ATKINS

Member of the SNC-Lavalin Group

Regional Simulator Workstream

WRSE regional simulator

WRSE

August 2021

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Notice

This document and its contents have been prepared and are intended solely as information for WRSE and use in relation to provide a summary to WRSE of the first phase of the regional simulator workstream

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Rev 1.0	Draft – for WRSE review	JD	JJ	LP, AG	BA	20/07/2021
Rev 2.0	Final – update following WRSE review comments	“	“	“	“	12/08/2021

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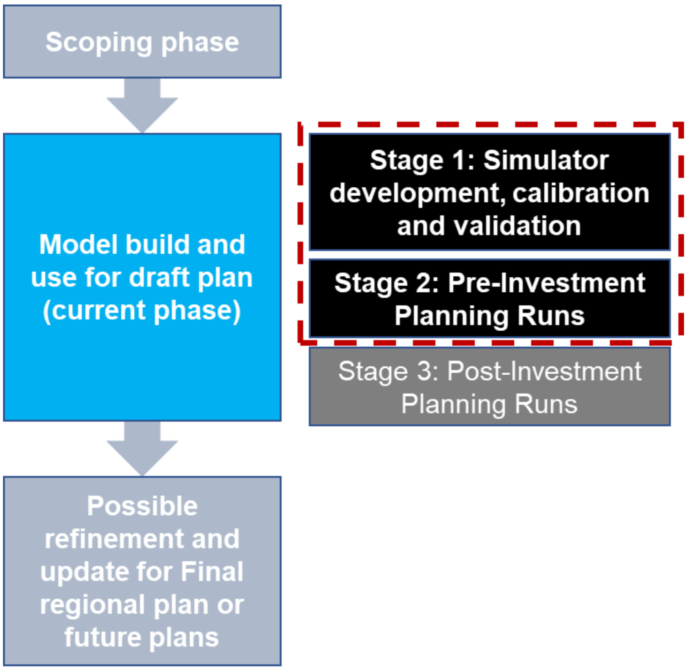
1. Introduction

1.1. Purpose of this report

The purpose of this report is to describe the water resources modelling that has been developed and undertaken for WRSE to support its draft regional plan (RP). The report therefore includes discussion of the following:

- A summary description of the model build process, in terms of:
  - Building the sub-models
  - Combining the sub-models into the regional system simulator (RSS).
- A summary of the validation processes and key assumptions for each sub-system.
  - Validation of the sub-models against WRMP19 water company models and/or data
  - Validation of the regional simulator against the sub-models and against expected behaviour
- A description of the modelling applied during the pre-investment planning runs.

1.2. Scope of works



The scope of works was defined through an earlier Scoping Phase.

The current phase of model build and use for the draft regional plan is summarised in Figure 1-1 below, highlighting the processes and sign-off approach (developed from the Scoping Phase[1]). The figure presents the stages involved for this current phase of modelling work, including a high level summary of the actions, interfaces and outputs.

There are three key stages involved within this current phase of work for the regional simulator to support the development of the draft regional plan:

- **Stage 1 – Build and validate the regional simulator**.
- **Stage 2 – Pre-investment planning runs**: Providing a baseline assessment to generate some of the **inputs needed for the investment model**.
  - Outputs are generated at the level of Water Resource Zone (WRZ) – which is the spatial building block used in the supply demand balance.
  - Review and sign-off of outputs by water companies
  - Each sub-model can simulate DO individually within the RSS (which is required to derive WRZ-level DOs) with dynamic links enabled between sub-models to ensure the appropriate interaction through the RSS. The RSS has the functionality to be simulated as a single model, however this was not required in Stages 1 and 2
- **Stage 3 – Post-investment planning runs**: Using the simulator to undertake **portfolio sensitivity testing** using the outputs from the WRSE investment model. [*Note that the outputs of Stage 3 are not part of this report*]

These three Stages are discussed further in Section 1.3, and then in subsequent sections.

[1] Atkins, Feb 2020, WRSE Simulator Scoping: Addendum – Sign-off process and model performance framework

Figure 1-1 - Summary of stages, tasks, activities and interfaces

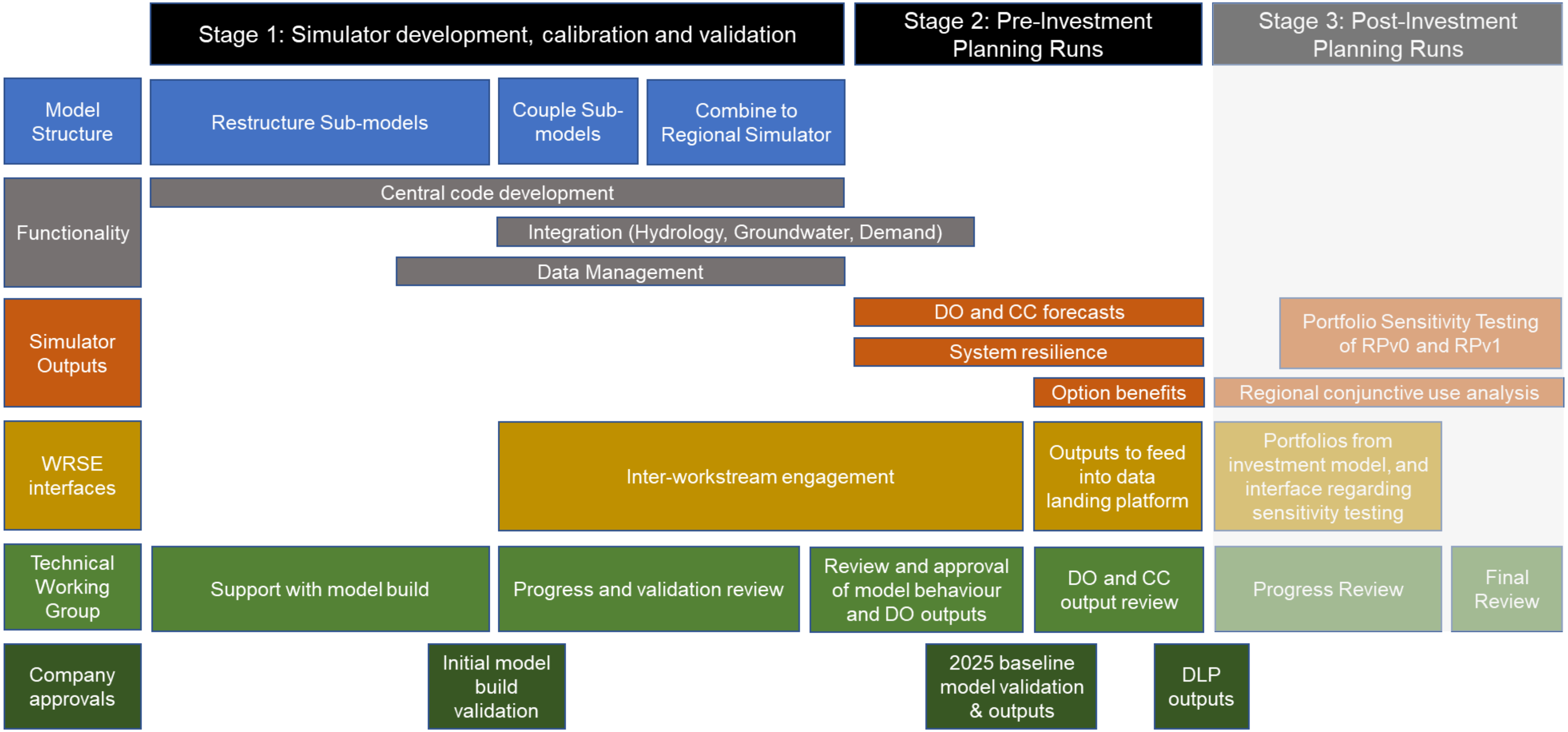
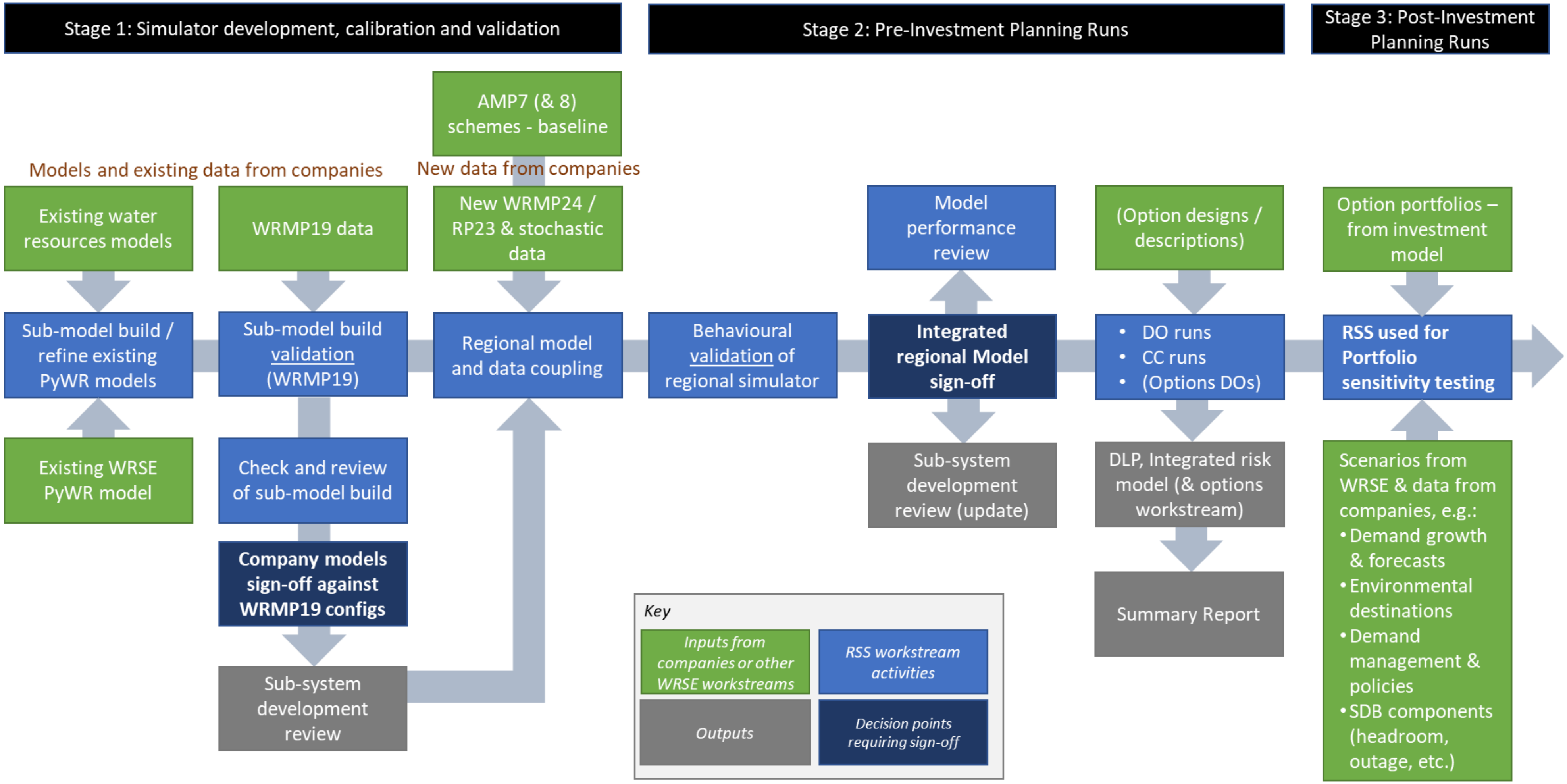


Figure 1-2 - Model development, validation and outputs



1.3. Modelling stages

The modelling approach has been summarised in the flow chart presented in Figure 1-2 above. There were effectively three stages of modelling work. Stage 1 and Stage 2 have been completed with Stage 3 pending. The actions under each stage were:

Stage 1: Development of the regional simulator for WRMP24

- Reviewed and used existing WRSE PyWR model structure (where it was appropriate to do so)
- Gathered WRMP19 company water resource models and reviewed representation of supply system
- Built WRSE sub-models in PyWR
- Validated WRSE sub-models against company WRMP19 water resource models and data
- Captured the process to review the PyWR model build and identified the refinements needed to update the model for a 2025 baseline
- Companies provided sign-off on each of the WRSE sub-models
- Companies provided new WRMP24 data, such as new hydrology developed from the updated regional stochastics work, and relating to climate change scenarios
- Data processed for integration in new WRSE regional model
- The new WRSE sub-models were integrated into the RSS.

