WRSE Resilience Technical Appendix

1. Overview and Need

This technical appendix describes the rationale, approach and methodology use in the Resilience Framework. As described in the main consultation document, a specific Resilience Framework is needed for the WRSE Regional Plan because there are a number of important aspects of water resources resilience that are not covered by ‘conventional’ economic and environmental water resources assessments of the type that have been carried out in England in the past.

At the same time, it is important to recognise that the Regional Plan will be used to support water company statutory Water Resources Management Plans (WRMPs). Water company Business Plans will also continue to explore wider concerns around resilience as part of the Periodic Review process. Certain aspects of WRMPs, such as the need to justify ‘best value’ in the proposed investments and the need to provide a secure public water supply in accordance with national standards therefore need to be reflected as primary concerns in this framework. The scope of the framework also needs to be considered in relation to the Business Plan. The purpose of this Resilience Framework is to support and add value to the *decision making* that is used in the Regional Plan to identify the preferred options and strategies that the Region should adopt to ensure secure and resilient water resources across the planning horizon.

Because the Regional Plan is designed to support the statutory WRMP process, we have used some of the key terminology to describe the actions that we can take to promote resilience from the England & Wales Water Resources Planning Guidance. Key terms used in this document include:

- ‘Interventions’, which refer to individual supply options, demand management strategies or other schemes (e.g. catchment management) that provide a specified benefit, usually relating to the supply/demand balance.
- ‘Portfolios’, which refers to packages of interventions that are planned and scheduled within the Regional Plan.
- ‘Best Value’ modelling, which refers to the process of selecting the most appropriate options to meet the required Levels of Service, to form an overall portfolio of investment that provides the best balance between affordability (economic cost), environmental impacts and, in this case, system resilience.

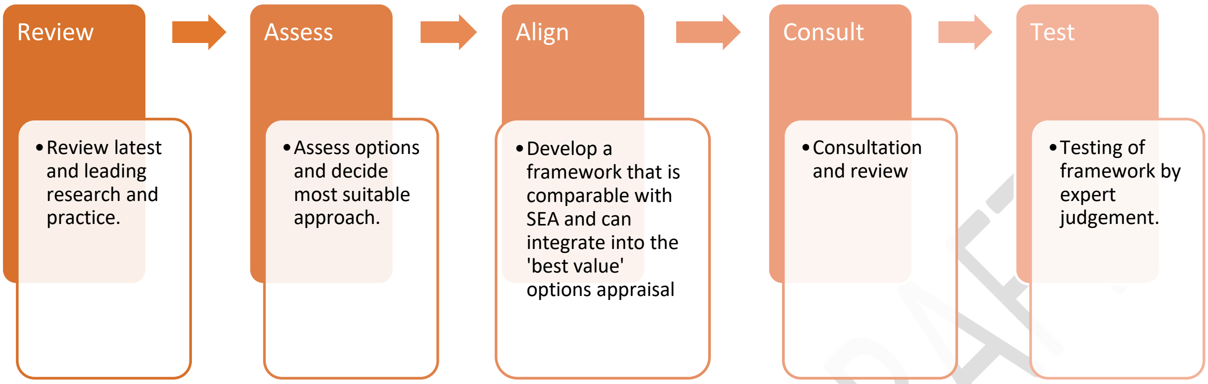
2. Principles of Framework Development

To practically incorporate resilience thinking into the Best Value modelling process the following objectives were identified for the Resilience Framework:

- enable mechanistic and consistent assessment of shortlisted water resource options resilience.
- ensure outputs of option assessment are able to be inputted into the Best Value modelling.
- assess the change in resilience of water/environmental systems delivered by different portfolios of options.

- be coagent with the underlying premises of adaptive planning.
- use existing data collected on options as far as possible.
- balance needs of supply and environment.

To make sure that the framework aligned with these requirements, the development of the resilience framework followed the process shown below:



This report covers the first three stages of development – i.e.:

- The review of the latest concepts and research in resilience assessment
- The assessment of options and selections of the preferred concept underlying the framework
- The development of the framework methodology to a sufficient level of detail to allow it to be incorporated into the Best Value options appraisal process.

It also describes the calculation processes and expected outputs from the framework, along with the assurance and QA processes that will be adopted.

Some initial testing of the framework has already been carried out through initial peer review by international experts (Resilience Shift, Pacific Institute, National Infrastructure Commission, Rockefeller Foundation) . The feedback gained from those sessions has been incorporated into this methodology.

3. Review of Available Concepts and Frameworks

We carried out a review of latest leading research and practice to identify some possible frameworks for assessing resilience that would fit with the requirements of the 'best value' process. This was focussed primarily on current resilience work and best practice in UK water resources planning and the UK water sector more generally. To ensure our review was as effective as possible we also looked beyond water sector resilience approaches, taking into account wider and multi – sector approaches. In addition to this we also took into account the findings of other similar literature reviews. This includes the City Water Resilience Approach Literature Review (Arup 2018), which proved to be a useful guide due to its wide outlook, allowing us to ensure we had taken into account as many different approaches as possible, despite its strict focus on urban water systems.

From our review of research and practice we identified three different options which we identified as meriting further investigation to understand potential for integration into the 'best value' process.

- Dimensions / goals of resilience approach.
- Risk and impacts of system failure approach.
- Resilience attributes / characteristics approach.

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Below we describe the results of our further investigations of these approaches before explaining which approach we deemed most suitable apply to the ‘best value’ process.

Dimensions / goals of resilience approach

This approach assesses the resilience of a system through a series of goals and sub – goals which are usually grouped into ‘dimensions’ or ‘functions’. Sometimes the goals are labelled as outcomes or values, but the premise remains that the system’s resilience is defined by achievement of (or strong performance against) these goals. Indicators are used to measure progress against the goals and the intention is that this creates a resilience focussed line of sight for decision making. The City Water Resilience Framework is a leading example of this approach, focussed on urban water systems. It has four dimensions (Leadership & Strategy; Planning & Finance; Infrastructure & Ecosystems; Health & Wellbeing) supported by 12 goals and 53 sub goals. All of these are supported by indicators measuring progress against the goals.

Key examples of this approach include:

- City Water Resilience Approach
- City Resilience Index
- California Department of Water Resources

Risk and impacts of system failure approach

This approach is the most commonly utilised in the UK water industry for both water resource and operational resilience. Generally, resilience is assessed by understanding the nominal reduction an option or intervention will bring to the likelihood and consequences of system (or asset) failure. The reduction in risk can be understood using a range of different metrics, common typologies of metric identified in the UK water sector include… In addition, this approach can be aligned with organisational service measures or key performance indicators to create a clear line of sight for decision making and help to evidence prioritisation of investment.

Key examples include:

- Bristol Water paper.
- Arcadis for United Utilities

Resilience attributes / characteristics approach

This approach assesses resilience of a system against a number of characteristics or attributes of resilient systems. The most widely used assessment framework conforming to this approach is the Cabinet Office’s *Keeping the Country Running: Natural Hazards and Infrastructure* (2011), which outlined the resilience characteristics of ‘Redundancy’, ‘Resistance’, ‘Reliability’, ‘Response & Recovery’. The approach is scalable, meaning that the characteristics can be applied and assessed at option, sub – system and system scale. This approach is also flexible in that it can be used easily to assess the impact the option (or a number of options) will bring to the resilience of a whole system.

Key examples of this include:

- Resilience by Design
- Cabinet Office 4 Rs.

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4. Selection of the Preferred Framework and Core Concepts

The review of potential general frameworks was used to carry out a 'benefits' and 'drawbacks' analysis for this context (i.e. water resources planning). The results of this process are shown in Table 1 to Table 3 below.

Table 1 Dimensions/Goals of Resilience Approach

Benefits	Drawbacks
The holistic approach allows ample room for engagement with system interdependencies. Allows for clear connection to wider outcomes of resilience. Allows for integrated approach to decision making and planning. Can be used as an engagement tool when proposing new approaches and interventions. When applied it provides a comprehensive baseline assessment and provides architecture for ongoing monitoring of performance.	Takes time and engagement to develop. Difficult to comparatively assess the resilience of options. Tendency towards a high number of indicators and sub-indicators can make it difficult to understand what is critical and not. Most existing frameworks rely on a high degree of subjectivity or interpretation for scoring. Due to its holism the approach is reliant on a wide range of reliable and often disparate datasets or evidence.

Table 2 Risk and impacts of system failure approach

Benefits	Drawbacks
Performance focussed, easy to relate resilience to levels of service / customer outcomes. Provides line of sight for decision making and a clear assessment of current 'level' of asset or system resilience. Resilience assessment methodology leaves little scope for subjectivity or interpretation. Approach most used in UK water sector across operations and water resources planning.	Relies on a large amount of asset and network data. Also relies on a significant amount of sophisticated network modelling to have a nuanced understanding of consequences. Relies on assumption that historical data sets are representative of future, this is in conflict with latest understanding of deep uncertainty in infrastructure. The approach can be perceived to favour built interventions over operational, green and human factor ones.

Table 3 Resilience attributes / characteristics approach

Benefits	Drawbacks
Approach is scalable and can be easily used to assess options and systems The framework does not inherently rely on historical datasets or forecasts and so aligns with leading deep uncertainty thinking. The frameworks of this approach can be easily tailored or made specific to different sectors and information available. The assessment methodology can be applied to a wide range of levels of detail. The approach is conducive to mechanistic comparative assessment of multiple options.	Methodologies for measuring characteristics / attributes can leave room for subjectivity. Option relies on existence of complete and reliable datasets or information to support assessment. Not as strong a connection between resilience and levels of service as other approaches.

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Based on this analysis we consider the ‘resilience attributes / characteristics approach’ as the most suitable for incorporation into the ‘best value’ process for the following reasons.

- This approach is the most conducive in practice for the comparative assessment of large numbers of options as well as combinations of options and their impact on resilience of water resource systems. Furthermore, the frameworks of this approach would lend well for the generation of a small number of resilience indicators for each option to input into ‘best value’ modelling process.
- The approach also fundamentally aligns extremely well with most recent thinking on deep uncertainty and infrastructure systems.
- Applying a pre – existing framework from this approach to a water resource context allows for integration of existing metrics and information into the assessment.

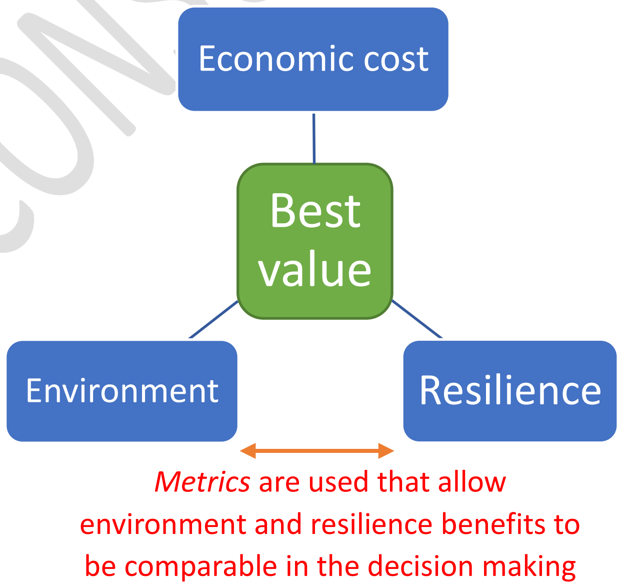
Associated network modelling work and need for data to use a ‘risk and impact of failure’ approach makes it impractical at the regional scale. Furthermore, the reliance of such an approach on probabilistic forecasts of failure risk mean that there is a chance of contradiction with the approach of the ‘best value’ process, especially if this is based on historic datasets.

