WTW on River Weaver) and BHS04 (Swynnerton boreholes) based on the cost / benefit criteria given to the model. This demonstrated that the optimised supply / demand programme should include new option development of up to 27Ml/d. However, our review of the WRZ geographical supply/demand distribution and the reasons for zonal deployable output constraint demonstrated that these chosen solutions would not deliver water to the required locations. Instead we proposed options UNK07 (Changes to Tittesworth WTW treatment capacity) and GRD18 (New treatment process at Peckforton boreholes) as these North Staffs WRZ options are more effective in delivering water to the location where the model predicts a supply / demand balance failure.

Our September 2018 *Statement of Response* explained that there have been updates to the preferred programme of options since our draft WRMP was prepared and following the consultation exercise. The new preferred programme of options is described in Appendix D.

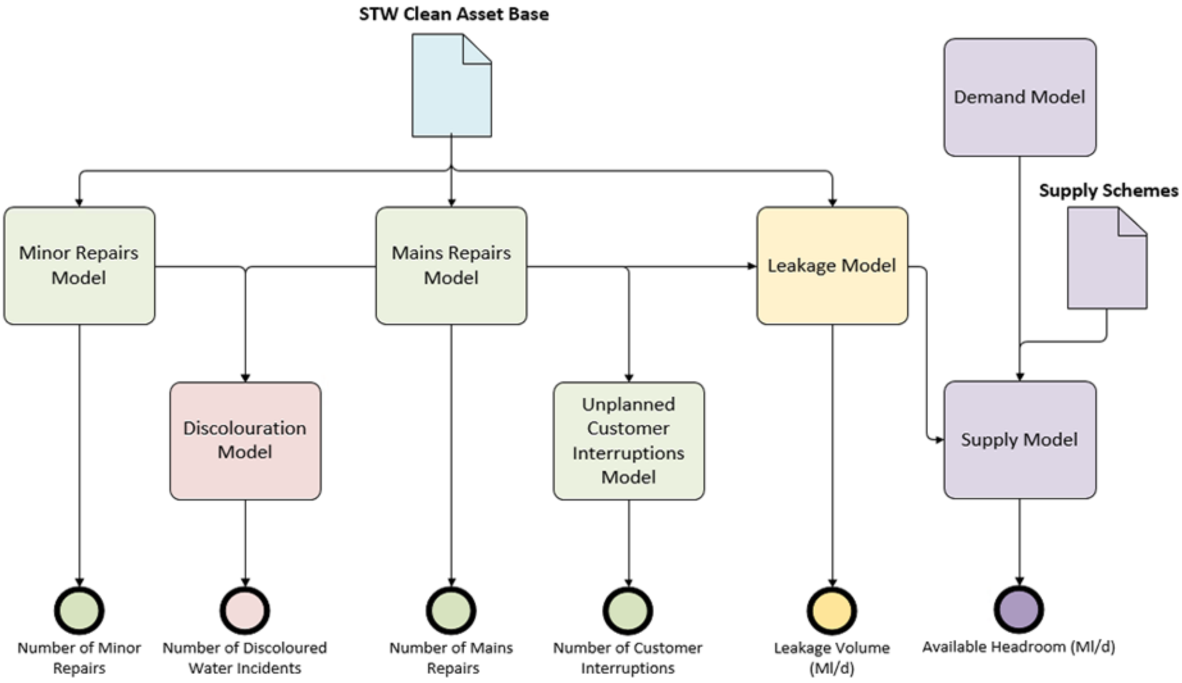
E1.1 Overview of the Water Infrastructure Supply Demand Model (WiSDM)

The WiSDM model is made up of six linked sub-models:

- Headroom
- Leakage
- Mains repair
- Interruptions
- Discolouration
- Ancillaries

The relationships between each of these sub-models are illustrated in Figure E1.3 overleaf.

Figure E1.3: The components of the WiSDM model



Key	Category
	Asset Maintenance
	Water Quality
	Leakage
	Supply Demand Balance

There are essentially three primary sub-models that predict the performance of our infrastructure asset base; mains repairs, minor repairs and leakage. The mains repairs model calls upon the asset attributes such as pipe material, diameter, year laid and soil setting to generate a mains deterioration profile. The repairs, by failure mode and diameter are then input to two secondary sub-models; unplanned customer interruptions and discolouration.

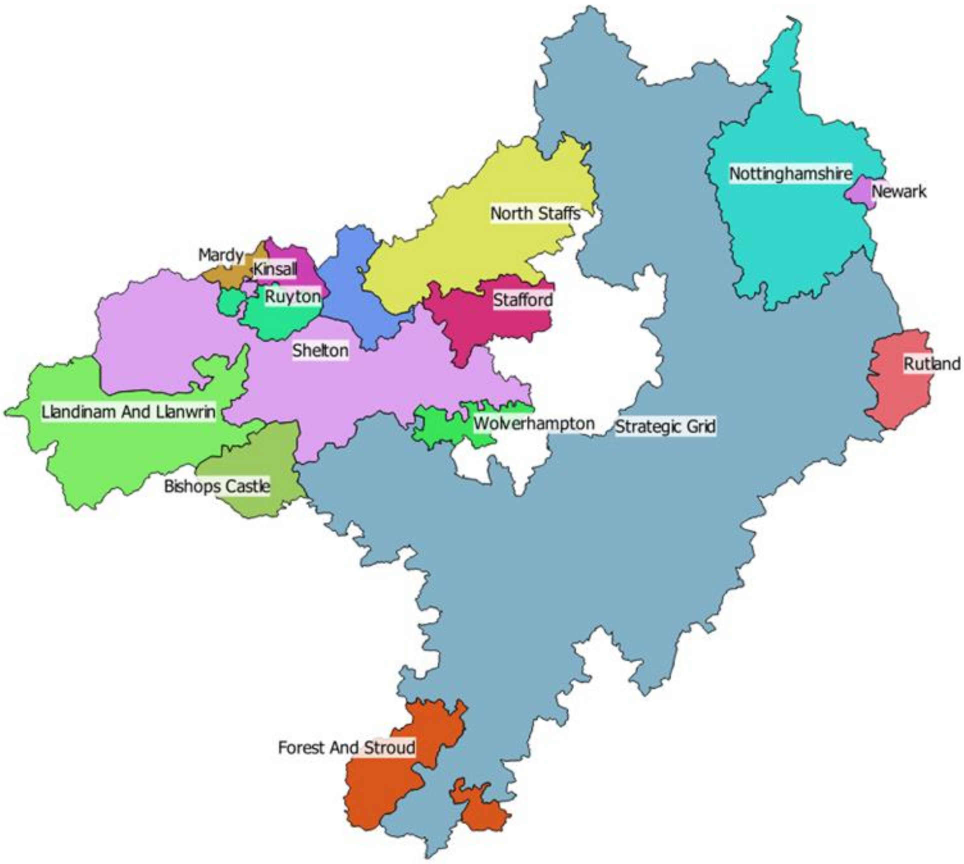
The minor repairs model is driven by the weighted average mains age of each WRZ, a component of which is also used by the discolouration model (valve repairs).

The leakage sub-model contains the base level of leakage by WRZ and applies a leakage deterioration component (NRR), which is driven by the weighted average age and material type of mains in the WRZ. Future demand and headroom requirements are also taken into consideration in the model.

The integrated model calculates, for each water resource zone, the least cost mix of capital and operational interventions needed to prevent mains bursts and leakage increasing due to network deterioration, as well as to achieve the desired service targets for burst frequency, supply interruptions and leakage as well as maintaining target headroom throughout the planning horizon. Social and environmental costs of the chosen interventions are included in the least cost calculation resulting in a plan that is holistically least cost.

The model was built for Severn Trent's water investment plans based on the original company boundary and split into Severn Trent's original 15 WRZs as shown in Figure E1.4. For future WRMPs, we will update our investment modelling approach to incorporate the new Chester WRZ, and the Hafren Dyfrdwy WRZs.

Figure E1.4: Severn Trent's WRZ split for WiSDM



The following sections provide a summary of the methodologies used in the WiSDM sub-models. They define the assumptions made, the data used in the models, the inputs that have been taken from other studies and modelling, and the outputs that are available.

E1.2 The Headroom and Demand sub-model

The Headroom and Demand sub-model calculates the available headroom for each water resource zone based on water available for use, demand and leakage projections. The objective of the model is to achieve and maintain target headroom by using demand management, reducing leakage or selecting new resource options to increase available headroom. Figure E1.5 shows how sub model fits into the overall WiSDM hierarchy.

Figure E1.5: Headroom sub model

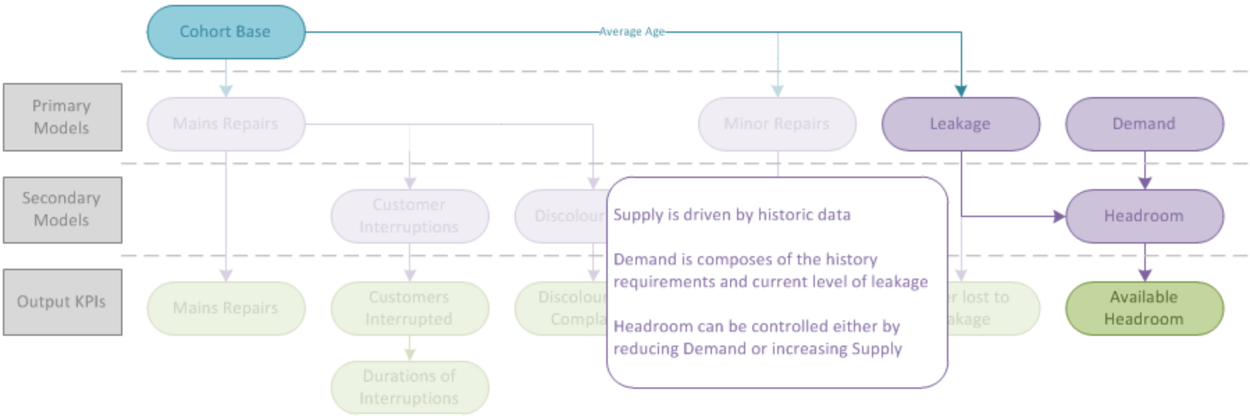
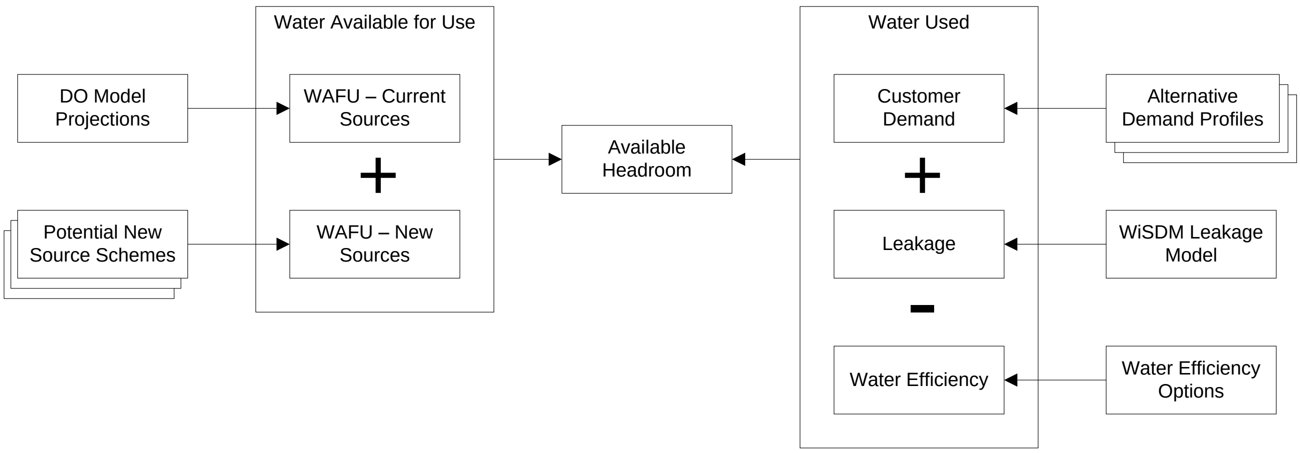


Figure E1.6 outlines the calculations that are carried out within the model. Water available for use (WAFU) is made up of the predicted output from existing sources plus the contribution from any new resource options that the model has chosen.

The default baseline demand projection includes the benefits of our ongoing free meter policy and a continuation of our AMP6 water efficiency activities. The model then has options available to reduce demand further using compulsory metering, additional water efficiency measures or reducing leakage.

Leakage levels are calculated dynamically by the leakage sub-model and are a function of the underlying network deterioration and the chosen mains renewal and active leakage control interventions.

Figure E1.6: Calculation of available headroom in the WiSDM model



The WAFU and demand saving benefits of new supply-side and demand-side options are input to the model at water resource zone level. Each option has associated with it the following data:

- Available daily output/benefit
- Construction costs
- Operation costs
- External costs (carbon and amenity / social)
- Dependencies with other options
- Inter-zonal effects if an option involves transferring water between zones

The key outputs from the Headroom and Demand sub-model are:

- Total water available for use
- Available headroom
- Distribution Input
- Household water delivered
- Numbers of meters installed
- Amount of active leakage control required
- Change in leakage level
- Level of enhanced water efficiency activity
- Resource options chosen
- Supply / demand balance

Final Distribution Input (DI) is calculated through the arithmetic addition of water efficiency effects, metering benefits and the outputs from the leakage sub-model.

Total WAFU is calculated by adjusting WAFU with water provided from new supply schemes or water taken using transfer schemes.

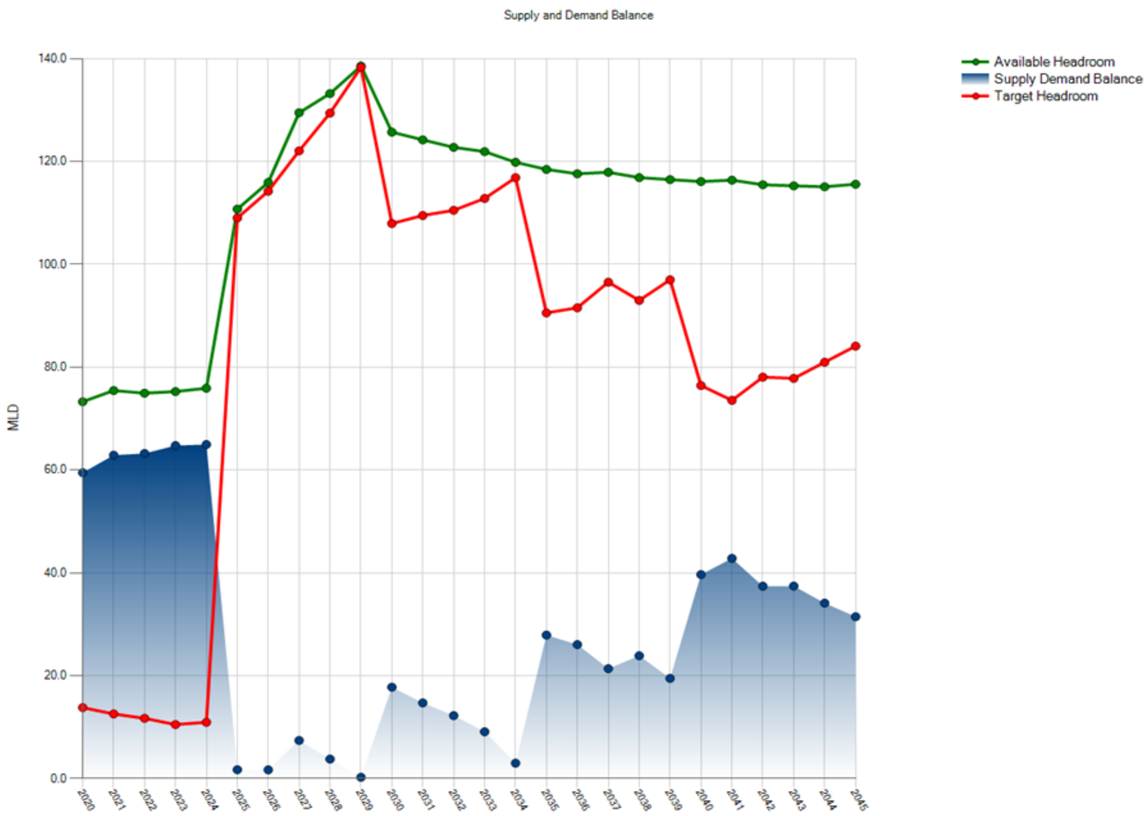
Available headroom is modelled through the following calculation:

Available Headroom (Ml/d) = Total WAFU – (Leakage + Demand)

Target Headroom is an input to WiSDM and is derived using a risk-based approach for assessing uncertainty, which is described in detail in Appendix C.

The supply and demand balance is calculated by calculating the difference between the Available Headroom and the Target Headroom, as shown in Figure E1.7 overleaf.

Figure E1.7: Supply and Demand Balance



E1.3 The Leakage sub-model

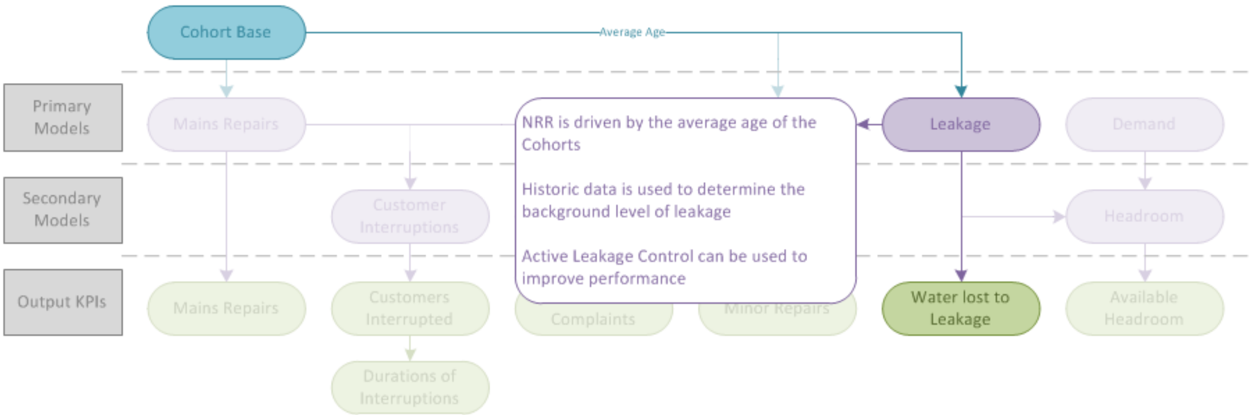
The purpose of the Leakage sub-model is to calculate the quantities of water lost through leakage based on the relationship between the mains age, mains type and soil setting for each WRZ. The objective of the model is to calculate the level of leakage reduction required to achieve a least cost solution taking into account supply demand challenges and practical constraints.

We use the model to calculate the Economic Level of Leakage (ELL). The ELL is calculated in the optimisation by balancing the relative costs and benefits of combining different supply-side and demand-side interventions, alongside achievement of different service performance targets. The leakage target is an output not an input of the overall WiSDM model.

The leakage sub model allows us to explore the true economic level of leakage as well as the short and long run costs of achieving different leakage targets. One important constraint in the modelling assumptions is the policy decision that WRZ leakage can never rise over time. Therefore, decisions to reduce leakage to meet short term supply / demand balance needs have long term cost consequences, as any reduction must be maintained over time using mains renewal and active leakage control. This modelling approach allows us to explore the 'true' economic level of leakage and understand long term mains renewal implications.

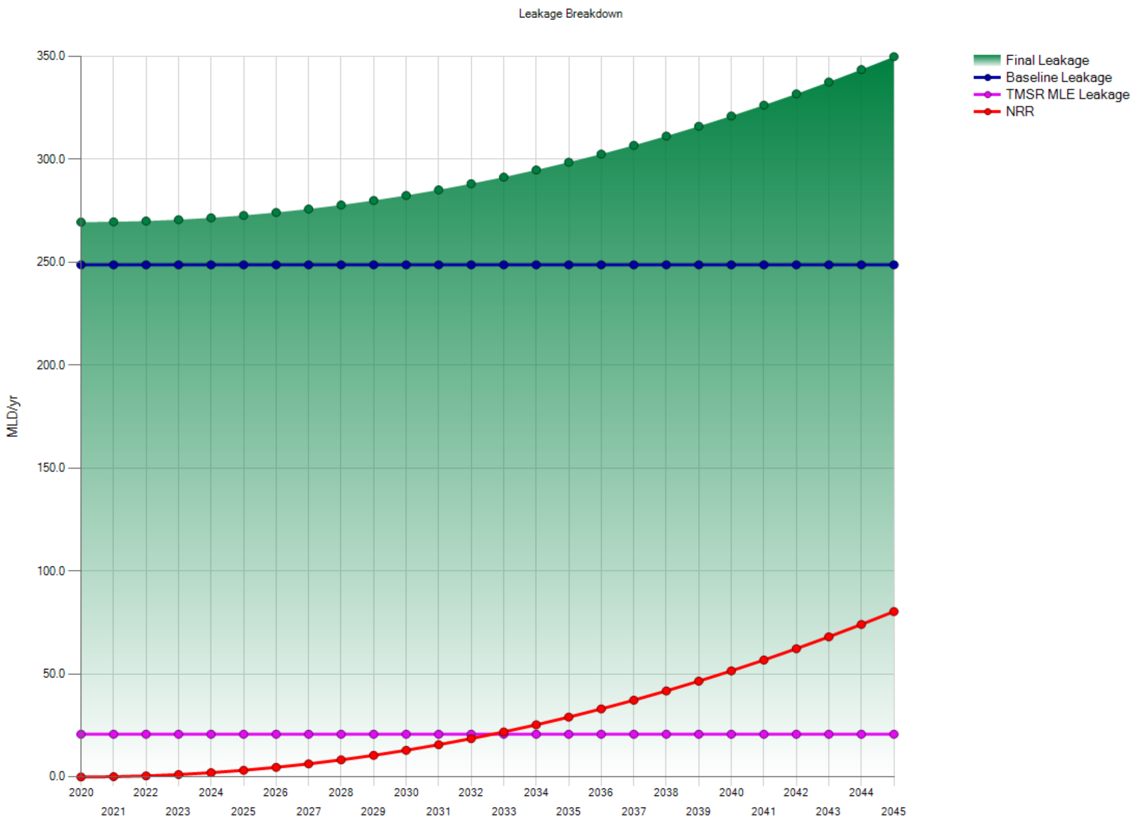
Figure E1.8 overleaf shows how the leakage sub model fits into the overall WiSDM hierarchy.