Stage 2: Use the simulator to provide inputs to the investment planning workstream

- Companies advised the assumptions to use in the WRSE regional model to represent the 2025 baseline
- Validated the new WRSE RSS incorporating the new stochastic data and set up the models with a 2025 baseline
  - Companies reviewed initial outputs to ensure they were consistent with expected results and any available relevant comparative data.
  - Where necessary, revisited the model and initiated any further development or refinement as required.
  - Models signed-off
- Developed WRZ-level deployable outputs (DO)
- Developed DOs for demand savings from drought interventions, where requested (to aid comparison with WRMP19 analyses)
- Developed WRZ-level climate change DOs for all 28 climate change scenarios
- Provided outputs to the Data Landing Platform and to companies to upload to the Options Database
- Companies reviewed the outputs and accepted their use for the investment planning workstream

  The original scope included the potential to model a small selection of 30 options in the RSS. However, there was insufficient time to undertake this during stage 2. Although DO analysis was provided to a number of SRO schemes, and to inform company allowances for demand-side drought interventions.

Validation of the regional simulator in both Stage 1 and Stage 2

- The first phase of validation occurred in Stage 1 and involved validation of the sub-model build against WRMP19 models, configurations and outputs
- The second round of validation of the simulator in Stage 2 was to ensure that the model behaved appropriately given a number of key changes from the Stage 1 model build validation, and against the new stochastic hydrology provided by the companies.

Stage 3: Use the simulator to assess the outputs from investment planning

The scope of stage 3 will be reviewed and agreed prior to commencement of that work. The below describes potential elements of scope that may be considered under stage 3:

- Agree scenarios that require testing in the simulator
- Obtain data relating to the key scenarios for two future points in time (referred to here as “time slices” for testing the portfolios available at that point in time, e.g. in the years 2040 and 2050, or similar) – from water companies and/or other WRSE workstreams and data landing platform

- Set up the simulator for the time slices with demand growth and other scenarios
- Agree portfolios to test (informed by investment modelling workstream outputs review)
- Incorporate options details into the simulator
- Run the simulator for the selected portfolios – for both time slices
- Produce required outputs, including metrics for the resilience framework
- Potentially, there may also be a requirement to support companies with DO assessments of certain strategic options (including supply side drought options) and to examine conjunctive use benefits, to inform necessary revisions to the options data sets for future regional plan iterations.

Each of these stages is described in greater detail in the following sections. However, the outputs from Stage 3 do not form part of this report.

1.4. The Technical Working Group

A key component to the successful delivery of the regional simulator was close engagement with each company's designated modeller or representative, and the formation of a Technical Working Group to oversee the direction of the project.

This was a component identified during the Scoping Phase, which concluded that a Technical Working Group would be formed with the following broad responsibilities:

- Assist the developers with the model structure build / enhancement
- Review development progress and help to update and reprioritise the development plan where necessary
- Review final outputs and provide technical advice to overall approvers.

During the simulator development (Stage 1) the review by the Technical Working Group covered four aspects:

- Performance against model framework
- Functionality against scope, for example the ability to run stochastic datasets
- Progress against the latest programme
- Consistency with other (developing) WRSE workstreams.

The Technical Working Group worked together to consider and update the development programme to ensure that:

- Development tasks were appropriately prioritised
- Activities were still in-line with the programme
- Outputs were still aligned with the requirements of other workstreams and the overall WRSE assessment.

Once simulations were underway (from Stage 2), the group were required to perform an active role in reviewing the outputs to ensure they would meet the requirements of WRSE. Whilst the scope set out a defined period for the development phase, the reality was that modelling runs tended to highlight the need for some additional development or refinement – i.e. the process was more iterative.

The designated modellers in each company identified key aspects and components of the sub-models that required detailed validation and satisfactory performance before being signed off.

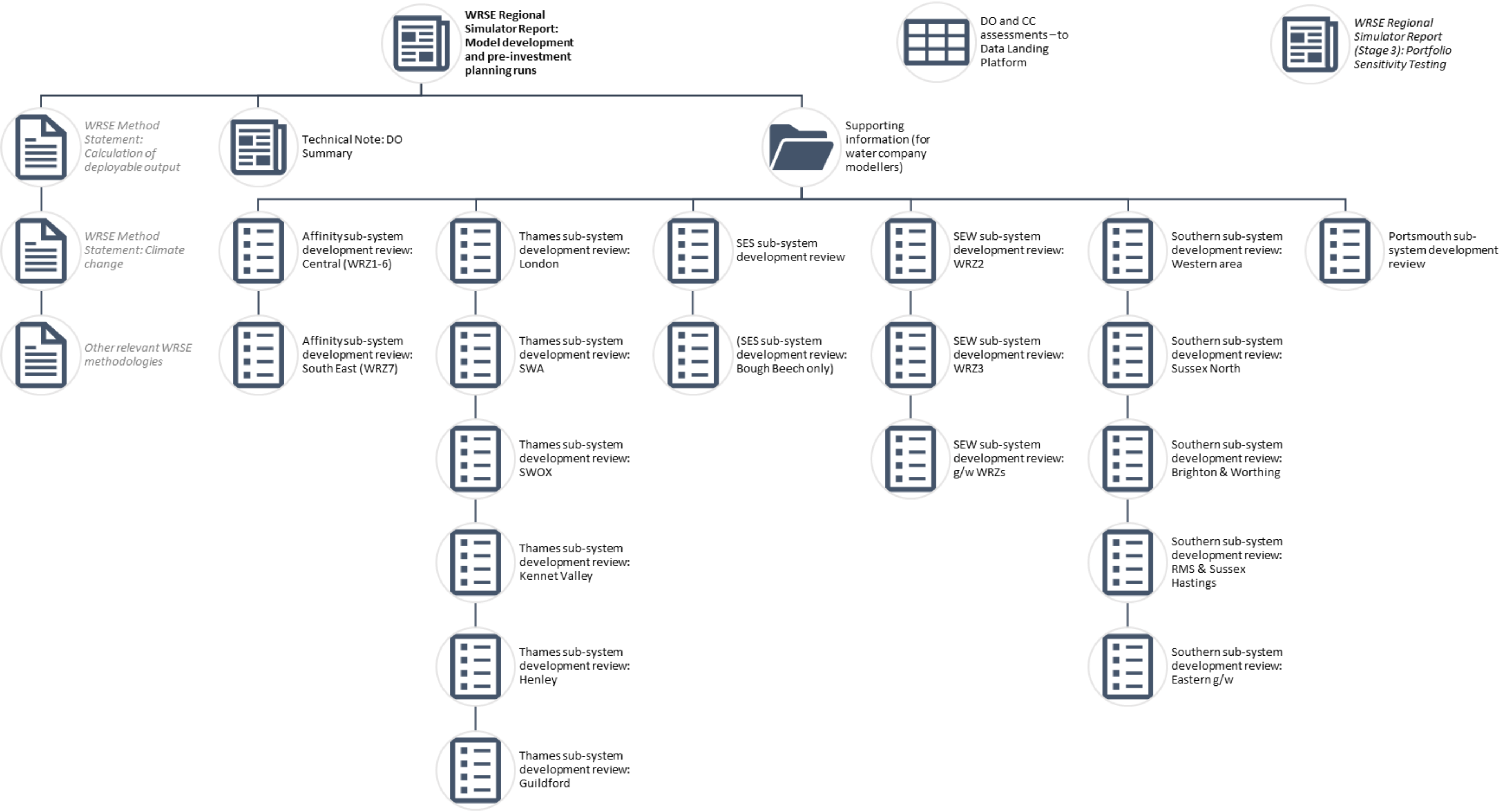
1.5. Outputs from Stages 1 and 2

The outputs from Stages 1 and 2 have been summarised in Figure 1-3.

For each sub-system, a development review sheet was produced – these describe both the model build and testing process (Stage 1), and the 2025 baseline set up and validation (Stage 2).

The DO assessments were fed into the Data Landing Platform (along with other supply side data inputs). Climate change assessments were also assessed in the Simulator, with post-processing out of the simulator, prior to being submitted to the Data Landing Platform (as described in Section 3.8). A separate Technical Note was produced to describe the process for undertaking DO assessment for each WRZ and the outputs that fed into the Data Landing Platform.

