Method Statement: Hydrological Modelling

Consultation version

July 2020

Title	Method Statement: Hydrological modelling
Last updated	July 2020
Version	Consultation version July 2020
History of Changes made to this version	June 2020 – First Draft Written July 2020 – comments from PMB, comments from technical working group, and comments from QA review incorporated
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Executive Summary

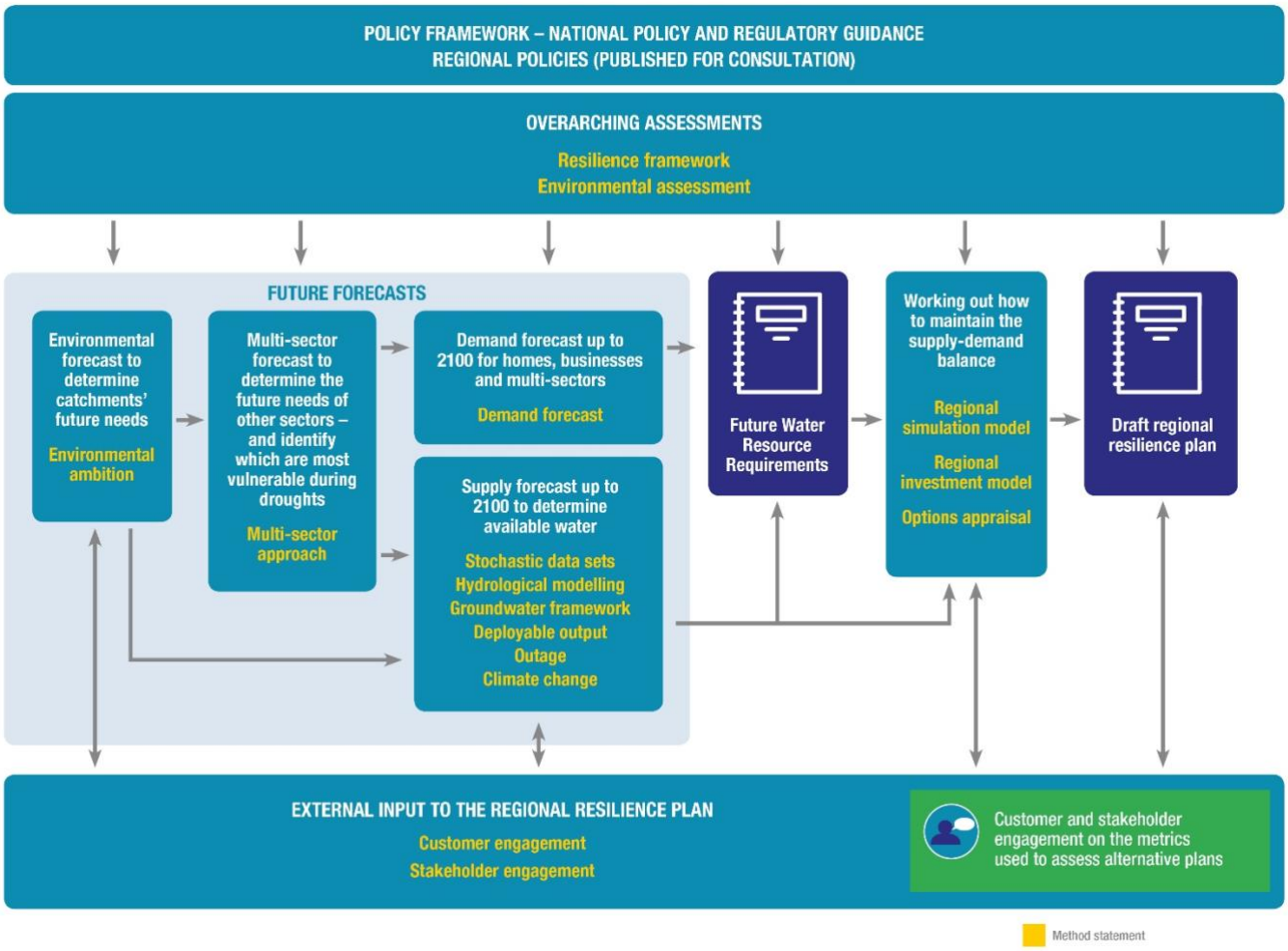
Water Resources South East (WRSE) is developing a multi-sector, regional resilience plan to secure water supplies for the South East until 2100.