The dimensions / resilience goals approach is considered impractical as well due to the need for mechanistic comparative assessment of schemes. The number of indicators and sub – indicators would make it infeasible to analyse and compare a large number of options as well as providing clear input into modelling.

5. General Principles

The general framework was developed to allow resilience to be integrated into the ‘best value’ assessment process, in a way that is comparable with the environmental metrics that are being used. This is summarised in Figure 1 below.

Figure 1 Summary of the Trade-offs Required by the Best Value Assessment



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In order to achieve this requirement, three core principles were adopted that governed the nature of the final framework:

- **Transparent and meaningful.** The framework should contain sufficient structure and detail to ensure that resilience is covered on a sufficiently broad basis, and so that subjectivity can be reduced as far as is practicable. The analysis and creation of definitions and metrics should satisfy the basic questions posed by Freeman St George et al (2020): 'Resilience of what, to what, for whom, and what can be done?'. Where there is subjectivity this should be clear and transparent, and scores that aggregate resilience across different metrics (e.g. reliability of yield with physical vulnerability to other factors) should only be used so that the 'best value' modelling is able to explore an appropriate range of investment portfolios. Customers and stakeholders should still be able to see, and be engaged on, the underlying, quantified metrics that describe the resilience benefits that are provided by different portfolios.
- **Comparable.** The scoring used, both on an individual option and portfolio level, needs to be reasonably comparable with the environmental metrics that will be used in the decision making process. As the environmental aspects will be largely based on SEA objectives, the proposed scoring approach should 'feel' similar to SEA.
- **Focused and integrated.** The framework needs to draw out the benefits of the Plan in terms of resilience. Although the basis of the preferred framework is one of systems resilience assessment, the framework needs to be able to both examine the interactions between systems (i.e. a 'system of systems' approach), and meaningfully expose the *resilience shift* caused by the Plan.

Based on the above, the definition framework developed by Boltz and Brown (Boltz et al 2019) was used and adapted for WRSE. The Boltz & Brown definition framework uses three key indices, which are summarised below.

Persistence refers to a human or natural system's ability to maintain coherent function under changing conditions and disruption without altering its identity. The existing components, configuration and interactions of the system enable it to return to its prior function under the exogenous stresses and shocks to which is it exposed

Adaptability refers to a system's ability to maintain coherent function by modifying its identity to accommodate change. Adaptability is about continually adjusting responses, innovating, and reorganizing system parts and relationships relative to changing external conditions and internal interactions. Adaptability allows for system development and realignment within its current equilibrium – adjusting to sustain its present function

Transformability refers to a system's ability to change its identity and to establish a new function in a novel equilibrium when pushed beyond the threshold of its present state. It is the ability to change from one type of system to another with different controlling variables, structure, functions, and feedbacks. Transformation results in a change in both system identity and function. Transformability is the capacity to create a new system when ecological, economic, or social conditions make the existing system untenable

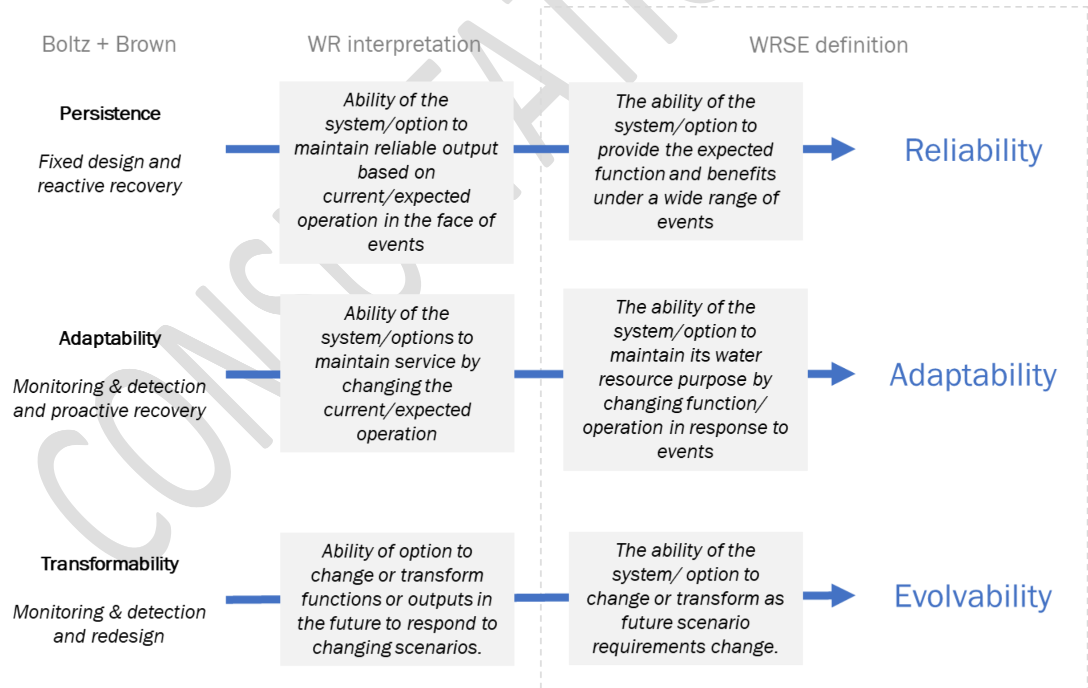
This framework is compatible with the latest National Infrastructure Guidance on Resilience (NIC 2020), a it covers aspects of resilience that we can actually measure, whilst at the same time allowing us to encompass the *anticipate-resist-absorb-recover*, plus *adapt and transform* elements of resilience that form the basis of the NIC framework.

Although this represented the most compatible framework, these three indices needed to be modified to the specific needs of the Regional Plan assessment. These slight modifications are mainly required to allow the assessment to focus the impact of different sets of development options/solutions, rather analysing the pre-existing framework and seeking to address all issues.

One of the core principles is that the Plan needs to be *focused and integrated.* To achieve this, the assessment and modelling is *intervention led.* We concentrate on the 'what can be done' part of the resilience question by examining the resilience shift provided by supply options, catchment schemes and demand management strategies, and use this to build our understanding of how resilience changes for the *systems* that we have incorporated into the Plan. We use options appraisal and system simulation to examine how interventions affect our multiple systems and the 'touch points' between those systems on both a stand-alone basis and in combination as part of a portfolio of investment.

A summary of the three indices recommended by Boltz and Brown, and the way in which these were adapted for the purposes of the WRSE assessment is provided in Figure 2 below.

Figure 2 Modification of the Boltz and Brown Definition Framework



These three basic indices – **reliability, adaptability and evolvability** were used as the main basis for the framework.

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6. Development of the Modelling and Measurement Methodology

Clearly it is not possible to objectively model against these descriptions, so a process of service, risk and mitigation mapping was used to identify ***sub-metrics*** that are able to quantitatively describe aspects of the three resilience indices that are important to water resources and are not inherently covered in 'conventional' economic/environmental water resources modelling.

We used two guiding pieces of research when developing our systems definition, measurement metrics and modelling approach:

- The sub-metrics needed to cover the NIC (2020) *anticipate-resist-absorb-recover*, plus *adapt and transform* elements of resilience
- The development of the systems, metrics and overall model followed the Freeman St George et al (2020) questions of: 'Resilience of what, to what, for whom, and what can be done?'

The first stage of this required us to answer the 'resilience of what, to what, for whom'? part of the question. The purpose of the WRSE Plan is to incorporate an understanding of *systems resilience in the context of water resources.* We therefore identified and defined the systems involved based on the desired scope of the Plan (a 'multi-sector' resilience Plan) and the primary purpose, which is to understand the role of water resources stresses and interventions in that context. This first stage focused on defining the systems that are covered by the scope of the Regional Model (i.e. the 'for whom' aspect of the resilience question). Four, interlinked, systems were identified, as shown in Figure 3.

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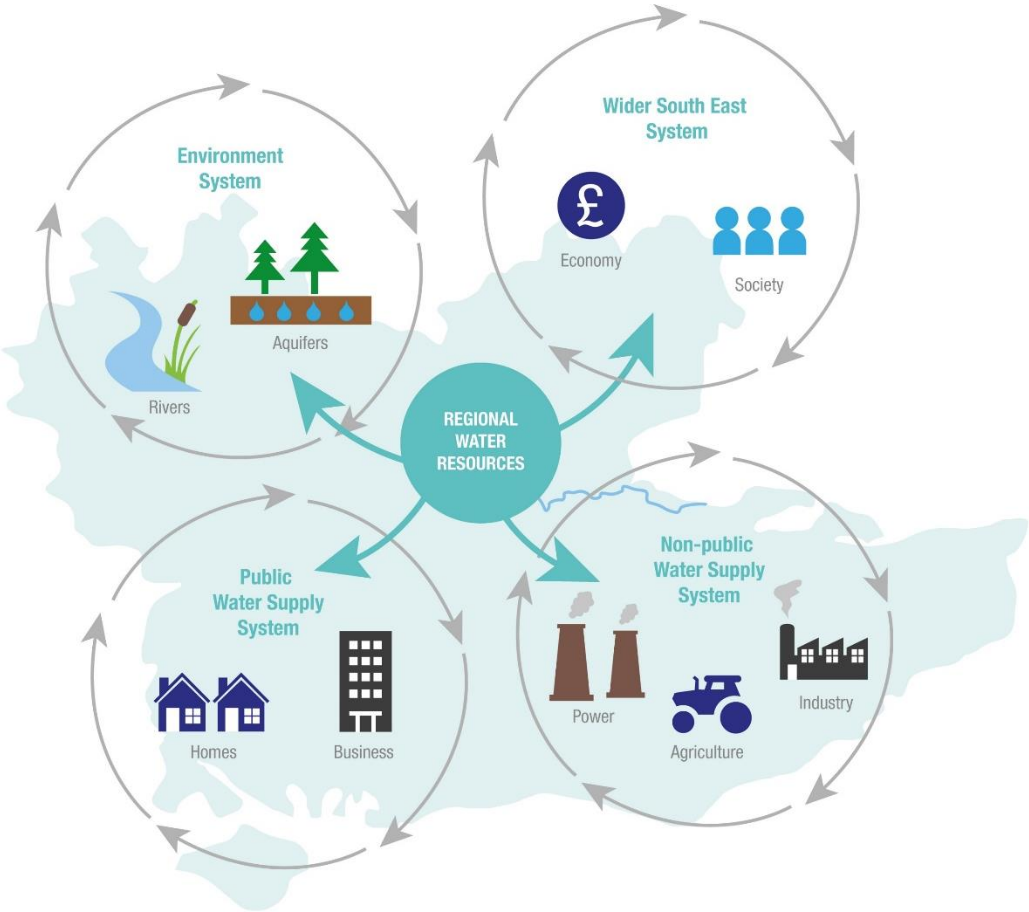
Figure 3 Outline of the Four Systems Covered by the Framework



Of these systems, the 'wider south east' is important as it provides a link between more general economic health, wellbeing and the environment and the three systems that are more directly relevant to water resources. The inclusion 'wider south east' system is therefore proposed as a final stage used for context setting and to help identify touch points within the 'system of systems' that were not covered by the core modelling. It does not form one of the three key systems that were used as the main basis of the framework, and is addressed separately at the end of the methodology.