Figure 1-3 - Summary of outputs from the RSS workstream



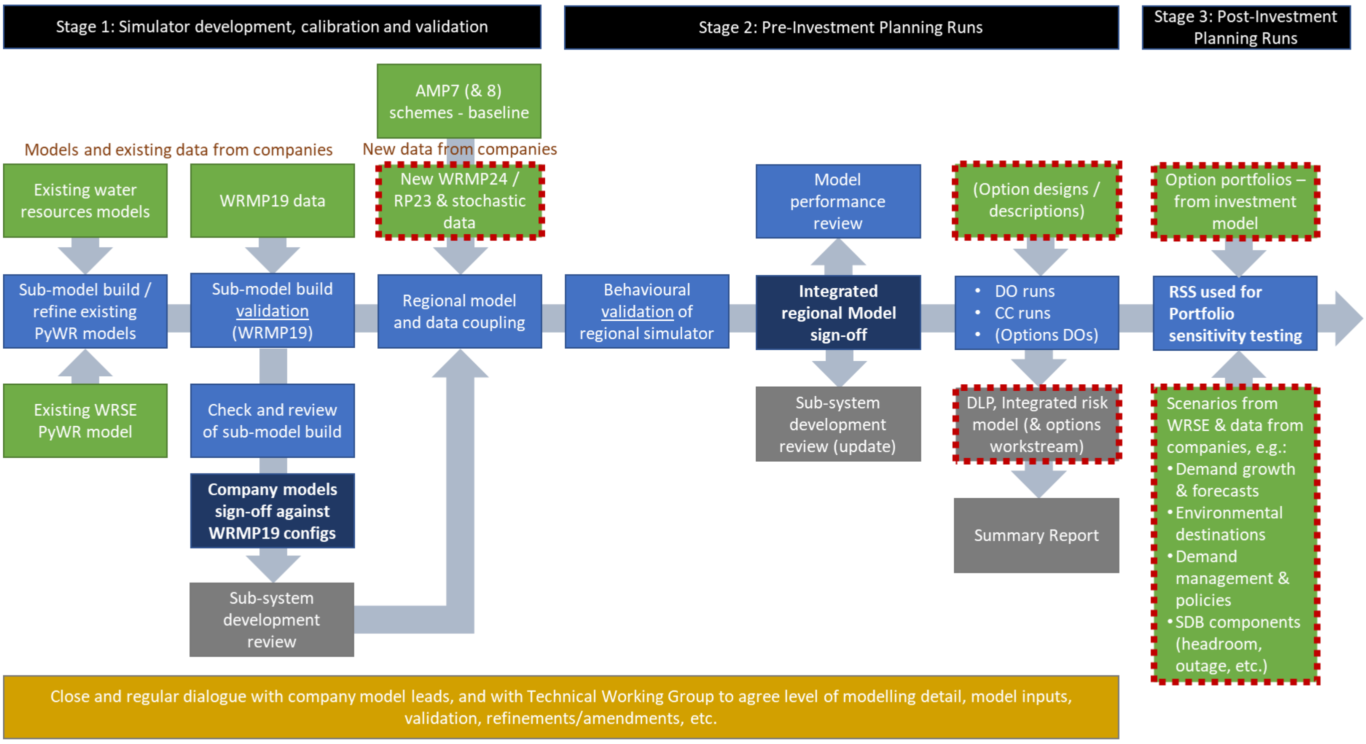
1.6. Dependencies on other WRSE workstreams

The RSS is dependent on inputs from other WRSE workstreams, in addition to inputs direct from the water companies. The outputs from the simulator are also required as inputs to other WRSE workstreams.

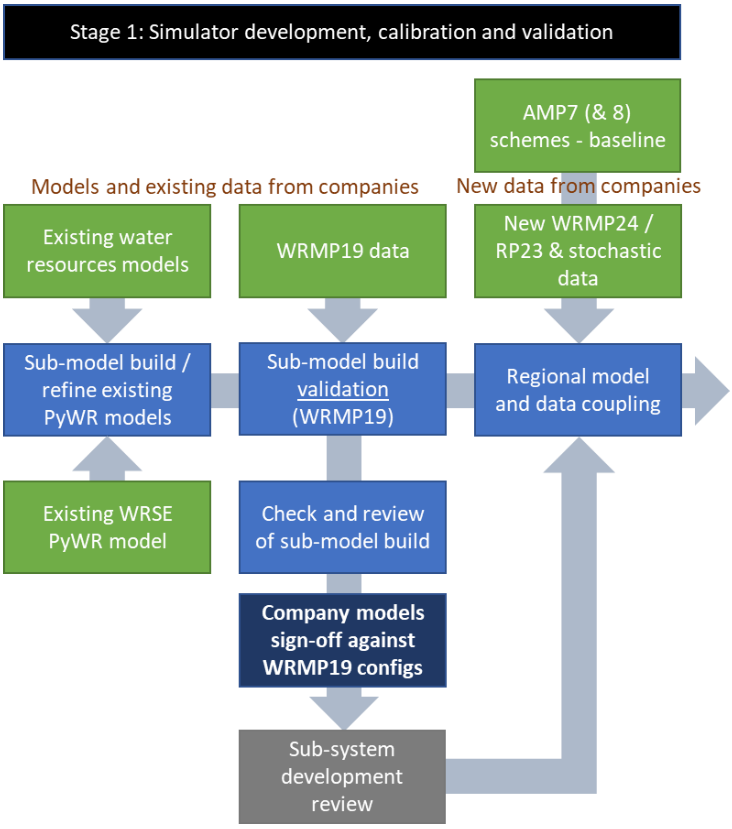
The flow chart below summarises the key interfaces between the workstreams – these have been highlighted as boxes with dotted red lines. The box highlighting new WRMP24 data had the greatest potential number of workstream inputs – these are described further in section 2.6.

Note also the regular dialogue with the companies throughout Stages 1 and 2 – in accordance with the scope of the Technical Working Group (as previously described in section 1.4), to ensure that the model would meet company requirements.

Figure 1-4 - How the RSS fits with other WRSE workstreams



2. Stage 1: Development of the regional simulator for WRMP24



2.1. The Regional supply system

The WRSE region is comprised of six companies:

- Thames Water
- Affinity Water (Central and South East)
- SES Water
- South East Water
- Southern Water
- Portsmouth Water

Each company area is broken down into water resource zones (WRZs) – the base spatial unit used in water resource planning. Figure 2-1 shows the location of the 36 WRZs in WRSE. These WRZs and the geographical spread of companies across the south east leads to a number of distinct sub-areas – as indicated in Figure 2-2. These were used to inform the structure of sub-systems in the RSS.

Figure 2-1 – WRZs in the regional supply system

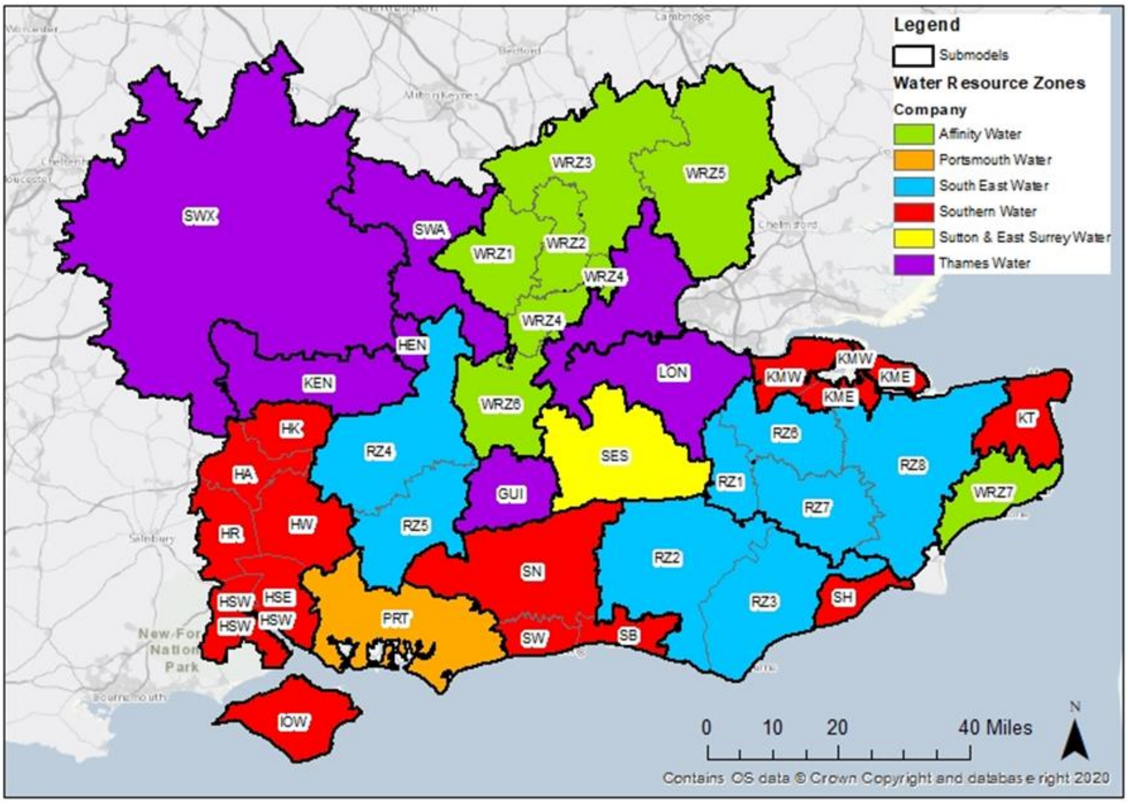
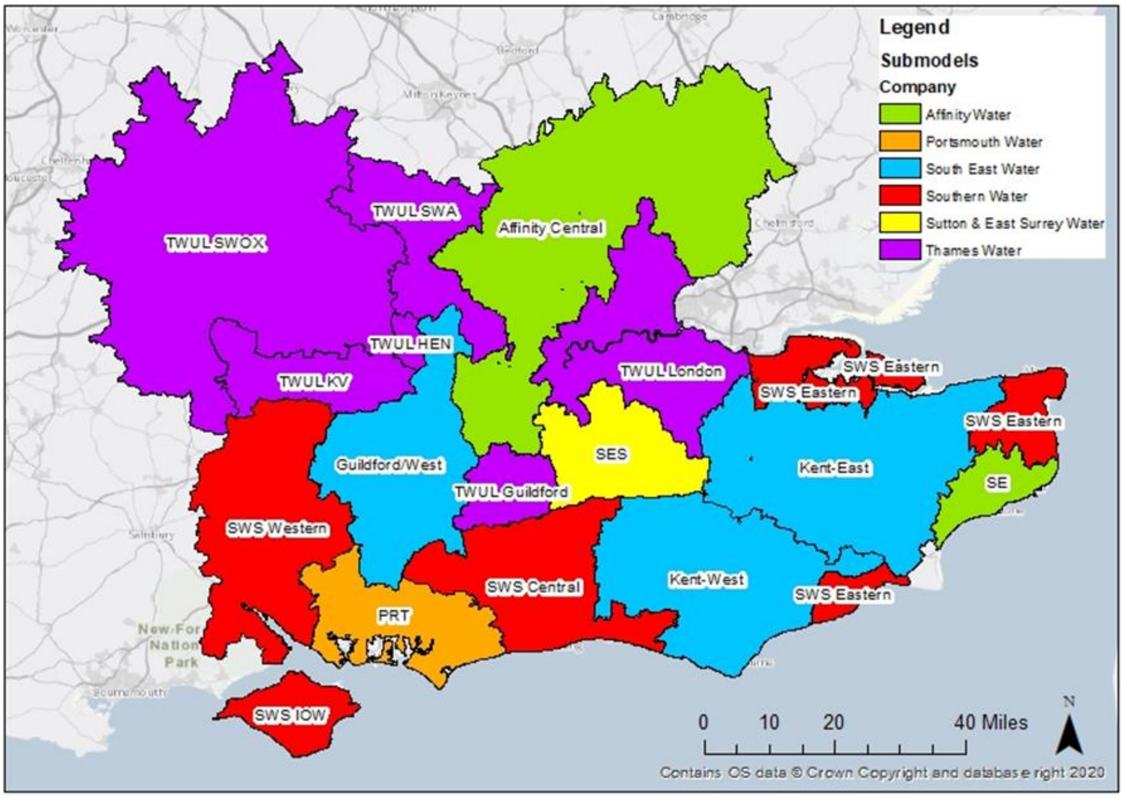


Figure 2-2 – Company supply areas in the RSS



2.2. Sub-model build and validation of WRMP19 configuration

The previous WRSE PyWR model (developed in AMP6 to inform companies' WRMP19 submissions) was used as a starting point to generate a model structure (i.e. model nodes and connections representing the supply network). The objective was to build on the previous work, build in additional complexity and functionality, including simulating a greater number of WRZs, whilst also providing a pragmatic trade-off between run speed and accuracy (particularly in terms of replicating existing, more detailed company water resource models).