We have prepared method statements setting out the processes and procedures we will follow when preparing all the technical elements for our regional resilience plan. We are consulting on these early in the plan preparation process to ensure that our methods are transparent and, as far as possible, reflect the views and requirements of customers and stakeholders.

Figure ES1 illustrates how this hydrological modelling method statement will contribute to the preparation process for the regional resilience plan.

The supply forecast for WRSE's regional plan relies heavily on outputs from the regional simulation model. The regional simulation in turn relies heavily on hydrological and hydrogeological inputs and so this method statement details the hydrological modelling being undertaken for the WRSE regional plan.

Figure ES1: Overview of the method statements and their role in the development of the WRSE regional resilience plan



1 Introduction

1.1 Hydrological modelling underpins much of the supply-side analysis undertaken in water resources planning. Many different hydrological modelling approaches exist due to the wide variety of applications required of these models, for instance the models used to investigate flooding are quite different to those used to investigate drought. Different hydrological models also perform differently when applied to different catchment types, for instance some models may be better at predicting flows in chalk catchments, while others may be better suited to application in sandstone or clay catchments. Different water companies within WRSE rely on different hydrological models and take different approaches to dealing with non-natural influences on river flows. WRSE will not have an aligned approach to a specific hydrological model in AMP7 due to the variety of catchments, although the weather input datasets that are used to derive flows using the hydrological models will be consistent and coherent.

1.2 The regional system simulator (WRSE regional system simulator method statement) requires river flows as inputs to the model, and rainfall-runoff models will not be included within this model. System simulation will also be undertaken on a wider range of areas than has previously been the case. These two things mean that some companies have undertaken developmental work on hydrological modelling to underpin the new WRSE regional system simulator. This is not the case for all water companies.

1.3 Water companies have made significant commitments to reducing groundwater abstractions where this abstraction is potentially environmentally detrimental. The most notable recent commitments relate to reductions that WRSE companies will make in 'chalk stream' catchments. The Environment Agency are also doing a significant amount of work to investigate how climate change may impact the environment in the future, and have indicated that other, very significant reductions in abstraction may be required to protect the environment (refer to WRSE Environmental ambition method statement). It is recognised that reductions in groundwater abstraction can affect streamflow, which as well as providing environmental benefit can in turn have an impact on the downstream availability of surface water for abstraction. However, system simulation methods used in WRMP19 do not account for the streamflow benefits associated with reductions in groundwater abstraction. As such, analysis has been undertaken to allow the regional system simulator to include mechanisms that will allow an assessment of the impacts that potential future reductions in groundwater abstraction may have on downstream surface water abstractions and/or environmental receptors.

1.4 As described in other method statements (WRSE regional system simulator method statement and WRSE groundwater framework method statement), the regional simulation model will represent groundwater yields in a more dynamic way than has previously been the case. For some companies, this has necessitated the development of 'algorithms' to allow them to determine groundwater yields based on bringing together information from detailed source deployable output assessments and results from less detailed modelling to develop time series inputs for the simulation model. It is recognised that the hydrological modelling method statement may not seem appropriate for the inclusion of this method. However, the work for this method was procured and undertaken alongside the work presented in this method statement and doesn't fit well into other method statements.

1.5 This method statement contains the following sections:

a) Development of hydrological models for WRSE
b) Methods for simulating groundwater-surface water interaction
c) Development of 'algorithms' for determining groundwater yields

2 Methods and approach

Development & use of hydrological models for WRSE

2.1 River flows are an important input for a water resources simulation model. The regional simulation model will not incorporate rainfall-runoff models directly, but requires flows as an input, and these flows must be based on the rainfall and PET data from the stochastic climate datasets which have been developed for the WRSE region.

2.2 In some cases, existing company hydrological models exist which are suitable for providing flows for use in the WRSE regional simulation model. In other cases, existing company hydrological models either do not exist or are not suitable for inclusion in the regional simulation model, and as such new hydrological models have been generated in some locations. Please see WRSE-commissioned report(s) (HR Wallingford, to be written, WRSE file tbc) for technical details about the models used, calibration methods and calibration results for new models which have been produced.

