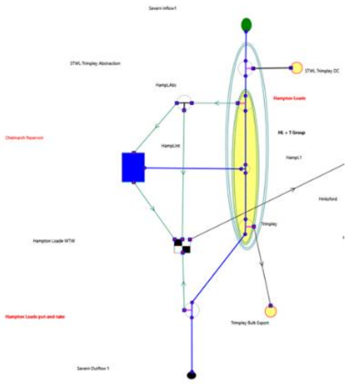

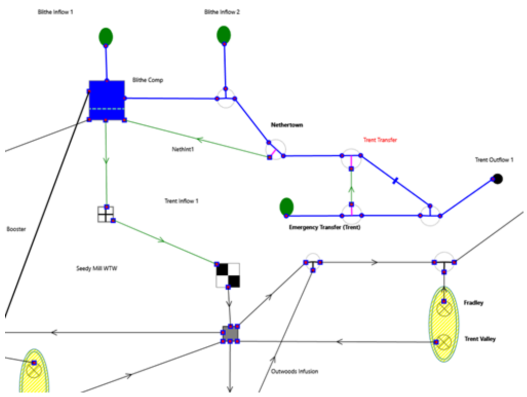

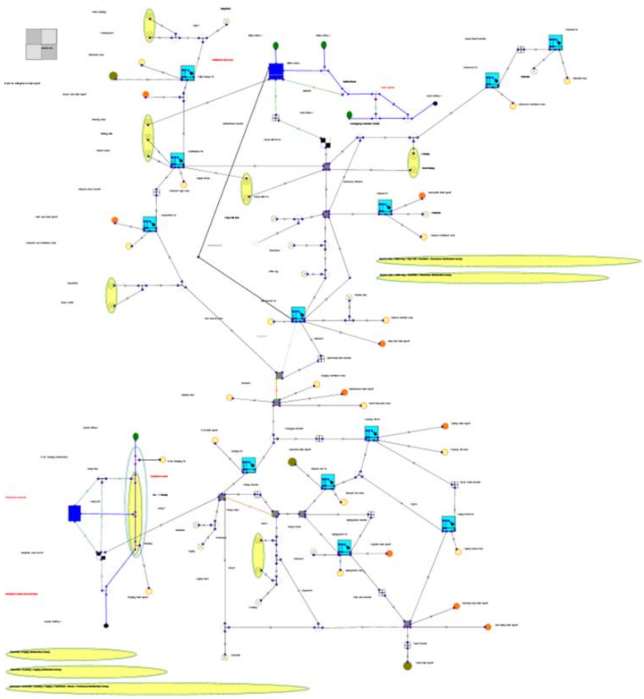

WRMP24 Options modelling: Technical report

Project ref: W0150

Report for South Staffs Water
July 2022

hydro-int.com

Table of Contents

Quality assurance record

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1. Introduction and approach

1.1. Background

As part of the Water Resource Management Plan 2024 (WRMP24) and regional planning cycle, South Staffs Water (SSW) are required to carry out water resources options modelling to assess and quantify supply demand balance benefits of proposed options/schemes. The benefit of option schemes and options portfolios is a critical element of ensuring the resulting plans deliver the required benefits in practice. DO impacts and benefits can be non-linear to the source level WAFU on conjunctive use systems, and so DO testing in an Aquator modelling environment allows a better understanding of the benefits in future (and under different) scenarios. The findings not only allow confidence that the benefits of options will be realised in practice, but they also allow feedback to the options designs teams where options could be refined.

The project builds upon previous work by Hydro-Logic to model 1:500 DOs with SSW's Aquator model using stochastic hydrology and climate change scenarios, including a follow-on project to assess the DO impacts under various WINEP/ED scenarios. Through that process, the first-time application of stochastics and 1:500 DO assessment using the Scottish DO approach has resulted in significant learning and insight on the SSW system, that can be applied to this new project.

The assessment of DO was completed using Aquator XV/XM, using a further developed version of SSW's existing Aquator model.

1.2. Deliverables and project scope

The core project scope included:

- Build in 21 WRMP24 options into the existing Aquator model, drawing on existing information and further discussion with SSW;
- Model baseline stochastic DO with option portfolios;
- Model stochastic DO with climate change[1];
- For each DO run, the 1:500 for Level 4 restrictions is the driver of the Scottish DO assessment, the DO for Level 2 and Level 3 events (1 in 40 and 1 in 80 respectively) will also be presented. The 1 in 200 DO under Level 4 conditions will also be provided, recognising that Companies have a choice to operate to this lower LoS prior to 2040.