A significant amount of development was dedicated to updating and improving the "central code" of the simulator. This included, for example:

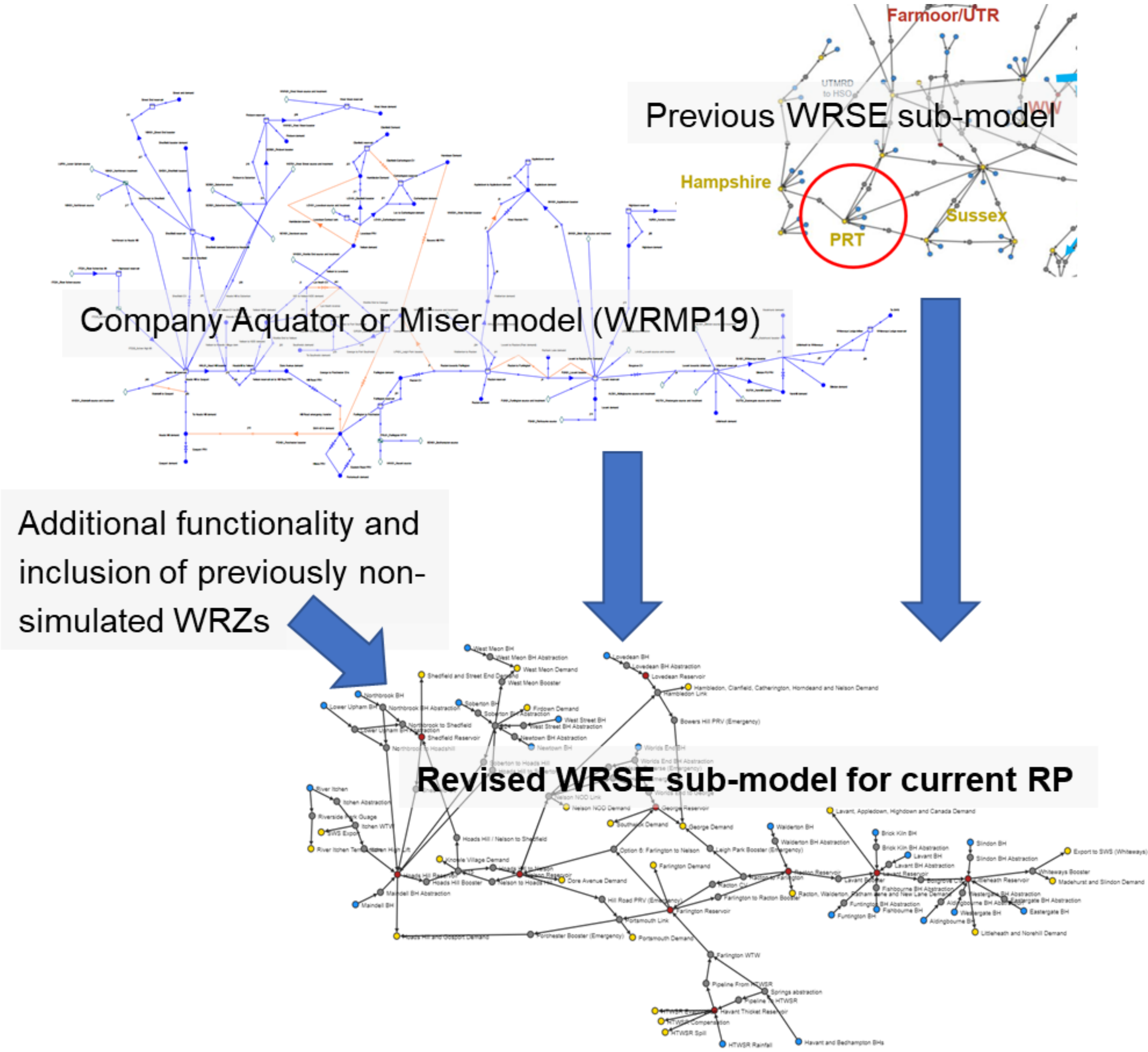
- Reflecting the latest existing water company water resources models
- Updating to the most recent version of PyWR
- Development of new PyWR models and inclusion of previously non-simulated WRZs, for which there were no previous company PyWR models / representation in the AMP6 version of the regional model, or where there was no company water resource model available (for example: SEW groundwater, SES groundwater, Medway/Thanet groundwater, Brighton and Worthing groundwater, Affinity Central and South East)
- Incorporating the capture of required system performance metrics into the simulator
- Implementing a daily timestep (the previous model had a weekly time step)
- Implementing additional functionality requirements from the Phase 1 scoping report, for example adding a deployable output (DO) analyser.
- More dynamic representation of groundwater sources, where appropriate, in accordance with the groundwater framework approach adopted by WRSE. The companies provided the groundwater inputs to the regional model as time series, profiles, etc.
- Use of Azure and the Github flow process to manage model development ensuring that code is checked and reviewed before being merged into the master branch, thus embedding quality assurance into the model development process.

Every effort was made to incorporate elements of companies' supply systems which they deemed to be important to their own planning. This was to ensure that the model would provide a useful tool for the companies, not just for the initial development of the draft WRSE plan, but for iterations and sensitivity testing of the regional plan and through to development of the companies' WRMPs. There was close collaboration with the companies to try to ensure that the RSS would run efficiently, perform well in the areas of high strategic importance to WRSE and the companies, and facilitate the high priority functionality requirements specified during the Scoping Phase in 2019. The companies' requirements were captured in the document review sheets for each sub-model and used to prioritise and focus the model build and validation process.

It is worth noting that, at the request of companies, the model is significantly more complex than the previous regional model developed during WRMP19. The PyWR model developed for the current regional planning process has many more links, nodes and customer parameters than was present in the AMP6 version of the PyWR model. Whilst the additional level of complexity did vary across different sub-systems, across the regional model there are around five times more nodes and 16 times more custom parameters.

The regional sub-models were set up to validate against the outputs of the companies' WRMP19 models, where they existed, and against WRMP19 data. Previously non-simulated WRZs were also incorporated into the regional model sub-systems – so that in the current regional model almost all WRZs have been modelled.

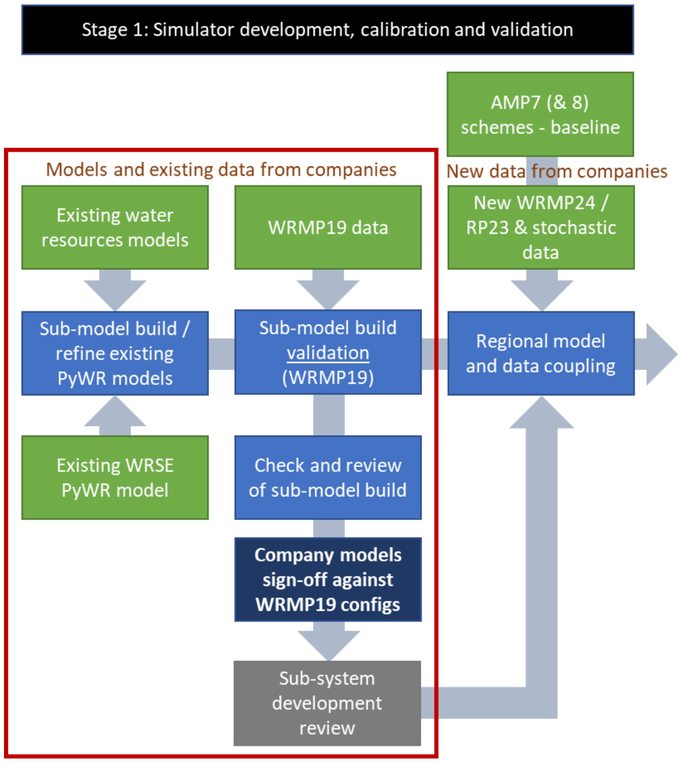
Figure 2-3 - Process of developing the RSS



2.3. Validation of sub-models against company WRMP19 models

The first phase of validation was the Stage 1 validation of the sub-model built against WRMP19 models, configurations and outputs.

For most areas, the performance of the new PyWR model, network configuration and any revised assumptions, was tested against the existing WRMP19 models, using the WRMP19 data inputs for consistency.



2.3.1. WRMP19 hydrology data

The hydrological data used in Stage 1 was that which was available from the companies. The aim was to use the same data to ensure that the validation of the models against existing WRMP19 models was comparable.

2.3.2. WRMP19 demand data

Demand profiles were based on those used in the WRMP19 models, or in WRMP19 analyses. These were provided by the companies.

Again, the key was to use the same data to ensure that the validation of the models against existing WRMP19 models and outputs was comparable.

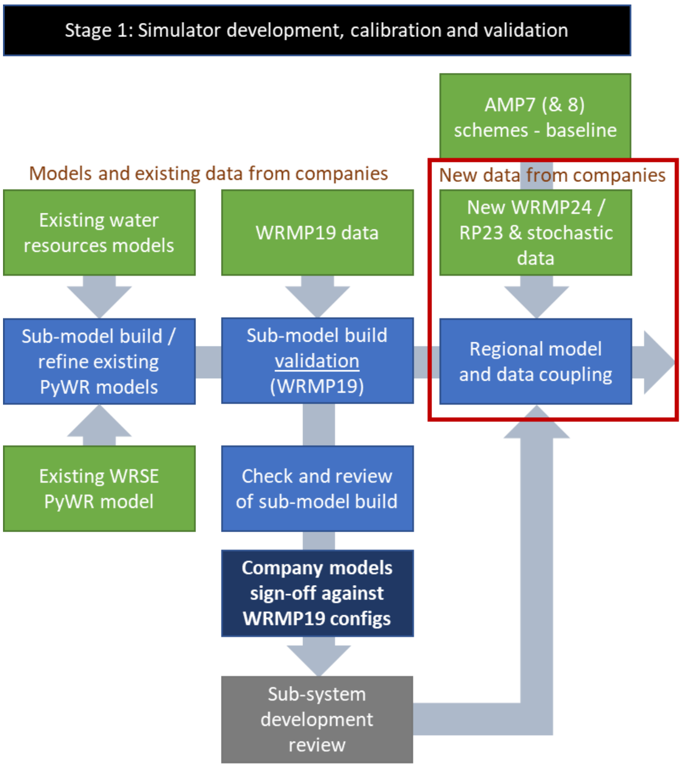
2.4. Sub-system development review

To ensure consistency in approach across the region, between different companies and sub-regions, a standard approach was adopted to recording the model build process and the check and review of the model build process. This involved the check and review process performed by the modelling team, and then also by each company on the PyWR model representation of their supply system.

The check and review process was recorded in the sub-system development review sheets for each company. These underpin the development and approval of the model set up, based on WRMP19 information and data. Regular working group meetings (monthly between April and September for Stage 1; and then fortnightly from October through to March for completion of Stage 1 and throughout Stage 2) also ensured consistency in the model development process.