2.3 An important aspect to consider in hydrological modelling is whether flows produced are 'naturalised' or 'denaturalised'. Where flows are denaturalised, the abstraction time series that underpin denaturalisation are also important. In all cases it is important that the combination of flow inputs and adjustments are consistent such that the flows account for abstractions and effluent returns which apply to the situation being considered (e.g. a DO run).

2.4 WRSE companies are applying methods appropriate for their WRZs to ensure that, whether inside or outside of the regional simulation model, appropriate flows exist within the regional simulation model. Denaturalisation routines may be different for different model uses. For example, the DO methodology (WRSE deployable output method statement) states that when finding DO for one zone/sub-region, the demand in other zones should be held at WRMP19 Year 5 Final Plan DI. As such, flow inputs for DO runs should be reasonably representative of abstractions & effluent returns corresponding with this situation. Water company technical representatives should document how flows have been produced and the denaturalisation approaches that have been applied.

2.5 Where a company's approach to denaturalisation has the potential to impact on flows in another company's WRZ(s), the relevant companies should work together to determine appropriate methods. WRSE technical leads will review approaches across the region to ensure consistency. It is possible that the consideration of denaturalisation may result in feedback loops, with a denaturalisation being carried out using a set of assumptions regarding abstraction which may not hold true in system simulator model runs; it is hoped that this feedback loop will not have material impact.

2.6 It is recognised that WRSE member companies will use different methods for denaturalisation, for determining the impacts of both abstractions and discharges, and it is acceptable that different methods are applied, so long as the use of different methods is justified and the impact is understood. Allowing

companies to determine denaturalisation methods will help in providing consistency between company plans and the WRSE regional plan.

2.7 The impact of changing other abstractors resulting from the multisector approach (WRSE multisector approach method statement) will also be taken into account where there are significant changes to the denaturalisation process.

2.8 The generation of flows has been considered as being outside of the remit of the WRSE regional system simulator (RSS) project. Water companies are responsible for providing flow inputs to the WRSE RSS and water company technical leads are responsible for ensuring that the impacts of abstractions and discharges have been accounted for, but have not been double counted within their sub-model area(s) (e.g. advising/checking on representation of effluent returns and impacts of abstraction within the model and ensuring that flow inputs are appropriate).

2.9 The RSS has been developed with significant company guidance. The RSS is made up of company/ WRZ/sub-regional sub-models. Water companies will know the locations for which flows inputs are needed for their sub-model(s).

2.10 Flows should be produced for the four hundred 48-year replicates produced by the WRSE stochastic dataset work package.

2.11 For climate change scenarios, WRSE will inform companies of the replicates which will be used and the change factors to be applied. Companies will again provide flows required for the RSS to be run.

2.12 Stochastic data which has been produced for WRSE has been produced for point locations. The various hydrological and hydrogeological models that companies use will have been calibrated using different datasets. Direct application of the stochastic data may result in bias of model outputs and some models may require gridded input data; as such companies may need to factor and/or re-grid stochastic datasets. Companies will inform WRSE how they have applied the stochastic data and WRSE will collate responses.

2.13 There are some cases in which different companies abstract from the same rivers. In these cases, different companies may have different models for the same river and may also make different assumptions around denaturalisation. In such cases, changing models and/or denaturalisation methods has the potential to cause differences between regional assessments and past company assessments. Initially, company sub-models will use existing hydrological inputs, in order to validate new models against existing company models/assessments. When applying WRSE models and conducting regional assessments, companies and the WRSE modelling team will work together to formulate ways to validate and use models in these circumstances, as well as understanding differences that will be created through conducting analysis on a regional scale, though these have not yet been determined.

2.14 It is recognised that there are uncertainties and potential feedback loops in the application of hydrological models in underpinning WRSE's modelling assessments, with companies initially uncertain how to use data and the denaturalisation scenarios that should be used. WRSE will collate details of how companies

have carried out denaturalisation and will feed back on how this could be improved, either for inclusion in the initial WRSE regional plan, or for inclusion in later iterations of the plan.