As detailed later in the report, it is important to note that the scope of model runs was expanded to move beyond modelling option portfolios to include individual options; this was undertaken to gain a better appreciation of the benefits of the individual options. On the counter-side, as per the original scope options were to be assessed under Environmental Destination (ED)

[1] A single RCM scenario was chosen by SSW based on the central estimate (RCM12).

scenarios with and without climate change (to ascertain option benefit), however, these additional runs were not completed at the request of SSW.

The key deliverables for this project are summarised below from the work specification:

- Aquator database with the latest model incorporating the 21 options. The database includes:
  - Stochastic baseline and climate change scenarios used to assess options
  - User form to allow rapid switch on/off of option and to allow testing different combinations of options.
- Tables and plots of DO versus frequency of Level 4 (combined demand and storage failures), Level 2, and Level 3 events, with presentation of the overall DO benefits for modelled individual options (baseline and one climate change scenario RCM12);
- A technical report outlining the modelling analysis completed and the methods used, including outputs of post processing analysis (this report).

It is important to note that, to meet the needs and challenges for this complex modelling work, precise aspects of the approach have evolved through the project from that originally envisaged in the proposal. For example, significant additional work has been completed in some cases to understand and investigate the initial model outputs, and refine the approaches beyond what could have been defined by SSW and Hydro-Logic in advance of the detailed modelling e.g. DO benefits of individual options were investigated as opposed to that of option portfolios (as initially envisaged). This technical report therefore focusses on the approach finally taken and delivered for, and in agreement with SSW, and explains any evolution of approach through the process.

1.3. Structure of this report

The report is structured as follows:

- Section 1 – Background context and summary of deliverables
- Section 2 – Explanation of model preparation and subsequent options integration
- Section 3 – Summary of modelling approach to assess DO benefits of *option portfolios* and corresponding results
- Section 4 – Summary of modelling approach to assess DO benefits of *individual options* under climate change conditions and corresponding results
- Section 5 – Summary of modelling approach to assess DO benefits of *individual options* under baseline conditions and corresponding results
- Section 6 – Conclusions and future considerations

2. Model preparation and options integration

Prior to implementation of options into the model, an extensive gap analysis was undertaken on scheme information provided by SSW to ensure the requisite information (to reflect an option sufficiently in a model) was present.

Rather than a consolidated single options proforma, the SSW options at that time were provided across a range of documents, and so significant care was needed to determine the option design for implementation in the model.

To that end, a workshop between HLSI and SSW was held to discuss scheme design / data. The level of detail provided differed between options and in some instances, practical modelling assumptions were made[2], e.g., detailed modelling on options relating to canal systems or the River Severn were not undertaken in line with the project scope assumptions, rather, water availability was modelled as bulk imports using the WAFU values provided. Furthermore, hydrology for the bankside refill element of the Trent to Seedy Mill transfer (via bankside storage) options was not provided by the options team, and as such, have been modelled as bulk supplies with capacity equating to the WAFUs.

Please refer to Appendix 1, for further detail on individual option builds, option ID and schematisation and subsequent implementation in Aquator.

Database version 1.15[3] was used to implement options. Throughout the project life, a succession of model updates was carried out to either build further new options or refine existing option detail, resulting in a final master database v1.1.19.

Upon completion of option implementation, a bespoke VBA form titled 'WRMP24_OptionsSelector' was created, accessible via the VBA IDE/Macros dropdown list (see Figure 1 below):

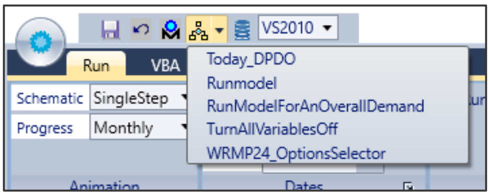

Figure 1: A visual of the WRMP24_OptionsSelector form

Once activated, a list of built options appears, with the form allowing for rapid enabling/disabling (and grouping of options, if desired), as can be seen in Figure 2 overleaf:

[2] As a general point, the option benefits quoted in this document will be influenced by the operational assumptions (e.g. point to commence use depending on reservoir levels or system status) determined at this point. This is normal as part of the WRMP options process, but as SSW progress with their plan build, if options and/or portfolios are represented in the preferred or alternative plans, it would be sensible for further modelling of different operating rules or variants to be completed to guide the detailed implementation for SSW in future. This increasing precision is then commensurate to the risks and focus on the option. Where options give a different level of benefit to expectations, SSW may wish to review the operational assumptions further.