Figure E1.8: Leakage sub model



The Leakage model sums the baseline level of distribution mains, trunk mains and service reservoir leakage, to which leakage natural rate of rise (NRR) is applied to calculate the amount of leakage control and mains renewal investment needed to prevent performance deteriorating over time. The effects of active leakage control and mains renewal needed to drive leakage down further for supply / demand balance purposes are then modelled to produce a 'Final Leakage' projection. Figure E1.9 illustrates how Final Leakage is broken down into the components of baseline leakage, trunk mains and service reservoir leakage and NRR.

Figure E1.9: Leakage Breakdown



The Active Leakage Control (ALC) intervention represents the effort and cost involved in finding and fixing leaks. It is configured in the model as a series of levels of reduction from current leakage to background levels (the minimum possible). The model can choose to do any number of leakage reduction levels in any one time step. The costs incurred for ALC include the cost of the effort to reduce leakage from one level to another and the cost of the additional effort needed to maintain leakage at the new lower level. The additional number of repairs, equipment needed, carbon and amenity costs associated with ALC are also calculated in the model and included in the calculation of the least cost solution.

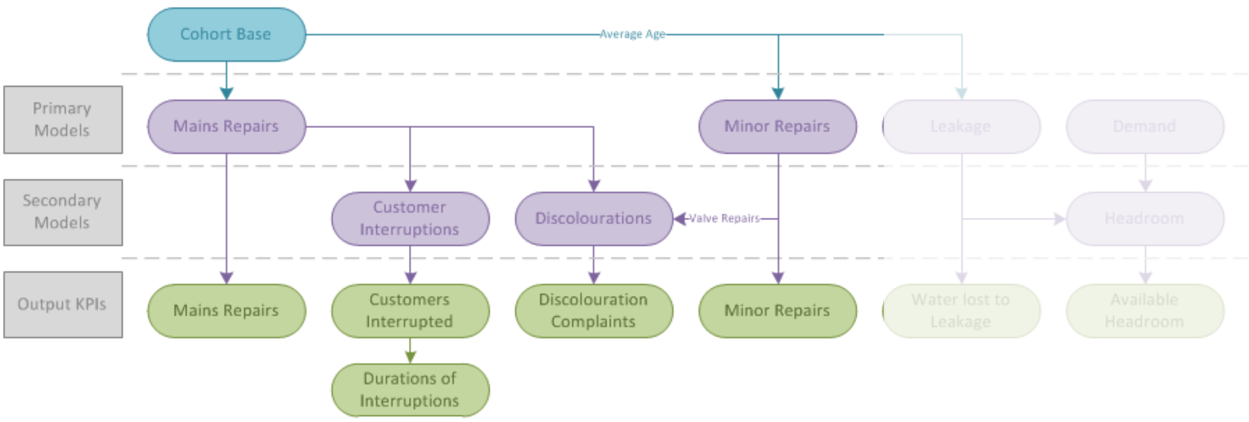
E1.4 The Mains Repair Sub-model

The purpose of the Mains Repair Sub-model is to predict the number of mains bursts based on relationships with the age and makeup of the network for each WRZ. The number of bursts and the mains material has a direct effect on the number of predicted unplanned customer supply interruptions. There is also a secondary effect on the number of predicted discolouration complaints as mains bursts are a trigger of discolouration events. The objective of the model is to calculate the length of mains renewal required to maintain a stable number of mains bursts, prevent leakage from increasing and prevent an increase in the number of unplanned customer interruptions of greater than 12 hours and the number of unplanned customer interruption minutes greater than three hours.

Mains renewal, as well as acting on leakage breakout rate as described in the leakage sub-model section, is also used in the model to control the number of mains bursts and resulting unplanned interruptions through the moderation of the average age and material profile of the asset base. By holistically considering the benefit of mains renewal to leakage, mains bursts, unplanned interruptions, ancillary repairs and discolouration, we have ensured that the mains renewal investment profile is optimal. Decisions to reduce leakage as a means of meeting supply / demand targets have consequences for long term mains renewal rates needed to prevent leakage from increasing in future. This allows us to explore the true long run economic level of leakage through our WRMP analysis.

Figure E1.10 shows how the mains repair sub model fits into the overall WiSDM hierarchy.

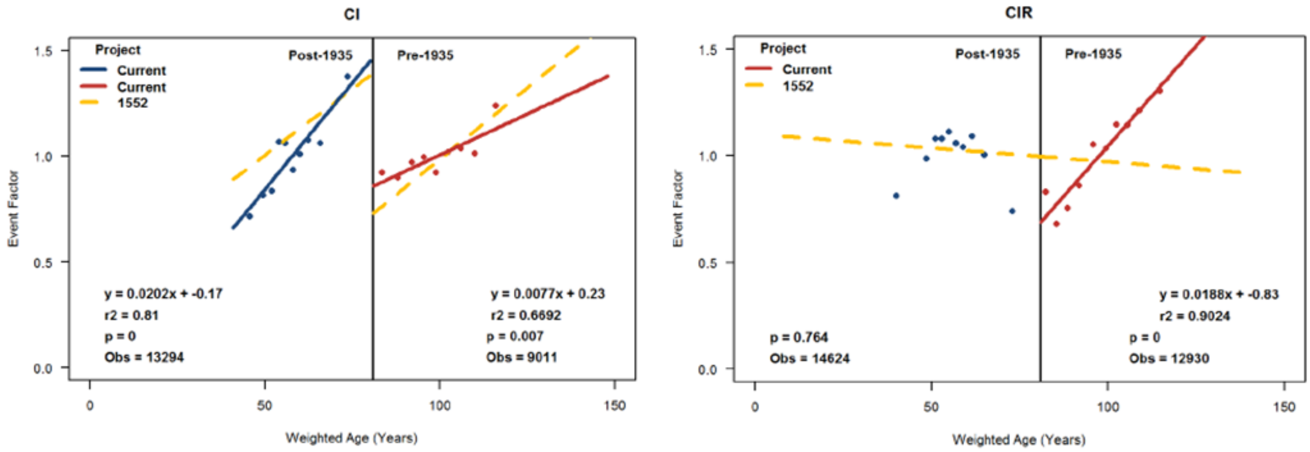
Figure E1.10: Mains Repairs Sub Model



Company specific burst data is used to derive the deterioration relationships for each material, age, diameter and soil type. The two key relationships derived are detailed below with an example in Figure E1.11:

- A linear burst factor relationship for each material type by age. This is used to calculate the change in the number of bursts as the average age of the mains cohorts change.
- A multiplier relationship for each soil/diameter combination by material. This is used to modify the number of expected bursts taking into account ground conditions.

Figure E1.11: Burst factor relationships



The number of predicted unplanned customer interruptions resulting from mains burst is calculated in the Customer Interruptions sub-model. We have derived relationships between pipe diameter, material and location (urban or rural) and the number of customers interrupted and the duration of those interruptions. We constrain the model to keep the number of interruptions greater than 12 hours in a stable position, this focuses mains renewal on larger diameter pipe in materials which tend to cause longer duration interruption events (such as asbestos cement and PVC pipelines). The benefit to discolouration complaints is a secondary effect as the number of complaints isn't constrained or targeted in the model.

This approach means that the short and long term decisions taken for supply / demand balance needs are fully integrated with the wider PR19 maintenance and service delivery investment plans.

E1.5 Model outputs

The WiSDM model produces output files by water resource zone for each simulation / optimisation run as well as a series of graphical and tabular summaries. Figure E1.12a and E1.12b overleaf illustrates the type of graphical output produced.

Figure E1.12a: Illustrative graphical output from the WiSDM supply-demand balance modelling system

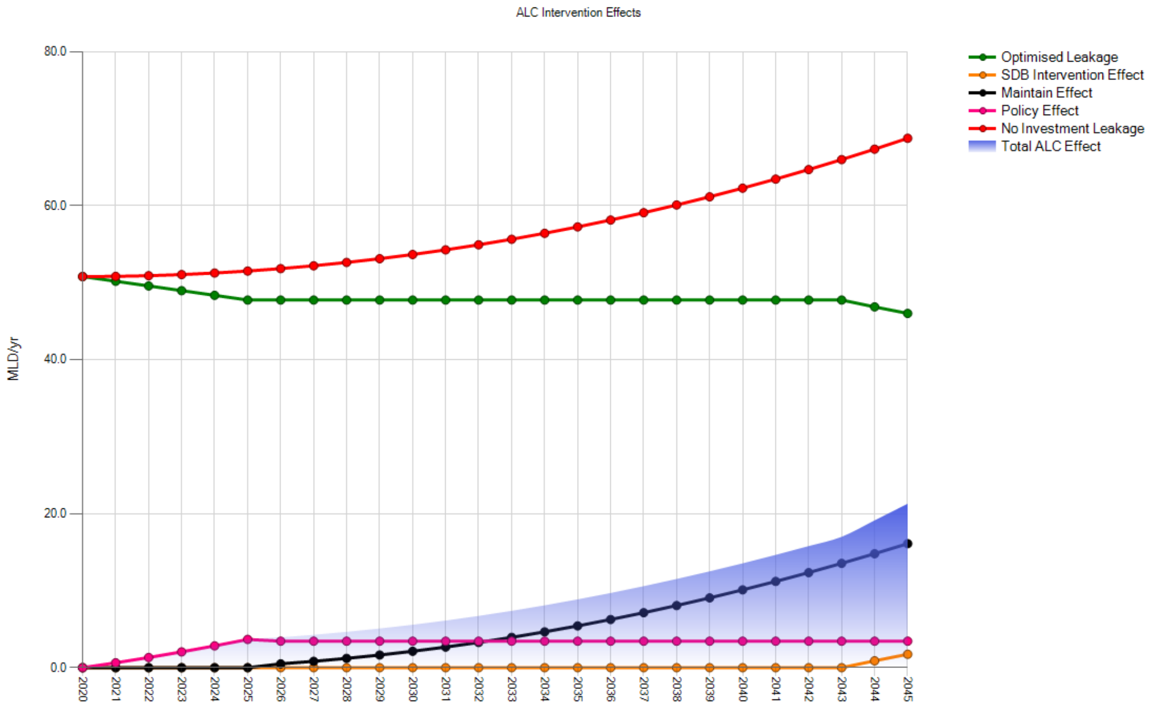
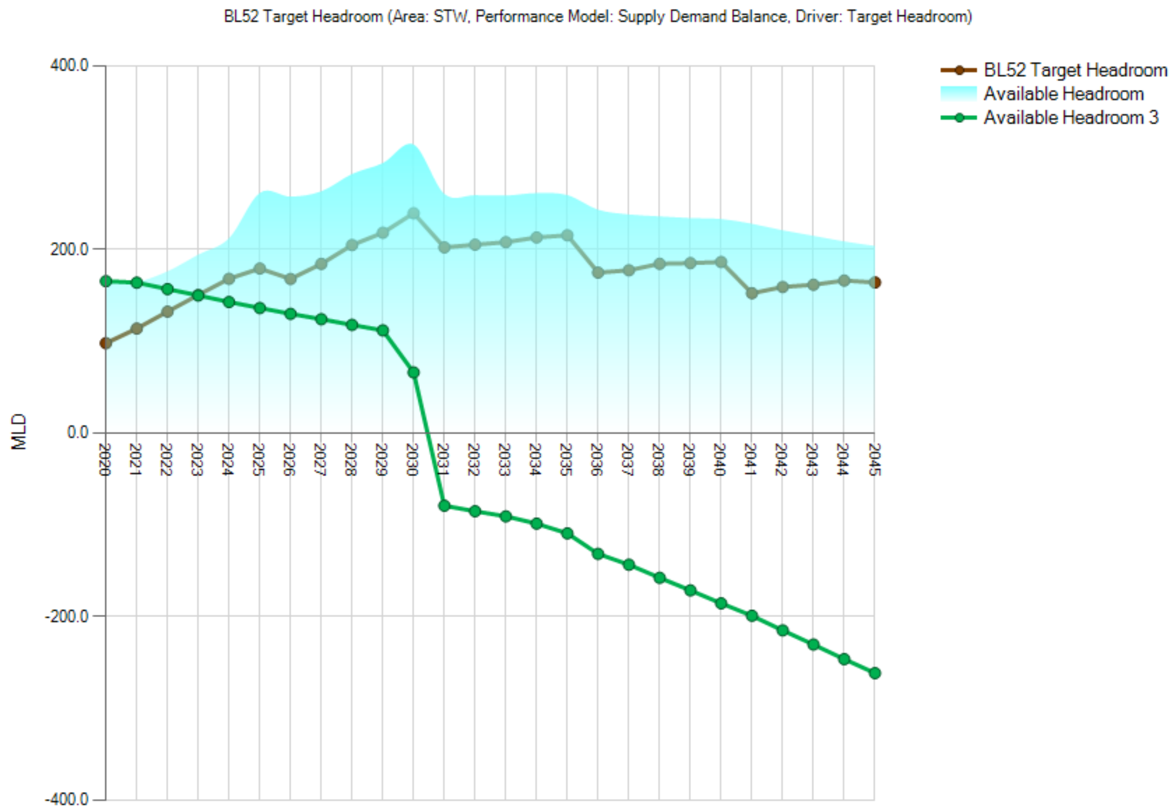


Figure E1.12b: Illustrative graphical output from the WiSDM supply-demand balance modelling system



E1.6 Using WISDM outputs to inform our draft WRMP

The outputs of our WiSDM approach have allowed us to generate a number of potential long term investment programmes which represent different ways of securing our long term supply and demand objectives. We have also used the WiSDM model to test the costs and benefits of adopting different top-down policy decisions on issues such as leakage, metering and the pace at which we adapt to abstraction licence changes needed to achieve Water Framework Directive objectives. We have also examined water trading scenarios to explore how these options could impact on our long term investment needs, and what investment would be needed to achieve the strategic objectives of Water UK's Water Resources Long Term Planning Framework.

As a result, we have been able to generate a range of different feasible investment programmes and use these to test the cost implications of maintaining the supply / demand balance while achieving stakeholders' expectations.

We began running WiSDM investment scenarios in late 2016 when we first understood the potential scale of the abstraction licence changes needed to prevent future environmental deterioration and achieve Water Framework Directive objectives. As our understanding of the future supply and demand challenges improved through 2017, and with the releases of WINEP1 and WINEP2 by the Environment Agency, we ran further WiSDM modelling scenarios. The outputs of these evolving supply / demand investment scenarios allowed us to understand the expenditure implications for AMP7 and longer term, and allowed us to test alternative leakage and demand management scenarios.

Discussion of the supply-side and demand-side options, including definitions of "Fropt" and "Enhanced Hwec and social housing" is included in Appendix D.

Table E1.1 summarises the list of WiSDM scenarios and potential investment programmes that we generated through 2017 as our understanding of the supply / demand challenge and of our options evolved.

Table E1.1: WiSDM investment scenarios used to inform our WRMP

Scenario	Supply and demand assumptions	Leakage, metering and water efficiency scheme assumptions	Purpose
0	Used WRMP14 assumptions	Minimum 3% leakage; Free Meter Optants	Test run – checking that the WiSDM reconfiguration and improvements were operating correctly
1	Using first view of dWRMP supply and demand assumptions from AMP8 onwards	Minimum 3% leakage; Free Meter Optants	To inform the first PR19 portfolio optimiser run
2	As scenario 1	Minimum 3% leakage; Free Meter Optants; updated water efficiency profiles	Testing implications of changing the water efficiency inputs and solutions
3	As scenario 2, with first view of dWRMP supply and demand assumptions from 2017 onwards	As scenario 2	Testing impact of capping AMP 6 mains profile and using first view dWRMP supply and demand assumptions from 2017

Scenario	Supply and demand assumptions	Leakage, metering and water efficiency scheme assumptions	Purpose
4	Revisions to supply demand balance. Updated target headroom profiles.	Minimum 6% leakage; Updated PR19 Free Meter Optants profile; revised water efficiency profiles	Utilising updated supply and demand data and revised metering profiles.
5	As scenario 4, with delayed start of WFD no deterioration impacts	As scenario 4	Testing the cost implications of delaying licence changes required for WFD no deterioration (based on WINEP1)
6	RSA impacts from 2025, WFD No Deterioration impacts excluded from supply demand balance, Rank 50 Climate Change used as central estimate reduction from deployable output	Minimum 15% leakage; Updated PR19 Free Meter Optants profile; enhanced water efficiency	Testing the cost implications of WFD no deterioration – this run excluded WFD no deterioration impacts from the supply demand balance.
7	As scenario 6 but with revisions to supply and demand inputs	As scenario 6	Utilising updated supply and demand data
8	As scenario 7	As scenario 6 with enhanced metering profile	Testing cost implication of using an enhanced metering programme
9	As scenario 7 with reconfigurations to enable water trading	Minimum 15% leakage; Updated PR19 Free Meter Optants profile; enhanced water efficiency	Testing cost implications and scheme selection under a scenario facilitating water trading
10	RSA from 2025, zone specific High, Medium or Low WFD No Deterioration from 2030, Rank 50 Climate Change	As scenario 9	First view assessment of impacts of WINEP 2 abstraction licence changes - high, medium or low impact scenario (based on WINEP1 water resources modelling) was applied based on a "best fit" review of WINEP2.
11	Calculated re-optimisation		
12	Remodelled WINEP2 impacts	Leakage can never rise; Updated PR19 Free Meter Optants profile; enhanced water efficiency	Testing the implications of the fully remodelled impacts of WINEP2 and enforcing a policy of leakage never being allowed to increase again
13	Calculated re-optimisation		
14	As scenario 12 with revised demand inputs	Leakage can never rise; enhanced 70k plus Free Meter Optants;	Testing the cost implications of an enhanced metering programme

Scenario	Supply and demand assumptions	Leakage, metering and water efficiency scheme assumptions	Purpose
		enhanced water efficiency	
15	Revision to North Staffordshire baseline deployable output	As scenario 14	Testing the cost implications of an enhanced metering programme with a revised North Staffordshire baseline deployable output (which improved the supply demand balance outlook)
16	Calculated re-optimisation		
17	Re-optimisation of scenario 15 with schemes reordered (based on planning, environmental and engineering criteria)		

Through this approach, to inform our draft WRMP we arrived at three feasible supply / demand investment programmes that could be used to achieve our long term supply / demand needs at very similar overall programme costs, but using different options: scenarios S12, S14 and S15. The overall net present value (NPV) difference between these three feasible programmes was approximately 3.5%, and was not considered material.

The headline difference between the supply and demand options we recommended in the draft WRMP and the two alternative feasible programmes of similar NPV, related to the potential impacts on a strategic water trade with Thames Water. The two alternative least cost programmes we derived included differing levels of leakage and metering ambition, but both included an option to develop a new water import to our region from United Utilities' Vyrnwy Reservoir via the River Severn. This transfer option also had the potential to feature in Thames Water's draft WRMP as part of a larger scale, national water trade. We did not include this water trade in our recommended preferred plan, but we have committed to continuing to explore this option with United Utilities as part of future WRMP reviews.

Instead, our recommended least cost programme included a new option to purchase a third party quarry and develop it into raw water storage to help meet our long term supply / demand balance needs. This is an innovative solution to develop strategic raw water storage in a way that minimises environmental impact. This option features in our proposed investment plan for the period 2025-2030, which means that we have flexibility to continue exploring it alongside the water trading alternative during AMP7.

We then needed to go through some final steps to translate the outputs from S15 into the supply / demand inputs that have been used to populate WRMP Tables 6 (Preferred Option) and 9 (Final Plan SDB). These steps are summarised as follows:

Step 1: Re-order S15 outputs based on environmental and engineering delivery risks

The outputs of WiSDM S15 represented the 25 year, least whole life cost package of demand, leakage and supply interventions needed to maintain the target supply / demand balance as derived for the draft WRMP. Appendix D of the WRMP explains the option appraisal process that was used to derive the feasible list of options, and the costs and benefits assumed for each. The sequence of schemes generated in WiSDM S15 was optimised by the cost and benefit of each option, and that sequence generated the lowest net present value over the 25 year investment modelling horizon.

We took the outputs from this 25 year optimised package and reviewed them based on planning, environmental and engineering criteria. In doing this we also had regard to our overall WRMP strategic objectives:

1. We will use demand management measures to reduce the amount of water we need to put into supply by:
    - Reducing leakage on our network;
    - Influencing customers' water use behaviour using water efficiency activities and education; and
    - Increasing the coverage of water meters across our network to improve our understanding of water demand patterns.

2. While making the best use of our sustainable sources of supply by:
    - Reducing abstraction from those water sources that may be having a detrimental impact on the environment;
    - Making sure our future water abstractions do not pose a risk of environmental deterioration, as required by the Water Framework Directive;
    - Increasing the flexibility and resilience of our supply system;
    - Increasing or optimising deployable output from existing, sustainable sources where possible;
    - Using catchment restoration techniques to improve habitats and ecological resilience to low flows; and
    - Using catchment management measures to protect our sources of drinking water supply from pollution risks.