To answer the 'of what' question adequately, it is important that we define the *service* that the three key systems are providing in the context of water resources.

> To answer the 'of what' question adequately, it is important that we define the *service* that the systems are providing in the context of water resources. Varga et al (2019) in their work for NIC, describe these as 'foundational values', but in this document we use the more familiar term of 'service'. Critically they introduce the concept of 'decomposition' of the service to allow a the development of a measurement framework, and it is this concept that we have adopted to carry out the analysis provided below.

Figure 4 provides a summary of the analysis that was used to define and decompose the systems and services covered by the WRSE method. Because of the nature of the assessment, which needs to be well enough defined to support the statutory Water Resources management Plans that will rely on the Regional Plan, this assessment has concentrated on ensuring that the links to the final part of the Freeman St George et al (2020) question *'and what can be done?'* are in place at the earliest conceptual stage.

It is important to note that some of the main aspects of system services are already included in the supply/demand inputs that are used in the 'Best Value' modelling. These are generally driven by existing Level of Service agreements, or policy and licencing requirements. Whilst they still effectively form part of the resilience framework, they are described and incorporated into the basic economic 'supply/demand balance' modelling. This includes many of the key elements of uncertainty, which are often incorporated into a resilience framework. Similarly, there are various aspects of what can be considered to represent environmental 'resilience' that are included within the environmental framework that also feeds into the 'Best Value' modelling.

However, many aspects of service resilience are *not* inherently included in these other inputs to the 'Best Value' modelling, so need to be considered for input via the Resilience Framework. The analysis of which aspects are covered elsewhere in the modelling assessment, and which aspects need to be incorporated directly into the Resilience Framework is provided for each of the three key systems in Figure 5 to Figure 7.

Interaction with 'Best Value' decision making and environmental assessment frameworks

The analyses on the next three pages highlight the fact that there are many key elements of resilience, particularly associated with drought severity, future uncertainty and environmental impacts, that are covered elsewhere in the Best Value decision making and environmental assessment frameworks. The analysis presented here is used to ensure that the metrics that *are* included in the Resilience Framework do not 'double count' such aspects, whilst at the same time ensuring that relevant aspects of resilience are adequately covered.

Figure 4 Definition of System Services and Identification of Generic Measures for the Framework

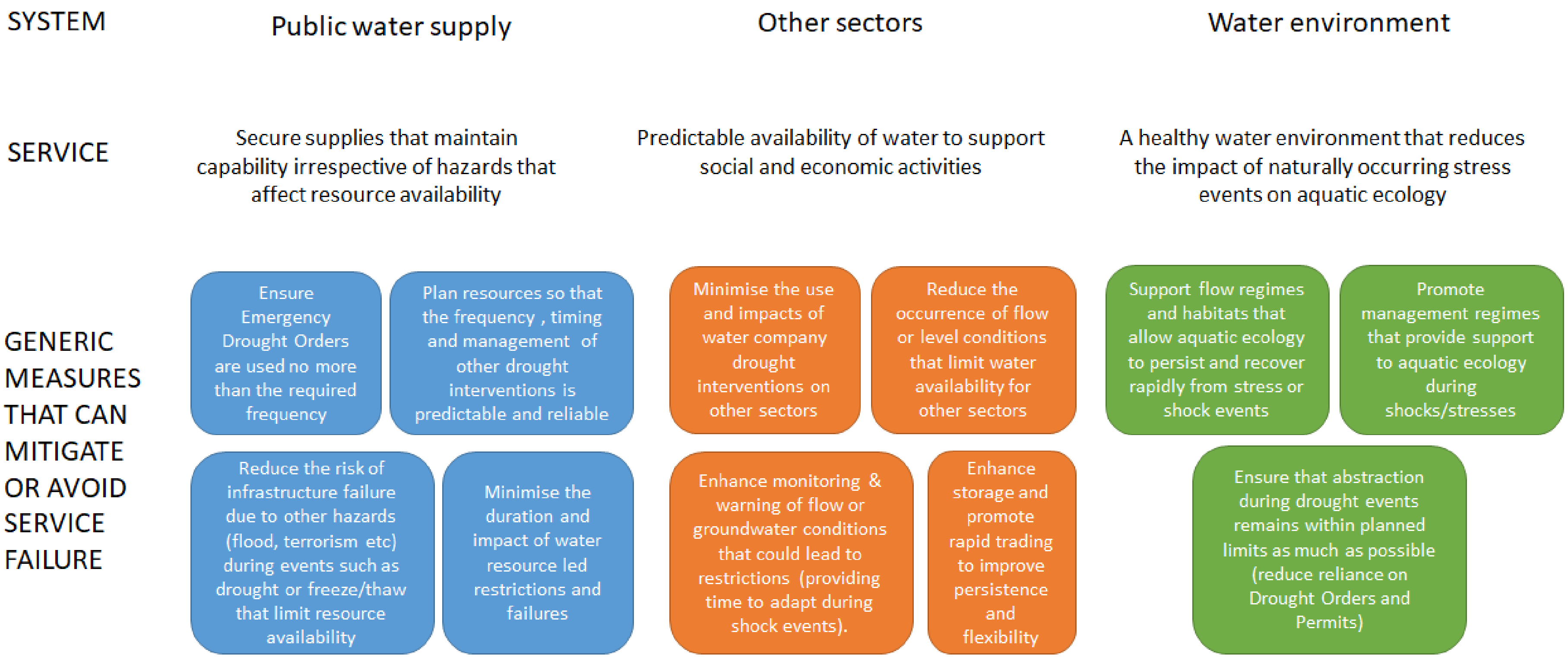


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Figure 5 Analysis of Service Failure Aspects that Need to be Incorporated for the ***Public Water Supply System***

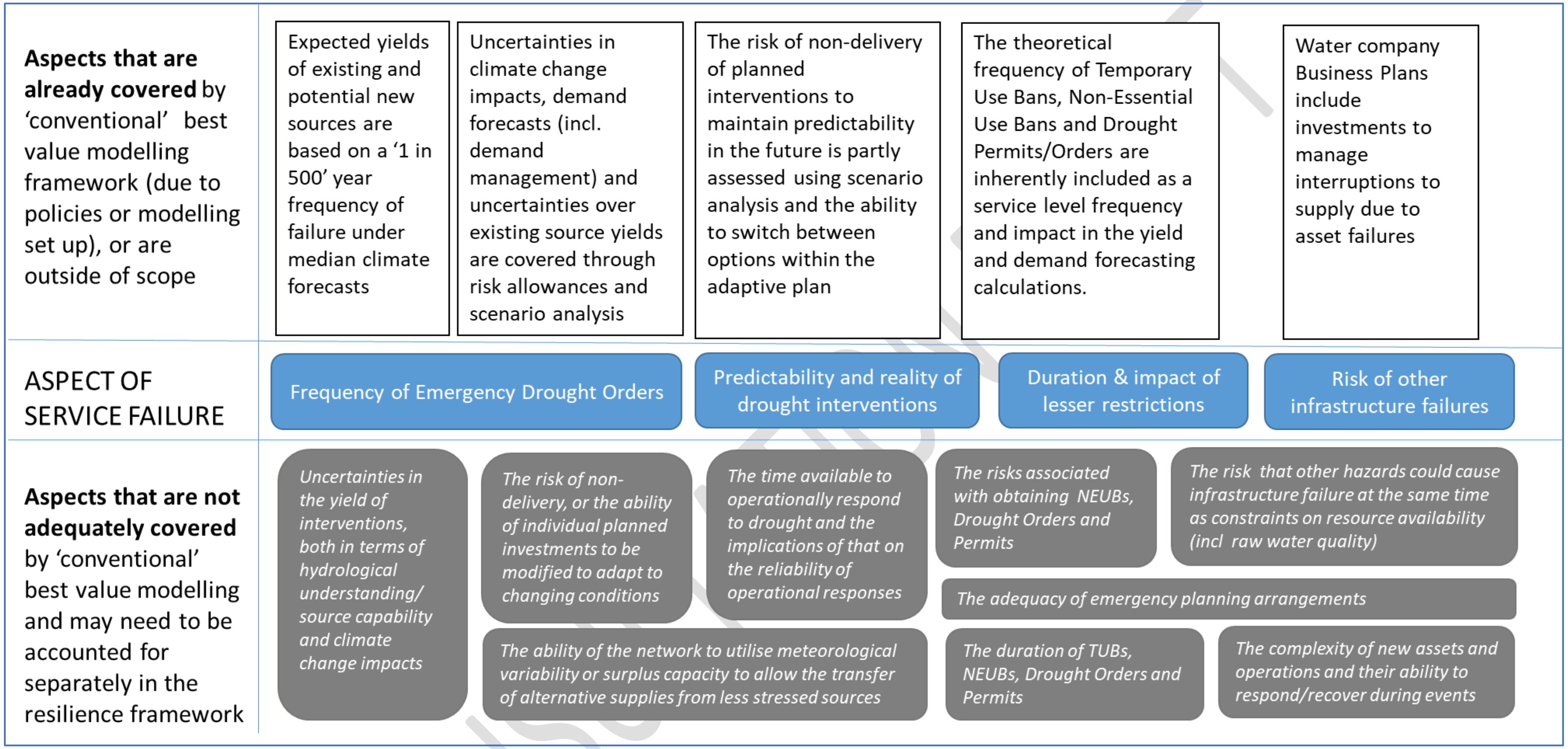

Figure 6 Analysis of Service Failure Aspects that Need to be Incorporated for the ***Non-Public Water Supply System***