2.5. Regional model coupling

The RSS was developed by coupling the sub-models together, including the previously non-simulated sub-models, new AMP7 data sets (see section 2.6), and any updated network configurations and assumptions that would better reflect a 2025 "baseline" for the sub-system and the region as a whole. This therefore included newly implemented schemes that would affect the supply system, but did not include previously selected WRMP19 schemes that had not been implemented during AMP7 (or for which the uncertainty of the successful implementation of the scheme was too great). Any non-implemented WRMP19 schemes were instead included by the water companies as options that would be available to be selected as part of the WRSE investment modelling workstream.



The DO methodology meant that the sub-models developed required separate DO simulations, as the objective of the project was not to develop a regional DO, and therefore the RSS needed functionality to simulate WRZ level DO. Each sub-model can simulate DO individually within the RSS, with dynamic links enabled between sub-models to ensure the appropriate interaction through the RSS. The RSS has the scope to be simulated as a single model, however this had not been a requirement during the modelling for Stages 1 and 2.

The document review sheets detail how the sub-models interact with each other through the RSS. Not all connections between different WRZs and Company Areas were simulated. Only the ones agreed with the Water Companies were simulated. For example, most small emergency connections between WRZs or Company Areas were not simulated, although bulk supply arrangements were included.

2.6. Data coupling

The data coupling task involved collating relevant input data for use in the 2025 baseline model from the companies (some of this was developed by the companies, some by other WRSE workstreams). Figure 2-4 below summarises those data sets that were coupled in the PyWR model. A consistent database format was developed to enable Water Companies and WRSE to provide the data in a way that could be readily utilised in the RSS, updated and quality assured.

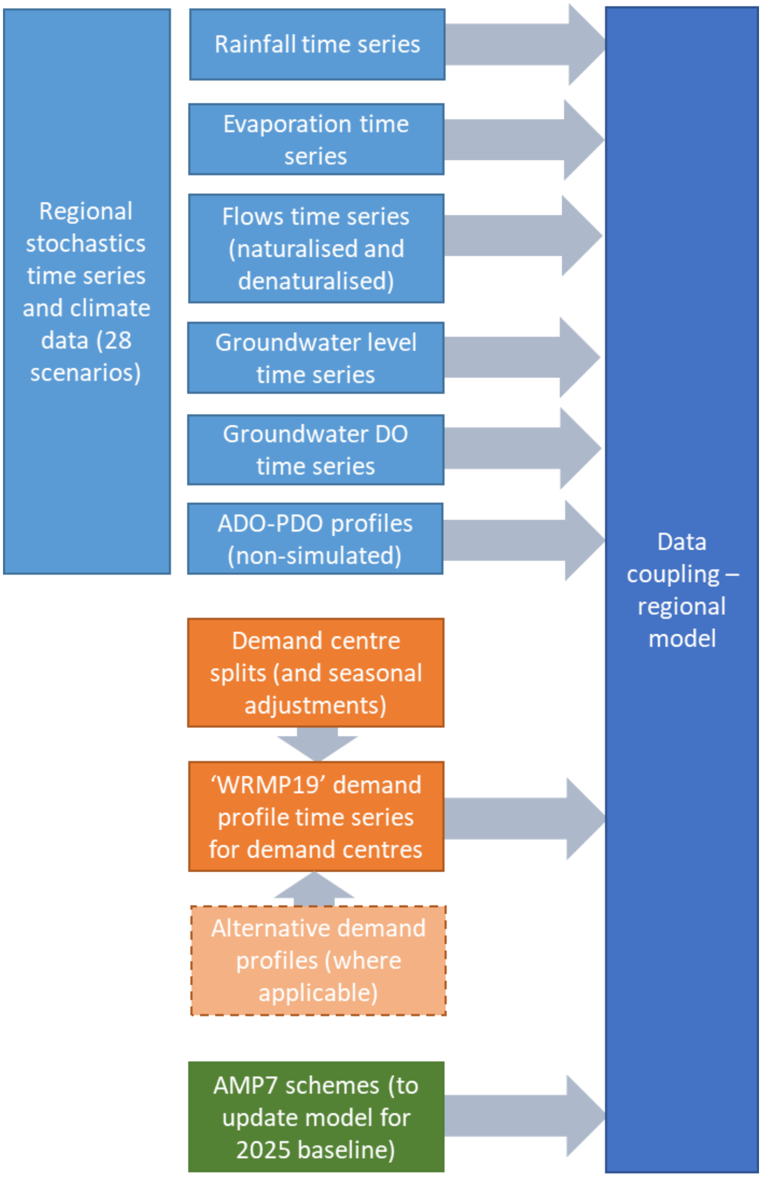
Even though the data was quality assured by the Water Companies and/or WRSE prior to being received for the RSS, all the temporal data-sets provided were run through a generalised PyWR model to ensure that the data provided was in the correct format and did not cause any errors prior to integration in the RSS. The stochastic data provided was also compared with data used in WRMP19 to check that the scale and ranges of data provided were appropriate.

The demand inputs applied existing water company demand information, profiles and demand centre splits, with only limited adjustments made for the RSS where necessary.

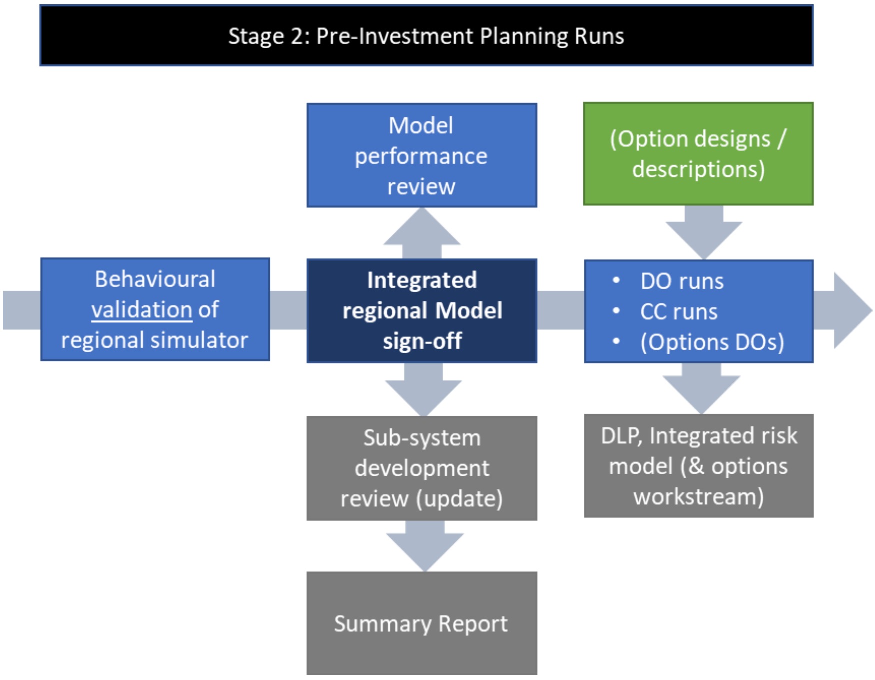
The Water Companies also provided information on AMP7 schemes and / or operational changes in AMP7 which were simulated directly in the RSS baseline model. Demands and AMP7 configurations are detailed in the sub-system development review sheets.

Whilst the full stochastic datasets were run through the RSS, the climate change methodology constrained the climate data-series applied in the RSS. Further detail is provided in the WRSE climate change methodology.

Figure 2-4 - Baseline 2025 model data integration – data from each water company



3. Stage 2: Use the simulator to provide inputs to investment planning



3.1. Factors and principles for validation of the regional model against latest WRSE data

The Scoping Phase identified a number of factors and principles to be followed in the validation of the regional model. These have been considered through the validation of the regional model in Stage 2:

- It will not be necessary for all metrics to be checked across all parts of the simulator, as this would be inefficient
- Comparisons should focus on key nodes and metrics, which will vary across different parts of the model and according to the outputs of other WRSE workstreams
- The design of the simulator is governed by a series of trade-offs, the most important of which is system detail and accuracy versus model run speed
- Creating a RSS is significantly more challenging than simply reproducing the existing water company model outputs as we need a simulator which both:
    - Achieves a good match against water company models using the same input data; and
    - Adapts to the new types of conditions that will be present in the WRSE scenarios.
- Company water resources models and their real operational rules have all been developed using historic conditions (sometimes focusing on only a single drought event). Introducing new patterns and severities of droughts and climate change perturbations can cause significant issues with the rules contained within water resources models
- The development of the simulator should be performance-led. Decisions should be taken with a view to maximising the performance of the model for its specified roles, required WRSE performance metrics and in the WRZs which are most critical to the WRSE regional plan
- The vast majority of water company models are at present checked qualitatively, for example by visual inspection of plots or sense-checking of behaviour

- It is critical to ensure that the sign-off process is as efficient as possible – there is not sufficient time to spend chasing smaller or less relevant gains in performance
- Key to focus on those metrics and nodes which relate best to the simulator role and WRZ under review
- Focusing checks on downstream nodes means that the operation of nodes further up the chain is inherently accounted for
- Comparison of outputs from simulating new WRSE scenarios will need to be constrained and targeted to the types of conditions that are most likely to influence the regional plan.

Not all the principles apply to each sub-model; the sub-system development review documents for each sub-model outline how the focus varied across the RSS.