[3] Project SSW XV migrated v1.15

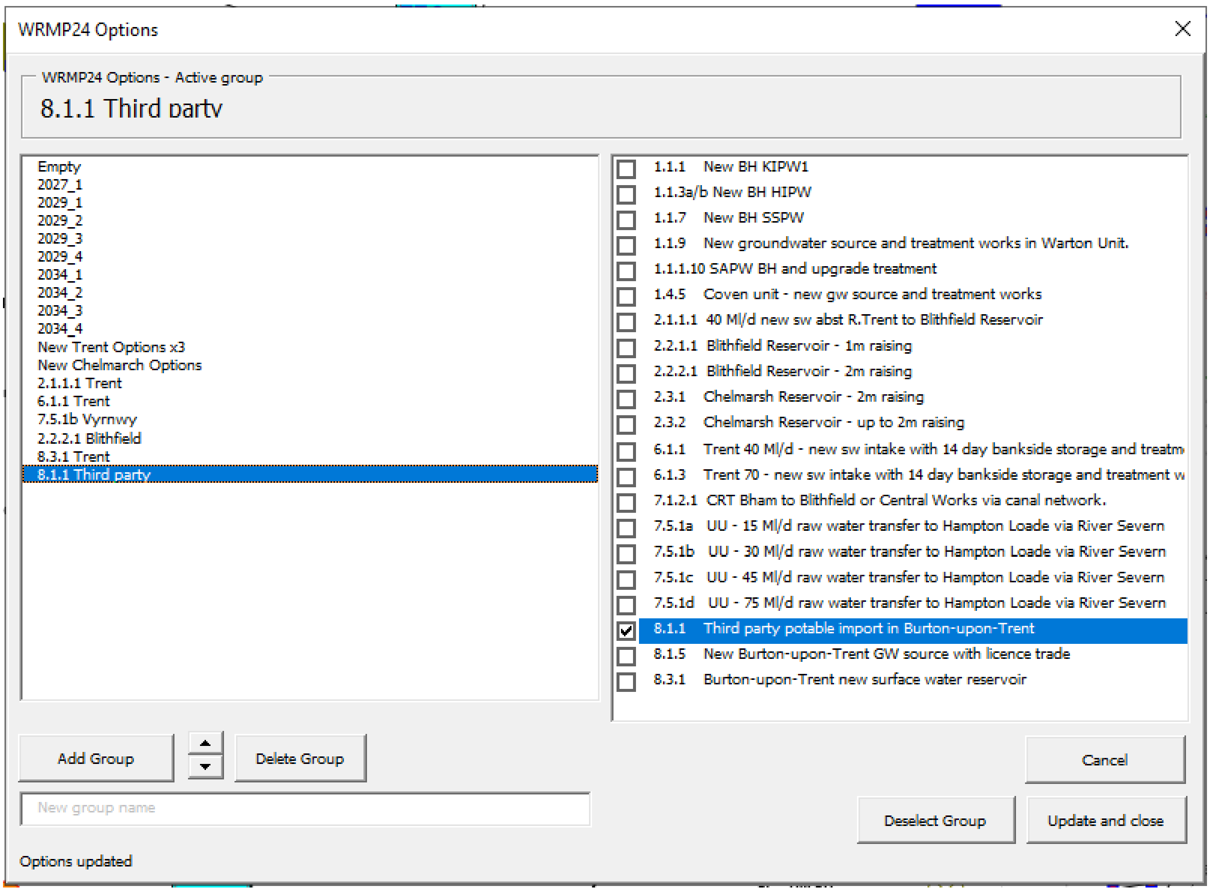

Figure 2: List of options that can be enabled, disabled or grouped

The appropriate options were selected and placed in a group corresponding to their respective batch/portfolio IDs. It should be noted that a group can also contain a single option, as can be seen towards the bottom of the list of group names on the left-hand side of Figure 2

3. Batch Option DO Assessment (Baseline)

Initially, as per the original scope, HLSI undertook DO analyses on pre-defined option batches (with an option batch comprising a number of individual options (as detailed in Table 1)).

The analyses were carried out on stochastic batches 4 and 7, in line with previous supply work for scenario impact assessment. Furthermore, this gives a baseline against which, batch option runs with climate change can be compared. This ascertains the sensitivity in option benefit through the imposition of climate change.

The initial aim of SSW grouping portfolios was to reduce the number of scoped model runs for DO assessment, although as described later, given the nature of the SSW planning problem, a change in modelling approach was subsequently agreed with SSW based on the results found in the initial baseline portfolio modelling.

SSW determined portfolios of options to be tested based on defined timeslices through the WRMP planning horizon (2027, 2029 and 2034). One combination of options was to be chosen to progress to the next time-slice, in other words, an option portfolio would be selected from 2029 to be brought into the options combination in 2034 for example. The options per timeslice were understood to be based upon SSW's initial option appraisal modelling.