Methods for Simulating Groundwater-Surface Water Interactions

2.15 As outlined above, it is important that the impact of abstractions on river flows is considered appropriately within water resources models. This is particularly the case when substantial changes in abstraction are expected. This section does not include a detailed technical description of methods developed and applied for this purpose, nor does it highlight sources/areas where it is applied. For full details of the methodology, please see the technical report (WRSE commissioned HR Wallingford report, not yet written, WRSE file tbc).

2.16 Water companies have made significant commitments to reducing groundwater abstractions where this abstraction is potentially environmentally detrimental. The most notable recent commitments relate to reductions that WRSE companies will make in 'chalk stream' catchments. The Environment Agency are also doing a significant amount of work to investigate how climate change may impact the environment in the future, and have indicated that other, very significant reductions in abstraction may be required to protect the environment.

2.17 It is important that impacts of reductions in groundwater abstraction on downstream surface water abstraction are accounted for in future planning. However, in many cases it is difficult to isolate the impact that changes in groundwater abstraction have on flows, due to the many other factors that have an impact on flows and ecosystem quality. It is often not the case that one unit of reduction in groundwater abstraction leads to an increase of one unit in surface water flows, and the relative amount of surface water gain can be heavily impacted by groundwater levels and hydrogeological conditions and so can vary through the year and from year to year, as well as being different from source to source due to the characteristics of the aquifer body.

2.18 Initially it was proposed that a simplified approach would be taken, adjusting 'flow-duration curves' for rivers where abstraction reductions are proposed. However, determining adjustments to make is difficult and would have involved so many simplifying assumptions that it was likely to end up being invalid.

2.19 As such, work has been undertaken in which an analytical modelling approach has been used to determine the impact of groundwater abstractions on river flows. This method requires flows as an input, and so can consider the time-variant impact of changes in abstraction. This approach provides a more conceptually sound way of considering this impact while providing inputs which can be incorporated into the regional simulation model. The computational effort that is needed to determine the magnitude of flow adjustments using this method is non-trivial and so cannot be incorporated directly within the regional simulation model, and so time series outputs from this work will be used as inputs to the simulation model. There will not be a specific method statement on this approach, but a technical report will be written (HR Wallingford report, not yet written, WRSE file tbc). These approaches are being developed by external consultants, will be reviewed by separate external consultants as well as water

company technical experts, and will be consulted on with the Environment Agency. Since this approach is to be applied outside the simulation model, companies should ensure that abstractions assumed are reasonably representative of appropriate scenarios, either by applying the method iteratively, or by applying the method at different levels of abstraction and applying results appropriately during model runs. It is recognised that this brings a potential feedback loop in this analysis.

Development of Algorithms for Determining Groundwater Yields Based on Groundwater Levels

2.20 The regional simulation model will consider groundwater yields in a more dynamic way than has previously been the case. For some companies, this has necessitated the development of 'algorithms' to allow them to determine groundwater yields based on bringing together information from detailed source deployable output assessments and results from less detailed modelling to develop time series inputs for the simulation model.

2.21 One form of these algorithms will involve the translation of results from groundwater model(s) to levels used in determining source deployable outputs (SDOs). In some cases, results directly from 'fast' groundwater models will be used to determine source yields. In other cases, results from 'fast' groundwater models will be used in conjunction with results from more detailed models (which cannot practically be run using thousands of years-worth of input data), using some form of interpolation. Existing methods for determining source yield will then be used to give a time-variant yield output.

2.22 Companies may apply other methods for determining groundwater yield based on groundwater levels where it is appropriate/necessary to do so and should document methods appropriately. In some cases, WRSE has commissioned work to develop methods to be applied (for example a method has been developed for a limited number of Affinity Water sources – see WRSE-commissioned report by HR Wallingford, WRSE file tbc). Yields will be considered as inputs to the regional simulation model and will not be verified by the regional simulation modelling team.

2.23 The regional simulator will contain rules around when peak, average and minimum SDO values could reasonably be expected (e.g. it would generally not be reasonable to expect a peak DO output during a drought event in December, when groundwater levels are likely to be very low). The rules applied may be different for different scenarios, for example if a company wishes to explore high demand freeze-thaw events, it would be unreasonable to consider this in conjunction with severe drought, and so a company may choose to relax restrictions on when peak DO can be achieved. Company technical leads have worked with model development leads to ensure that representation is appropriate for different companies' sources and have documented approaches to the representation of peak/average/minimum DO in the regional simulation model. Where companies are providing time series of yield inputs, they should state the assumptions that underly them. Where assumptions are made in the model, companies will inform consultants producing the models as to the assumptions that should be made.