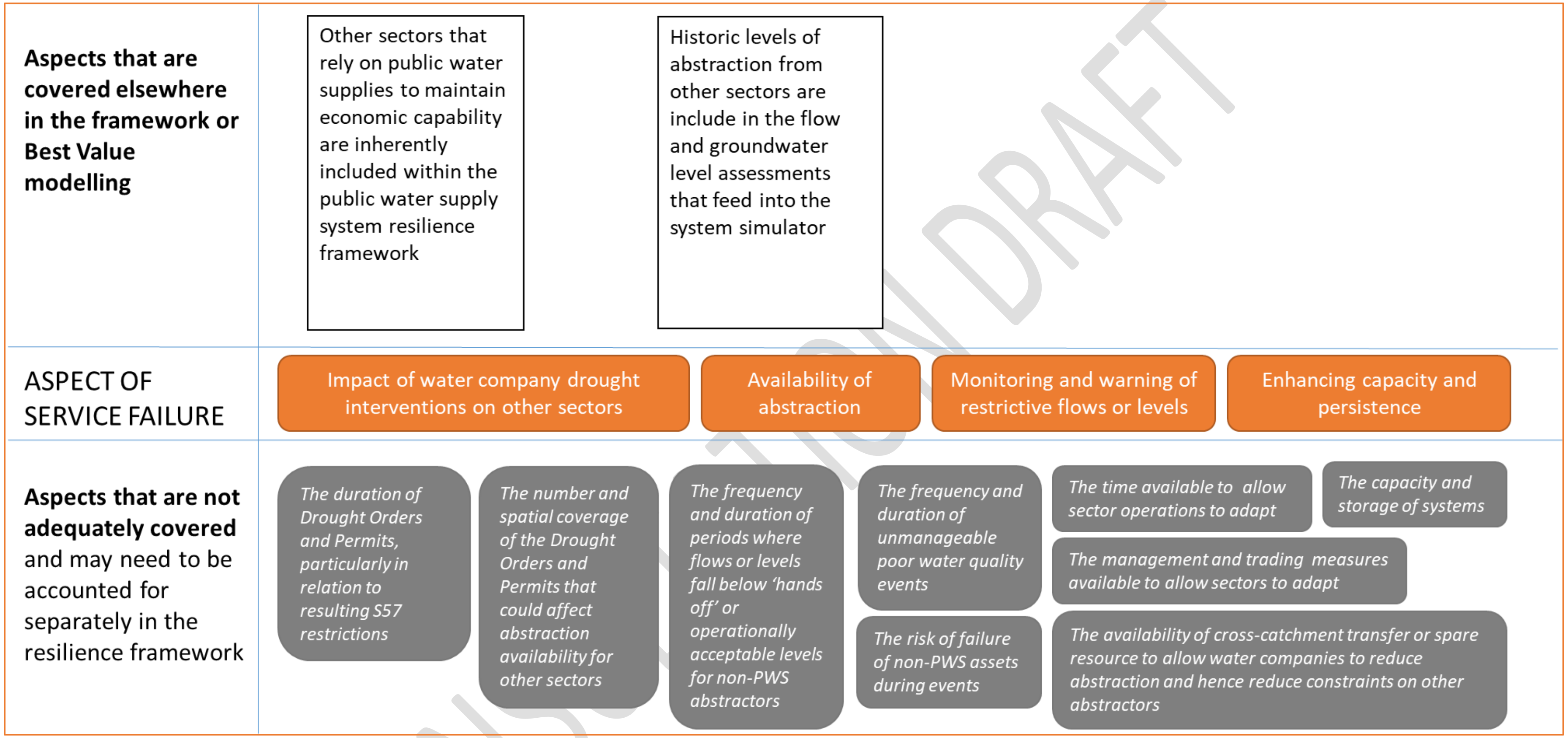

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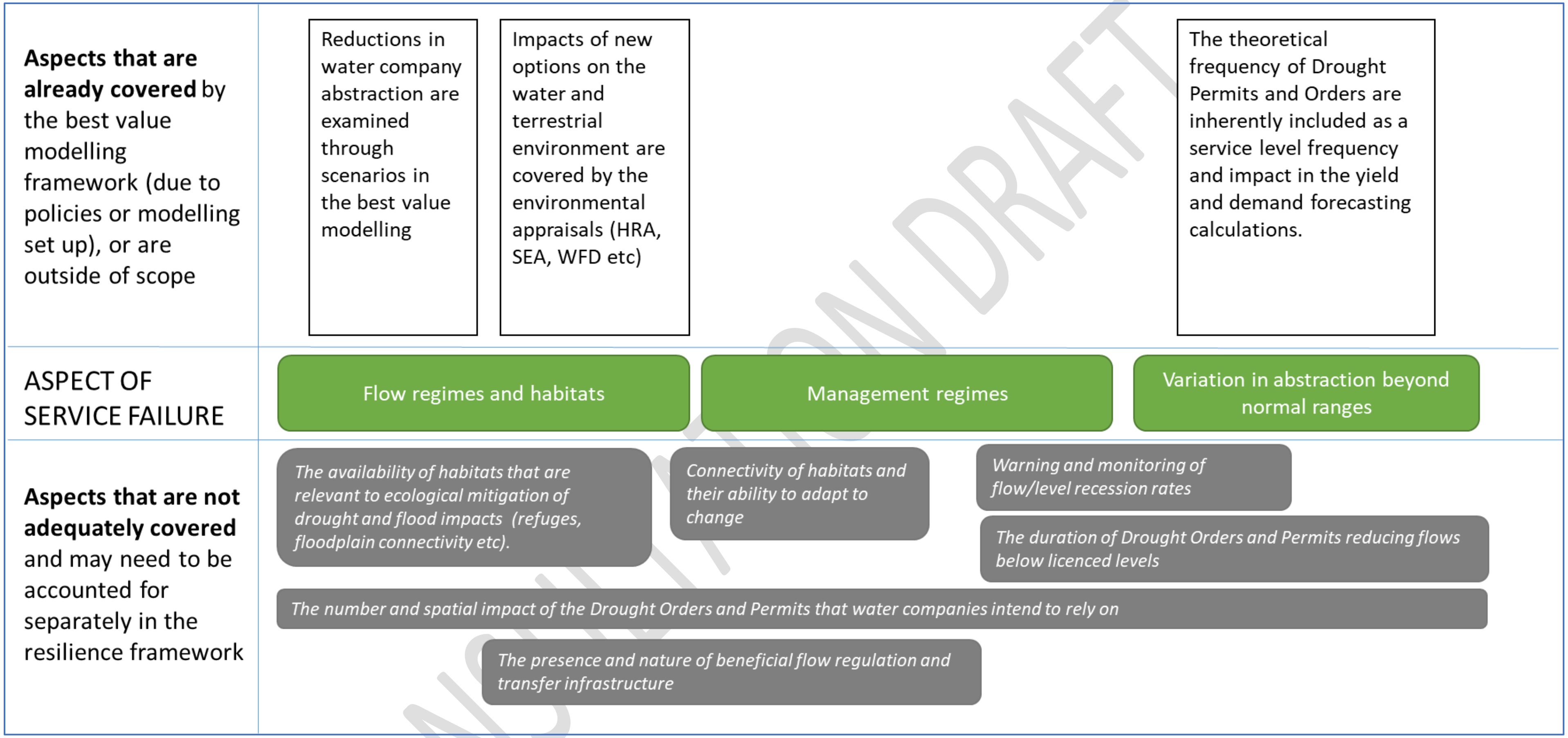
Figure 7 Analysis of Service Failure Aspects that Need to be Incorporated for the ***Water Environment System***



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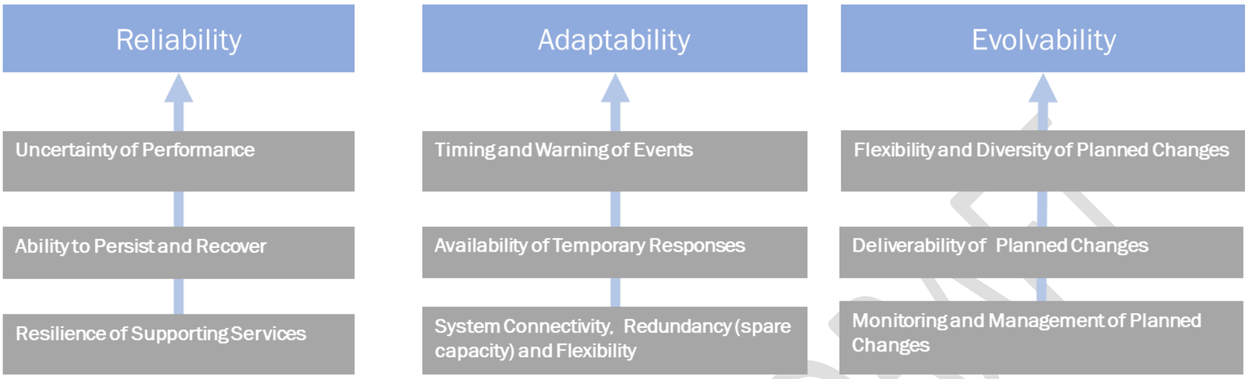
These analyses were used to provide a *decomposition* (see Varga et al 2019) of the three headline resilience indices contained in the Boltz & Brown definition framework. This resulted in a set of generic metrics that could be used to measure resilience in the context of a Regional Water Resources Plan. These generic metrics (which apply to all the key systems) are provided in Figure 8 below.

Figure 8 Generic Assessment Metrics Developed for the Resilience Indices



Although these generic metrics are useful to understand the components of resilience that we are interested in, we need to be able to actually apply these generic metrics in a way that can be *measured* for interventions and portfolios, and then mapped onto the three systems. A series of *sub-metrics* were therefore identified that represented quantifiable aspects of the Plan. These can be assessed either for individual options or for portfolio of planned interventions as a whole.

The modelling methodology and sub-metrics that are used to measure resilience of interventions, portfolios and systems within that methodology are described within the modelling methodology section below. In terms of development it is important to note that the outputs of the resilience framework have to feed into the Best Value modelling in order to allow tradeoffs between cost, environment and resilience to be examined. At the same time we need to maintain transparency and allow stakeholders to understand how particular options and strategies have informed the resilience score.

As detailed in the modelling methodology section, the performance of the different investment portfolios and the final preferred Plan is actually measured through the *sub-metrics*. This performance is then mapped onto the systems to demonstrate the benefits of the Plan.

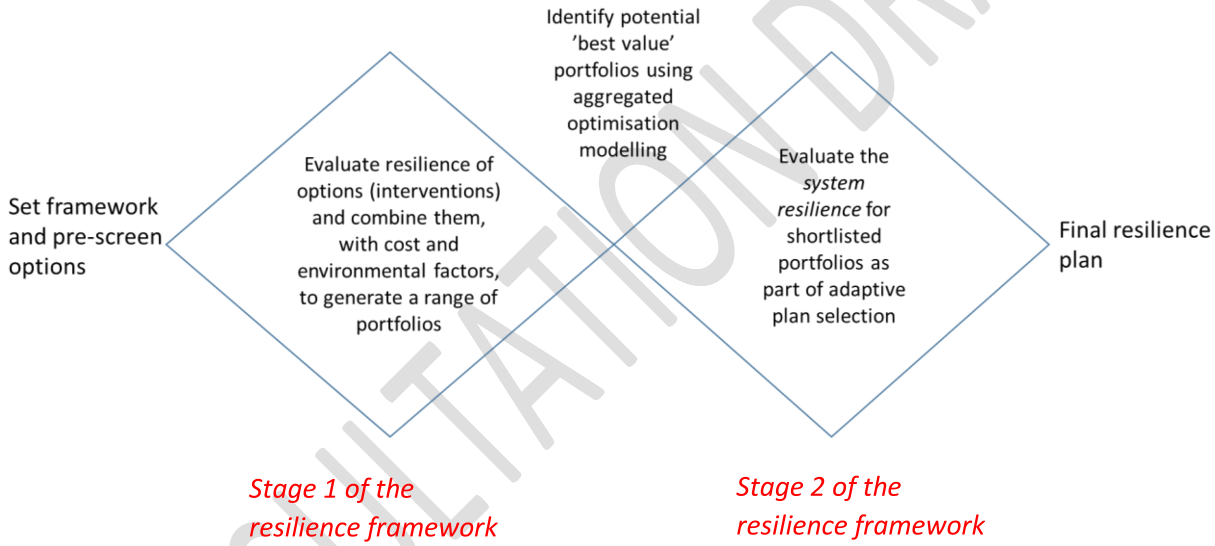
These *sub-metrics* are the main tool used to demonstrate the resilience shift, by system, to customers and stakeholders. Where these sub-metrics are combined to an overall score for each of the three resilience indices (reliability, adaptability and evolvability) within the methodology, this inevitably involves a degree of weighting and subjectivity. **The main use of these overall index scores is therefore limited to the option optimisation tool used in the 'Best Value' modelling,. Their key purpose is to provide a framework that allows us to demonstrate that an appropriate range of trade-offs have been considered** when examining the portfolios that could be used to 'solve' the regional need.