It is important to remind the reader that the Scottish DO method employed for the basis of this project using stochastic hydrology uses a 'derived' approach to the DO level. This is by contrast to the English and Welsh DO method, which is based on a single 'first failure' value. The 1:500 (and other) return-periods of failures is based upon a distribution of failures Vs demand. This is important, because whilst DO may be quoted to 2 d.p., in practical terms small changes in the demand steps run (for example) can produce minor changes in the DO values at these greater precisions. When subsequently applying DO results in the wider planning process, it is important to be mindful of the practical level of accuracy of the modelling process.

All DO values quoted are consistent with SSW's previous Aquator modelling process, being based on the summation of specified demand centres in the analyser. The Aquator model accounts for process losses and includes export demand centres, and so inherently are a 'net DO' accounting for these integrated elements of the modelling process.

Table 1 overleaf presents Level 2 (1:40 DOs), Level 4 (1:200 and 1:500 DOs) and corresponding benefits versus the baseline (obtained in previous SSW work) with no options implemented for the portfolios tested:

Option Batch	Individual Options in Batch[4]	Level 4 1:200 DO (Ml/d)	Level 4 1:500 DO (Ml/d)	Level 2 1:40 DO (Ml/d)	Level 2 1:40 Benefit	Level 4 1:500 Benefit	Expected WAFU (Ml/d)
Baseline	-	355	355	337.94	-	-	
2027_1	1.1.3a/b	357.68	357.56	339.82	1.88	2.56	4.9
2029_1	1.1.3a/b 1.1.1 1.1.7 1.1.1.10 7.1.5 2.1.1.1 7.5.1a	372.5	372.5	360.81	22.87	17.5	83.5
2029_2	Identical to 2029_1 except using 7.5.1b	371.68	371.12	361.36	23.42	16.12	98.8
2029_3	Identical to 2029_1 except using 7.5.1c	371.99	371.17	362.14	24.2	16.17	113.5
New Trent Options	8.1.1	357.5	357.5	351.02	13.08	2.5	

Table 1: Initial DO results and associated benefit compared to the baseline for the first timeslice of option batches, and New Trent options

Option batch 2027_1 provides a Level 2 benefit of 1.88 Ml/d, lower than the expect WAFU of 4.9 Ml/d. The benefit of option batch 2029_1 increases dramatically as expected, owing to an increase in the number of individual options added to the portfolio. The only difference between Option batch 2029_1, 2029_2 and 2029_3 is the size of transfer from UU in option 7.5.1 (Vyrnwy), where it can be seen that there is no difference in the benefit for this option, increases in transfer (15, 30 and 45 Ml/d) notwithstanding (this observation is borne out in the testing of Vyrnwy options individually – refer to Section 5, where it can be seen that the Level 2 benefit (with and without climate change) caps out at 5-6 Ml/d).

Take option batch '2029_2' for instance - based on summation of individual source level WAFUs, the expected WAFU hypothetically should equate to 98.8 Ml/d. However, there is a limit to how much of this water can be deployed before capacity type considerations take over, and so the DO benefit is 23.42 Ml/d (interestingly, the options do address some capacity aspects in parts of the zone, because the Level 4 DO has also increased as well as Level 2). In short, there is a limit to the DO benefit that adding more source availability can achieve, under baseline conditions (which ultimately are not driving SSW's potential supply-demand

[4] Please refer to Appendix 1.

deficits). This combined with the fact that individual option benefits are masked when modelled as a batch, necessitated a change in modelling approach.

These early findings were highlighted to SSW, and a recommendation was made to assess options individually (such that this would highlight the true value an option can bring) and under climate change[5] (with the premise being that the benefit of an option will come to the fore when the system is stressed). This change in approach was also deemed sensible from a budget utilisation and time perspective (especially given the stretching timescales), thereby adding maximum value to the process for SSW.

[5] The same principle applies for environmental destination, and further testing under these conditions could also be applied by SSW to understand the benefit of candidate options portfolios.

4. Individual Option DO Assessment Under Mid Climate Change Conditions

After recommending a change in course of action to get a better feel for the potential benefit of each WRMP option, a collaborative decision between SSW and HLSI was reached, whereby analyses for specified individual options would be undertaken next[6] under SSW's central estimate Regional Climate Model scenario (RCM12), i.e. an expected middle impact. Details on and around implementation and schematisation of the individual options builds are specified in Appendix 1.

The priority for modelling of the individual options was based upon expected WAFU and option feasibility, to allow the hypothetical individual options benefits to be compared to actual DO modelled estimates.