Using this approach we reordered the S15 sequence of scheme outputs so that we prioritised options that involve increasing / optimising output from existing water sources, and schemes with relatively low delivery uncertainty. Options that carried more delivery or environmental uncertainty were rescheduled to be later in the sequence so as to allow time for further feasibility studies.

Specifically for the North Staffordshire WRZ, we chose to deviate from the options picked in WISDM S15. The WiSDM output chose solution Option UNK01 (New WTW on River Weaver) and Option BHS04 (Swynnerton boreholes) based on the cost / benefit criteria given to the model. This demonstrated that the optimised supply / demand programme should include new option development of up to 27Ml/d. However, our review of the constitution of the WRZ and zonal deployable output constraints demonstrated that these chosen options would not deliver water to the points of supply / demand balance failure that were predicted by the model. Instead, we opted to include options UNK07 (Changes to Tittesworth WTW treatment capacity) and GRD18 (New treatment process at Peckforton boreholes). These North Staffs options are more effective in delivering water to the location of model failure.

The reason we had to make this change to North Staffordshire WRZ is due to the definition of a Water Resource Zone. The baseline WRZ deployable output reflects the zonal demand that can be sustained at a common level of service, based on the number of temporary use bans implemented throughout the zone. By making the RSA / WFD baseline licence changes in the Peckforton system, the effect is to either break the integrity of the WRZ and create a new smaller Peckforton / Coopers Green zone with a different level of service or leave the current zone with a large amount of "locked up DO", because once the failure point is reached in the Coopers Green demand centre, the other sources stop supplying water to the rest of zone as well. WiSDM does not recognise this WRZ effect, and instead assumes that there is still one North Staffordshire WRZ with a much lower overall deployable output, and it seeks to replace this with the large new River Weaver scheme plus Swynnerton. Our Aquator model review demonstrated that a much more effective approach is to prevent the loss of output from Peckforton boreholes and retain the integrity of the original

WRZ, therefore increasing the DO of the WRZ by 6.5Ml/d and retaining 29.5Ml/d of DO that would be lost if zonal integrity was compromised. Hence the selected options provide a total benefit to the WRZ of 36M/d. This overall improvement to the WRZ deployable output occurs because the Peckforton option is targeted at the area of the zone which causes the failure. This means that not only does this demand centre receive more water (up to 6.5Ml/d), but also because the rest of the zone is now not being constrained by this failure. Other supplies are no longer "locked up" and they can continue to other parts of the WRZ and bring the overall zonal DO back up to around that of baseline, an increase of 29.5Ml/d across the rest of the zone.

Step 2: Test that the reordered schemes still satisfy the supply / demand problem

We reconfigured the WiSDM S15 results to reflect the re-sequenced scheme options from Step1. We then tested whether this reordering combined with the chosen metering, demand management and optimised leakage reduction profile still satisfied the supply / demand balance problem.

This revealed that some re-profiling of the optimised leakage reductions was needed to ensure no small target headroom shortfalls within AMP periods. The end of AMP7 and end of AMP8 leakage reduction, metering and demand management volumes remained the same as output by S15. The list of supply enhancement schemes also remained the same as output in S15, but with the rescheduling described in Step 1. We renamed this output WISDM S17.

We tested whether rescheduling the optimised package of supply solutions caused any material change to the calculated NPV of the overall optimised S15 investment programme.

Step 3: Import the rescheduled WISDM S17 outputs into WRMP Table 6.

We copied the leakage reduction, demand management, metering savings and supply enhancement benefits and schedule from the WiSDM S17 outputs into WRMP Table 6 preferred list of water management options.

E1.7 Updates for our final WRMP

Since we published our draft WRMP, we have carried out a number of additional WiSDM investment scenario assessments to inform our final WRMP. These additional assessments have included:

- Updates to supply and demand data.
- Updated option costs and benefit data.
- WINEP3 revisions (which the Environment Agency released in April 2018) – we modelled the potential WINEP3 licence changes and tested the implications on the plan of implementing the licence changes at 2025 and 2030.
- Water trading – we tested the implications of incorporating trades outlined by other water companies in their draft WRMPs.

Table E1.2 summarises the WiSDM scenarios and potential investment programmes we generated following the publication of our draft WRMP to understand the implications of these changes on preferred plan.

Table E1.2: WiSDM investment scenarios used to inform the final WRMP

Scenario	Supply and demand assumptions	Leakage, metering and water efficiency scheme assumptions	Purpose
18	----- Calculated re-optimisation (as S17 with updated option costs) -----		
19	As our draft WRMP	Updated option costs and inclusion of water trading options (potential bulk imports)	Full re-optimisation to assess whether updated scheme costs and inclusion of potential bulk imports change the schemes selected to meet the draft WRMP supply demand challenge.
20	As our draft WRMP	Updated option costs and exclusion of water trading options (potential imports)	Re-run of scenario 19 to assess whether updated scheme costs change the schemes selected to meet the draft WRMP supply demand challenge.
21	Inclusion of full modelled WINEP3 impacts and updates to demand and target headroom following consultation responses.	Option list included a reservoir option which was later discounted	Testing the implications of the full WINEP3 impact on option selection and demand management decisions.
21a	----- Calculated re-optimisation of S21 (with water trading options included) -----		
22	Inclusion of WINEP3 groundwater impacts only (surface water impacts removed). All other assumptions as S21	Option list included a reservoir option which was later discounted	Testing the impact of a smaller WINEP3 impact if the large reduction caused by the Egginton licence change was not included.
22a	----- Calculated re-optimisation of S22 (with water trading options included) -----		
23	Inclusion of full modelled WINEP3 impacts commencing in 2025. All other assumptions as S21	Option list as S20. New metering and water efficiency profiles.	Testing the implications of the full WINEP3 impact and new demand management profiles on option selection.
24	Inclusion of WINEP3 groundwater impacts only from 2025 (surface water impacts removed). All other assumptions as S21	Option list as S20. New metering and water efficiency profiles (as S23).	Testing the implications of a smaller WINEP3 impact and the new demand management profiles.
25	Inclusion of Strategic Grid WINEP3 groundwater impacts from 2025 and surface water impacts from 2030. All other assumptions as S21	Option list as S20. New metering and water efficiency profiles (as S23).	Testing the implications of staggering the Strategic Grid WINEP3 impacts.
26	Re-optimisation of S23 with options reordered (based on planning, environmental and engineering criteria)		
27	Re-optimisation of S25 with options reordered (based on planning, environmental and engineering criteria)		
28	----- Water trading scenario -----		
29	----- Water trading scenario -----		

Scenario	Supply and demand assumptions	Leakage, metering and water efficiency scheme assumptions	Purpose
30	----- Water trading scenario -----		
31	----- Water trading scenario -----		
32	----- Water trading scenario -----		
33	----- Water trading scenario -----		

As a result of this additional analysis, we have made changes to the scope and timing of some of the options that were proposed in our draft WRMP. These changes are described in chapter 6 and Appendix D of this final WRMP document.

We have also used complex scenario and uncertainty modelling to test how sensitive certain investment decisions are to our underlying supply and demand assumptions. For PR19, we enhanced our WiSDM investment optimisation model to go beyond the traditional approach to sensitivity analysis. These enhancements allow the investment optimisation to more explicitly account for uncertainty parameters around the supply and demand options, as well as considering a range of alternative future scenarios. This Decision Making Upgrade (DMU) to our WiSDM investment model has given us the ability to compute large amounts of supply / demand and option data and present it in a repeatable format. This has informed our decision making, and our ability to test the cost implications of meeting different supply / demand balance challenges and what our whole life cost investment plan might look like under a range of alternative futures. Since publishing our draft WRMP we have further developed the DMU to enable us to derive adaptive plans. This is described in more detail in section E2.1.5.

E1.8 Extending the Planning Horizon Period

Our draft WRMP focussed primarily on a planning horizon of 25 years. As explained in section E1.7, since our draft WRMP was published and as part of our PR19 strategic modelling programme, we have made significant updates to our cost optimisation model, WiSDM (Water Infrastructure Supply and Demand Model), improving model configuration, data inputs, model processing and building the Decision Making Upgrade (DMU), which has improved our decision making capabilities. Building on the long time horizon analysis we carried out for PR14, we have made a number of further adaptations to WiSDM to enable us to consider an 80 year analysis period to 2100.

In order for WiSDM to consider the water resources investment decisions holistically over this longer period, the pipe infrastructure planning component and supply options were reconfigured from 1 year (as in the baseline WiSDM model) to 5 year blocks to simplify the complex optimisation problem, reducing pipe replacement decision granularity and the sheer number of decision combinations. This ensured that the 80 year scenarios captured and optimised the benefit of pipe renewal to the long term leakage profile and hence overall headroom contribution.

We ran a number of scenarios using the adapted ‘80 year’ WiSDM model, with baseline supply and demand planning assumptions extrapolated to 2100. Two scenarios varied the climate change assumptions:

- Central estimate reduction in deployable output based on our rank 50 2030s climate change projections.
- 2080s climate change projections used to inform the reduction in deployable output.

Both of these scenarios used the same leakage assumptions as our final WRMP until 2030. The model was then allowed to find the economic level of leakage from 2030 onwards, with the key prerequisite that leakage should not rise over the planning period.

Our extended horizon modelling indicates that beyond the 25 year plan, increasing demand may mean we need to develop options to increase supply to some of our smaller water resource zones, including Whitchurch and Wem, Mardy, Ruyton and Kinsall. This could be done using inter-zone transfers, making these zones more resilient by connecting them to larger zones, or by enhancing treatment capacity at some of the existing sources within these zones.

In our larger water resource zones, including the Strategic Grid and Nottinghamshire, the combined impact of increasing demand and the impacts of climate change beyond 2045 may mean we need to consider developing a number of new water supply options, including:

- Final effluent reuse schemes.
- Exploit existing underground void dewatering activities for potable water supply with enhanced water treatment methodologies.
- Additional surface water storage.
- New river intakes with new water treatment works.
- Aquifer storage and recovery.

In the longer term, we may also need to consider increasing capacity at some of the larger reservoirs in our region.

We will continue to refine our long term strategy, using our long horizon modelling in conjunction with our other modelling tools to inform the decision making process and help build a robust long term plan greater than 25 years for inclusion in our 2024 Water Resources Management Plan.

E2 Sensitivity testing the least cost plan

As discussed in section E1, previous versions of the WiSDM decision support tool have been used to inform Price Reviews (PR) and Water Resource Management Plans (WRMP) since 2009. For PR14 and WRMP14, extensive sensitivity testing was carried out on the WiSDM model to better understand the assumptions behind it. Our previous approach to sensitivity testing the WiSDM outputs gave the following benefits:

- Helping determine the robustness of the plan - a plan can be considered robust if changes to input parameters do not significantly alter the proposed solution;
- Identifying the critical input parameters (those that have large effects on the plan) – this may trigger a review of the original parameter specification or how these parameters are treated within the model;
- Improving communication – having a range of outputs and increased understanding of the system removes the 'black box' nature of optimisation;
- Identifying modelling errors – sensitivity analysis sometimes throws up strange results that cause the analyst to reconsider modelling assumptions.

For this WRMP, we made enhancements to our WiSDM model to go beyond the traditional approach to sensitivity analysis. These enhancements have allowed the investment optimisation to more explicitly account for uncertainty parameters around the supply and demand options, as well as considering a range of alternative future scenarios. This Decision Making Upgrade (DMU) to our WiSDM investment model has given us the ability to compute large amounts of supply / demand and options data and present it in a repeatable format. This has informed our internal decision making, and our ability to test the cost implications of meeting different supply / demand challenges and what our whole life cost investment plan might look like under a range of alternative futures.

We have carried out a number of assessments using our DMU model, each using between 40 and 60 different supply / demand scenarios per model run. Each scenario was optimised over 100 iterations. These scenarios tested the sensitivity of the plan to:

- Changes to abstraction licences due to Water Framework Directive no deterioration (captured within the WINEP programme) – we used high, mid and low impact scenarios based on WINEP data available at the time of preparing our draft WRMP to understand the implications of losing different quantities of licence and the significance of the timing of these licence changes.
- Demand – we used high, low and mid demand profiles to understand which options may or may not be required if demand increases or reduces from the baseline assumptions.
- Inclusion or exclusion of specific options (such as a potential new bulk imports).
- Climate change uncertainty in target headroom.
- Extreme drought.
- Inclusion or exclusion of specific options (such as third party bulk imports).
- Revisions to option costs, time to benefit and deployable output assumptions.
- Refinements to option uncertainty assumptions.

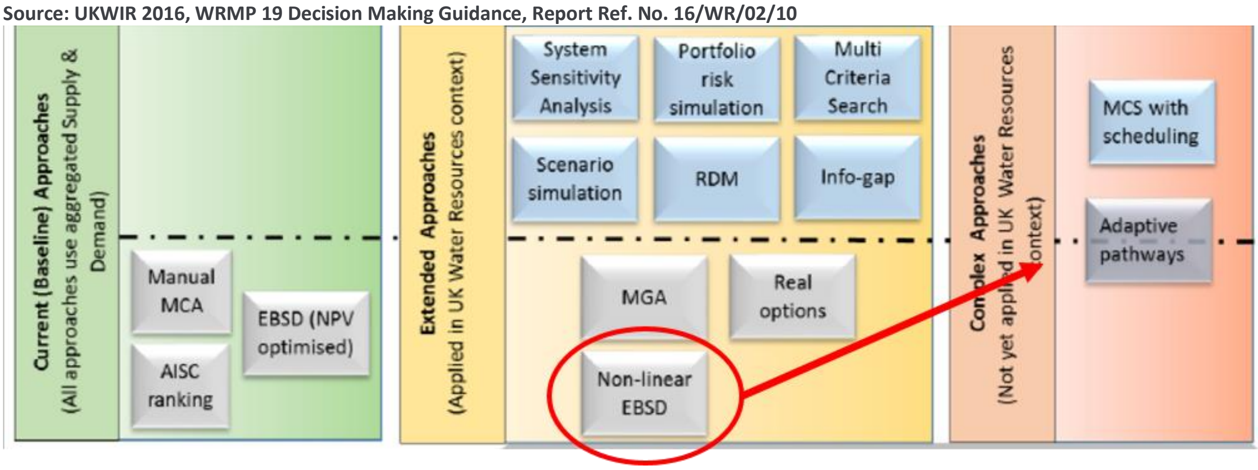
Further detail on the above can be found in Section E3. The remainder of this section provides an overview of the DMU tool and visualisations that we have developed.

E2.1 The Decision Making Upgrade (DMU)

Early on in our preparation for the WRMP, we applied the UKWIR problem characterisation approach, which demonstrated that our emerging supply / demand challenges presented a large and complex problem to solve and so would require enhanced investment modelling methods. As seen in Figure E2.1, our WiSDM model already sat within the "Extended Approaches" category. The DMU enhancement was designed to move our investment modelling capability further into the "Complex Approaches" category. This Decision Making Upgrade (DMU) to our WiSDM investment model has given us the ability to compute large amounts of supply / demand and options data and present it in a repeatable format. This has informed our decision making, and improved our ability to:

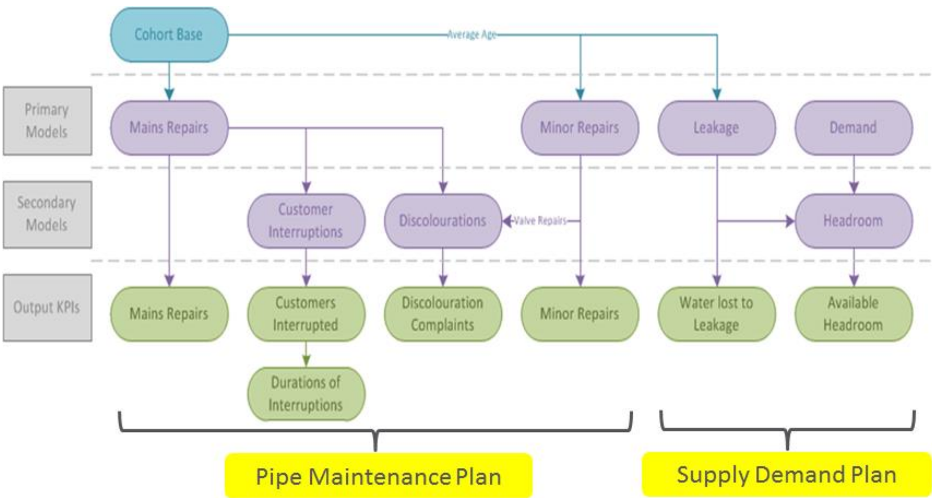
- Test the cost implications of meeting different supply / demand challenges and what our whole life cost investment plan might look like under a range of alternative futures
- Ensure we select schemes that offer a very low chance of regret when planning over a 5 and 10 year period where the future is somewhat uncertain.

Figure E2.1: The UKWIR decision making methods and tools.
Source: UKWIR 2016, WRMP 19 Decision Making Guidance, Report Ref. No. 16/WR/02/10



The DMU builds on the WiSDM approach to investment optimisation modelling. Figure E2.2 shows how the components of WiSDM create two linked outputs – the pipe maintenance investment plan and the supply / demand investment plan.

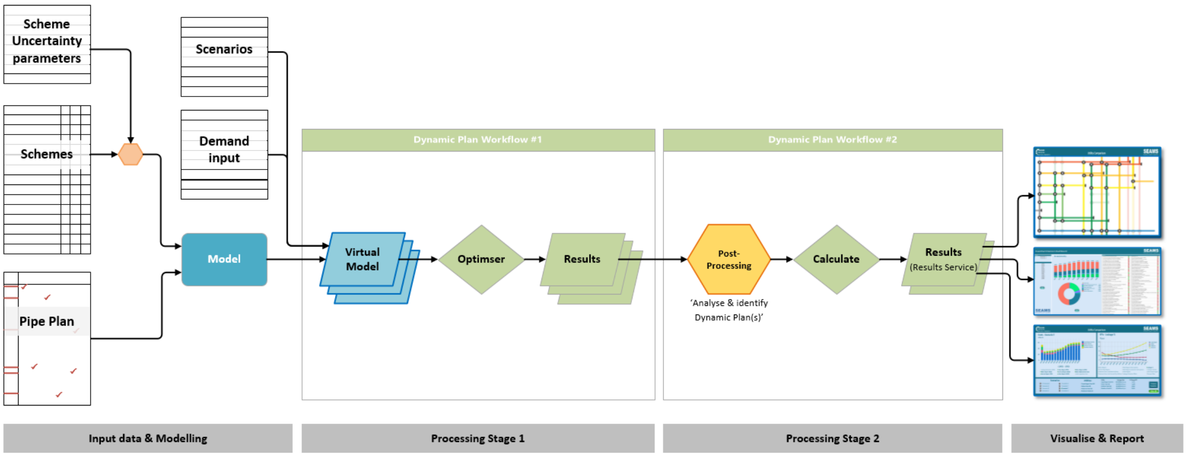
Figure E2.2: The components and the outputs of WiSDM



The overview of the DMU process is shown in Figure E2.3. There are 4 main stages:

- Input data & Modelling
- Processing Stage 1
- Processing Stage 2
- Visualisations and Report

Figure E2.3: Overview of the DMU process



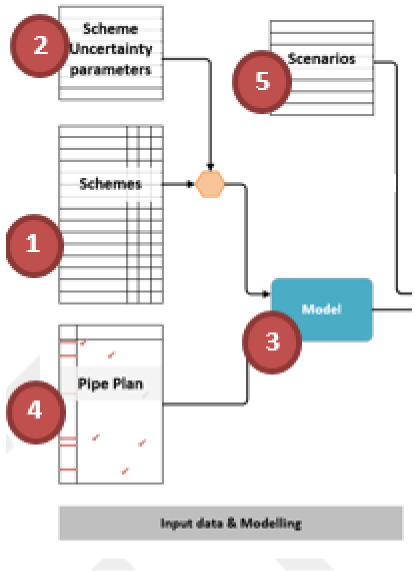
This section of Appendix E gives an overview of the DMU process and shows some of the visualisations and analysis that have been used to inform the WRMP.

E2.1.1 DMU – Stage 1: Inputs data and modelling

The first stage of the process has five steps, which are shown in Figure E2.4 overleaf. These are:

1. Define supply and demand schemes (same as in WiSDM).
2. Uncertainty Parameters around supply and demand schemes for 3 parameters:
    a. Time to benefit
    b. Additional WAFU or Demand reduction
    c. Totex Costs
3. Run WiSDM model using 'best central estimates' of data
4. A fixed pipe maintenance plan from WiSDM.
5. Define alternative supply / demand scenarios – which cover a span of different potential supply / demand futures which reflect different planning assumptions including:
    a. Climate change
    b. Headroom uncertainty
    c. Demand projections
    d. Water Framework Directive (WFD) no deterioration
    e. Extreme Drought

Figure E2.4: Overview of stage 1 of the DMU process



To generate the pipe maintenance plan (or 'Pipe Plan') used in step 4, WiSDM is run under a best central estimate scenario. This generates a long term mains renewal and pipe plan that will prevent long term leakage increasing due to mains deterioration. The pipe maintenance plan output is then fixed and used as an input to the DMU process.

In WiSDM, the cost / benefit variables for the different intervention options (time to benefit, cost, benefits) are all fixed, but for the DMU uncertainty ranges are considered. The values for the uncertainty around these cost / benefit variables are statistically distributed using a Normal Distribution. The intervention options include the new supply-side options, as described in Appendix D as well as the potential demand interventions including Active Leakage Control (ALC) and enhanced Water Efficiency programmes.

The DMU model generates multiple optimisations of a supply / demand scenario, taking account of the uncertainties around the costs and benefits of the potential intervention options. To take account of these uncertainty parameters, sampling analysis must be undertaken. In the DMU we use Latin Hypercube sampling, as opposed to the traditional Monte Carlo analysis. This is discussed in detail in section E2.1.2. One hundred optimisations are taken per scenario, each taking different samples from the options' cost / benefit uncertainty ranges using the Latin Hypercube approach. Each of these 100 optimisations is the equivalent to a single run of the supply / demand components of WiSDM.