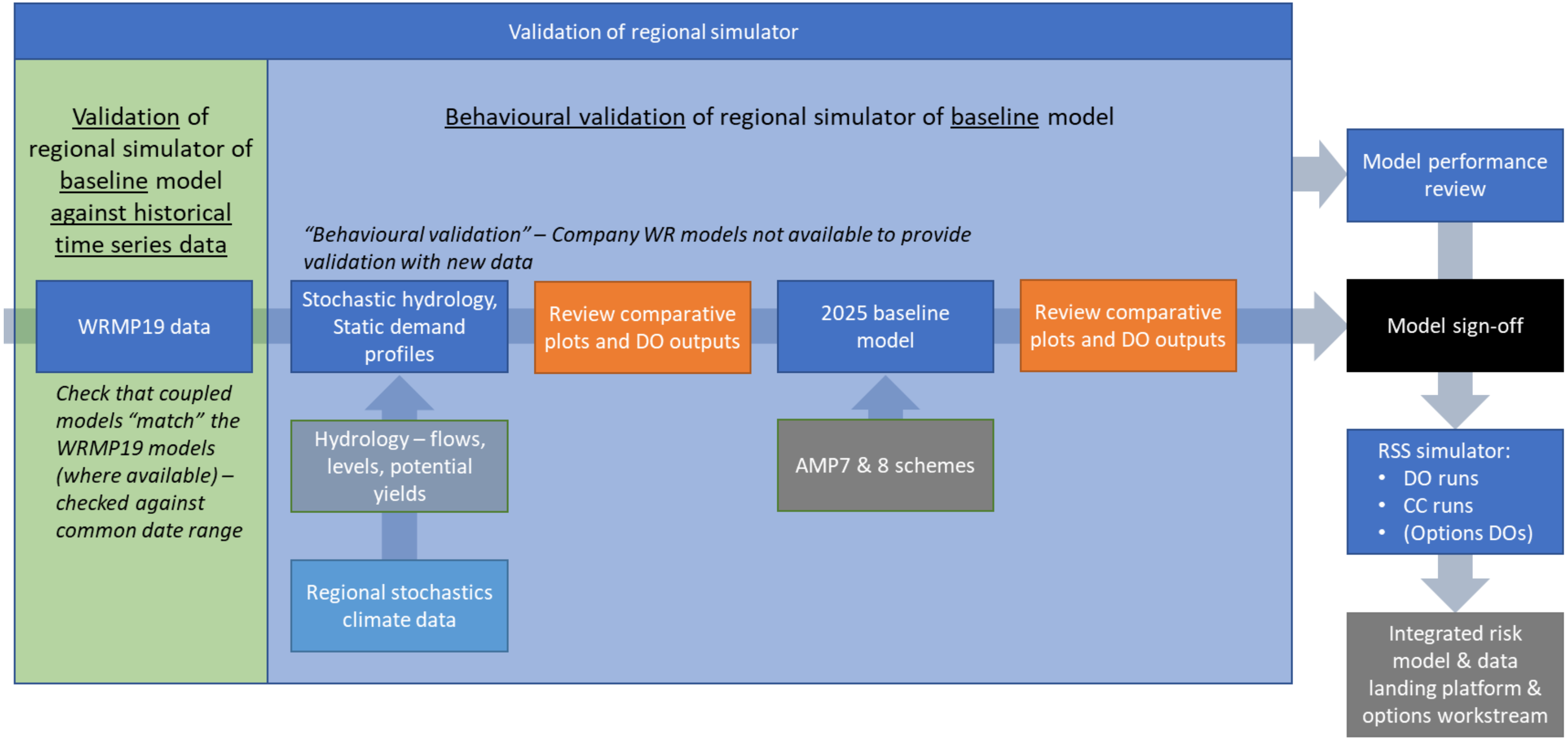
3.2. Validation of the regional simulator

The second round of validation of the simulator was targeted at ensuring that the model was behaving appropriately given a number of key changes from the model build validation that took place in Stage 1. These were:

- Inclusion of new stochastic hydrology that was developed for the current regional plan
- The coupled regional model incorporating changes to reflect a 2025 baseline condition – i.e. including key changes from WRMP19 and funded changes to the supply system during AMP7
- Potential revisions to the demand profile used – in a limited number of cases, alternative demand profiles were applied to reflect, for example 2018 demands.

The companies advised that there would not be sufficient time to update their existing WRMP19 models (Aquator, etc.) to reflect the 2025 baseline and to incorporate the latest WRSE data sets, so the performance of the 2025 baseline PyWR model outputs was examined through a behavioural validation – as represented in the flow chart in Figure 3-1 below.

Figure 3-1 - Validation of the RSS in Stage 2



3.3. Model performance review

The model build phase took longer than originally projected to ensure there was the desired level of detail in the model as requested by the companies. The benefit of this was a more detailed tool for WRSE to use in future iterations and refinements of its plan, and for companies to use for their own scenario testing purposes. However, the trade-off was the impact this had on the programme – with a subsequent need to reduce the amount of detail developed for the pre-investment planning runs in Stage 2. This was explored within the Technical Working Group.

Some elements identified during the scoping phase were not included – generally because there was insufficient time:

- For another workstream to complete its work to feed into the RSS; or
- to include it in the RSS given the desired increase in complexity of the model; or
- to generate all the input data across the full range of stochastic time series.

The review of these elements and decisions on whether or not to amend the scope were discussed over the course of the project and agreed with the Technical Working Group. Some examples include:

- The demand workstream, which feeds into the RSS. Dynamic demands would have been required early in the programme to ensure they could be appropriately incorporated in the model and to understand the impact they were having on the modelled system; but the dynamic demands were not available and signed off by the companies in sufficient time to do this. Instead, existing company profiles were maintained and used. It may be a potential future refinement to the model to apply dynamic demand, although it will require sufficient time to ensure the model can be appropriately validated (which may also require some dynamic demand modelling in the companies' own water resources models).
- Options assessment was intended to be run for a small number of options, but this was not achievable in the timescales. Instead companies developed their own DO estimates for all options, while a small amount of DO assessment runs were conducted for some of the SRO schemes – see Section 3.9.
- Climate change was sub-sampled, not fully run. This was due to two factors – the time and computing needed to generate the inputs required for the RSS from the company hydrological models if using the full stochastics set of 400 replicates for all 28 climate scenarios, and the time to then generate DO impacts in the RSS for all 28 scenarios. See section 3.8 for further description.
- Whilst the RSS workstream provided input into the environmental ambition workstream by outlining the model set-up so they could undertake an assessment of environmental impacts, no environmental ambitions were examined in the RSS during Stage 2. This was not specifically identified as a requirement at the outset, and nor was the work of the environmental assessment workstream available in time to feed into the RSS.

Nevertheless, the primary output from Stage 2 – baseline DO and climate change impacts – were delivered to the data landing platform to combine with other inputs to generate the supply demand balances required as inputs to the investment planning workstream.

3.4. Sub-system development review (2025 baseline update)

The changes from the Stage 1 model development to the 2025 baseline with the latest data sets were captured as part of the sub-system development review and were examined through frequent (roughly fortnightly) Technical Working Group meetings. Note that for some sub-models there was no prior WRMP19 model to use for the earlier development, so they were set up from the outset as 2025 baseline models.

3.5. Model sign-off

Each sub-system was reviewed with the relevant company to confirm that the key parts of the system were performing as expected, and to understand the magnitude of changes to DO and what was driving those changes from WRMP19 DO values. Changes from WRMP19 DO values do not necessarily imply that the RSS sub-system model was not performing well or was poorly validated; instead, different DO values can reflect the impact of changes to the input data sets, the model configuration, and updates that have occurred since the WRMP19 models were developed. They may therefore reflect a more appropriate DO value for use in the current WRMP24 plans. The key is to understand, for DO values that have changed, where the changes have occurred and why.

Each company confirmed their acceptance of the regional model configured for a 2025 baseline (i.e. incorporating key changes to the supply system since previous modelling for WRMP19) combined with the new stochastic hydrology. This was captured in the Sub-system Development Review documentation. Table 3-1 below sets out the sign off of the models by each company.

With confirmation that the 2025 baseline model was acceptable for each company, the pre-investment planning runs were undertaken to develop the outputs needed for WRSE's investment model. This is discussed in the section below.

Table 3-1 - Model sign-off by sub system

Sub-system	Sign-off date confirmed
Affinity Central (WRZs 1-5, and 6)	12 Mar 2021
Affinity South East (WRZ7)	24 Mar 2021
Thames London	12 Feb 2021
Thames (other)	12 Feb 2021 (Henley). Other WRZs through Mar 2021, as DO outputs were produced
SES	19 and 26 Feb 2021
South East Water WRZ2 WRZ3	5 Mar 2021
South East Water g/w zones WRZs 6 and 7	12 Mar 2021
Southern Water – Eastern Surface water KM and KT WRZs	 10 Mar 2021 5 Mar 2021
Southern Water – Central Sussex North Groundwater (SB/SW)	 3 Mar 2021 2 Mar 2021
Southern Water – Western	18 Feb 2021
Portsmouth Water	10 and 19 Feb 2021

Various model outputs were examined by the companies in order to satisfy themselves that the model and the outputs were appropriate, given any changes since WRMP19 and the use of models applied to some areas that had not been previously modelled.

The model outputs needed for sign-off of any given subsystem depended on the key features of that part of the supply system. Typically, this might involve plots of drawdown and abstractions to allow comparison with previous models, as highlighted below in Figure 3-2. It might entail close examination of particular years to observe the behaviour under different drought events or periods of interest.

Other outputs included "heat maps" to more easily understand where failures occurred across the stochastic data set (Figure 3-3), and plots of the deployable output against return period for different sources of failure in a given supply system (Figure 3-4).

The model sign-off process included examination of the DO outputs at a range of return periods compared to previous WRMP19 DOs for WRZs. Comparisons needed to be considered on a like-for-like basis – i.e. taking account of, for example, whether demand restrictions were on or off, including adjustments for known changes since WRMP19, and consideration of the inclusion or exclusion of transfers and bulk supplies, etc.

Figure 3-2 - Example outputs showing validation of the simulator using plots of drawdown and abstraction

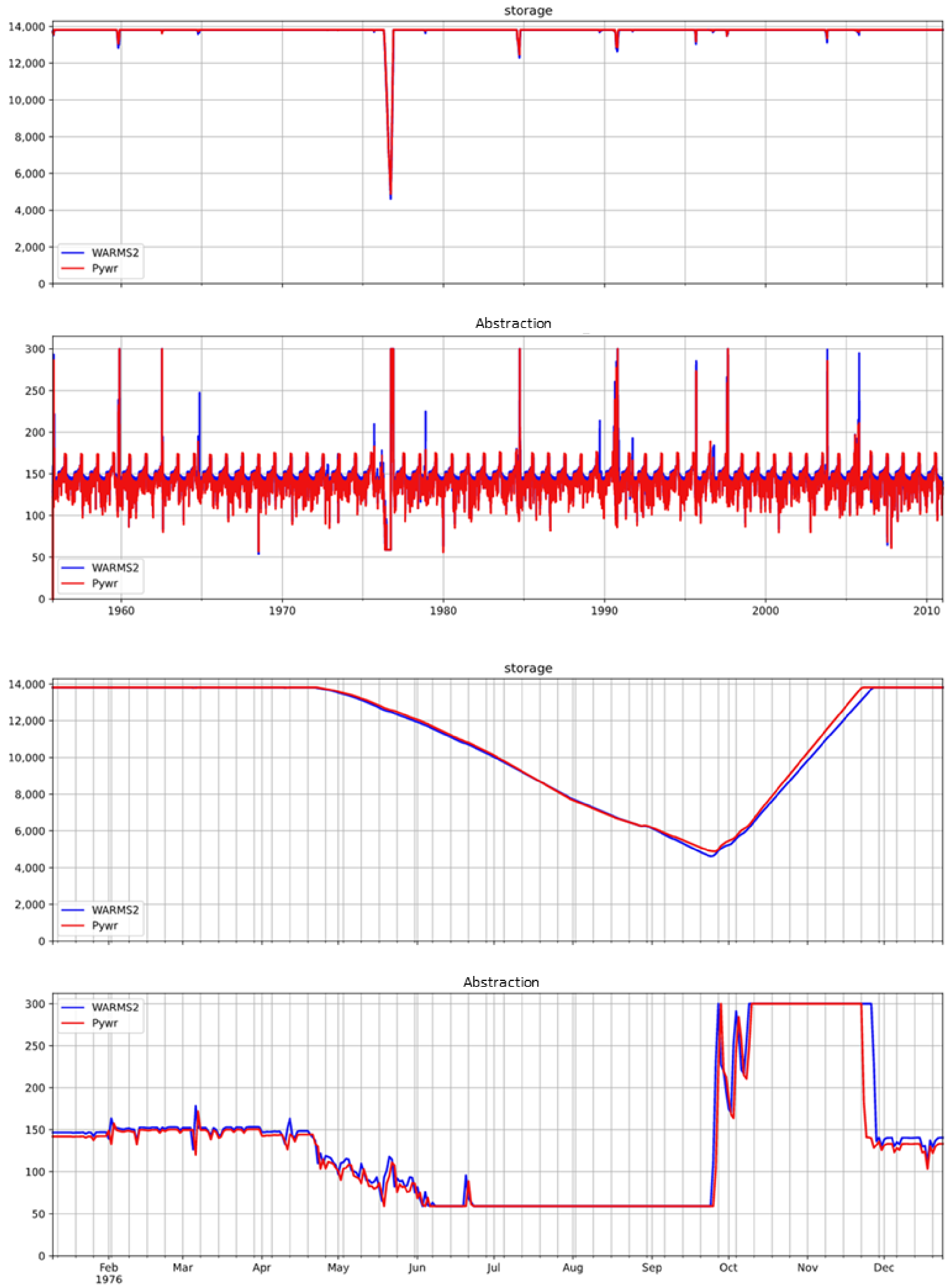


Figure 3-3 - Indicative "heat map" plot showing failures in different drought events over all 400 stochastic replicates