The outputs from the 21 individual option runs were used to give a high-level overview of the benefit produced in Aquator, thereby allowing SSW to select the preferred options for further exploration under ED conditions by HLSI. The 21 individual options agreed upon are detailed below and in descending order of stated priority at the time:

Option	Area	Description
2.1.1.1	Trent	40 Ml/d new abstraction from River Trent to Blithfield reservoir
6.1.1	Trent	40 Ml/d new intake from River Trent to Seedy Mill WTW with 14-day bankside storage
6.1.3	Trent	70 Ml/d new intake from River Trent to Seedy Mill WTW with 14-day bankside storage
8.3.1	Trent	Burton-upon-Trent new surface water reservoir (0.5Mm^3)
7.5.1a	Vyrnwy	UU 15 Ml/d raw water transfer to Hampton Loade via River Severn
7.5.1b	Vyrnwy	UU 30 Ml/d raw water transfer to Hampton Loade via River Severn
7.5.1c	Vyrnwy	UU 45 Ml/d raw water transfer to Hampton Loade via River Severn
7.5.1d	Vyrnwy	UU 60 Ml/d raw water transfer to Hampton Loade via River Severn
2.2.2.1	Blithfield	Blithfield reservoir rising by 2m (increase volume by 6600 Ml)
2.3.1	Chelmarsh	Increasing volume of Chelmarsh reservoir by 3060 Ml
2.3.2	Chelmarsh	Increasing volume of Chelmarsh reservoir by 6120 Ml
1.1.7	SSPW	A new 4.9 Ml/d borehole at Shenstone with links before and after a service reservoir

[6] At this stage, the expectation was also that further equivalent testing would be undertaken with environmental destination also, but SSW subsequently confirmed this was not required at this time (in part offsetting increased numbers of model runs from the revised approach).

Option	Area	Description
1.1.9	Warton	A new groundwater source (2.5 Ml/d) and waterworks at Chilcote enabling a transfer to Outwoods combined demand centre
1.1.1.10	SAPW	A new groundwater source of 4.9 Ml/d at Sandhills
1.4.5	Coven	A new groundwater source of 3 Ml/d at Slade Heath
7.1.2.1	CRT	Transfer of 5 Ml/d from CRT Birmingham to Blithfield reservoir
8.1.1	Burton	Third party potable transfer of raw water (1.2 Ml/d) to the service reservoir fed by Seedy Mill waterworks in Burton-upon-Trent area
8.1.5	Burton	A new ground water source of 2.5 Ml/d supplying Seedy Mill waterworks
1.1.1	Kinver	A new groundwater source at the Kinver site to increase the supply to 18Ml/d
1.1.3a/b	Hinksford	Increase groundwater production at Hinksford borehole by 6.5 Ml/d to provide a total of 12.1 Ml/d
2.2.1.1	Blithfield	Blithfield reservoir rising by 1m (increase volume by 3180 Ml)

Table 2: Individual options and respective definitions agreed to be modelled with SSW

Once the requisite option was activated through the options selector form, two 2400-year analyses were carried out (noting the range was kept consistent within a scenario, i.e. for the overall analysis of stochastic Batches 4 and 7), with Table 3 showing an example of the set up used in Aquator XM.

DO models runs	Parameter value
Use worksheet matrix	FALSE
Apply Reduction Factors	TRUE
Start demand	300.00
End demand	370.00
Initial demand step	10.00
Modelling start date	01/01/1902
Modelling end date	31/12/4301
Step reduction factor	2.0
Minimum step size	5.000
Failure demand precision	5.000

Table 3: DO set-up in Aquator XM for individual option runs on BT4/BT7

The post-processing analysis was then used to obtain Level 4 (1:200 and 1:500) DOs and Level 2 (1:40) DOs.

The resulting DO values were compared to the RCM12 baseline DO values (as determined during the stochastics and climate change modelling exercise) to provide an indicator of the benefit an option can provide to SSW's system. For each run, the demand range was manually altered to provide a span of failures for Level 2 and Level 4 events. For example, if the range was set to 330-380 Ml/d and the Level 4 DO was found to be 335 Ml/d, the Level 2 DO will most likely lie below (given SSW's traditional DO constraints observed in English and Welsh DO assessment, e.g. pre-WRMP24) the lower limit of the range specified, therefore the Level 2 DO would be inaccurately represented. In this instance, the range would be lowered and/or widened to capture the true Level 2 DO, noting this is the typically constraining event to SSW's DO.