This process is repeated for each of the different supply / demand scenarios considered, resulting in thousands of optimisations per DMU modelling run. A supply / demand scenario, or "Alternative Future", has been defined by different combinations of the various planning assumptions that affect WAFU, demand and headroom. The scenarios used in the DMU are discussed in section E3.

E2.1.2 DMU – Latin Hypercube sampling

Traditionally (for example in the WiSDM sensitivity analysis at PR14), Monte Carlo Analysis is used as a sampling technique. In the DMU, 1,000 Monte Carlo samples for 60 scenarios would result in 60,000 optimisations which is computationally intensive as well as requiring large amounts of data storage and creating a tremendous amount of data to analyse.

Latin Hypercube sampling is a variant of Monte Carlo Analysis in which input distributions are sampled in a more structured way. Each input distribution is split into N quantiles (i.e. equal percentile ranges which, therefore, each contain the same probability), where N is the number of simulations to be calculated in the study. The splitting of the distribution is completed using the inverse of the cumulative distribution function of the input distribution, the quantile function.

When sampling an input distribution, instead of selecting a value fully at random as with the more traditional variations of Monte Carlo Analysis, we first randomly select a percentile range. Specifically, a percentile range that has not yet been used before and randomly selecting a value from within that range.

As a result of the more structured Latin Hypercube approach to sampling, two significant benefits are gained:

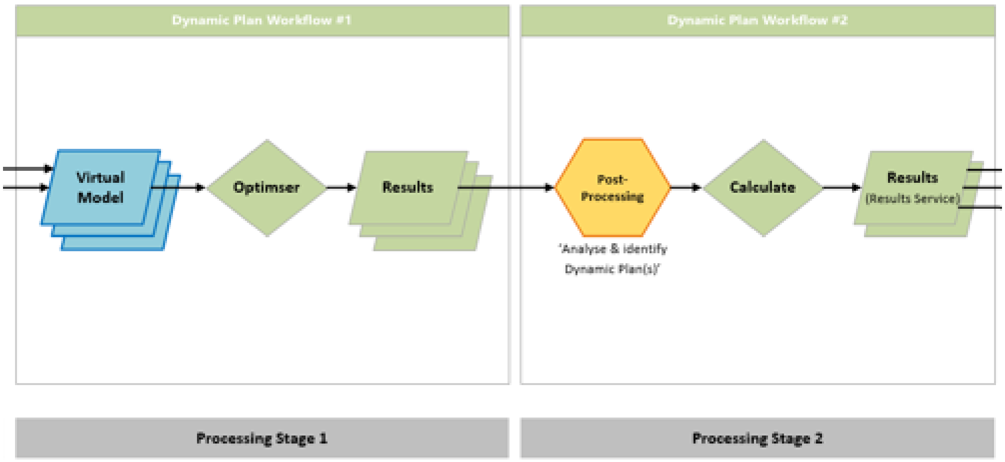
1. The aggregate result is not prone to skewness.
2. Convergence occurs in a smaller number of iterations.

As such, a better result can be obtained with a smaller sample size. For the DMU, we use a sample size of 100.

E2.1.3 DMU – Stage 2 and 3: The Processing Stages

In processing stage 1, "Virtual models" are created to optimise least cost plans for the chosen scenarios under the sampling conditions defined. For 60 scenarios this results in 6,000 optimisations, each of which generate their own results file. This process is illustrated in Figure E2.5.

Figure E2.5: Overview of stage 2 and 3 of the DMU process



The optimisations are independent, and so can be carried out simultaneously to cut down on the amount of time required. As the pipe maintenance plan is fixed, the amount of time required for each optimisation is significantly shorter than for a WiSDM run.

All of the results are collected in a large database and in processing stage 2, they are collated into a suitable format for processing in a dashboard. From the thousands of optimisations there is a vast amount of data, so the process of importing to the Dashboard is defined using a data model. This makes the process efficient, robust and repeatable. The use of this data is defined in Stage 4.

E2.1.4 DMU – Stage 4: Visualisations and reports

By using a dashboard, data can be collated and presented in a simple and repeatable way that allows for more efficient data processing. The following figures represent a sample of the visualisations that have been created, and an explanation of how they have aided our decision making process.

We have continued to make improvements to the DMU capabilities and dashboard in preparation for the final WRMP. Figure E2.6 shows a new visualisation we have added to the dashboard to clearly show the input parameters we are considering for each scenario or group of scenarios. This can easily be compared with details from the solution make up visualisations (shown in Figures E2.14 and E2.15) and other outputs.

Figure E2.6: Visualisation example - scenario input profiles

Figure E2.7 shows an executive summary of scenarios that were analysed in the DMU in the preparation for the draft WRMP. It also provides information relating to the scenarios:

- Demand
- Headroom
- Pipe Plan
- Other description (e.g. WFD and RSA)

Average results for the 100 iterations within each scenario are presented for the Whole Life Cost of the solution, the average additional WAFU provided from new supply schemes over the planning horizon and the overall reduction in leakage.

Figure E2.7: Summary overview of DMU scenarios used to inform the dWRMP

Summary

Group

- Baseline
- Climate Change
- Extreme Drought
- WFD

Scenario

- 1 - WiSDM
- 2 - 2030 High WFD and ...
- 3 - 2025 High WFD and ...
- 4 - 2035 High WFD and ...
- 5 - 2040 High WFD and ...
- 6 - 2030 High WFD and ...

Demand

- High
- Low
- Medium

PipePlan

- Scenario7

Sce... ID	High Group	Name	De...	Headr...	Pipe Plan	Average WLC £Billic...	Average Additional WAF...	Average % Change in Leakag...
S1	Baseline	WiSDM	Medium	CC Uncertainty	Scenario7	£4.639B	260.5 Ml/d	-8.80%
S2	Alternative Futures	2030 High WFD and Medium Demand	Medium	No CC Uncertainty	Scenario7	£4.564B	268.6 Ml/d	-9.54%
S3	Alternative Futures	2025 High WFD and Medium Demand	Medium	No CC Uncertainty	Scenario7	£4.714B	287.2 Ml/d	-12.08%
S4	Alternative Futures	2035 High WFD and Medium Demand	Medium	No CC Uncertainty	Scenario7	£4.433B	262.2 Ml/d	-8.27%
S5	Alternative Futures	2040 High WFD and Medium Demand	Medium	No CC Uncertainty	Scenario7	£4.387B	264.0 Ml/d	-8.76%
S6	Alternative Futures	2030 High WFD and High Demand	High	No CC Uncertainty	Scenario7	£4.608B	296.6 Ml/d	-12.22%
S7	Alternative Futures	2025 High WFD and High Demand	High	No CC Uncertainty	Scenario7	£4.788B	318.5 Ml/d	-14.90%
S8	Alternative Futures	2035 High WFD and High Demand	High	No CC Uncertainty	Scenario7	£4.475B	287.3 Ml/d	-11.73%
S9	Alternative Futures	2040 High WFD and High Demand	High	No CC Uncertainty	Scenario7	£4.418B	285.6 Ml/d	-11.95%
S10	Alternative Futures	2030 High WFD and Low Demand	Low	No CC Uncertainty	Scenario7	£4.371B	171.3 Ml/d	-6.15%
S11	Alternative Futures	2025 High WFD and Low Demand	Low	No CC Uncertainty	Scenario7	£4.456B	173.5 Ml/d	-7.48%
S12	Alternative Futures	2035 High WFD and Low Demand	Low	No CC Uncertainty	Scenario7	£4.295B	160.6 Ml/d	-5.91%
S13	Alternative Futures	2040 High WFD and Low Demand	Low	No CC Uncertainty	Scenario7	£4.259B	163.1 Ml/d	-5.58%

In preparation for the final WRMP we tailored the DMU analysis to consider scenarios with and without climate change uncertainty, with and without WINEP3 impacts and with WINEP3 impacts staged across a number of AMPs. Figure E2.8 shows examples of the scenarios we considered.

Figure E2.8: Summary overview of DMU scenarios used to inform the final WRMP

Summary

Group

- Alternative Futures
- dWRMP baseline
- fWRMP baseline
- fWRMP baseline Egginton at 2025
- fWRMP baseline GW only WINEP3 impacts
- fWRMP baseline without WINEP3

Scenario

- 1 - dWRMP baseline and Medium Demand and With...
- 2 - dWRMP baseline and Medium Demand and No C...
- 3 - fWRMP baseline and Medium Demand and With...
- 4 - fWRMP baseline and High Demand and With CC...
- 5 - fWRMP baseline and Low Demand and With CC...
- 6 - fWRMP baseline and Medium Demand and No C...
- 7 - fWRMP baseline and High Demand and No CC u...
- 8 - fWRMP baseline and Low Demand and No CC u...
- 9 - fWRMP baseline without WINEP3 and Medium...
- 10 - fWRMP baseline without WINEP3 and High De...
- 11 - fWRMP baseline without WINEP3 and Low De...
- 12 - fWRMP baseline without WINEP3 and Medium...
- 13 - fWRMP baseline without WINEP3 and High De...
- 14 - fWRMP baseline without WINEP3 and Low De...
- 15 - fWRMP baseline Egginton at 2025 and Mediu...
- 16 - fWRMP baseline Egginton at 2025 and High De...
- 17 - fWRMP baseline Egginton at 2025 and Low De...
- 18 - fWRMP baseline Egginton at 2025 and Mediu...
- 19 - fWRMP baseline Egginton at 2025 and High De...
- 20 - fWRMP baseline Egginton at 2025 and Low De...

Demand

- High
- Low
- Medium

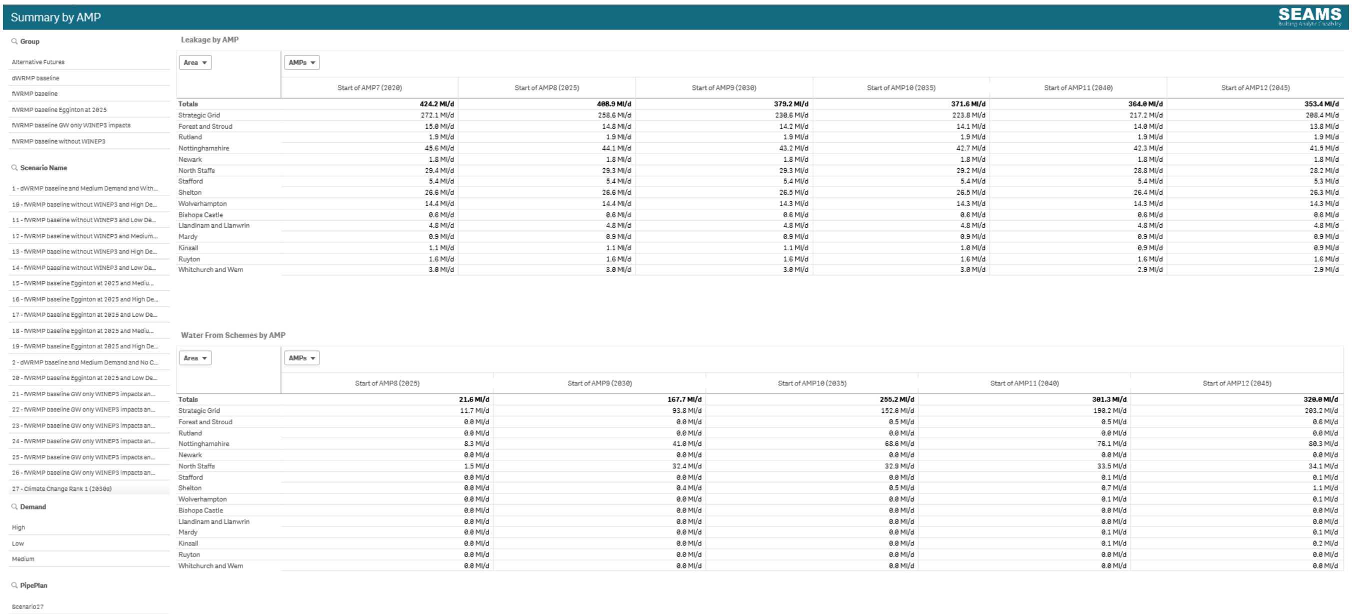
PipePlan

- Scenario27

Scenario ID	High Group	Group	Name	Dema...	Headroom	Pipe Plan	Average WLC £Billion	Average Additional WAFU	Average % Change in Leakage
S1	dWRMP	dWRMP baseline	dWRMP baseline and Medium Demand and With CC uncertainty	Medium	With CC uncertainty	Scenario27	£5.293B	327.3 Ml/d	-20.88%
S2	dWRMP	dWRMP baseline	dWRMP baseline and Medium Demand and No CC uncertainty	Medium	No CC uncertainty	Scenario27	£4.647B	208.1 Ml/d	-20.11%
S3	fWRMP	fWRMP baseline	fWRMP baseline and Medium Demand and With CC uncertainty	Medium	With CC uncertainty	Scenario27	£5.288B	346.7 Ml/d	-20.63%
S4	fWRMP	fWRMP baseline	fWRMP baseline and High Demand and With CC uncertainty	High	With CC uncertainty	Scenario27	£5.377B	370.0 Ml/d	-21.34%
S5	fWRMP	fWRMP baseline	fWRMP baseline and Low Demand and With CC uncertainty	Low	With CC uncertainty	Scenario27	£4.824B	243.3 Ml/d	-18.97%
S6	fWRMP	fWRMP baseline	fWRMP baseline and Medium Demand and No CC uncertainty	Medium	No CC uncertainty	Scenario27	£4.628B	219.6 Ml/d	-19.70%
S7	fWRMP	fWRMP baseline	fWRMP baseline and High Demand and No CC uncertainty	High	No CC uncertainty	Scenario27	£4.698B	251.8 Ml/d	-20.89%
S8	fWRMP	fWRMP baseline	fWRMP baseline and Low Demand and No CC uncertainty	Low	No CC uncertainty	Scenario27	£4.413B	169.9 Ml/d	-6.69%
S9	fWRMP	fWRMP baseline without WINEP3	fWRMP baseline without WINEP3 and Medium Demand and With CC uncertainty	Medium	With CC uncertainty	Scenario27	£4.744B	153.6 Ml/d	-19.15%
S10	fWRMP	fWRMP baseline without WINEP3	fWRMP baseline without WINEP3 and High Demand and With CC uncertainty	High	With CC uncertainty	Scenario27	£4.819B	180.0 Ml/d	-18.93%
S11	fWRMP	fWRMP baseline without WINEP3	fWRMP baseline without WINEP3 and Low Demand and With CC uncertainty	Low	With CC uncertainty	Scenario27	£4.461B	119.5 Ml/d	-8.31%
S12	fWRMP	fWRMP baseline without WINEP3	fWRMP baseline without WINEP3 and Medium Demand and No CC uncertainty	Medium	No CC uncertainty	Scenario27	£4.340B	74.6 Ml/d	-4.23%
S13	fWRMP	fWRMP baseline without WINEP3	fWRMP baseline without WINEP3 and High Demand and No CC uncertainty	High	No CC uncertainty	Scenario27	£4.368B	82.3 Ml/d	-8.63%
S14	fWRMP	fWRMP baseline without WINEP3	fWRMP baseline without WINEP3 and Low Demand and No CC uncertainty	Low	No CC uncertainty	Scenario27	£4.250B	30.0 Ml/d	-0.08%
S15	fWRMP	fWRMP baseline Egginton at 2025	fWRMP baseline Egginton at 2025 and Medium Demand and With CC uncertainty	Medium	With CC uncertainty	Scenario27	£5.377B	345.9 Ml/d	-20.94%
S16	fWRMP	fWRMP baseline Egginton at 2025	fWRMP baseline Egginton at 2025 and High Demand and With CC uncertainty	High	With CC uncertainty	Scenario27	£5.488B	375.3 Ml/d	-21.47%
S17	fWRMP	fWRMP baseline Egginton at 2025	fWRMP baseline Egginton at 2025 and Low Demand and With CC uncertainty	Low	With CC uncertainty	Scenario27	£4.901B	250.4 Ml/d	-19.15%
S18	fWRMP	fWRMP baseline Egginton at 2025	fWRMP baseline Egginton at 2025 and Medium Demand and No CC uncertainty	Medium	No CC uncertainty	Scenario27	£4.659B	219.4 Ml/d	-19.69%
S19	fWRMP	fWRMP baseline Egginton at 2025	fWRMP baseline Egginton at 2025 and High Demand and No CC uncertainty	High	No CC uncertainty	Scenario27	£4.729B	248.0 Ml/d	-21.02%
S20	fWRMP	fWRMP baseline Egginton at 2025	fWRMP baseline Egginton at 2025 and Low Demand and No CC uncertainty	Low	No CC uncertainty	Scenario27	£4.416B	168.7 Ml/d	-7.08%
S21	fWRMP	fWRMP baseline GW only WINEP3 impacts	fWRMP baseline GW only WINEP3 impacts and Medium Demand and With CC uncertainty	Medium	With CC uncertainty	Scenario27	£5.064B	287.7 Ml/d	-20.02%
S22	fWRMP	fWRMP baseline GW only WINEP3 impacts	fWRMP baseline GW only WINEP3 impacts and High Demand and With CC	High	With CC uncertainty	Scenario27	£5.157B	310.8 Ml/d	-21.21%

An example of an ‘AMP by AMP’ summary for leakage levels by WRZ and additional WAFU by WRZ is presented in Figure E2.9. The example provided here is an average for 4,600 optimisation, which were carried out between the draft and final WRMP. The dashboard has the ability to select individual scenarios or to “drill down” in to specific WRZs and different groupings of scenarios.

Figure E2.9: DMU scenarios summary by AMP



A frequency analysis of all of the supply-side options is presented in Figure E2.10. This is a simple proportional representation of how many times an option was picked at any point in the planning horizon. In Figure E2.11 a similar analysis is presented but this time the percentage represents the proportion of times that the decision was made to start implementing an option in that year. This analysis enables us to understand which options are being picked in a range of scenarios, as well as the timing of when those options are chosen and required.

Figure E2.10: Summary overview of the DMU scenarios – frequency analysis

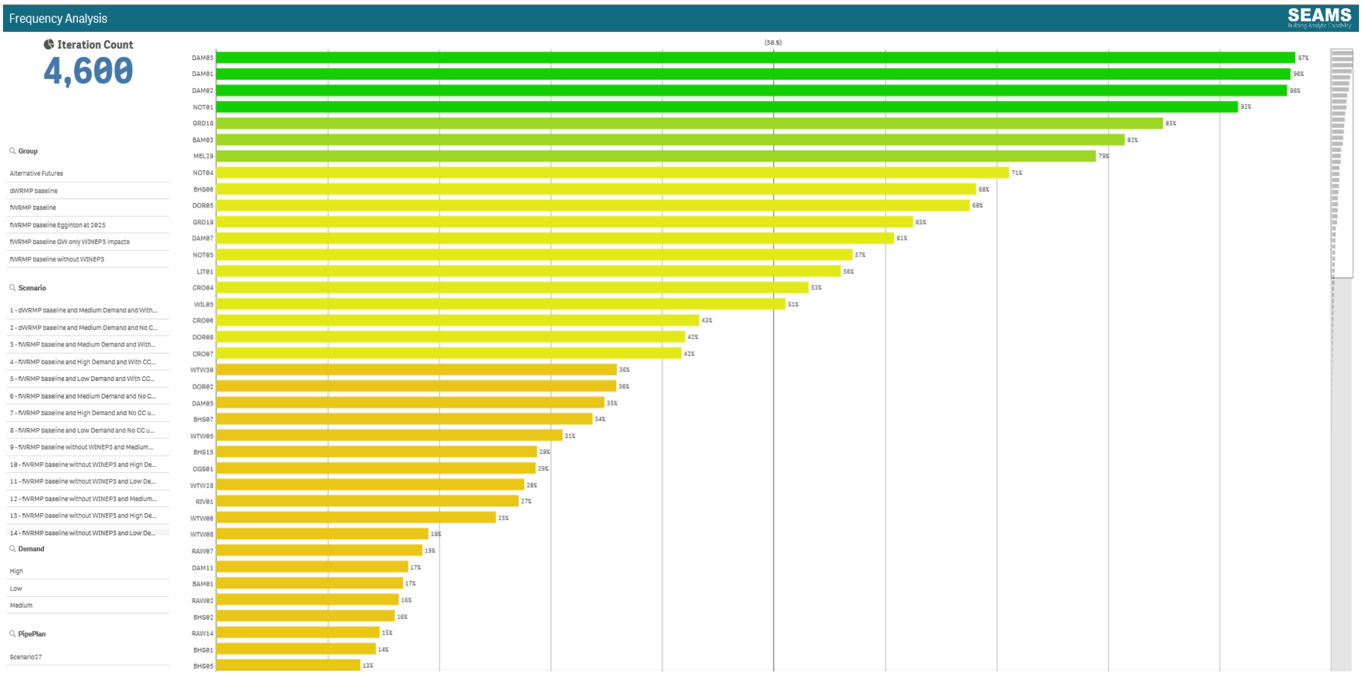
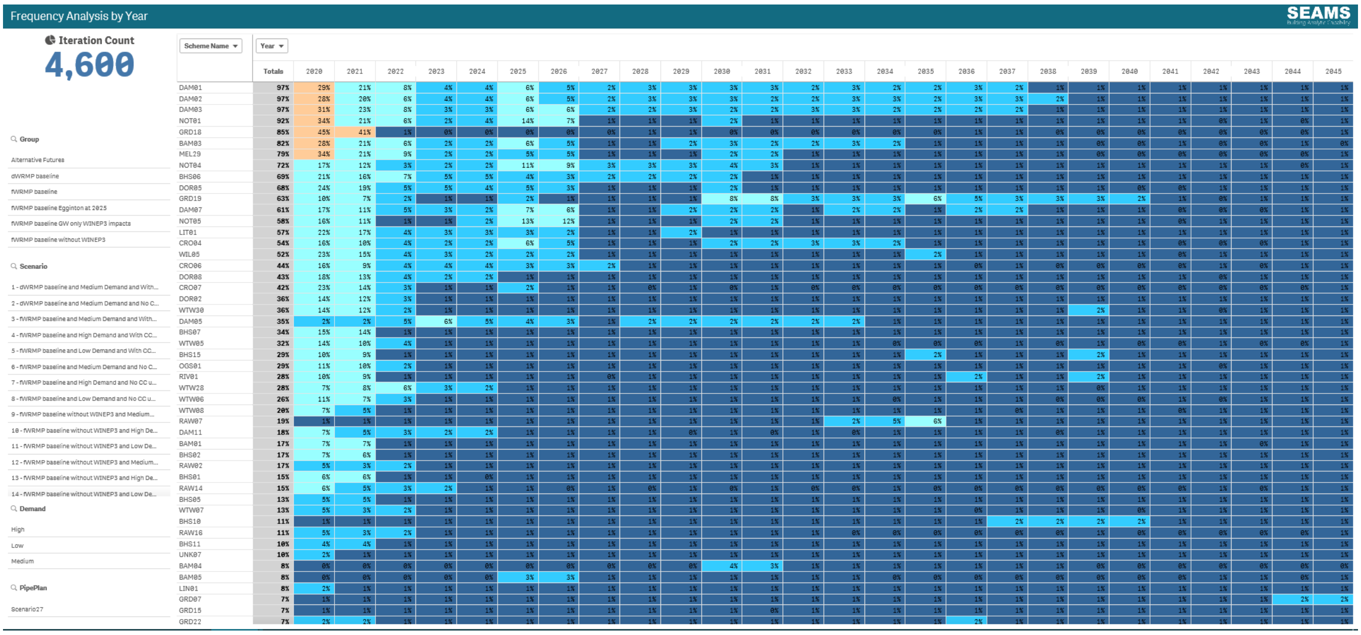


Figure E2.11: Summary overview of the DMU scenarios – frequency analysis by year



Information about specific options can be extracted from the model, an example is shown in Figure E2.12. In this example, for a single option in one scenario all 100 samples are shown. The green/red colour coding denotes whether an option was chosen or not chosen. From this example, it can be seen that the main driving factor for this option being chosen in this specific scenario was the time to benefit (TTB) – when the TTB=10 years, the option was nearly always chosen; however when the TTB=11 years, the option was not chosen very often. The spread of the green/red dots also gives the sampling range that was used. The related row from the frequency analysis by year for the scenario being tested is also embedded under the graphs.