7. Modelling Methodology

7.1. Summary of the Process and Integration with the Best Value Modelling Framework

At a conceptual level the modelling methodology follows a typical 'double diamond' approach (Rodrigues 2020), as illustrated in Figure 9. This approach allows us to generate the likely resilience shift at the option/intervention level, which we use to explore the potential portfolios that could make up the regional solution. Actual system simulations at this first stage are limited to large, strategic options, and most options are scored through assessment and simpler modelling exercises through the options appraisal process. This means that we can use simpler *aggregated* best value modelling to understand the range of potential portfolios that could reasonably be used to solve the regional need (see 'Best Value' modelling method technical report). Once these portfolios are defined, then we can use system simulation modelling that includes all of the relevant information to generate the sub-metric scores that describe the overall performance of the portfolio.

Figure 9 High Level 'Double Diamond' Concept for the Resilience Modelling



This approach allows us to fully integrate the resilience framework into the overall 'Best Value' modelling approach and final adaptive planning analysis. A summary of the practical processes involved in doing this are summarised in Figure 10 below. The Steps of the Best Value modelling framework, as described separately in that Technical Report, are referenced within this figure to show how the resilience framework integrates into that wider Best Value modelling work.

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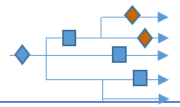
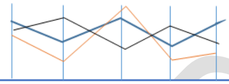
Figure 10 Summary of the Integration of the Resilience Framework with the Wider Best Value Modelling Process

Stage 1 of the resilience framework

Integrates into Steps 8 to 11 of the Best Value Modelling Framework





Stage 2 of the resilience framework

Integrates into Steps 13 to 15 of the Best Value Modelling Framework

A. All pre-screened options/interventions are assessed against:

- Cost and DO benefit
- **Intervention level resilience sub-metrics**
- Environmental indices

B. The potential contributions of each intervention to each of the three resilience indices is calculated in the **Resilience Assessment Tool** using a **weighted aggregation calculation**. The Real Options (RO) EBSD Modelling uses these index scores, along with environmental scores and costs, as objectives that it can seek to maximise in the best value modelling assessment

C. The RO EBSD tool generates a range of alternative investment portfolios for each of the future scenarios based on the tradeoff between the cost (affordability), environmental indices, and **resilience indices.** The resulting **sub-metric** scores for the different portfolios are tested with customers and stakeholders to identify preferences and improvements in the assessment process

D. A sample of the range of portfolios is selected based on these preferences and tested in the system simulator. The full suite of r**esilience sub-metrics are generated** for each portfolio **based on whole, integrated system response.** Outcomes for the different portfolios and trade-offs between cost, environment and resilience are reviewed with stakeholders and customers as part of the creation of the adaptive plan.

Note: as discussed previously, stakeholder engagement and the benefits of resilience are expressed via the sub-metrics. The *weighted aggregation process* highlighted under step B, which generates an overall resilience index score for portfolio selection in the RO EBSD tool is simply used to provide a structured process for generating the range of portfolios that seek to demonstrate the tradeoff between affordability (cost), environment and resilience. Engagement at that stage is focused on confirming that the resilience framework has covered those aspects that customers and stakeholders, and that the indexing has generated a reasonable range of portfolios. The indices are not themselves used to try and identify a 'preferred' portfolio, as they are considered to be too subjective and cannot have the same transparency as the sub-metrics.

7.2. Generation of the Measurement (sub) Metrics

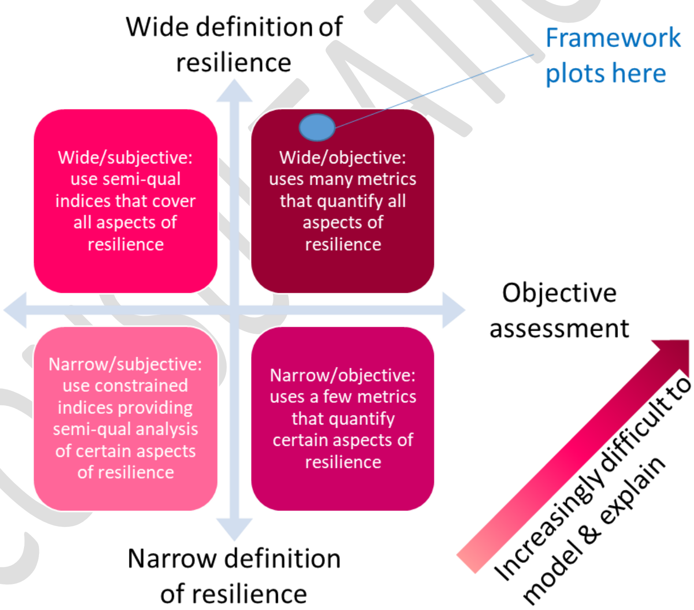
In order to model resilience it is necessary to identify representative aspects that can actually be quantified to provide customers and stakeholders with a measured understanding of the resilience shift provided by different portfolios of investment. These need to be appropriate within the context and description of the generalised metrics described within the previous section.

A structure based on *sub-metrics* is therefore used to evaluate the resilience shift for selected portfolios. As noted previously, this structure is also used to generate the overall impact that each option has on the three resilience indices. This evaluation at the index level is then used to ensure that the 'Best Value' modelling generates an appropriate range of alternative portfolios,

It is recognised that, where possible, such metrics should be objectively modelled. However, at the current time there are some important aspects off resilience that cannot realistically be objectively modelled. These could be excluded from the analysis, but that would limit the breadth of our resilience analysis.

As shown in Figure 11, the generation of monitoring metrics will always represent a trade-off between breadth of understanding, objectivity and complexity of analysis. We have therefore proposed a *hybrid* assessment framework that we think provides the breadth of understanding that is needed to understand the resilience shift across our three systems, and provides a list of metrics that are largely (65%) objective in nature. There are 20 sub-metrics in total, which, when they are mapped to the three systems, results in a maximum of 14 sub-metrics for any one system.

Figure 11 Conceptual Compromises Involved in the Selection of Resilience Metrics



Based on the assessments and tools that are available to WRSE and water companies within WRSE (as a result of Water Resources Management Plan and Business Plan assessment tools), the sub-metrics described in Figure ZZ are proposed for the current round of Regional Planning. In the second 'diamond' of the modelling assessment, these are mapped onto the three systems according to Figures YY to ZZ. As noted in those figures, even with the broad range of metrics proposed there are some aspects that cannot reasonably be include in the modelling and will need to be considered in a qualitative way after the main Plan has been generated.

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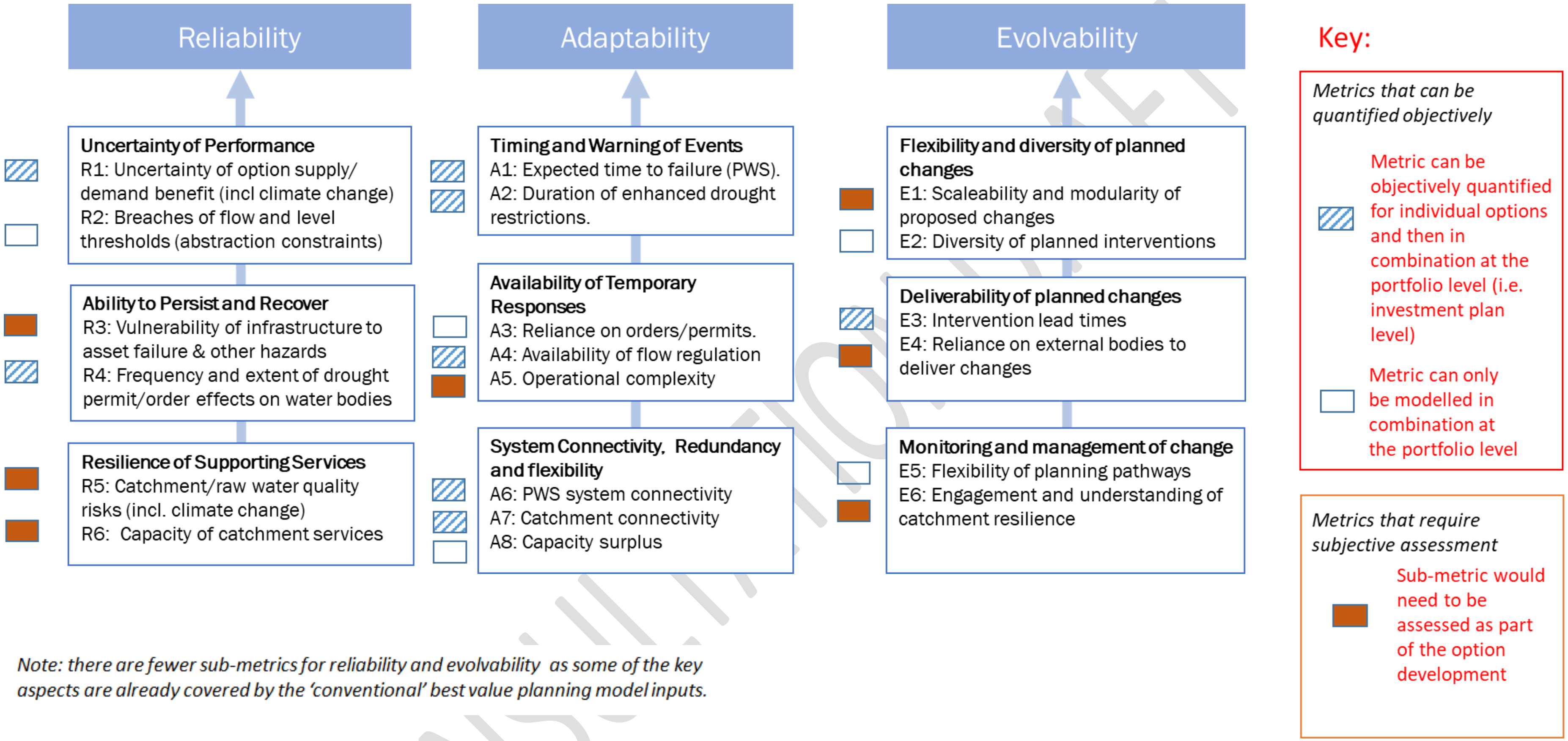
Figure 12 Overview of all Sub-Metrics Generated at the Intervention and Portfolio Level



Note: there are fewer sub-metrics for reliability and evolvability as some of the key aspects are already covered by the 'conventional' best value planning model inputs.