Initially, when comparing option DO results to the RCM12 baseline (as calculated in the previous supply work for SSW), some options were yielding small negative Level 2 benefits; this is considered counterintuitive when options inject additional water into the system. Further investigation showed the RCM12 baseline was previously interpolated over a coarser demand step (20 Ml/d) and was incomparable with the option runs (ran at a finer demand step)[7]. The RCM12 baseline was therefore rerun with a finer demand step, subsequently eliminating the negative Level 2 benefits. The Level 4 (1:200 and 1:500) and Level 2 (1:40) DOs and respective benefits are presented in Table 4:

Option	Level 4 1:200 DO (Ml/d)	Level 4 1:500 DO (Ml/d)	Level 2 1:40 DO (Ml/d)	Level 2 1:40 Benefit*	Level 4 1:500 Benefit*
RCM12 Baseline	355	355	321.18	-	-
RCM12 Baseline re-run	348.54	345.65	316.25	-	-
2.1.1.1	350.09	348.04	324.95	8.7	2.39
6.1.1	345.72	345.24	336.79	20.54	0
6.1.3	350.27	350	365.66	49.41	4.35
8.3.1	351.48	350.87	326.4	10.15	5.22
7.5.1a	347.34	340.03	322.51	6.26	0
7.5.1b	346.89	339.69	318.93	2.68	0
7.5.1c	344.39	339.61	319.39	3.14	0
7.5.1d	344.2	339.38	322.67	6.42	0
2.2.2.1	345.38	340.56	332.62	16.37	0
2.3.1	350.57	350.26	321.81	5.56	4.61
2.3.2	352.61	352.5	320.45	4.2	6.85
1.1.7	353.32	350.86	323.95	7.7	5.21
1.1.9	348.04	345.56	320.71	4.46	0
1.1.1.10	353.5	350.91	322.05	5.8	5.26
1.4.5	351.29	347.51	318.06	1.81	1.86
7.1.2.1	350.42	350.11	327.16	10.91	4.46
8.1.1	349.9	346.28	318.08	1.83	0.63
8.1.5	352.4	350.44	324.23	7.98	4.79
1.1.1	350.9	346.79	316.19	0.66	1.14
1.1.3a/b	351.87	348.27	316.23	0	2.62

[7] This links to the comments flagged in the 'call-out box' in Section 3.

Option	Level 4 1:200 DO (Ml/d)	Level 4 1:500 DO (Ml/d)	Level 2 1:40 DO (Ml/d)	Level 2 1:40 Benefit*	Level 4 1:500 Benefit*
2.2.1.1	350.05	346.51	327.13	10.88	0.86

** negative L2 and L4 benefits have been reported as 0 for practical purposes*

Table 4: DO results for each individual option and associated benefits compared to the RCM12 baseline rerun.

Option 2.2.2.1 (Blithfield reservoir rising by 2m) provides a large Level 2 benefit compared to the baseline. The greater storage addresses the Level 2 constrained Blithfield reservoir directly. The negative Level 4 benefit for this option (reported as 0 for practical purposes) could potentially be attributed to a larger reservoir volume, and thus a healthier resource state (in Aquator terms), therefore drawing upon this resource to a greater extent relative to other resources (even though the actual Level 4 constraint is upon Blithfield, the model sees all resource states 'equally' across resource types). A more depleted resource state in the original setup could, perhaps counterintuitively, result in the model protecting the resource more fully against the more extreme Level 4 DO events than with the option implemented. The Level 2 benefit can also be seen in Option 2.2.1.1 (Blithfield reservoir rising by 1m), albeit to a lesser extent owing to a lower reservoir volume. These options indicate the potential for further optimisation on Blithfield reservoir and as such, is recommended to be explored as part of future work as to how the additional volume is best utilised.

Options 6.1.1 and 6.1.3 initially provided an unexpected negative Level 2 benefit. Upon investigation, it was observed that Blithfield reservoir was being utilised preferentially over the Trent bankside storage reservoir. The objective of this bankside storage reservoir option is to provide support to Blithfield reservoir in dry periods (reducing drawdown speed and aiding recovery). It was discovered that the model was making an arbitrary choice to take water from RV1 (Blithfield) as opposed to RV15 (Bankside storage) as there was no cost information on both resources in the SSW model, and both contained an 'infinite' resource state. Therefore, there was no logical preference of path for the system to route water, and therefore Aquator simply selected to take water from RV1 rather than RV15 because of the lower component ID number. The decision was made to apply some parameter and sequence changes to provide some logical behaviour to the operation of the option in terms of source preference. A cheap unit cost was placed on RV15 (an arbitrary value of £1/Ml), such that the model utilised this source more often, recognising however this resource should not be used if Blithfield reservoir is in a healthy resource state. Therefore, a control curve was also implemented on RV1, such that the model would only take water from the bankside reservoir (RV15) when Blithfield reservoir's resource state was below a certain value. The control curve choice was also arbitrary, with the '*Blithfield 1b (725)'* curve assigned to the *RV1.Control level.Supply*. HLSI strongly recommend undertaking Genetic Algorithm (GA) analyses to explore trade-offs to determine optimal cost, DO and HoFs should the option be a key candidate for implementation in the plan.