Figure E2.12: Option level Analysis

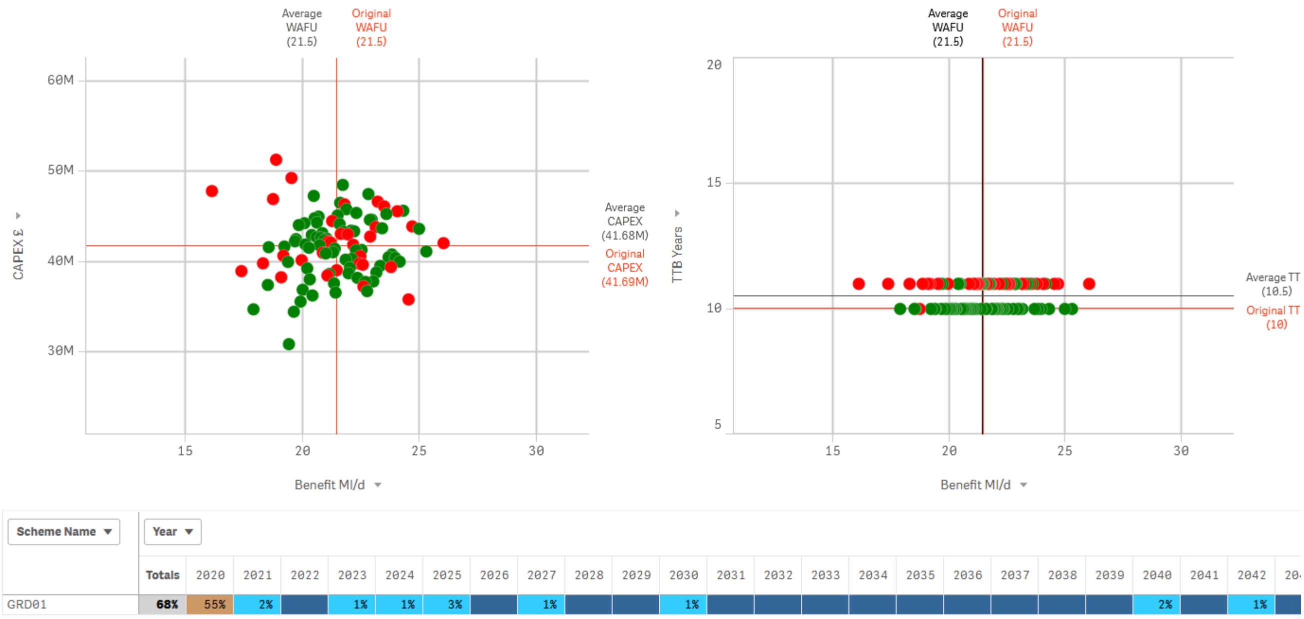


Figure E2.13 is a tabular view of Figure E2.13, and allows the user to see the range of each of the variables sampled, as well as being able to filter by whether or not the option was selected. The combination of these two figures provided invaluable information to engineers who work on the supply-side options to see when each option was chosen, and the conditions under which they were selected.

Figure E2.13: Option level analysis 2

Scenario Name	Scheme Name	% Selected	Minimum TTB	Average TTB	Max TTB	Min Benefit	Average Benefit	Maximum Benefit	Min CAPEX £k	Average CAPEX £k	Max CAPEX £k
6 - 2030 High WFD and High Demand	BHS15	100	3.00 Years	5.51 Years	8.00 Years	13.73 Ml/d	15.00 Ml/d	16.17 Ml/d	£7,329K	£12,094K	£17,442K
6 - 2030 High WFD and High Demand	DOR05	98	4.00 Years	5.49 Years	6.00 Years	7.24 Ml/d	9.00 Ml/d	10.97 Ml/d	£2,398K	£3,924K	£5,772K
6 - 2030 High WFD and High Demand	GRD15	98	5.00 Years	5.50 Years	6.00 Years	3.92 Ml/d	5.00 Ml/d	6.16 Ml/d	£0K	£0K	£0K
6 - 2030 High WFD and High Demand	DAM03	97	3.00 Years	5.49 Years	8.00 Years	1.50 Ml/d	2.50 Ml/d	3.71 Ml/d	£192K	£327K	£476K
6 - 2030 High WFD and High Demand	DAM07	96	5.00 Years	5.51 Years	7.00 Years	7.23 Ml/d	9.00 Ml/d	10.96 Ml/d	£561K	£1,035K	£1,470K
6 - 2030 High WFD and High Demand	LIT01	96	9.00 Years	10.51 Years	13.00 Years	7.91 Ml/d	10.00 Ml/d	12.16 Ml/d	£3,098K	£5,812K	£8,181K
6 - 2030 High WFD and High Demand	WTW30	96	8.00 Years	10.50 Years	13.00 Years	8.66 Ml/d	15.01 Ml/d	22.23 Ml/d	£2,377K	£3,990K	£5,623K
6 - 2030 High WFD and High Demand	GRD11	93	4.00 Years	5.50 Years	7.00 Years	8.52 Ml/d	15.01 Ml/d	23.40 Ml/d	£67,092K	£142,932K	£199,050K
6 - 2030 High WFD and High Demand	NOT01	93	5.00 Years	8.51 Years	12.00 Years	14.42 Ml/d	24.99 Ml/d	35.57 Ml/d	£19,942K	£37,277K	£57,969K
6 - 2030 High WFD and High Demand	DAM01	85	3.00 Years	5.50 Years	8.00 Years	1.48 Ml/d	2.50 Ml/d	3.50 Ml/d	£276K	£531K	£754K
6 - 2030 High WFD and High Demand	NOT02	80	5.00 Years	8.49 Years	12.00 Years	8.02 Ml/d	14.99 Ml/d	21.52 Ml/d	£14,332K	£26,228K	£37,390K
6 - 2030 High WFD and High Demand	CRO06	77	8.00 Years	10.49 Years	13.00 Years	12.66 Ml/d	17.00 Ml/d	21.23 Ml/d	£8,049K	£13,514K	£19,392K
6 - 2030 High WFD and High Demand	DAM02	75	4.00 Years	5.50 Years	8.00 Years	1.50 Ml/d	2.50 Ml/d	3.52 Ml/d	£510K	£985K	£1,378K
6 - 2030 High WFD and High Demand	NOT03	72	5.00 Years	9.49 Years	13.00 Years	14.69 Ml/d	30.00 Ml/d	44.81 Ml/d	£30,607K	£53,657K	£79,404K
6 - 2030 High WFD and High Demand	DOR02	69	4.00 Years	5.50 Years	7.00 Years	1.46 Ml/d	2.00 Ml/d	2.55 Ml/d	£305K	£1,084K	£1,558K
6 - 2030 High WFD and High Demand	GRD01	68	10.00 Years	10.50 Years	11.00 Years	16.13 Ml/d	21.49 Ml/d	26.03 Ml/d	£30,835K	£41,677K	£51,257K
6 - 2030 High WFD and High	CRO05	65	4.00 Years	5.50 Years	7.00 Years	9.15 Ml/d	12.00 Ml/d	14.61 Ml/d	£7,775K	£13,365K	£19,396K

Figure E2.14 shows, for a single scenario, the average solution make up along with the corresponding supply demand balance and leakage profile at a Severn Trent level for the planning horizon. The map of the Severn Trent region by WRZ in the bottom left is coloured red or green. Red indicates that in at least one of the 100 iterations a WRZ has fallen into deficit and an investment solution could not be found. Green denotes that there is always a solution found to keep a zone in surplus.

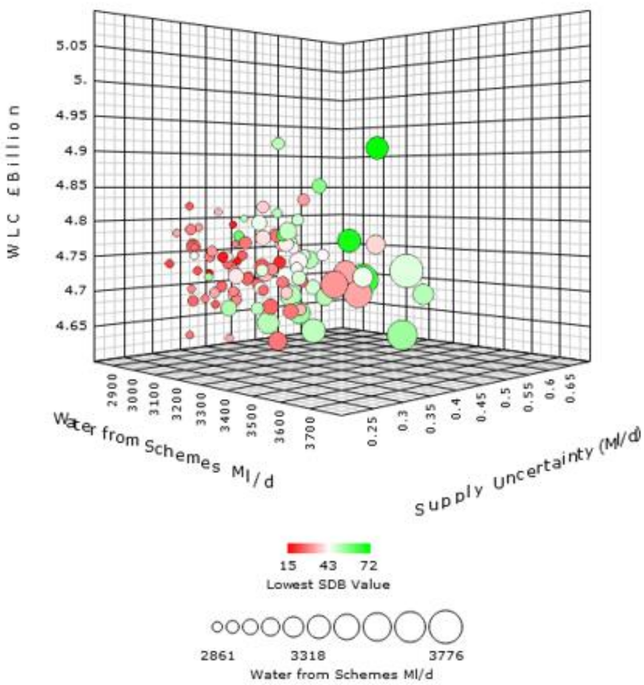
Figure E2.14: Solution make up at company level

An individual WRZ (shown in Figure E2.15) can be selected allowing the data just relating to that zone to be viewed. Using this example, Figure E2.15 shows for this given scenario, on average, there is a SDB deficit through most of AMP 8.

Figure E2.15: Solution make up for individual WRZ

The 3D analysis in Figure E2.16 shows a combination of the whole life cost, the average SDB surplus, uncertainty and the amount of additional water required from supply schemes, presented for one scenario.

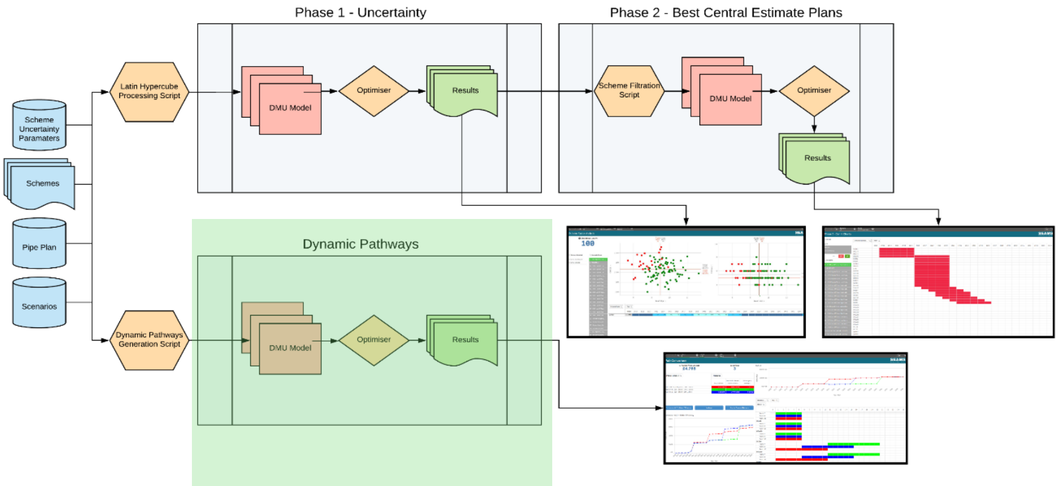
Figure E2.16: 3D Analysis



E2.1.5 Development of the DMU since the draft WRMP

We have continued to develop our DMU model to enable us to carry out a "dynamic pathways" approach, investigating the timing of option selection when different "paths" are taken between low and high deficit scenarios. Figure E2.17 shows the dynamic pathways phase of the DMU process. It uses the same inputs as the first 2 phases of the DMU (as described in section E2.1.1) in terms of our pipe maintenance plan, options and the demand, WAFU and target headroom scenarios. However, the uncertainty and best central estimate plans produced by the DMU assume optimum timing of options for the 25 year period of analysis based on individual scenarios. The dynamic pathways phase allows us to move between scenarios, taking into account potential step changes in deficits (at the start of each AMP period) which could be caused by worsening impacts of climate change, increased demand or changes in legislation which result in loss of deployable output beyond the individual scenario assessments.

Figure E2.17: High Level Process of DMU



Using 62 deficit scenarios (shown in Figure E2.18), with varying climate change, demand, target headroom and sustainability reduction assumptions, a pathways grid was developed. Five scenarios were selected. These were the 20th, 40th, 60th, 80th and 100th percentiles from the 62 deficit scenarios. A pathways grid (shown in Figure E.2.19) was then created using node points for each AMP from the five scenarios. A different set of input scenario would result in a new pathways grid.

Figure E2.18: Deficit scenarios (left graph) and the 20th, 40th, 60th, 80th and 100th percentile scenarios selected for the pathways grid

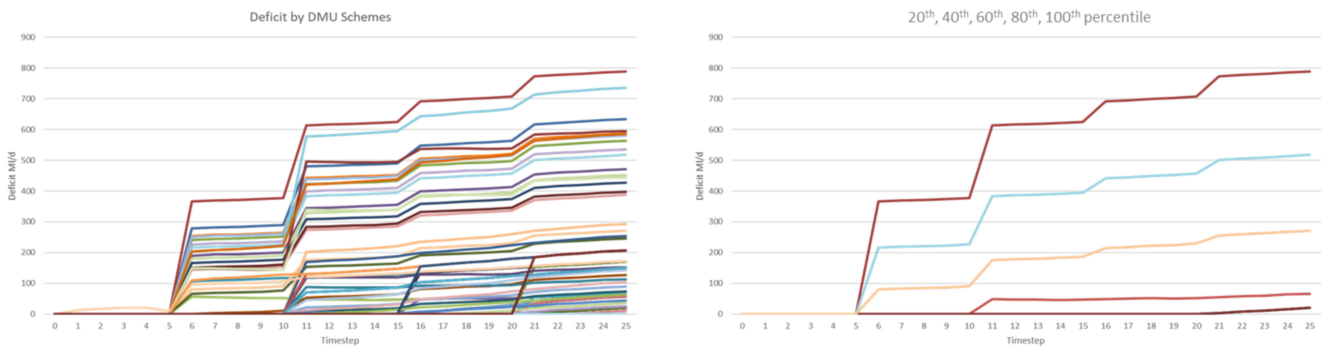
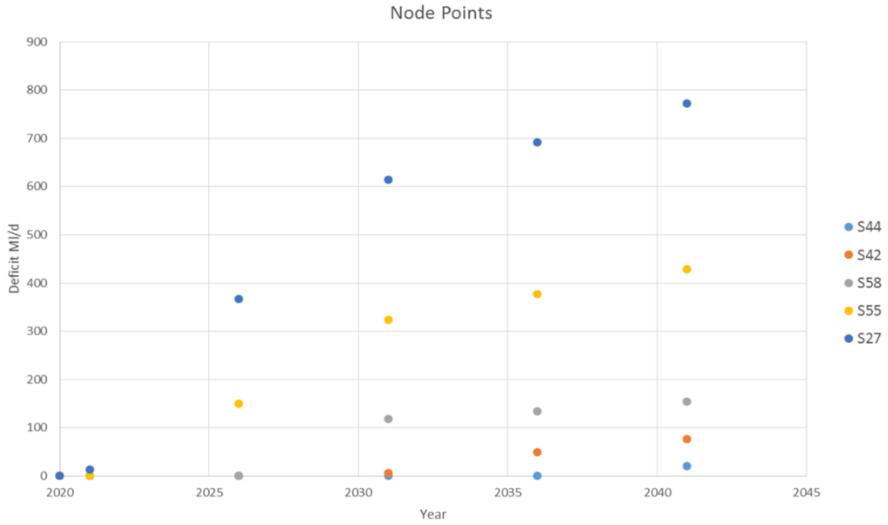


Figure E2.19: Pathways grid



Each path through the pathway grid is optimised. A filtering rule has been applied to remove any nonsensical paths (such as sudden large reductions in deficit) limiting the number of optimisations required and therefore, computation time required. The deficit can increase at any node point but can only reduce by 10% of the maximum deficit.

Numerous visualisations have been created within the dynamic pathways phase. The following sections overview each visualisation detailing how the dashboard should be used for analysis.

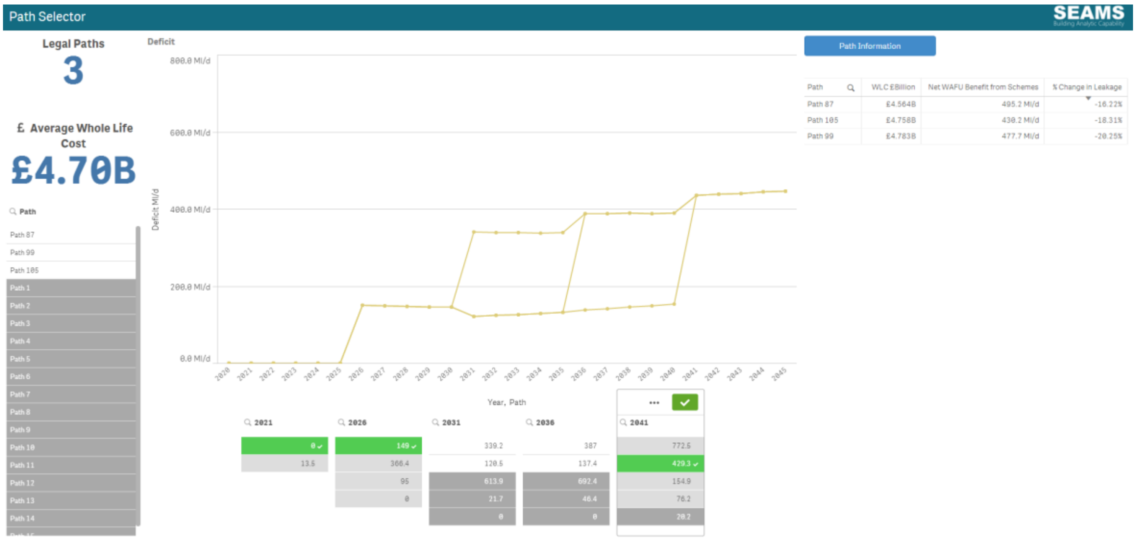
Path Selector

The path selector, shown in Figure E2.20, provides both a visualisation of paths and a way to filter all the paths which have been sent to the optimiser. Paths can be filtered using the line chart or the filter boxes below the line chart. The table on the right hand side of the visualisation details the whole life cost, leakage reduction and benefit provided from schemes for each path.

Figure E2.20: Path Selector visualisation

In Figure E2.21 three paths have been selected. The deficits used for each path, whole life cost, leakage reduction and benefit provided from options are clearly shown. This information will help us understand the implications of specific changes, such as loss of deployable output due to sustainability reductions, or sudden loss of deployable output due to climate change and highlights potential decision points in the option selection construction process (i.e. whether we need to accelerate options or push them back to a later AMP).

Figure E2.21: Example selected paths



Path comparison

The path comparison tool enables the user to compare the results from multiple paths. The visualisations are designed to work with 10 or less paths selected. Attempting to select and compare all viable paths at once would result in the charts becoming overwhelmed and detracting from the ability to make meaningful analysis.