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*Figure 13 Mapping of Intervention and Portfolio Sub-Metrics to the **Public Water Supply System***

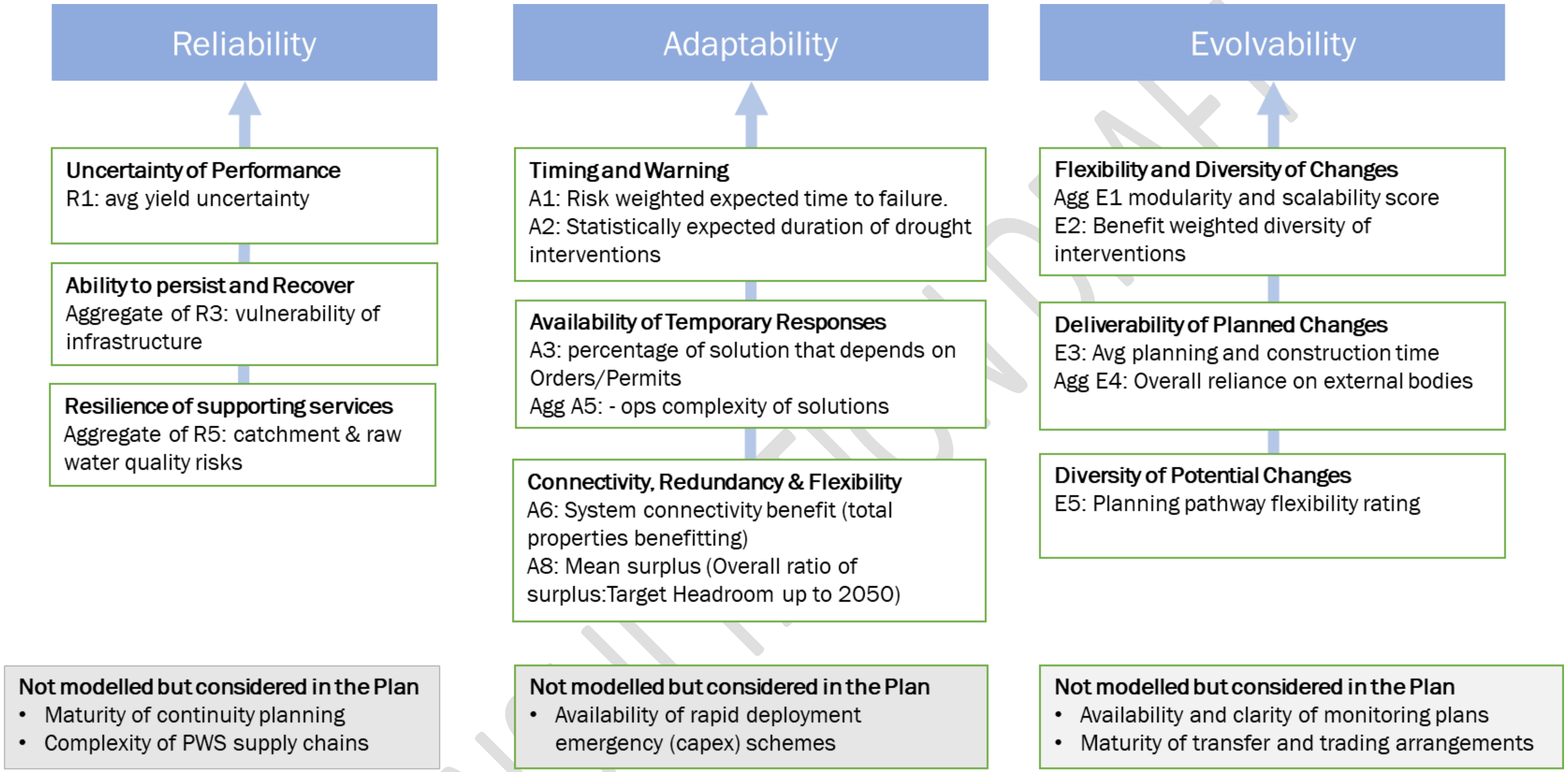

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Figure 14 Mapping of Intervention and Portfolio Sub-Metrics to the ***Non-Public Water Supply System***

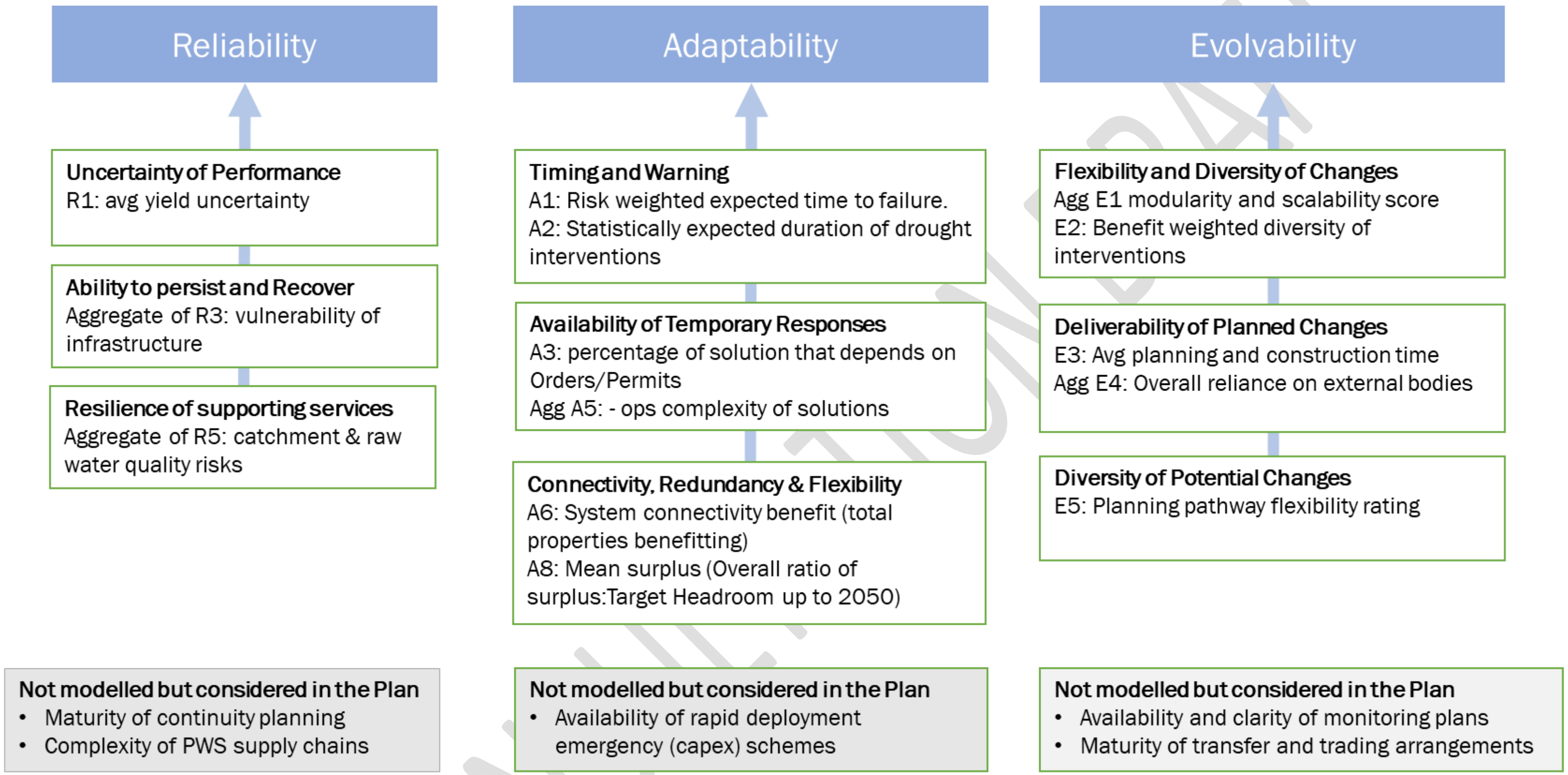
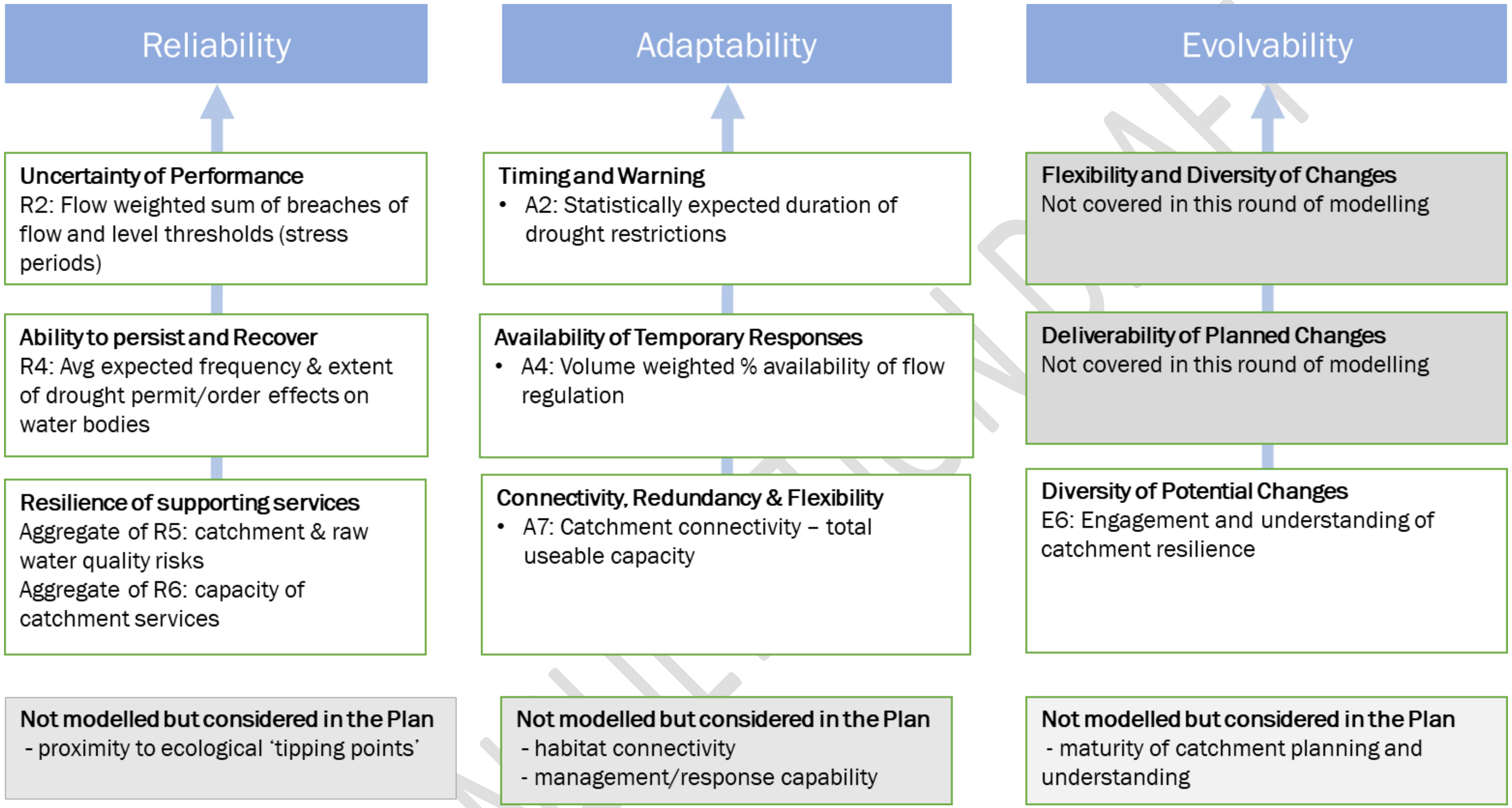