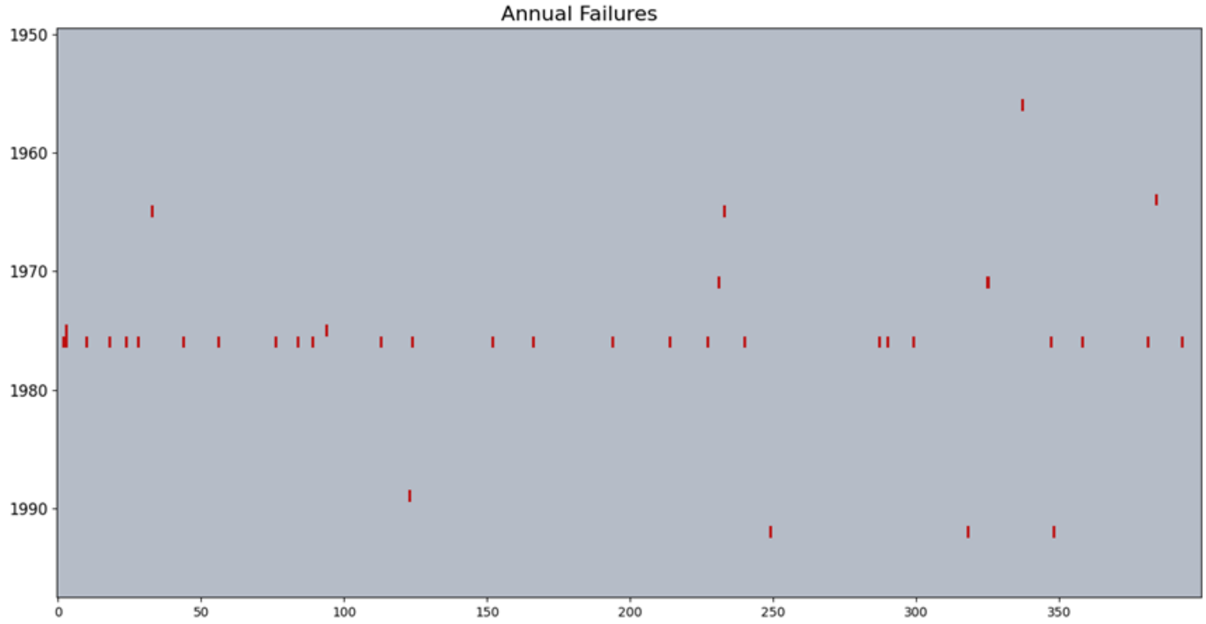
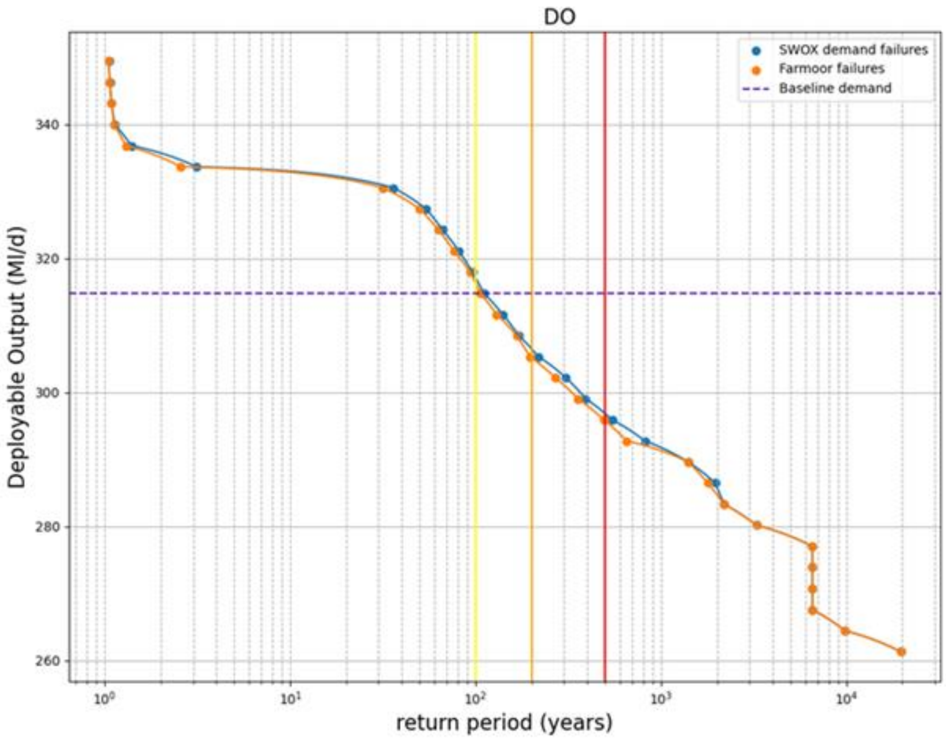


Figure 3-4 - Indicative plot of failures used to develop the DO at each return period



3.6. Pre-investment planning runs: inputs to the regional investment model

The objective of Stage 2 was to *undertake "pre-investment planning" model runs to generate and support inputs needed for the investment model*. This entails two key components:

- Provide **baseline assessments of key aspects of the supply forecast**. This predominantly focused on assessing the deployable outputs of each WRZ
- Use the RSS to assess the non-conjunctive **deployable output of key regional options**. This was only carried out to a limited extent – for a number of SRO schemes

Table 3-2 - Baseline 2025 model runs for Stage 2 supply forecast

Run	Hydrology	TUBs	NEUBs	"Minor" DPs	Comments and dependencies
1	Baseline (400 replicates)	off	off	off	WRZ-level DOs. Used as part of review to inform model sign-off by companies. Primary model output
2	Baseline (400 replicates)	on	off	off	TUBS savings from existing assumptions (not drought plan workstream). Used as part of review to inform model sign-off for some companies.
3	Baseline (400 replicates)	on	on	off	NEUBs savings from existing assumptions (not drought plan workstream). Used as part of review to inform model sign-off for some companies.
4	CC 2070s (21 replicates x 28 scenarios)	off	off	off	28 climate scenarios for 21 selected replicates of the stochastic series. Primary model output – following post-processing

The outputs of run 1 were input directly into the supply forecast template. Run 4 model outputs were post-processed to develop climate change impacts for all 28 climate scenarios, and these were also input directly into the supply forecast template.

Runs 2 and 3 were conducted primarily to allow companies to understand the DO impacts with demand-side drought interventions in place, which was necessary in some of the sub-systems to allow direct comparison to WRMP19 DO values.

3.7. Baseline deployable output assessments

The approach to developing and assessing the WRZ-level deployable output for the baseline supply forecast was described in the WRSE deployable output Method Statement[2].

This methodology identified the use of a "Scottish DO" method in which the full stochastic dataset (19,200 years of daily data) was used to assess the system response of each WRZ at varying levels of demand. The stochastic dataset comprises 400 replicates each 48 years in length, based on the historical period 1950-1997. The development of the stochastic climate data set was carried out by a separate WRSE workstream.

In the simulator, demands were increased incrementally and the frequency of failure at each demand step was assessed. Demand was increased until failures occurred at the required frequency to define the dry year annual average (DYAA) and dry year critical period (DYCP) DO at each of the required return periods – 1 in 500, 200, 100 and 2 years.

Failure was defined by each company to reflect the point at which emergency drought orders (EDO) would be imposed. This could either be defined by a deficit occurring in a demand centre or group of demand centres, or it could be related to crossing a control line in a reservoir (for instance the emergency storage volume of a reservoir), or flow in a river. In general, the companies agreed that 4 days continuous failure to meet demand

[2] WRSE (July 2020) Method Statement: Calculation of deployable output, Consultation version

(e.g. four days of deficit) would be classed as a failure, along with reservoir storages reaching emergency storage or dead water for some companies.

The DYAA DO was the annual average level of demand that could be sustained at each return period when failures occurring at any time of year were considered.

The DYCP DO was the peak level of demand that could be met in a period defined by each company, and that caused failure at the specified frequency. The period over which failures were to be considered was identified by each company and was generally a summer critical period (e.g. June to August). The peak demand that was considered to be met was over a period also defined by the company and was in some cases shorter than the period over which failures were considered. For instance, a company may have considered failures in the June to August period, but defined the peak demand being met as the average day peak week (ADPW), average day peak fortnight (ADPF) or another selected peak. The DYCP DO was also assessed using a Scottish DO method in which demand was increased until the frequency of failure reached the required return period – 1 in 500, 200, 100 and 2 years.

In accordance with the EA WRPG, DO assessments "should not include the contributions from any demand or supply drought measures such as drought permits or orders." Therefore, no demand or supply side drought measures were incorporated in the baseline models used to assess DO (i.e. corresponding to Run 1 in Table 3-2). However, where requested by companies, additional DO assessment runs were undertaken with drought measures in place to allow comparison to WRMP19 results (Runs 2 and 3).

Bespoke arrangements for specific parts of the regional supply system were agreed directly with companies – e.g. for areas not previously modelled (such as Affinity), and also for some systems like Thames (London WRZ compared to other WRZs) and the Bewl-Darwell system (to calculate the split between SWS and SEW). This also reflected company-specific assumptions around operation and system responses in 1 in 500 drought events and the level of risk that was acceptable – e.g. relating to use of emergency storage in a 1 in 500 event.

The general principles for the baseline DO runs were discussed and agreed with the Technical Working Group, and were as follows:

- No drought interventions were included in the main DO run (i.e. no demand savings from TUBs/NEUBs, no drought permits).
- Transfers (imports and exports, and intra-zonal transfers) were assumed to be off, unless there was a specified reason to include them in the DO runs;
    - E.g. locked in DO, unrealistic DO without import.
- Demand profiles were based on the WRMP19 profiles, unless otherwise directed (e.g. Affinity preferred to use a 2018-based demand profile).
- It was assumed there were no sustainability reductions, except where these were confirmed as part of WRMP19 (e.g. Test, Itchen). Sustainability reductions were derived outside of the RSS, but may be tested in scenarios in Portfolio sensitivity Testing (Stage 3).
- It was assumed that there would be no use of emergency storage in the 1 in 500, unless otherwise directed by a company for one of its sub-systems.