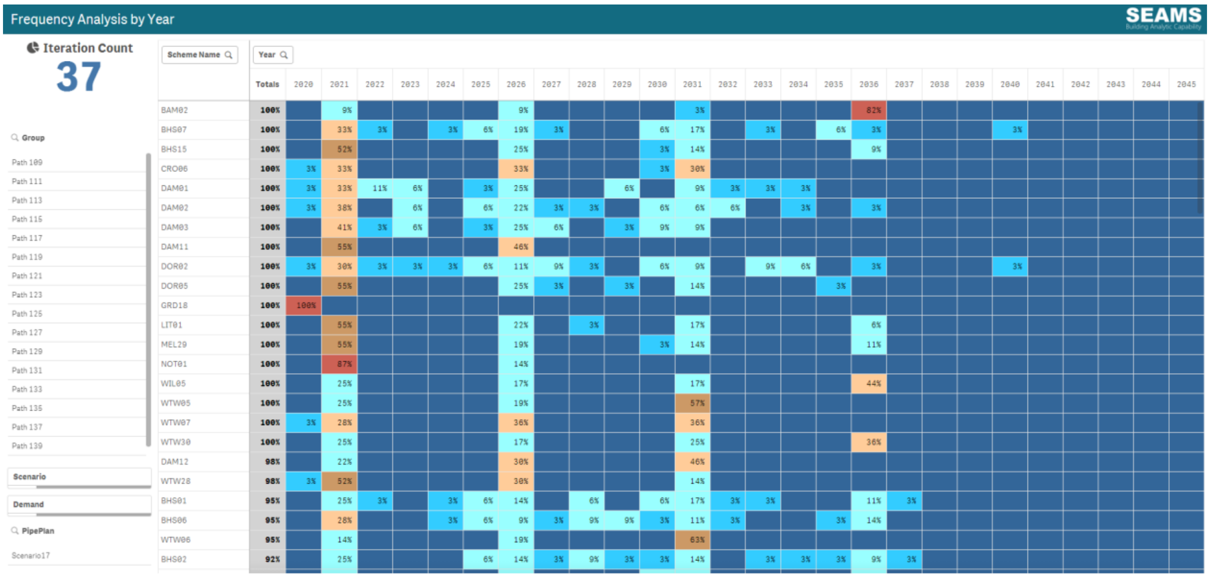
Figure E2.22 shows the path comparison tool visualisations. This tool enables comparison of which options are selected for each path but most importantly, it enables comparison of the timings of when each option is selected by the optimiser. The chart on the bottom left can be changed to either compare leakage, supply/demand balance or benefit produced from options / ALC / water efficiency.

Figure E2.22: Path comparison tool

Frequency Analysis

The frequency analysis visualisation as shown in Figure E2.23 is similar to the option uncertainty analysis described in section E2.1.4 and illustrates for the filtered paths which options are selected by the optimiser and in which year.

Figure E2.23: Pathway frequency analysis



We will continue to develop the dynamic pathways approach and will utilise the tools we have created as part of our feasibility and option design process which will be undertaken during AMP7.

E3 Testing alternative supply / demand scenarios

In preparation for our WRMP we have used the DMU to model 290 supply / demand scenarios, each representing different “alternative futures”, to examine how sensitive our investment decisions are to different planning assumptions. These scenarios used different combinations of potential supply / demand events occurring at different times. These alternative futures were generated by varying those supply / demand factors that have the greatest uncertainty, including sustainability reductions, impacts of Water Framework Directive, climate change and future demand for water. Each scenario used a bespoke “water available for use” (WAFU) profile reflecting the deployable output impacts of the component being investigated and a “high”, “medium” or “low” demand profile.

Scenarios considered in the final DMU run carried out prior to publication of our draft WRMP are shown in Table E3.1. To validate the results we included a “benchmark” scenario representing the reordered WiSDM scenario 15 run, which formed the baseline to our draft WRMP. The outputs of this scenario showed that the options selected by WiSDM as part of the least cost plan were also chosen preferentially by the DMU.

Using this approach, we generated 60 different supply / demand scenarios that we used to explore a wide range of possible alternative supply / demand futures. The full list of the 60 possible supply / demand futures that we have explored using the DMU optimisations is shown in Table E3.1.

Table E3.1: Scenarios modelled using the DMU to inform our draft WRMP

		Component			
Run	**Scenario**	**RSA**	**WFD No Deterioration**	**Demand**	**Climate change**
1	Benchmark	High	-	Medium	Rank 50
2	High WFD 2030	High	High	Medium	-
3	High WFD 2025	High	High	Medium	-
4	High WFD 2035	High	High	Medium	-
5	High WFD 2040	High	High	Medium	-
6	High WFD 2030	High	High	High	-
7	High WFD 2025	High	High	High	-
8	High WFD 2035	High	High	High	-
9	High WFD 2040	High	High	High	-
10	High WFD 2030	High	High	Low	-
11	High WFD 2025	High	High	Low	-
12	High WFD 2035	High	High	Low	-
13	High WFD 2040	High	High	Low	-
14	Low WFD 2030	High	Low	Medium	-
15	Low WFD 2025	High	Low	Medium	-
16	Low WFD 2035	High	Low	Medium	-
17	Low WFD 2040	High	Low	Medium	-
18	Low WFD 2030	High	Low	High	-
19	Low WFD 2025	High	Low	High	-
20	Low WFD 2035	High	Low	High	-
21	Low WFD 2040	High	Low	High	-
22	Low WFD 2030	High	Low	Low	-

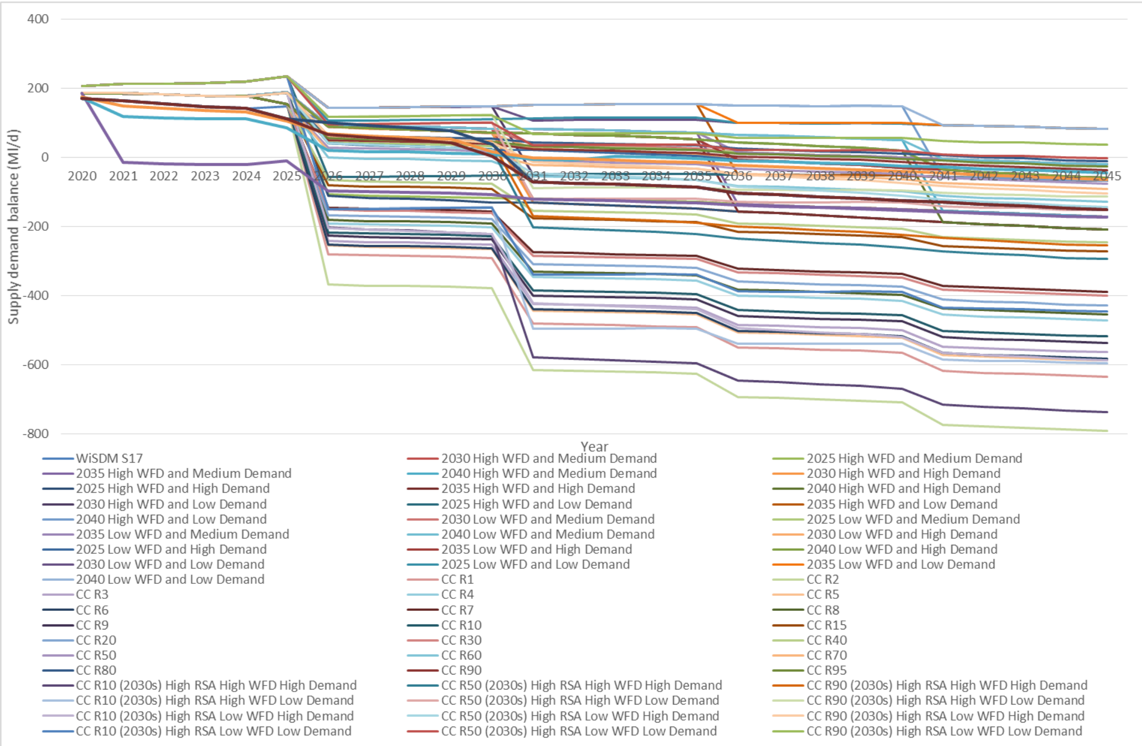
Run	Scenario	RSA	Component		
			WFD No Deterioration	Demand	Climate change
23	Low WFD 2025	High	Low	Low	-
24	Low WFD 2035	High	Low	Low	-
25	Low WFD 2040	High	Low	Low	-
26	Climate Change Rank 1 (2030s)	High	-	Medium	From 2025*
27	Climate Change Rank 2 (2030s)	High	-	Medium	From 2025*
28	Climate Change Rank 3 (2030s)	High	-	Medium	From 2025*
29	Climate Change Rank 4 (2030s)	High	-	Medium	From 2025*
30	Climate Change Rank 5 (2030s)	High	-	Medium	From 2025*
31	Climate Change Rank 6 (2030s)	High	-	Medium	From 2025*
32	Climate Change Rank 7 (2030s)	High	-	Medium	From 2025*
33	Climate Change Rank 8 (2030s)	High	-	Medium	From 2025*
34	Climate Change Rank 9 (2030s)	High	-	Medium	From 2025*
35	Climate Change Rank 10 (2030s)	High	-	Medium	From 2025*
36	Climate Change Rank 15 (2030s)	High	-	Medium	From 2025*
37	Climate Change Rank 20 (2030s)	High	-	Medium	From 2025*
38	Climate Change Rank 30 (2030s)	High	-	Medium	From 2025*
39	Climate Change Rank 40 (2030s)	High	-	Medium	From 2025*
40	Climate Change Rank 50 (2030s)	High	-	Medium	From 2025*
41	Climate Change Rank 60 (2030s)	High	-	Medium	From 2025*
42	Climate Change Rank 70 (2030s)	High	-	Medium	From 2025*
43	Climate Change Rank 80 (2030s)	High	-	Medium	From 2025*
44	Climate Change Rank 90 (2030s)	High	-	Medium	From 2025*
45	Climate Change Rank 95 (2030s)	High	-	Medium	From 2025*
46	Climate Change Rank 10 (2030s)	High	High	High	From 2025*
47	Climate Change Rank 50 (2030s)	High	High	High	From 2025*
48	Climate Change Rank 90 (2030s)	High	High	High	From 2025*
49	Climate Change Rank 10 (2030s)	High	High	Low	From 2025*
50	Climate Change Rank 50 (2030s)	High	High	Low	From 2025*
51	Climate Change Rank 90 (2030s)	High	High	Low	From 2025*
52	Climate Change Rank 10 (2030s)	Low	Low	High	From 2025*
53	Climate Change Rank 50 (2030s)	Low	Low	High	From 2025*
54	Climate Change Rank 90 (2030s)	Low	Low	High	From 2025*
55	Climate Change Rank 10 (2030s)	Low	Low	Low	From 2025*
56	Climate Change Rank 50 (2030s)	Low	Low	Low	From 2025*
57	Climate Change Rank 90 (2030s)	Low	Low	Low	From 2025*
58	Extreme Drought S161	High	-	Medium	-
59	Extreme Drought S64	High	-	Medium	-
60	Extreme Drought S169	High	-	Medium	-

* Climate change impacts implemented from 2025 with step change in 5 year increments

For the scenarios listed in Table 3.1 we excluded uncertainty around climate change from the target headroom profiles. Target Headroom instead comprised of accuracy of supply, gradual pollution and demand-side uncertainty. By doing this we are able to consider the impacts of each of the climate change scenarios – which are all equally likely. Our DMU climate change analysis is described in more detail in section E3.2.

Figure E3.1 shows how the scenarios translate into a range of supply demand balances – one per scenario. The biggest deficits at 2045 (ranging from -780Ml/d to -270Ml/d) are caused by the 13 most extreme climate change scenarios. The low WFD combined with low demand scenarios cause the least severe deficits (and in some cases surpluses) as they do not include climate change uncertainty.

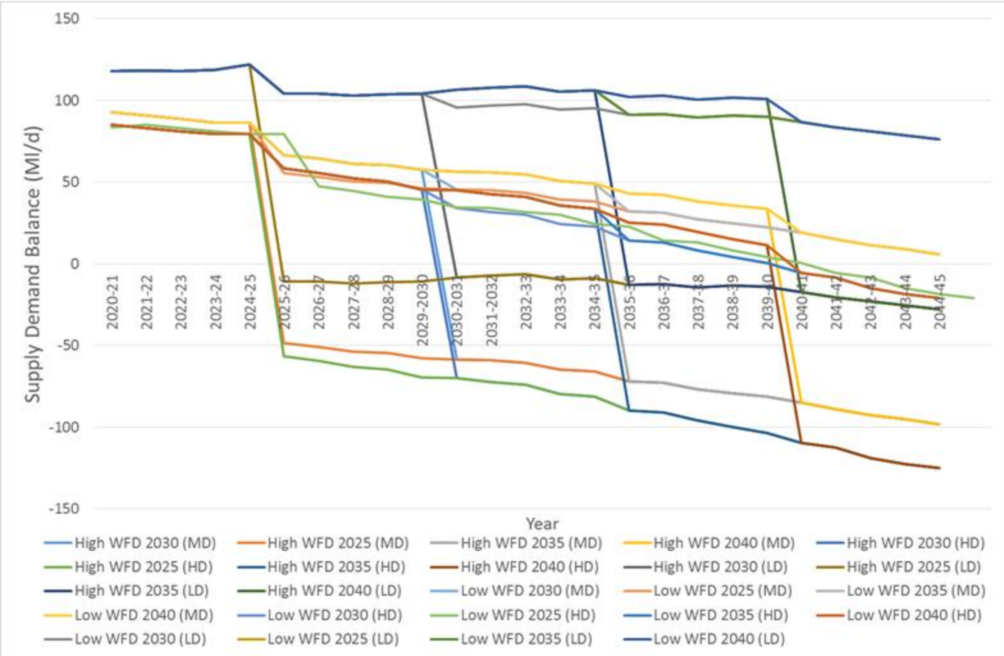
Figure E3.1: Range of supply demand balance surplus and deficits considered at a company level



E3.1 Using WFD No Deterioration scenarios to test investment decisions

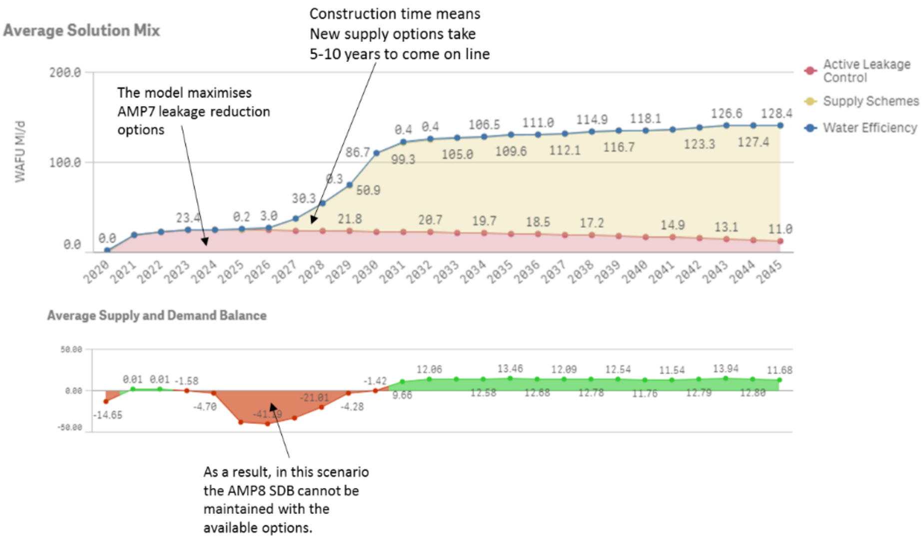
Combining different WFD No Deterioration impacted WAFUs with either "high", "low" or "medium" demand produced a range of supply demand balance deficits for the DMU to solve. Figure E3.2 shows the range of WFD No Deterioration impacted supply demand balances for the Strategic Grid WRZ modelled using the DMU.

Figure E3.2: Range of supply demand balance surplus and deficits considered for the Strategic Grid WRZ based on varying severity and start year for WFD impacts



By varying the timing and scale of Water Framework Directive no deterioration impacts on our supply / demand balance (with impacts starting in 2025, 2030, 2035, 2040) we were able to determine the potential impact of adhering to the Environment Agency's timeframe and assess the least regrets options for overcoming any resultant supply demand balance deficits. Figure E3.3 shows an example DMU model output of one of the Water Framework Directive scenarios for Nottinghamshire WRZ, one of the zones with the greatest number of licences affected by potential WINEP3 licence changes. The figure shows that the deficit caused by the WINEP changes being implemented in 2025 was too large to resolve within the timeframe allowed by the Environment Agency even with the maximum practicable leakage reduction.

Figure E3.3: Nottinghamshire zone DMU scenario analysis



The outputs of our analysis informed our discussions with the Environment Agency regarding the pace of WINEP3 licence changes. The scenario testing demonstrated that it would be preferable for our investment strategy to stagger the abstraction changes needed to meet Water Framework Directive and sustainable abstraction (RSA) objectives in our Strategic Grid and Nottinghamshire WRZs over a ten year period. Our DMU modelling showed that making these abstraction licence reductions in just one AMP period, ready for 2025, would put security of supply at severe risk and would drive very high cost, short term investment decisions. Conversely, if these changes were to be made over a ten year period, ready for 2030, our DMU model demonstrated that this would incur a lower whole life cost investment programme and would mean much lower risk to security of supply. Assessments such as these made possible by our DMU model were integral to shaping the underlying supply / demand planning assumptions used in our WRMP.

Our DMU analysis also helped focus our efforts for option design development and highlighted where additional new resource or transfer options would be beneficial. Nottinghamshire WRZ in particular required a wider range of options, with varying time to benefit assumptions to help resolve the challenges posed by the expected deployable output losses as a result of Water Framework Directive no deterioration requirements. Consequently, we developed additional options for inclusion in further DMU and WiSDM runs. Refinements to options as a result of the scenario modelling has helped to reduce the whole life cost of the 25 year plan.

E3.2 Using climate change scenarios to test investment decisions

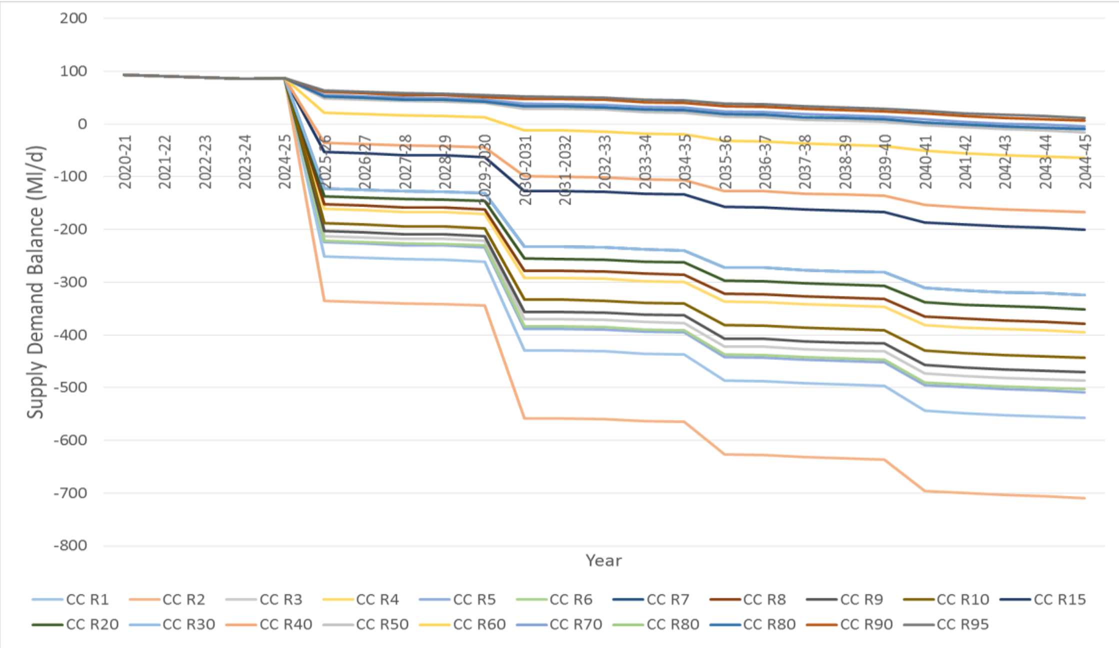
As demonstrated in Appendix C2.3.2, climate change is the biggest source of uncertainty in our two largest water resource zones, the Strategic Grid and Nottinghamshire. Alongside the sensitivity testing of the target headroom climate change uncertainty distribution (described in Appendix C2.1), we used our DMU model to investigate how climate change is influencing this WRMP.

As part of our climate change assessment (described in Appendix A3) we modelled the potential impacts of 20, equally likely, UKCP09 projections for the 2030s using our Aquator water resources model. Within the DMU we considered each of these 20 UKCP09 climate projections as individual 'Water Available For Use' (WAFU) scenarios, removing climate change uncertainty from target headroom to prevent double counting the potential impact. Our DMU tool enables us to consider the different climate change scenarios as individual supply / demand optimisations, each generating their own preferred programme and associated frequency analysis. Our analysis of specific scenarios or groups of scenarios allows us to examine 'least regret' decisions. These are investment options that feature in a range of possible optimised futures, thereby improving our confidence in the decision or programme being proposed.

The climate change projections produced a wide range of impacts on WAFU, particularly for the Strategic Grid. As the driest climate change scenarios caused large reductions in WAFU, we scaled the impacts using five year step changes instead of a year on year reduction. This helped the DMU model to better optimise the AMP by AMP balance of leakage reduction and supply enhancement options. Within each scenario we applied the same climate change projections to all water resource zones to ensure consistency and to allow the model to correctly balance transfers between zones.

Figure E3.4 shows the range of supply / demand balance surplus and deficits for each scenario used in the DMU modelling for the Strategic Grid, which used the climate change impacted WAFUs combined with a "medium" demand profile. The DMU approach also allowed us to test the effects of completely removing the target headroom uncertainty around climate change scenarios from our decision making.