Decision points & documentation

2.24 As described throughout this method statement, there are several decision points when producing and using models. Examples of decisions to be made are: determining abstractions to underpin denaturalisation scenarios; choosing how to apply stochastic data; and determining rules around when minimum/average/peak source deployable outputs may be used.

2.25 For key decisions, keeping appropriate documentation is valuable for later justifying outcomes and decisions further down the modelling chain. In this section, key decision points are identified. Decision makers, those collating decisions across the region, and required documentation are described for identified decisions. There are of course many small decisions made in producing hydrological data for use in the RSS and it is infeasible that all decisions would be recorded, although all decisions should be justifiable if questioned. This section only focusses on high-level decisions.

2.26 Assumptions underlying data that companies provide in the development of RSS sub-models should be documented by companies. Again, it is recognised that there are many assumptions made in the development of models, and that documenting all of them is infeasible. However, for key assumptions companies should document and/or be able to justify assumptions, such that they can be justified when questioned.

2.27 Companies are required to document how they have applied the stochastic data. Where re-biasing or re-gridding methods have been used, they should be described. These need not be consistent across WRSE, but WRSE will collate details of methods that have been applied.

2.28 Companies will describe to WRSE how they have implemented denaturalisation compatible with the scenarios for which modelling is being undertaken. WRSE will collate this information and feedback as required.

2.29 WRSE and company experts will review technical methods associated with groundwater-surface water interaction. The results of these reviews will be documented to justify methods which are applied.

2.30 Since companies are producing hydrological data for the RSS, it is largely incumbent on companies to note key assumptions used in their hydrological modelling. WRSE will collate assumptions on aspects of hydrological modelling which apply across the region (e.g. denaturalisation) but cannot know all assumptions that companies will need to make.

Confidence Grades

2.31 It is recognised that a methodology will be required for assigning confidence grades to hydrological inputs. However, this has not yet been determined.

2.32 It is requested that companies provide confidence grades regarding their input hydrological data, although the criteria for determining grades have not yet been determined. Grades for different components (e.g. naturalised flows, denaturalisation process) will likely be used.

2.33 Resulting confidence grades will guide future sensitivity analyses.

3 Summary

3.1 This method statement has outlined the hydrological modelling methods being developed and applied to provide inputs for the WRSE regional simulation model.

3.2 In general, at the time of writing, models and methods are still in the development phase, and so a general overview of methods that will be developed and applied has been given, rather than a detailed description of models and methods.

3.3 Aspects of model development/application where key assumptions are required have been detailed, such as denaturalisation approaches and application of stochastic data. Reporting requirements regarding these aspects have been outlined.

3.4 Where improvements from WRMP19 methods are being made, for example in assessing surface water-groundwater interactions, new methods being developed have been outlined and technical reports which will be written have been highlighted.

4 Next steps

4.1 We are consulting on this method statement from 1st August 2020 to 30th October 2020. Details of how you can make comments can be found here – (consultation website).

4.2 We will take into account the comments we receive during this consultation process, in updating the Method Statement. Alongside this, the Environment Agency will shortly be publishing its Water Resource Planning Guidelines (WRPG) on the preparation of regional resilience plans. We may need to update parts of our method statements in response to the WRPG. We have included a checklist in Appendix 1 of this method statement which we will use to check that our proposed methods are in line with guidance where applicable.

4.3 If any other relevant guidance notes or policies are issued, then we will review the relevant method statement(s) and see if they need to be updated.

4.4 When we have finalised our Method Statement, we will ensure that we explain any changes we have made and publish an updated Method Statement on our website.

Appendix 1 Checklist of consistency with the Environment Agency WRMP24 Checklist

The Environment Agency published its WRPG on XXXXXX 2020, including the WRMP24 Checklist. The following table identifies the relevant parts of the checklist relating to this Method Statement and provides WRSE's assessment of its consistency with the requirements in the Checklist.

No.	Action or approach	Method Statement ref:	WRSE assessment of consistency