The development of DOs for each WRZ and the DO outputs produced by the RSS are described further in a separate Technical Note[3]. The DOs were reviewed as part of the model sign-off process (as described previously in Section 3.5), and the combined supply demand balance inputs were also reviewed as part of WRSE reconciliation process (not covered by this report).

3.8. Climate change scenario deployable output assessments

The approach to developing and assessing the WRZ-level deployable output for each of the climate change scenarios in the supply forecast was described in the WRSE climate change Method Statement[4]. In total, 28 different climate change scenarios were modelled, incorporating UKCP18 Regional Climate Model (RCM) and Global Climate Model (GCM) outputs. This was not based on the full stochastic time series, but on a selection of 21 replicates chosen to stress various parts of the regional supply system.

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[3] Technical Note: DO approach summary

[4] WRSE (July 2020) Method Statement: Climate change – supply side methods, Consultation version

Due to the overhead in creating flows and groundwater inputs for the simulator, the companies selected 21 replicates (48 year stochastic sequences) out of the 400 stochastic replicates available to use in the climate change assessment. These replicates were selected to represent severe drought events across the region – i.e. those with a return period of around 500 years in different parts of the region, as achieving resilience to events with a return period of 500 years is the key baseline planning scenario for WRMP24. The limited number of replicates selected made it possible for the companies to provide the outputs from their hydrological models within the WRSE timeframes (i.e. it avoided the companies having to run groundwater and hydrological models for all 400 replicates in each of the 28 scenarios, which would not have been achievable in the timescales required).

To assess the impact on DO from the various climate change scenarios, an “English and Welsh” DO method was applied. Each replicate was assessed separately and the demand in the WRZ was scaled until a single failure occurred. The level of demand that could be met at one demand step below which a failure occurred was the baseline DO for that replicate in that climate change scenario. The results of the baseline Scottish Method run with the full stochastic dataset were used to identify the indicative return period for the worst event within that replicate. The English and Welsh DO value was then compared to the DOs from the Scottish run, and the return period for that DO was assumed to be the return period of the most severe event in the replicate.

The English and Welsh DO was then assessed for each replicate in each of the potential climate change futures, utilising the climate change perturbed inputs. The DO impact of each climate scenario on each replicate could then be calculated.

The raw outputs from the PyWR model were processed directly by WRSE outside of the PyWR model to convert them into impacts on the DO at each of the key return periods. For each climate change scenario, the impact and return period for each replicate were plotted. Where there was a basic correlation between the data points a line was fitted through the data and the impact for each return period was calculated from that regression. Where there was a poor correlation between the data points the approach was different; the impacts from the replicates that had return periods closest to the target return periods were used instead.

Table 3-3 – Climate change outputs sign-off by sub system

Sub-system	Email issued to company to constitute sign-off
Affinity Central (WRZs 1-5, and 6)	30-31 Mar 2021; follow up sign off 1 and 8 Apr 2021
Affinity South East (WRZ7)	30 Mar 2021
Thames	31 Mar 2021
SES	16 Mar 2021
South East Water WRZ2 WRZ3	30 Mar 2021
South East Water g/w zones WRZs 6 and 7	31 Mar 2021
Southern Water – Eastern Surface water KM and KT WRZs	30 and 31 Mar 2021
Southern Water – Central Sussex North Groundwater (SB/SW)	 31 Mar 2021 30 Mar 2021
Southern Water – Western	30 Mar 2021
Portsmouth Water	30 Mar 2021

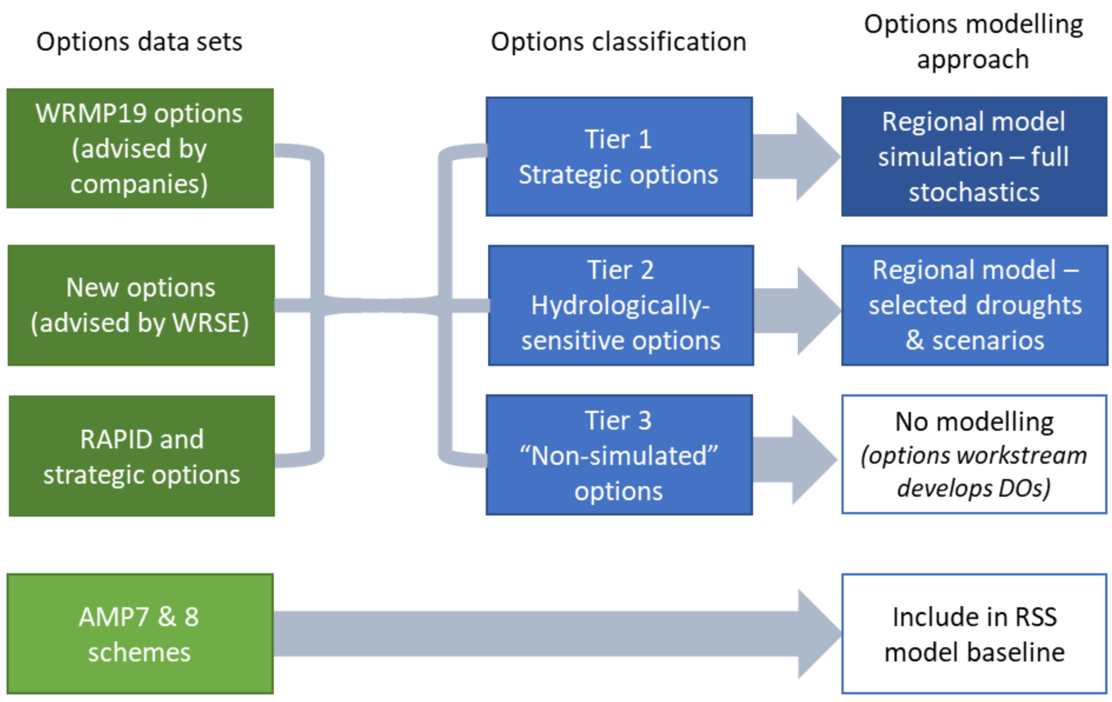
The development of the climate change DOs for each WRZ and the post-processed RSS outputs are described further in a separate Technical Note[5].

3.9. Option deployable output assessments

An initial assessment was carried out in the RSS workstream to identify and assign a Tier to each option to prioritise those options where modelling would be most appropriate – i.e. options whose output would be most hydrologically sensitive. The classification process is described in Figure 3-5 below. The assessment was carried out before the full options set was finalised and would need to be refined and updated for the final options set through the options workstream.

Most options were designated as Tier 3, which meant there was little or no likely impact of climate and / or triggers on the DO benefit of the option; and many others as Tier 2 – which meant that they may be susceptible to minor DO impacts. Tier 3 options were never intended to be modelled in the RSS during Stage 2. Only a small selection of Tier 2 options were expected to be modelled due to time and scope limitations.

Figure 3-5 - Classification of options into Tiers for possible assessment in the RSS



Notes:

- **Tier 1**: Major impact of weather/climate and/or triggers on DO benefit of option - will be modelled using 'Scottish Method' and whole stochastic weather sequence
- **Tier 2**: Minor impact of weather/climate and/or triggers on DO benefit of option - will be modelled using 'E&W' method, determining yield benefit for individual drought events
- **Tier 3**: Little/no impact of weather/climate and/or triggers on DO benefit of option - DO benefit will not be modelled and so initially will not be built into the simulator. May be built in later to test portfolios of options.

The original scope included the potential to model only a small selection of key Tier 1 options in the RSS (and Tier 2, if possible), however, there was insufficient time to undertake this during stage 2. Nevertheless, some analysis and DO support was provided to a number of SRO schemes, and to inform company assumptions for demand-side drought interventions.

[5] Technical Note: DO approach summary

3.9.1. Drought intervention impacts on deployable outputs

In accordance with the EA's WRPG for WRMP24, drought measures (demand restrictions and supply side drought permits and orders) are included as options available for selection in the investment model. However, they were assessed where requested in Stage 2 to develop appropriate estimates of the benefits each would provide in terms of conjunctive WRZ-level deployable output.

The model runs undertaken are presented in Table 3-2, above. The drought intervention runs to inform the DO benefits were carried out for both Temporary Use Bans (TUBs) and Non-essential Use Bans (NEUBs). The approach used the Scottish method with the same assumptions regarding transfers etc for each WRZ as was used to develop the baseline WRZ-level DO values. The TUBs and NEUBs runs were based on the information in the existing WRMP19 data sets relating to the assumed percentage savings from each.

3.9.2. Other strategic options

A number of options were examined using the WRSE PyWR model – to inform understanding of the DO benefits of these options. These included:

- The South East Strategic Reservoir Option (SESRO)
- The Severn-Thames Transfer (STT)
- Combined SESRO-STT
- Thames to Affinity transfer (T2AT)
- Anglian to Affinity transfer (A2AT)

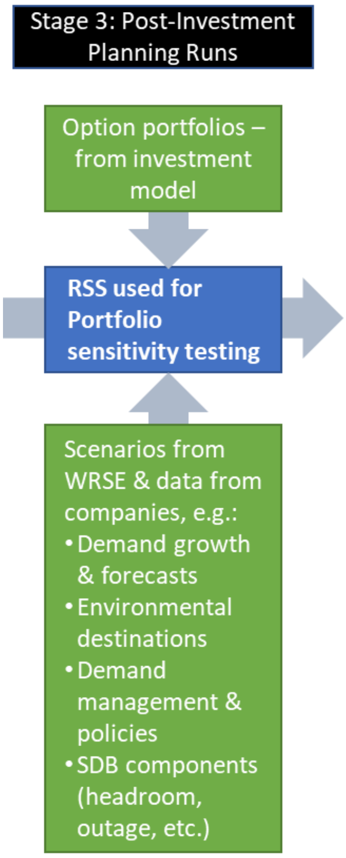
3.10. RSS outputs

The outputs from the RSS – WRZ-level DO and climate change impact DOs were uploaded into the Data Landing platform, to be incorporated with other components of the supply and demand forecast to generate a range of supply demand balances to be solved by the investment model.

That process is part of a separate WRSE workstream, and so is described in a separate WRSE report.

4. Stage 3: Use the simulator to assess the outputs from investment planning

4.1. Portfolio stress testing required to be performed by the regional simulator



The broad objective of this next stage – the post-investment planning runs, also referred to as "Portfolio Sensitivity Testing", is to examine the outputs of the investment model by using the RSS in simulation mode to evaluate how different portfolios perform against:

- A wide range of stochastic drought conditions, climate change and other scenarios
- A range of metrics defining resilience of the regional system
- To understand whether interactions of options within given portfolios have conjunctive use benefits or dis-benefits, according to where they are sited in the network, and in conjunction with other options.

At the time of producing this report, the exact scope of Stage 3 had not been fully defined. The Stage 3 modelling approach and outputs will therefore be the subject of a second report (if required).

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