Figure E3.4: Range of supply demand balance surplus and deficits considered for the Strategic Grid WRZ based on 20 UKCP09 climate change projections

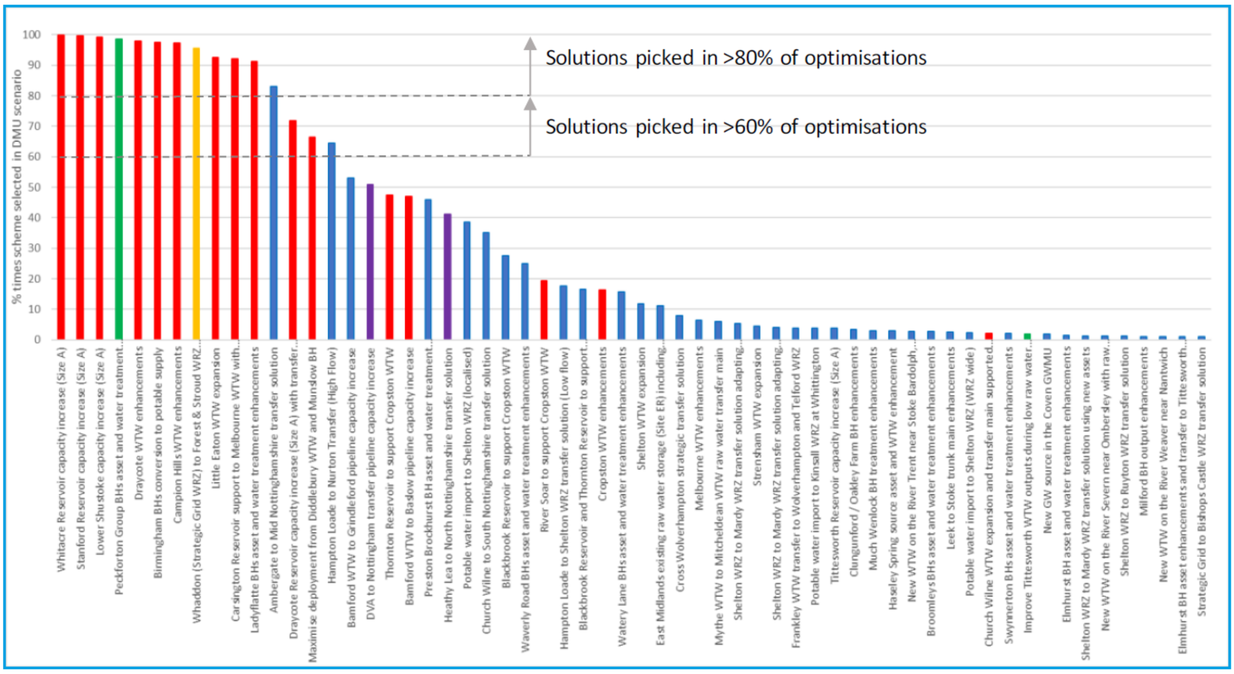


*Each line denotes a different climate change projection e.g. CC R5 is the Climate Change Rank 5 scenario (as described in Table E3.1 and Appendix A3)

Figure E3.5 overleaf shows the example outputs from one investment scenario where we excluded climate change uncertainty from our target headroom requirement, and instead we optimised around just our baseline projections of changing supply and demand needs. The outputs from this scenario showed us that even when climate change uncertainty is completely excluded from the analysis, almost all of the new supply-side options in our WRMP preferred programme still provide an optimal long term supply / demand investment plan. This sensitivity analysis gives us confidence that these are low risk investment options that are not only driven by our assessment of increasing climate change uncertainty.

Figure E3.5 is colour coded to represent the WRZ that the options benefit. Red bars related to the Strategic Grid WRZ, purple is Nottinghamshire WRZ, green is North Staffordshire WRZ and yellow is Forest and Stroud WRZ. The blue bars denote options that were picked in some iterations by the DMU but did not form part of the preferred programme in our WRMP. The majority of the options selected for our WRMP preferred programme by our cost optimisation model, WiSDM, are in the top 25% most frequently selected by the DMU across all scenarios. This indicates that we have greater confidence in these options addressing our future needs. The DMU incorporates uncertainty around costs and benefits of the options so in some iterations uncertainty sampling assumes it is cheaper and/or provides more WAFU benefit than our baseline WiSDM run, which uses fixed assumptions for costs and benefits of the options.

Figure E3.5: Planning for climate change uncertainty – DMU frequency analysis outputs



E4 Stakeholder Engagement and Consultation

We have been working on our WRMP since early 2016. During that time we have worked with regulators, stakeholders and customers to understand their priorities and shape our long term water resources strategy. Their views have directly contributed to the proposals set out in this WRMP19. A summary of how we have engaged with stakeholders at the different stages of producing the plan is as follows:

- We held our first stakeholder forum in September 2016.
- We issued the WRMP pre-consultation letter in December 2016.
- We completed consultation with planning authorities across the region to get an update on housing growth outlook.
- We published the PR19 Shaping Our Future consultation describing the water resource challenge.
- We consulted on the scope of our Strategic Environmental Assessment.
- We have worked with the regulators and stakeholders to understand priorities.
- We met twice with Ofwat in 2017 to share the emerging WRMP needs and likely impacts.
- We have updated our website to sign-post the WRMP work and to make it easier to access information.
- We held our second stakeholder forum in April 2017.
- We held two Welsh facing stakeholder forum events in July 2017.
- We held English and Welsh stakeholder forums in October 2017 to signpost what solutions are likely to feature in the WRMP.
- We held a number of customer engagement workshops during October 2017 to understand their priorities, attitudes to metering and willingness to pay.
- We published our draft WRMP for consultation in February 2018.
- We considered the outcomes of the consultation process and adjusted our WRMP where appropriate and provide our Statement of Response to the consultation in September 2018.

Through the water resources stakeholder forum events we gathered hundreds of items of feedback through the interactive breakout sessions and follow up correspondence.

Throughout our stakeholder engagement and discussions with regulators, we heard some clear messages that:

- We need to be more ambitious with our leakage reduction targets;
- Improving customer understanding is the biggest issue when tackling water efficiency, they need to be educated on the supply / demand challenges and engagement needs to be tailored to different communities;
- We should explore opportunities for more partnership working;
- We should explore innovative ways of broadening our catchment management thinking beyond just drinking water quality protection to deliver wider benefits such as biodiversity and flow attenuation/slow flow etc;
- New water supply schemes should deliver multi-benefits and we should explore options for water / waste water catchment thinking;

We have used these clear messages to shape our plan, and to guide our thinking as we worked through our different supply / demand scenarios and options. We also used it to guide our more focussed customer engagement workshops, where we have conducted more deliberative research into customer attitudes to drought restrictions, water metering and environmental impacts of abstraction.

This chapter explains how we engaged with our stakeholders and customers through the different phases of consultation, and what key messages we took from our stakeholders to feed into our plan. During the consultation phases we engaged with our stakeholders and customers in a variety of ways:

- written consultation
- external stakeholder technical workshops
- customer research, including willingness to pay
- discussion and scrutiny by our multi-stakeholder CCG (customer challenge group) which we refer to as Water Forum
- Severn Trent WRMP website
- face to face meetings

E4.1 Stakeholder engagement

WRMP External Stakeholder Workshops

Throughout the pre-consultation period we held a series of WRMP external stakeholder workshops as outlined in the table below. We have held separate workshops in our Welsh operational areas, including the area previously served by Dee Valley Water.

Table E4.1: WRMP stakeholder workshops

Date	Workshop	Objectives
13 September 2016	Severn Trent WRMP workshop	Understanding of water supply challenges Understanding the future demand of water Decision making considerations Environmental and social considerations
10 April 2017	Severn Trent WRMP workshop	Understand how we are acting on stakeholder feedback Understand how our water resources management plan fits in with our PR19 plans Understand the potential solutions
15 June 2017	Powys area WRMP workshop	Understanding water resource needs Water quality improvements Catchment management and waste water improvements
28 June 2017	Dee Valley area WRMP workshop	Understanding water resource needs Water quality improvements Catchment management improvements
6 October 2017	English WRMP workshop	To review and feedback on our draft English WRMP
12 October 2017	Welsh WRMP workshop	To review and feedback on our draft Welsh WRMP

'Shaping Our Future' Consultation

We aligned our WRMP pre-consultation with the consultation we are carrying out to inform our broader AMP7 business plan for the period 2020-25. Our consultation '*Shaping Our Future*' explained the future challenges we face that effect our business such as climate change, population growth, and future legislation.
One of the key areas we asked for views on in '*Shaping Our Future*' was how we make sure we have enough water to supply our customers. Some of the options we asked for comment on included reducing leakage,

reducing demand for water, metering, increasing supply, water trading and connectivity and catchment management.

Seven separate organisations attended the water resources focused workshop held on 3rd March 2017. The workshop provided an overview of Severn Trent's emerging supply and demand issues and opportunities, sustainable supplies, drought plans, resilience options, and customer impacts. This was followed by discussions on the following questions:

- How quickly should Severn Trent move away from using water resources that could be unsustainable in the longer term?
- What are your views on Severn Trent's resilience approach to reduce drought?
- Should Severn Trent increase their level of resilience?

Supporting Written Consultation

In addition to '*Shaping Our Future*' we consulted with stakeholders in line with the guidance set out in the Environment Agency's Guidelines for preparing WRMP's. The written consultations we undertook during 2017 include:

- WRMP pre-consultation letter in December 2016.
- Consultation with planning authorities across the region to get an update on housing growth outlook.
- Published the PR19 *Shaping Our Future* consultation describing the water resource challenge.
- Consulted on the scope of our Strategic Environmental Assessment.

Face to Face Meetings

We undertook numerous face to face meetings throughout 2017 to discuss aspects of our WRMP with our regulators, non-governmental organisations and other water providers including:

- Severn Rivers Trust
- Severn Trent Water Forum
- Natural Resources Wales
- Natural England
- Coventry University
- Environment Agency
- Wildfowl and Wetlands Trust

Water Forum

As part of our pre-consultation we regularly discussed the development of our WRMP with our Water Forums (English and Welsh) and relevant subgroups. These multi-stakeholder groups include representatives from CCW, CCG, Citizens Advice Bureau, Natural Resources Wales, Confederation of British Industry, Natural England, Environment Agency, East Midlands Councils, and Sandwell Metropolitan Borough Council.

The Water Forum has a remit to scrutinise both how well we engage with our customers, and how well our final business plan reflects the outcome of that engagement.

A Water Forum Investment sub-group has been formed to scrutinise the key elements of our WRMP in more detail on behalf of the full Water Forum. Members of this sub-group include representatives from the Environment Agency, Natural England, ARUP, and the Met Office

E4.2 Customer Research

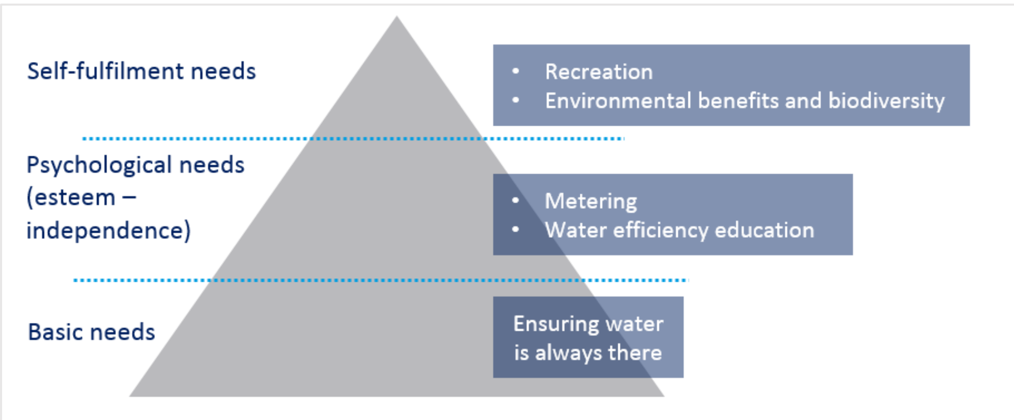
Our preferred programme of options included in our WRMP has been shaped, and is supported, by our customers. Since we published our draft WRMP we have continued to carry out customer research and engagement. During this engagement we held constructive, collaborative discussions with our customers about how we should approach delivering water supply demand improvements. To ensure we gained appropriate understanding of our customer views we used a variety of different approaches, including deliberative research. One of the biggest advantages of using deliberative research is that is allows for in-depth discussion with customers not just about needs and outcomes, but also in our approach. Customers also benefit from a gain in understanding as day-long workshops and sessions progress. This enables a more meaningful exploration of issues that could not be achieved using more traditional qualitative and quantitative approaches.

We have also used innovative techniques to gain insight from social media on our customers' views and priorities, as well as analysing comments from members of our online community, Tap Chat. We also commissioned some additional customer research in response to the stakeholder responses to our draft WRMP. As a result, we have expanded our explanation of how we have used customers' views to inform our WRMP.

At the heart of our strategic approach to customer insight is developing a more holistic understanding of the people and communities in our region, and understanding how we can make a positive contribution to their lives. As we have developed this understanding we have reflected on the fact that not all customer needs are equal. There is a hierarchy of needs and the tools which we use to understand these will be different at each level. Our categorisation of customer needs draws on Maslow's three levels – delivering basic needs, meeting psychological needs and creating opportunities for self-fulfilment, as demonstrated in Figure E4.2.

Our research consistently shows that customers take their water supply for granted, and ensuring water is always there is a basic need that, once met, is not given much further thought. Once this need it met, there are aspects within the delivery approach (in terms of how we balance supply and demand) which can meet higher needs. By giving customers information and choice we are able to ensure more psychological needs are met, for example by giving customers the tools to reduce their bills through water efficiency advice and metering. Customers and their families can also benefit from our public access sites, such as reservoirs, and river restoration projects. These can provide the opportunities for people to meet many different needs, for example basic needs in terms of promoting health and wellbeing whilst also providing opportunities for self-fulfilment through recreation and enjoying nature.

Figure E4.2: Hierarchy of customer needs – water supply



E4.2.1 Our approach to understanding customer views

Throughout the process of preparing our WRMP, our thinking and decision making was shaped by ongoing engagement with customers, stakeholders and our Water Forum. The Consumer Council for Water (CCWater), Ofwat and the Environment Agency all asked for more information on how customers had informed our draft WRMP and our decision making. In particular, they asked for more information on how customers had been consulted on their willingness to pay for different supply / demand options and in particular how customers had informed our leakage strategy. Our Water Forum challenged us early on to be more strategic in our research design, taking into account:

- Where the topic sits within the hierarchy;
- The extent to which the topic is conscious in customers' mind vs unconscious; and
- Whether the topic/issue occurs today or could occur in the future.

Since our draft WRMP was published, we have continued our customer research using face to face constructive, collaborative discussions with our customers about how we should approach delivering water supply and demand improvements. Our insight into customers' views on water supply and demand is now even richer than at the time of writing our draft WRMP, and comes from a number of sources. Issues such as leakage tend to be top of our customers' priorities and our evidence sources include our analysis of customer contacts, social media scraping and numerous research projects. For other aspects such as metering and water efficiency we have used co-creation to work with customers to understand how they can be part of the solution.

The challenge to ensure there is sufficient water resource availability for the future is something customers do not consciously consider – only 7% of customers think that we won't have enough water in 10 years' time, with only 10% thinking we won't have enough water in 20 years' time (customer tracker, Q1, 2018/19). Our joint research with Thames Water and United Utilities on water trading corroborates this finding – little is understood about the scale of the water scarcity issue, and once informed the emotional reaction is one of surprise and disbelief. Around seven in ten customers are concerned, particularly those in the Thames Water region, and any lack of concern is largely due to disbelief. Interestingly, younger or future customers were concerned to a lesser extent than current or more senior customers.

Since customers are not necessarily aware of the future pressures on water availability we have used deliberative research to explore perceptions of water stress and the best way we can meet these challenges. It is only when prompted that customers recognise the challenges to ensure there is sufficient availability of water for future generations and understand that everyone has to play their part to make this happen. In our joint research on water trading we find that water scarcity is seen as a national issue, to be coordinated by water companies, the regulator and government. A minority of household customers believe water company regions should sustain their own supplies.

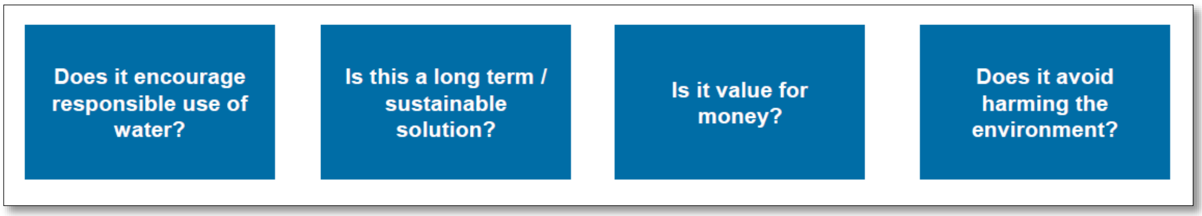
Our supply / demand deliberative research discussed a range of options to meet the projected future supply / demand balance deficit with customers. The research took participants on a 'journey' from obtaining their spontaneous reactions to a high level description of the options, through to more informed views when presented with a range of considerations for each supply-side and demand-side option, including relative cost, customer participation, certainty of outcome, environmental impact and lead time. The materials used to engage customers were both accessible and stimulating, and were designed by a leading research agency in deliberative research, with input from technical experts in the business.

A summary of what we have learned from customers is provided in the following sections.

E4.2.2 Approach to balancing supply and demand

Our research tells us that customers tend to consider four specific questions, demonstrated in Figure E4.3 when considering supply demand options.

Figure E4.3: Core customer questions



- **Does it encourage responsible use of water?**
  We have found customers have a strong moral frame when thinking about water usage, resulting in an emphasis on personal and corporate responsibility to use less water. Because of this, they tend to favour demand management approaches over supply side approaches, but they recognise that any solution will need to include a blend of both. Customers say they want to be involved in securing the long term supply of water, but there is an appreciation that changing behaviour is difficult so they want us to play an equal part in ensuring water is always there, including an emphasis on reducing leakage.

- **Is this a long term / sustainable solution?**
  Customers don't want options which present a short term fix as they tend to be sceptical about how effective they will be for the long term challenge that our WRMP considers.

- **Is it value for money?**
  Customers want us to pursue the best value supply / demand options, not necessarily just the most cost effective ones. Questions of value and bill impact were particularly important to customers when thinking about options that will take a number of years to implement. While most customers are happy to contribute to the cost of long-term water security, they are clear this should be spread out over time, so as not to cause undue financial burden for customers.

- **Does it avoid harming the environment?**
  Customers value the environment and are concerned about options which might be perceived to have a strong detrimental impact. For example, the high energy costs and chemicals involved with effluent reuse are a concern despite initial 'warmth' for the idea because it is recycling existing water. Customers want to be reassured that any new or increased abstractions from rivers would not cause harm.

Within the joint research on water trading, we asked customers to rank a number of factors in selecting supply-side and demand-side options. Sustainability emerged as their top priority, with 60% of our customers ranking it in their top two. The environment (whether an option has an environmental benefit or minimises any negative effects) is their second priority, followed by the volume of water produced and option resilience. The cost to build and customer acceptability were considered to be the lowest ranked priorities.

E4.3 Support for investment and impacts on bills

There is a clear expectation from customers that we should have plans in place to ensure a continuous water supply, both now and in the future. As part of this, customers expect us to be prepared to address any long term challenges which could affect water supply, such as climate change or population growth. Customers also expect us to meet our statutory obligations, including those related to restoring unsustainable abstraction and ensuring no environmental deterioration.

As noted previously, customers are happy to contribute to the cost of long-term water security provided that this is spread out over time to lessen any acute financial burden for customers.

As part of our overall PR19 research programme, we have engaged customers on the bill impact of our proposed investment plan through our 'Choices' research and our final acceptability research. Our PR19 plan aligns with the preferred programme of options set out in our WRMP. We have taken care to present bill impacts in a meaningful way and where there is a choice, only present realistic options to customers. We have engaged customers on Tap Chat (our online community) about their preferred presentation of inflation and bill profiles. Our acceptability research shows that 80% of our customers find the proposed plan and bill impact acceptable.

We have also conducted deliberative research on how we deal with climate change uncertainty and the impact on bills. Customers were given a choice about investing now in all the supply-side options that we expect will be required, compared to an initial focus on design and feasibility or waiting for more certainty before triggering the need for investment. We found that the feedback from customers shows a clear principled support for investing only when we have greater certainty, whilst taking action now to minimise the time to respond. Avoiding detrimental impact on the environment is also a key consideration for not investing in potentially unnecessary options.

The results of our discussions with customers on bill volatility are also supportive of the use of our PR19 Real Options approach to manage uncertainty. One concern raised by the Water Forum about Real Options is that it might create volatility in bills at the end of the AMP and therefore it would be better to have a small reduction from 2020-2025. However, the research results indicate that bill impacts are only considered volatile if they are above £3-10 per month - this helps allay concern that even if all options were needed, customers would not find the change in bills volatile (noting that the overall affordability impact is the same as if all options were included).

E4.4 Inter-generational fairness and future customers

We have used deliberative research as well as quantitative research with a representative sample on our online community, to explore how we ensure a fair balance of charges over time, and between generations.

We find that customers want bills that are stable, and charges to be set in a way which means each generation pays their fair share. Our proposed approach to longer term bill profiles received considerable support from customers, with 87% of those surveyed preferring a smaller bill reduction over the next five years, but a more stable profile over time.

We explored the views of future customers using a tailored and proportionate approach, focusing predominantly on those young people who live in their family home and are not currently contributing to the water bill, but who might be in the next 5-10 years. We focused on this group because they are the most immediate future bill payers.