Options 7.5.1a-d (UU water transfer) provide no Level 4 benefit. The only difference in these options is the quantity of water being transferred and, as observed in Table 4 above, the DOs are effectively around the 340 Ml/d mark and the benefit essentially hits a "ceiling" due to a capacity constraint at Hampton Loade and network connectivity (i.e. in terms of getting the water across from Vyrnwy to the Level 2 constrained Blithfield reservoir.

Similarly, network connectivity (or a lack of) means that Options 2.3.1 & 2.3.2 (increasing the volume of Chelmarsh reservoir) provide only marginal benefit as it is difficult to convey additional water from Chelmarsh to Level 2 constrained Blithfield reservoir.

Option 8.3.1 (Burton-upon-Trent new surface water reservoir) provides a sufficient Level 4 benefit of 5.22 Ml/d along with a Level 2 benefit of 10.15 Ml/d. This is perhaps a function of the new abstraction to Seedy Mill WTW, reducing the reliance on Blithfield reservoir.

Option 7.1.2.1 again shows the importance of Blithfield reservoir for Level 2 constraints. This transfer directly to the reservoir provides a large Level 2 benefit of 10.91 Ml/d compared to the expected WAFU of 5 Ml/d. The Level 4 benefit of 4.46 Ml/d fits closely with the expected WAFU.

The significance of Seedy Milly WTW drawing down Blithfield reservoir can be seen in options 8.1.1 and 8.1.5. Option 8.1.1 has a larger expected WAFU due to the import being 3 Ml/d compared to 2.5 Ml/d of Option 8.1.5, yet it produces a low benefit for both Level 2 and Level 4 DOs as it supplies the service reservoir downstream of Seedy Mill. This means Seedy Mill will continue to draw upon water from Blithfield reservoir to operate. However, Option 8.1.5 directly supplies Seedy Mill, reducing the intake from Blithfield and allowing the reservoir to recover more and in turn produce a large Level 2 benefit (7.98 Ml/d) compared to its expected WAFU (2.5 Ml/d).

5. Individual Option DO Assessment Under Baseline Conditions

After reviewing the initial previous option (with climate change scenario RCM12 applied) run results, SSW requested that baseline runs were to be carried out for selected individual options. These baseline option runs were required to understand the impact of climate change on the option. The 15 requested option runs at the baseline with no climate change conditions were calculated in an identical method to the RCM12 scenario runs stated previously.

Some initial results showed small negative benefit values in Level 2 DO as previously observed with the RCM12 scenario runs. This was a similar issue whereby the baseline was interpolated over a coarser demand step and was remedied in a similar manner by re-running the baseline with finer demand steps in the search range. DO results (at Level 4 and Level 2) for the 15 options under baseline and climate change, along with respective benefits are summarised overleaf in Table 5:

Option	Level 4 1:500 DO					Level 2 1:40 DO				
	Baseline	RCM12	RCM12 Impact	Option Benefit (Baseline)*	Option Benefit (RCM12)*	Baseline	RCM12	RCM12 Impact	Option Benefit (Baseline)	Option Benefit (RCM12)
No option	355	345.65	-9.35	-	-	336.5	316.25	-20.25	-	-
Option 2.1.1.1 Trent	355	348.04	-6.96	0	2.39	342.94	324.95	-17.99	6.44	8.7
Option 2.2.1.1 Blithfield	355	346.51	-8.49	0	0.86	345.44	327.13	-18.31	8.94	10.88
Option 2.2.2.1 Blithfield	349.77	340.56	-9.21	0	0	350.73	332.62	-18.11	14.23	16.37
Option 6.1.1 Trent	345	345.24	0.24	0	0	346.66	336.79	-9.87	10.16	20.54
Option 6.1.3 Trent	350.36	350	-0.36	0	4.35	375.02	365.66	-9.36	38.52	49.41
Option 7.1.2.1 CRT	355	350.11	-4.89	0	4.46	342.71	327.16	-15.55	6.21	10.91
Option 8.1.1 Burton	355	346.28	-8.72	0	0.63	337.28	318.08	-19.2	0.78	1.83
Option 8.1.5 Burton	355.02	350.44	-4.58	0.02	4.79	342.76	324.23	-18.53	6.26	7.98
Option 8.3.1 Trent	355	350.87	-4.13	0	5.22	343.58	326.4	-17.18	7.08	10.15
Option 7.5.1a Vyrnwy	350.37	340.03	-10.34	0	0	342.11	322.51	-19.6	5.61	6.26
Option 7.5.1b Vyrnwy	350.16	339.69	-10.47	0	0	341.82	318.93	-22.89	5.32	2.68
Option 7.5.1c Vyrnwy	350.11	339.61	-10.5	0	0	341.93	319.39	-22.54	5.43	3.14
Option 7.5.1d Vyrnwy	350.08	339.38	-10.7	0	0	341.87	322.67	-19.2	5.37	6.42
Option 2.3.1 Chelmarsh	350.43	350.26	-0.17	0	4.61	343.79	321.81	-21.98	7.29	5.56
Option 2.3.2 Chelmarsh	350.43	352.5	2.07	0	6.85	343.79	320.45	-23.34	7.29	4.2