Figure 15 Mapping of Intervention and Portfolio Sub-Metrics to the ***Water Environment System***



7.3. Evaluation of Resilience Shift for the Wider 'South East' System

The exact approach for the South East of England system has not been defined at this stage, but the focus will be on using the systems as a 'platform' to examine the touch points between the three key water resources systems and the wider issues of economic and social resilience across the South East. This assessment will be carried out in the final step of the Best Value planning, and will focus on:

- At a high level, evaluating how the differences in resilience shift between the potential alternative Plans might affect the wider South East (i.e. where the 'touchpoints' are and how significant are the differences in this wider context).
- Whether any of the specific aspects of resilience (highlighted through the individual sub-metrics) are particularly significant when viewed in this wider context, or whether there are sub-regional benefits that gain a higher level of importance when viewed in the wider context.
- How the three systems interact with each other both in terms of function and geographical location, once the scale of potential resilience shift is understood and the touchpoints with the wider south east system has been identified.

It is envisaged that a high level form of system mapping and service evaluation will be used to identify these key interactions, which will allow a qualitative assessment of how the wider South East context and 'system of systems' might influence the Plan.

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8. Inputs

8.1. Definition of the Sub Metric Evaluation Criteria

As shown in Figure 12, the resilience sub-metrics fall into three categories:

1. Semi-qual evaluations (7 sub-metrics) that are scored at the individual intervention level and have an element of subjectivity. These are scored on a 5 point scale according to the definitions and guidance provided in Table 4 below. Further guidance is also provided in Appendix A.
2. Modelled evaluations (8 sub-metrics) that are calculated initially at the individual intervention level, and then in some cases are re-calculated at the portfolio level in Stage 2 using the system simulator. These are described in Table 5.
3. Modelled evaluations (5 sub-metrics) that are calculated at the portfolio level only, using either the outputs from the 'best value' modelling or the system simulator. These are described in Table 6.

Most metrics are intended to be applicable to both supply and demand interventions, although in some cases they are only relevant to specific option type and other interventions score a 'default' value, as described. For reasons of practicality some of the modelled metrics are only evaluated at the intervention level using the system simulator for demand management strategies and large-scale strategic schemes with a Deployable Output > 20Ml/d.

The intention of this framework is to encourage thinking beyond the overly simplistic volumetric approach to assessing how much water an option/intervention could *theoretically* provide in volumetric terms during a drought event. For example, theoretically a desalination plant is 'reliable' under drought events as it is not hydrologically vulnerable. However, they tend to be complex to operate, are difficult to turn off and re-start and tend to be inflexible as far as the distribution system is concerned, as their water quality needs to be carefully managed to prevent taste and issues such as iron/manganese mobilisation in the pipe network. It is therefore likely that desalination plants will score poorly in the 'vulnerability to asset failure and other hazards', 'complexity of operation' and even 'PWS system connectivity' categories as a result of this.

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Table 4 Details of Semi-Qual Intervention Level Sub-Metric Scoring

Sub-metric	Description	Possible Approach
R3: Vulnerability of infrastructure to asset failure other hazards*	Relative risk of loss of service during a shock/stress event that is already causing constraints on the availability of water resources (drought, freeze/thaw etc), *combined with the ability of the infrastructure to re-start and operate following such failures*. These losses will tend to be caused by factors such as flooding, fire, cyber attack etc, and will be exacerbated by option and asset types that are difficult to repair or re-start following such events (e.g. desalination plants). Could affect demand interventions through information networks (e.g. smart metering loss of comms). Represents the net impact that the option has – if this causes benefit or detriment to existing infrastructure then this should be included within the scoring assessment.	5 point scale relative to the current 'typical' exposure and vulnerability (1 = notably vulnerable, vulnerable, typical, less vulnerable, 5 = notably less vulnerable). Consider key vulnerable points and operational facets based on remoteness and ability to restart/recover. See guidance table A.
R5: Catchment & raw water quality risks	Risk represented by transient water quality events occurring in the catchment beyond those that are adequately covered by outage (e.g. high colour/turbidity/metaldehyde affecting multiple sources during runoff events, algal blooms causing widespread treatment problems). Represents the net impact that the option has on the risk to service – if this causes benefit or detriment to the existing risk for abstractors or ecology during shock events then this should be included in the scoring assessment. Although it is acknowledged that control measures will be put in place, this is a resilience assessment, which means that options with highly complex measures will tend to score less well anyway, so unmitigated catchment risk scores are used.	5 point scale based on DWSP catchment risk assessment without control measures (1= notable increase in risk, 3 = 'typical', 5 = notable decrease in risk). Demand measures score in the neutral category by default. See guidance table B.
R6: Catchment ecological capacity	A measure of how interventions affect the ability of a catchment to 'absorb' shock events whilst maintaining ecological service (e.g. ability to maintain river ecology under abnormal low flow events) due to the presence of refuge habitats, localised habitat/water body connectivity etc. Demand management scores neutrally because the general benefits to flow are already accounted for in the environmental metrics.	5 point scale relative to a neutral impact (notably positive, positive, neutral, negative, notably negative). Only includes facets not covered by SEA or natural capital assessments. Demand management neutral by default. See guidance table C

A5: Operational complexity	A measure of the net impact that an option has on the complexity of operation of the abstraction, treatment and distribution infrastructure, which affect the ability of public water supplies to be reconfigured to cope with unexpected consequences of shock/stress events. Demand management that notably reduces flexibility of distribution will tend to score poorly.	5 point scale relative to the current 'typical' situation (notably complex, complex, typical, less complex, notably less complex). Base on reliance on multiple institutions, experience of operation and other factors**. See guidance table D
E1: Modularity and scalability	Ability of proposed interventions to be implemented on a modular or scalable basis [i.e. can they be planned and constructed on a staged basis that can be expanded at a later date to address the under-achievement of benefits or mitigate the risk of investment 'white elephants'). .	5 point score based on the overall flexibility. A score of 1 represents an initiative that can only realistically be a single sizescale with no flexibility (e.g. reservoir or certain approaches to national water labelling). A score of 5 represents a scheme that can be implemented on a fully staged, modular and extendable basis. See Appendix A guidance table E
E4: Reliance on external organisations	Is there a high risk that the intervention could be halted by external challenge, or relies on other institutions to implement and maintain policies to support the intervention?	5 point scale ranging from no risk (5) through to significant likely challenge but under well understood statutory planning arrangements (3) through to schemes that rely on new forms of co-operation between multiple, potentially conflicting institutions (1). See Appendix A guidance table F
E6: Engagement and understanding of catchment resilience	Likely to be on an exception basis with most interventions scoring 1. Reflects option benefits that improve the understanding and management of water environments and/or engagement of public and stakeholders with catchment needs.	5 point scale – notable, extensive positive benefits (5) down to localised but notable benefits (3) to no benefits (1). Positive benefits need to be described so that they can be moderated based on peer review.

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Table 5 Details of Scoring for Modelled/Fully Quantified Sub-Metrics Evaluated at the Intervention Level and Portfolio Level

Sub-metric	Description	Possible Approach
R1: Uncertainty of options supply/demand benefit	Baseline uncertainty in yield or reduction in demand from DM options. In the interests of simplicity this should be the combined uncertainty taking into account underlying factors (hydrological modelling etc) and climate change 90% confidence interval at 2050 . N.B. as this is part of the resilience assessment, then 'Final Plan' Target Headroom should not be included in the EBSD Real Options modelling.	Scores will be stored in the resilience assessment tool (RAT) based on the modelled option uncertainty ranges across all screened options. For each option a 90% confidence interval range should be input to the RAT using either the previous Target Headroom assessments (for smaller schemes) or the Pywr system simulator for larger schemes.
R4: Frequency and extent of drought permit/order effects on water bodies	Only relates to options that affect Drought Orders and Permits (i.e. mainly just Permit and Order options themselves, although there may be schemes that have indirect effects). At the individual option level the scoring just aims to capture the severity and magnitude of impact. Frequency is then introduced in the stage 2 system level modelling	Calculated based on extent of water body affected and level of risk severity as defined by the Drought Management Plan. See guidance table E. The sub-metric is then calculated as a frequency weighted impact using the system simulator once potential portfolios have been identified.
A1: Expected time to failure	Use baseline system simulator run to set initial value by WRZ. Impacts expressed as a percentage change from this for the option level, switched to impact at the sub-region level during Stage 2.	Metric calculated as mean time from resource state = 100% to resource state failure under critical events. Percentage change from this calculated across the same events.
A2: Duration of enhanced drought restrictions	Long term expected duration (days/annum) with Drought Orders/Permits and NEUBs in place. This is only modelled at stage 1 for strategic schemes; the main modelling will be carried out at the best value modelling Stage 2.	Straightforward system simulator (Pywr) output – change in duration multiplied by population affected.
A4. Availability of flow regulation	Measure of the length of river reaches where flows at the Q95 can be maintained at above the naturalised level throughout summer drought events	For each reach affected, value is equal to length benefitting multiplied by the Q95 as a scaling factor.