We found that the young people living in their family home group of future customers rarely consider the water service, and often lack the 'citizen' perspective seen in other customer groups. Friends, family, enjoying life, career and finances are all important to them, whereas the local community and the environment are less front of mind. These customers generally reported higher water usage and less concern and engagement with the environment, compared to our general customer base. Our research found that the main opportunity for engaging these audiences is when they become named bill payers and homeowners.

In addition to our engagement with this group, education with younger audiences (e.g. primary school children) as well as adults emerged as a key theme throughout our research programme. We are proposing an expanded education programme which will aim to inspire a generation of primary school aged children through experiential learning. This represents a step change compared to our current offering.

E4.5 Options to manage the supply / demand balance

Our supply demand deliberative research discussed a range of options to meet the supply demand deficit with customers. The research took participants on a 'journey' from obtaining their spontaneous reaction to a high level description of the options, through to more informed views when presented with a range of considerations, including relative cost, customer participation, certainty of outcome, environmental impact and lead time.

As well as discussing each option independently, to understand customer views and perceived pros and cons of each approach, we also probed customer views on their preferred package of options, including the balance of supply-side and demand-side interventions. Figure E4.4 provides a visual representation of the relative customer support for different interventions and initiatives that we presented during the engagement process.

Figure E4.4: Customer engagement support for different intervention options

Of the supply / demand options presented to customers in the deliberative research, increasing the roll out of water meters was the option receiving the most support, followed by water efficiency and reducing leakage. Metering also received considerable support from our employees when discussing supply and demand challenges in our company wide roadshows. Supply-side options received less support, due to concerns about the level of promotion of responsible water usage and the potential for environmental damage.

In addition to these general discussions about the supply / demand balance, we used co-creation to 'deep dive' into some specific solutions, such as metering. The 'deep dive' process seeks to provide concerted and targeted considerations into the specific topic. Our discussions with customers have helped uncover some of the misperceptions and myths that customers associate with metering, and how we could dispel these in the future. We have also used co-creation to talk to customers about water efficiency, and through our online community ‘Tap Chat’ we have tested water efficiency campaign materials with customers, uncovering valuable insight about their preferred creative images and messaging.

The findings from our customer research into supply and demand options were:

- **Increasing the coverage of water meters**
  As previously noted, of the supply / demand options presented to customers in the deliberative research, increasing the roll out of water meters received the most support. Customers felt that metering offers real benefits to both customers and ourselves. It was also considered to be the fairest way for us to charge for water. Customers found the possibility of saving money through a water meter highly motivating, and in addition to this, they welcomed the enhanced level of personal responsibility that water meters bring about. Not all customers supported metering and numerous research projects and our co-creation event explored the myths and uncertainties about meters. Customers with larger households tended to be especially fearful of a large increases to bills following installation of a water meter.

- **Helping our customers to use less water**
  Multiple sources of insight, including our deliberative research, our quarterly customer tracker survey and a review of twelve months’ of social media discourse tell us that customers expect us to provide advice on water efficiency. This also demonstrated that many customers want us to do more in future to provide them with support and guidance on water saving behaviours.

- **Reducing leakage**
  Reducing leakage consistently emerges as customers’ top priority for improvement, as it is seen as a pre-requisite to asking customers to reduce their consumption. Customers consider leakage reduction as non-negotiable and a moral responsibility for us, as the amount of water currently lost though leakage is perceived to be unacceptably high. Fixing leaks demonstrates a commitment to using the water resource responsibly. Analysis of social media also highlighted that leakage was a key metric dominating customer conversations. Primarily this was because most conversations relate to informing others about service issues experienced. Leakage also emerges as a key concern in discussions on Tap Chat.

  The extent of the leakage from customers’ supply pipes shocked participants in our deliberative research. Many were unaware that these underground pipes (between their home and property boundary) are the customer’s responsibility and there were concerns regarding the customers’ ability to detect or be aware of any leak.

  Both our WRMP and PR19 plans have been tested with customers at a regional level, rather than at the water resource zone or county level. Our research tells us that customers are not spontaneously aware of water resource zones and that specific zones face greater water scarcity issues than others. We find that our customers are altruistic – for example they support investment to reduce repeat sewer flooding incidents, or targeting investment in socially deprived regions particularly if we can deliver multiple benefits. Concern over which part of the region benefits from particular investment does not tend to emerge spontaneously in our research.

  In our Choices research we found that the AMP7 15% leakage reduction target is seen as stretching, although some feel it should be more ambitious (without fully understanding the scale of the improvement proposed or required to provide further reductions). Customers across the region will also benefit from improvements in the speed of response to leakage. In response to feedback on our draft WRMP we are now proposing much more ambitious long term leakage reduction targets.

- **More raw water storage**
  Initially in the deliberative research, the supply-side options weren't favoured as it was considered that they do not encourage the responsible use of water (from both consumers and ourselves). However, customers accepted that our preferred programme of options would be a combination of supply-side and demand-side options. Within our joint research on water trading we found that a minority of customers, with more technical knowledge, spontaneously mention supply-side options to address water scarcity. Overall, we find that preference for supply-side options is driven by a number of personal and social beliefs and experiences. However, customers are less certain about their preference for supply-side options compared to more familiar demand-side options. Customers want water companies to prioritise long term sustainability of supply when selecting the type of interventions to be implemented. Overall though, customers find it difficult to decide on the most appropriate supply-side option and put their trust in water companies to choose for them.

  Reservoir expansion could provide a long term, sustainable, and potentially straightforward (compared to options such as effluent reuse) supply-side option type to implement. Customers also recognised the potential for wider environmental benefits such as creation of habitats for wildlife after the initial disruption of construction.

- **More trades between companies**
  Water trading into the region created some concern regarding creating a dependence on external parties, even though the principle of sharing was thought to be sensible. Water trading was also seen as potentially costly and disruptive, and when customers were made aware of potential environmental concerns, such as the introduction of non-native species, this further heightened concern.

  In our joint research on this topic we found that 74% of customers agreed that they would support water trading as part of a national solution to water scarcity – it's logical and necessary to share resources. Despite this, multiple concerns emerge, relative to security of supply, environmental impacts and the financial cost. Those in donor regions are concerned as to whether water trading will negatively impact their own water supplies over time, and non-household customers are concerned about the impact of a perceived 'unreliable' supply on their business.

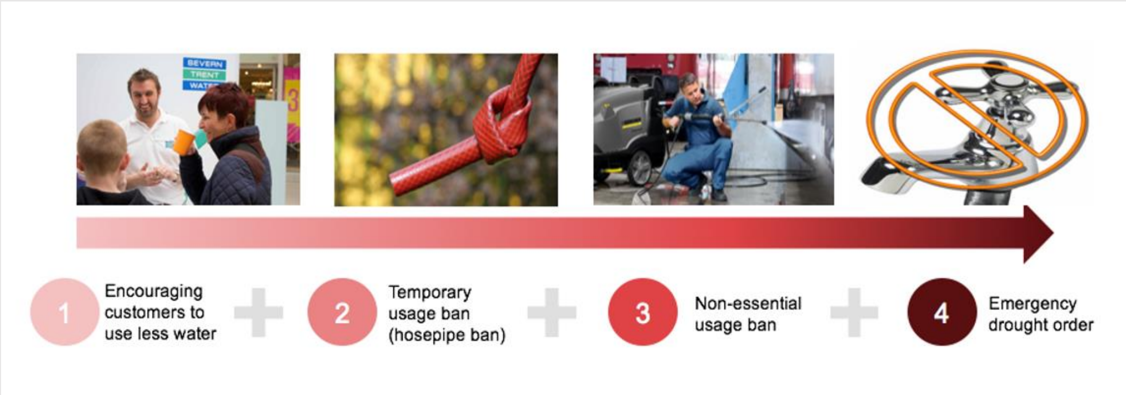
- **Abstracting more water**
  Abstracting more water from rivers caused some concerns amongst our customer groups, particularly around environmental impacts, although customers were more reassured on learning that abstraction is regulated. This approach was considered to be relatively simple and certain.

E4.6 Responding to customer views on drought

As described in the previous section, customer awareness of the supply / demand challenge is very low. According to our customer tracker only 7% of customers think that we won't have enough water in 10 years' time and 10% in 20 years' time. By inference, severe drought is therefore not something that customers anticipate will affect the UK.

Since drought is not something customers consciously consider, we used deliberative research to discuss and understand our customer's informed views (in line with our strategic research framework). We used a drought 'story board' to help customers imagine the development of a drought situation over time, with progressively more serious customer impact as outlined in Figure E4.5 overleaf.

Figure E4.5: Outline of drought consequences 'story board'



Our customer engagement established that the occurrence of a drought would be seen as exceptional and outside of the water company's control. Climate change and changing weather patterns give rise to some concern that droughts could become more common in the UK, and a feeling that this would have a negative impact on the water service. While 'hosepipe bans' were mentioned spontaneously, these are generally seen as quite common and linked to 'hot summers' and not 'droughts', which as a term is interpreted as an extreme scenario that is unlikely to occur. In the engagement quiz about Severn Trent that we ran on Tap Chat, and in our deliberative research, we found that most respondents mistakenly believed that there had been a hosepipe ban in the region since 1996.

Temporary Use Bans (TUBs) are considered acceptable in principle; customers describe them as a pragmatic approach in such circumstances, provided that we can demonstrate we are taking additional steps to limit own water loss. Some customers believed that they had experienced a TUB recently and were surprised to learn that it has been more than 20 years since one has been implemented in our region. Many customers noted that the likely impact on them from a temporary use ban was minimal.

Participants recognised that requiring the use of standpipes would only occur due to severe and exceptional weather conditions. Therefore they regard our response in those circumstances as proportionate to the seriousness of the situation. However, they are clear that support would need to be put in place for vulnerable customers. The predicted frequency of 1 in 200 years for these events is seen as acceptable by most customers. There was no willingness to accept a lower level of service in exchange for a bill reduction. Information on levels of drought resilience for other companies was discussed in the session and not found to influence our customers' view.

Overall, our deliberative research found little support for further investment for the purposes of reducing the risk of requiring TUBs from the current level. Likewise there was no support to reduce the risk of requiring standpipes. Our willingness to pay research also showed that reducing the risk of needing to use standpipes is a very low priority for customers. As part of our valuation research programme we did a survey which we have called the budget game. In the budget game we interviewed customers using a large "board game" to present them with different service levels (a current level and two improvement options). Each improvement option was costed in terms of a potential bill impact. Customers were able to select their preferred plan using tokens. The total 'cost' of the plan was then calculated and customers had the option of reviewing their choices. Using this approach we found that only 10% of customers selected an improved level of service for standpipe usage.

E4.7 Responding to customer views on Resilience

We have used our deliberative approach to talk to customers about resilience in general, as well as a specific focus on supply resilience. Resilience is a topic which is far from customers' conscious thought – for example the majority of customers have no experience of an interruption to their water supply of any duration. We conducted extensive qualitative and quantitative research on supply resilience during development of our PR14 plan, when we proposed a large investment scheme to improve resilience of our supply to Birmingham. We have further advanced the intelligence we gained at that time during the course of developing our WRMP.

For our PR19 and WRMP19 plans, we were mindful of our strategic research framework and the lack of conscious considerations that our customers give to resilience. To give us the best opportunity to extract our customers' views we used deliberative research to explore the subject more deeply. We found that low levels of service disruption have given rise to high levels of confidence in the resilience of our service, and an assumption that there are plans in place for disruptive events. It is only through raising awareness with customers that we were able to probe their views more deeply.

In terms of providing interventions specifically to increase resilience, we discussed with customers whether we should focus on anticipating the challenge or preparing a response when things go wrong. Instinctively customers can be risk averse and feel that we should pursue both aspects of resilience in all circumstances, focusing on both prevention (better than cure), but also being prepared for the rare occasions when things go wrong.

Initially customers did not think there were any circumstances where a reactive only plan for resilience could work. On reflection, views changed and customers accepted it might not be possible to prepare for every disruption eventuality (although this is an aspiration) and therefore a combined approach should be used to address the challenges facing the water system.

In addition to more general discussions on resilience, we have asked whether customers support the proposed investment on supply resilience through our Choices research on performance commitment targets, investment options and incentives. We found that customers are aware that essential infrastructure is old and therefore accept the need for investment. In fact there was some question on the timing of investment and why we were not intending on replacing these older assets as a matter of course. A total of 78% of customers supported the proposed investment, when presented with the bill impact and the context of future overall bill changes.

Figure E4.6 provides a visual demonstration of the wider challenges that customers consider are facing the water supply system in the future. Maintenance, supply, shortages and the price of water emerge as key themes.

Figure E4.6: Visual representation of customers view on challenges to the water supply system

When presented with more information about the future, customers are surprised by the challenges we face, but they do expect and trust us to be dealing with those challenges effectively. Overall we found that a large majority of customers (almost 80%) trust us to balance short and long term investment decisions and management of the network. A key theme that emerges across multiple research projects is that customers would prefer us to take a long term view and upgrade infrastructure now, rather than wait until there is a problem. This is despite the fact that such investments might not lead to visible immediate benefits.

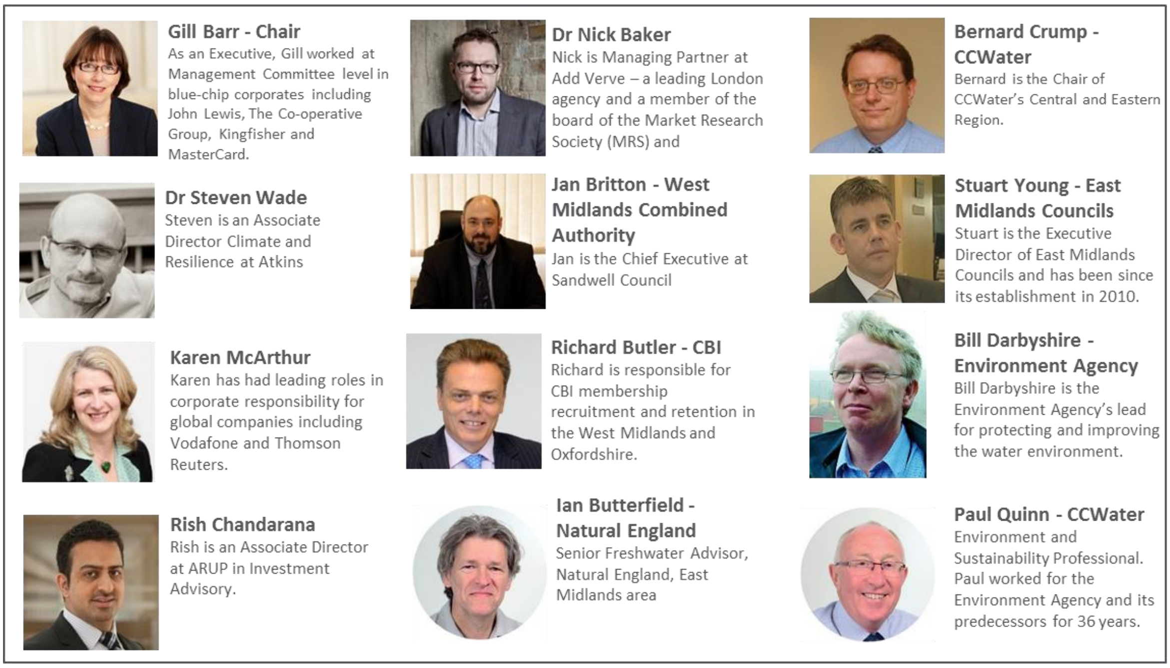
Customers also perceive a joint responsibility about the long term security of the water supply, and spontaneously talk about the importance of education on water efficiency.

E4.8 Water Forums

We have worked with our Water Forum (our Customer Challenge Group) for over two years and have been actively debating and developing our proposals over that time. In 2016 we welcomed a new independent chair, Gill Barr, who has bought extensive executive level experience from leading retailers including John Lewis and The Co-operative Group, swiftly following by four new members with expertise that include market research (Dr Nick Baker), social responsibility (Karen McArthur), investment planning (Rish Chandarana) and climate change (Dr Steven Wade). A summary of the core team of our Water Forum is provided in Figure E4.7.

They joined our existing members from the Consumer Council for Water (Dr Bernard Crump and Paul Quinn), the Environment Agency (Bill Derbyshire), Natural England (Ian Butterfield), the CBI (Richard Butler) with a further two new members with expert knowledge of our region from the East Midlands Councils (Stuart Young) and the West Midlands Combined Authority (Jan Britton).

Figure E4.7: Our Water Forum core team



The Forum has been organised to focus on key issues associated with WRMP19 and PR19. As a result we have a number of separate sub-groups established to better understand and challenge particular areas. These sub-groups bring together a diverse range of expert skill sets.

Customer engagement and the proposals relating to our WRMP have been principally challenged by the Water Forum's investment sub-group (ISG) and market research sub-group. The ISG comprises members from: the Environment Agency; Natural England Consumer Council for Water (two members; one Chair of CCWater's Central and Eastern Region); Confederation of British Industry; the West Midlands Combined Authority; and two from industry leading engineering consultancies (one of which started his role on the Water Forum as Head of Scientific Consultancy at the Met Office).

Dr Nick Baker, the Water Forum's expert in customer research, also sits on the Board of the Market Research Society, the world's leading research association. Drawing on this depth of experience, he led the Water Forum's market research subgroup, which includes Dr Bernard Crump, Regional Chair CCWater, and has been extensively involved in the development and application of our customer engagement. The subgroup has dedicated hours of challenge – across the full spectrum of our research – design, intent, sampling, execution and interpretation.

A significant amount of work and challenge has taken place in the 18 month period. The Water Forum wanted to understand;

- The challenges we are facing;
- The options we have considered;
- The benefits we are seeking to deliver;
- How we have engaged our customers;
- The preferences of our customers and how our plan responds to them, and;
- The areas of support we had for our proposed plan.

A key challenge from the Water Forum was in design of our research approach and deployment of the various techniques, which we have responded to in our strategic insight framework. At the heart of our strategic approach to customer insight is developing a more holistic understanding of the people and communities in our region, and understanding how we can make a positive contribution to their lives.

Our research consistently shows that customers take their water supply for granted. Ensuring water is always there is considered to be a basic need that, once met, is not given much further thought.

Our Water Forum have challenged us to be more strategic in our research design, taking into account:

- Where the topic sits within the hierarchy of customer needs;
- The extent to which the topic is conscious in customers' mind vs unconscious; and
- Whether the topic / issue occurs today or could in the future.

The Water Forum attended our deliberative research activities and directly witnessed the engagement levels and interest at those sessions, as well as the quality of the materials used to explain the issues in an engaging and accessible way.

E4.9 Responding to customers view on managing uncertainty

One of the key themes that came through our research and our wider customer engagement is that customers expect that our services represent value for money, are efficient and that we are mindful of the bill impacts of our investment choices.

However, we recognise that this doesn't mean customers simply want us to pursue the cheapest option, as reflected in our deliberative research on supply / demand options. Customers explicitly want us to pursue best value options and, similarly, customers do not want us to ignore risks to future supplies. Our customer engagement revealed a much more nuanced view that seeks to balance issues such as affordability, long term sustainability and resilience.

Our engagement on using a 'Real Options' approach to managing uncertainty occurred through both a deliberative workshop and engagement using our online community. Our Water Forum challenged us quite strongly on the need for the deliberative research to supplement the online community engagement. This is because the potential complexity of the issue and forward looking nature means it's important to explore whether the results are different when customers have a more informed understanding.

In the deliberative workshop we sought to understand customers' views on a range of issues, including:

- Water Framework Directive (WFD) – explore customers' views about how to manage uncertain options (those which are not certain to be progressed), with a preference for higher bills now with potential for a reduction in the future, or lower bills now with a risk of higher bills.
- Explore customers' views about different supply-side and demand-side solutions.
- Explore customers' attitudes about how we respond to uncertainty associated with climate change – including the balance between investing now versus investing later.
- Understand how customers feel about variation in their bill, and their perceptions of acceptable levels of variation.

Overall customers expressed strong support for finding a middle position to manage uncertainty. On climate change there was a clear desire to protect the environment through the use of demand-side measures. Customers were not supportive of large scale supply-side options, despite the research occurring during the notable hot weather conditions of summer 2018. Instead there was strong support for taking action to prepare for climate change uncertainty but not undertaking significant investment now (i.e. prepare to move quickly). We used our online panel to test different options for how we might respond to the uncertainty associated with climate change.

This research was undertaken using detailed polling on our online panel with approximately 800 customers taking part. We followed the polls with a discussion thread on the panel to explore customers' views about the approaches to uncertainty, their preferences and why.

In relation to climate change, 69% of customers expressed support of our approach to prepare now but to avoid significant investment until further information is available. We also note that 13% of customers supported no activity (including feasibility and design work), whilst 18% supported investment irrespective of the uncertainty.

Key feedback from our customers included:

- *"With the rapid changes in how water should be stored, managed and used, I think that it would be unwise to decide now what approach should be taken."*
- *"As a customer and shareholder I am definitely not in favour of large scale investment in one 'lump' but feel looking into the requirements for future investment is suitable at this stage."*
- *"I'm voting for research and project planning rather than leaping straight into solutions that may be outdated."*
- *"I believe it is reasonable to assume the demand for water will increase, not least due to the increase in house building. It therefore makes sense to make a start on building a 'base' provision for anticipated future requirements, rather than being caught on the back foot playing catch-up. Let's get on and make progress."*

The feedback from our customers shows that there is strong support in principle for managing uncertainty through a mechanism such as real options. Customers want us to balance a range of factors when making investment decisions, including:

- Protecting the environment;
- Promoting affordability by investing only in assets that required; and
- Promoting resilience by being able to respond to changes or new information quickly.

The results of the bill volatility engagement sessions also help to allay concern that even in the extreme event that all options are needed, customers would not find the change in bills volatile.