A6: PWS system connectivity	Population effectively provided with an alternative water supply where only a single source or bulk distribution route existed previously	The system simulator conceptual assessment should be used to identify bulk scale single points of failure (i.e. where a demand centre is fed by a single source, single transfer routes, or where there are limited existing transfer routes are already at capacity). The option is then scored according to the population that could effectively be switched to the new source of water. This is then checked again to review useable spare capacity at the stage 2 portfolio level within the system simulator.
A7: Catchment connectivity	Capacity of new transfers between catchments	Total transfer capacity between meteorologically distinct catchments, in Ml/d. It is important to demonstrate that there is evidence that the catchments have responded differently from each other during historic droughts (only some differences are required – e.g. the response to 1976 may be similar, but there is evidence that catchments responded differently during 1921).
E3: Intervention lead times	Lead time to plan and then implement option.	Total planning and construction/implementation time for the option/intervention

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Table 6 Details of Scoring for Modelled/Fully Quantified Sub-Metrics Evaluated at the Portfolio/System Level Only

Sub-metric	Description	Possible Approach
R2: Breaches of flow and level thresholds	Thresholds are identified and set for modelled water courses based on an assessment of representative Hands off Flow conditions for that water course. Measured as the percentage of time, on average, that flows fall below the HoF proxy threshold. Assessed in system simulator for stage 2 only.	Change in ratio – as a percentage
A3: Reliance on Drought Orders and Permits	Calculated from the economic model outputs. Percentage of Target Headroom that is addressed through Drought Orders and Permits.	Simple calculation form the economic model (DO of DPs divided by Target Headroom).
A8: Capacity surplus	Based on EBSD modelling. Indication of the amount of 'incidental' surplus generated by interventions (the plan still seeks to balance, but there will be periods of surplus). Sub-metric available at both Stages 1 and 2.	Percentage calculation - surplus divided by total demand as an average over the planning period.
E2: Diversity of planned interventions	Simple calculation of the probability-weighted relative contribution of yield/DM benefits from the interventions selected in a given portfolio. Sub-metric available at Stages 1 and 2.	Calculate based on EBSD RO model outputs. Equal to percentage of total supply/demand benefit delivered by each intervention category (demand, desalination, effluent re-use, reservoir/SW, groundwater). Applies to source only – resilience from transfers is reflected in other metrics.
E5: Flexibility of planning pathways	Assessed at the end of Stage 2 only, once adaptive pathways have been identified. Represents the ease and availability of pathway changes available under the adaptive plan.	Can only be assessed once the adaptive planning alternative strategies are known. Present to stakeholders as a mapped benefit based on the number and lead time available for pathway changes.

8.2. The Resilience Assessment Tool: Recording and Collation of Intervention Level Metrics

For all supply options, demand management strategies and other schemes, their water resource benefit, cost and resilience score is added to a database referred to as the 'Resilience Assessment Tool' (RAT). This tool has two main purposes:

1. It provides a reference, QA and cross check of the sub-metric resilience scoring and assessment for each intervention that is carried out by water companies or other parties involved in developing the Regional Plan.
2. It calculates the proportional benefit that each option contributes to the overall index score, which is used in the 'Best Value' model to generate an appropriate number of alternative investment portfolios that show the tradeoff between affordability (cost), environment and resilience.

The RAT will be an online database that can be reviewed remotely by water companies and allow for assurance and moderation by third parties as appropriate.

In order to calculate the contribution of each intervention to each of the three overall index scores that are used in the 'Best Value' modelling, it is necessary to apply the appropriate scaling and weighting coefficients to the sub-metrics so that they can be combined and optimised in the Best Value model.

This analysis only applies to the 15 sub-metrics that are evaluated at the individual intervention level. Metrics that are evaluated at the portfolio level are assessed once the initial range of potential Best Value portfolios has been identified, either from the initial Best Value runs, or from system simulation runs of the portfolios. The following method is used to generate an overall index impact score for each intervention.

- For the 7 subjectively sub-metrics the contribution for each option is calculated as:

$$Impact = \text{weighting factor} \times \frac{score \times option\ benefit}{total\ baseline\ deficit}$$

Where:

Impact = a non-dimensional score. The optimiser adds these together when it is carrying out multi-objective optimisation. In this case the intention is to minimise the total score for the index based on the sum of the intervention impacts.

Score = 5 point scale score for the intervention, as outlined in Table 4

Option benefit = supply/demand benefit of the intervention in Ml/d (i.e. the weighting is scaled according to the Ml/d benefit provided)

Total baseline deficit = the total deficit for that future situation for that year prior to investment (demand is based on 'business as usual' forecasts).

- For the 8 objectively modelled sub-metrics, the same calculation is used, but the RAT contains an internal calculation that places each intervention into one of 5 bands depending on how it scores in relation to all of the other shortlisted interventions in the database.

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This approach is simple and the weighting factors plus scoring of modelled sub-metrics can be readily shared with stakeholders. The outturn, benefit weighted impact factor for each intervention for each index will be clearly shown and can be sorted to examine how interventions trade against each other. This method is therefore transparent, whilst maintaining simplicity and avoid dynamic interactions between interventions within the Best Value optimiser. Stakeholders can see which interventions have been included within different alternative portfolios, with the intention that his provides confidence that a suitably wide range of tradeoffs between cost, environment and resilience factors has been considered in the Best Value modelling.

9. Key Assumptions

There are relatively few assumptions involved in the framework. The ones that are liable to have the most impact on the decision-making process are summarised in Table 7 below, along with the measures used to promote transparency and 'line of sight' between modelling steps.

Table 7 Description of the Implications and Management of Key Assumptions

Assumption	Impact on Decision Making	Measures Taken to Promote Transparency
Measured sub-metrics can be amalgamated to the index level in a scaled, additive way	Only affects the Stage 1 best value modelling and is used to generate ranges of potential alternative portfolios.	Resilience scores from individual interventions have been *scaled* according to the supply/demand benefit. The way that sub-metrics are weighted in the final index will be discussed with stakeholders and the RAT will allow for sensitivity testing.
Structured, subjective scores for interventions can be carried out consistently between different water companies and institutions	There is a danger that differences will be 'watered down' if similar option types are not being scored in a similar way.	Include a requirement to include justification of scores on a sample basis within the RAT so that this can be reviewed by a third party assurer
Frequency of Emergency Drought Orders (EDOs) is set at 1 in 500 as a 'must do' constraint rather than a modelled resilience variable.	The frequency of EDOs is set as a model constraint in the Best Value model, and does not feature in the resilience framework	The requirement has been clearly identified in the National Framework and the WRSE resilience framework clearly includes the role and impact of other restrictions as modelled variables, meaning that drought response and uncertainty is adequately and clearly covered

9.1. Engagement and Decision Making

As noted in the previous section, stakeholder engagement with the process and decision making is a key part of the resilience framework, and the framework has been designed so that engagement can feed into the process at relevant and meaningful points. At a conceptual level the inputs from customers, stakeholders and national policies are incorporated into the two stages of the resilience framework as shown in Figure 16. In practice this means we pose the questions to customers and stakeholders as described below that diagram. Further details of the customer and stakeholder engagement process are provided in the relevant engagement consultation methodologies

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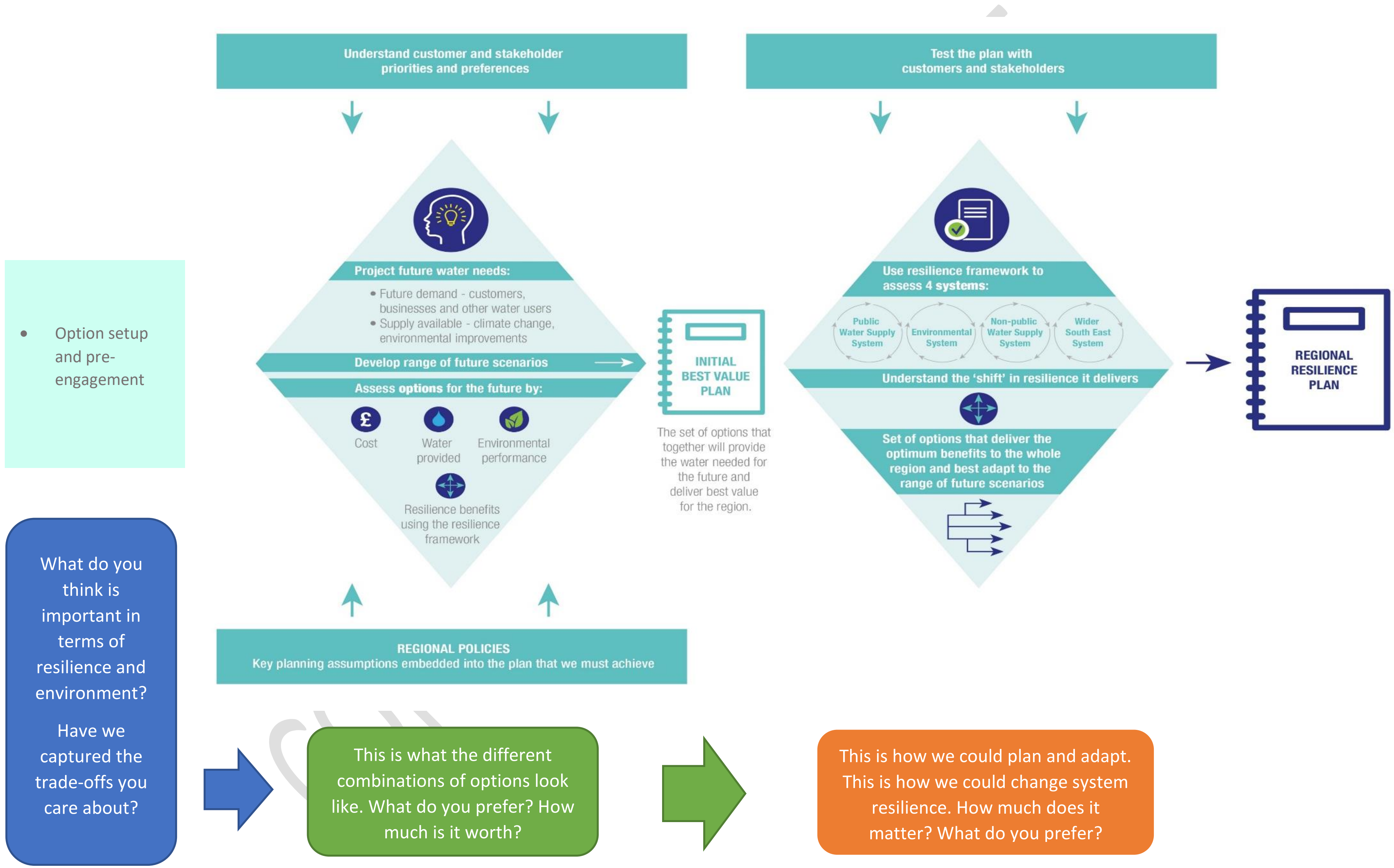
Figure 16 Summary of the Nature of the Engagement Questions Asked at Each Stage of the Process



10. Assurance and QA

Data assurance and QA is provided by the online RAT. This comprises of three elements:

1) Water companies carry out a self-checking process to ensure that information has been correctly uploaded.
2) For the subjective scoring, companies are provided with table guidance to support the process, and they are required to submit brief comments for a sample of schemes that score 1,2 4, and 5 against a range of sub-metrics. A third party assurance process is then carried out to ensure that there is a reasonable degree of consistency between company assessments.
3) Summary scores and visualisations will be explored and made available to stakeholders as required. The weighting system used to generate the overall index scores will be managed centrally and version controlled in the RA.

11. References

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Appendix A: Guidance on Structured Scoring

This will be added post consultation.

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