Table 5: DO results for each individual option and their associated benefit with and without climate change compared to the corresponding run with no option implemented.

** negative L4 benefits have been reported as 0 for practical purposes*

Option 6.1.3 proved to be a very robust option providing a large Level 2 benefit with and without climate change conditions. This can be attributed to alterations made by HLSI (control curve assignment and arbitrary unit cost implementation) to allow the model to utilise reservoirs based on relative resource states and costs.

Option 2.2.2.1 provides a good Level 2 benefit with and without climate change conditions as it directly increases the volume of Level 2 constrained Blithfield reservoir. The Level 4 DO decreases, but as discussed previously this is because the model recognises the healthy resource and draws down more in severe scenarios. HLSI advise that this behaviour can also be altered using a similar approach taken in option 6.1.3.

The results also show that under baseline conditions at Level 4, there a no option benefits owing to the capacity constrained nature of SSW’s system. There are resource benefits at Level 4 when the system is stressed owing to climate change. The benefit an option can provide is a function of the size of the option and/or where in the system the option is applied (the Vyrnwy options in particular epitomises this premise).

6. Conclusions and Future Considerations

21 options have been implemented in the SSW Aquator model. Using the Scottish method, DO values were obtained for 4 initial option batches, 21 individual options under RCM12 climate change conditions and 15 options at baseline conditions. Some main conclusions have been drawn and are detailed below:

- Options directly affecting the Blithfield reservoir significantly increase the Level 2 DO. This reiterates how significant the Level 2 constraints on Blithfield reservoir are for the overall Level 2 DO value.
- Option 6.1.1 and 6.1.3 provide the largest benefit to the SSW system. This is mostly attributable to HLSI's tweak in the system logic and operating rules by applying cost data and control curves to the relevant components.
- Option benefits may cap out under baseline conditions.
- Constraints to options inputting water into the Chelmarsh/Hampton Loade locale are observed due to system capacity limitations, as it was clearly seen that bulk inputs from Vyrnwy capped out at around 5-6 Ml/d (under baseline and climate change conditions at Level 2) which is 9-10 Ml/d below the smallest option (15 Ml/d transfer). More benefit may be possible but would involve further network interrogation.
- Benefits differ between Level 4 and other aspects of level of Service.

Some future considerations for SSW are outlined below:

- Additional operating tweaks to the system could prove to be beneficial (similar to Options 6.1.1 & 6.1.3) and increase the overall DO of the options.
- A commitment to explore the optimisation of operating and control rules to increase option DOs, e.g. through the use of the GA (Genetic Algorithm) analysis, or other testing of rule / operating principle alternatives.
- HLSI recommend a full re-optimisation and assessment of the current Level 2 rules throughout the SSW system. These typically are more constraining than Level 4 in DO terms, indicating a potential mismatch between the Level of Service curves and underlying resource risk.
- Further portfolio testing of the draft WRMP preferred and alternative plans would be advisable, including under ED.
- For future stages of the plan process, it is highly advisable to revisit the LoS remapping and Severn representation recommendations from previous supply reports, as this could further help refine SSW's underlying SDB confidence, and therefore in its long-term need for options.

The insight gained form this project, beyond the provision of the DO values themselves, is informative to help SSW progress their selected options and target future model update and/or refinement on balance of risk with other influences on their supply-demand balance.

Appendix 1: Individual Option Schematics and Definitions

For the benefit of the reader, this appendix lists the options implemented in SSW's Aquator model. An overview of the scheme operation is detailed along with schematisation (noting an option is circled in green). Finally, information on conceptualisation and implementation is tabulated under each option.

Option 2.1.1.1 Trent

New abstraction (40 Ml/d) on the River Trent to provide raw water support to Blithfield reservoir.

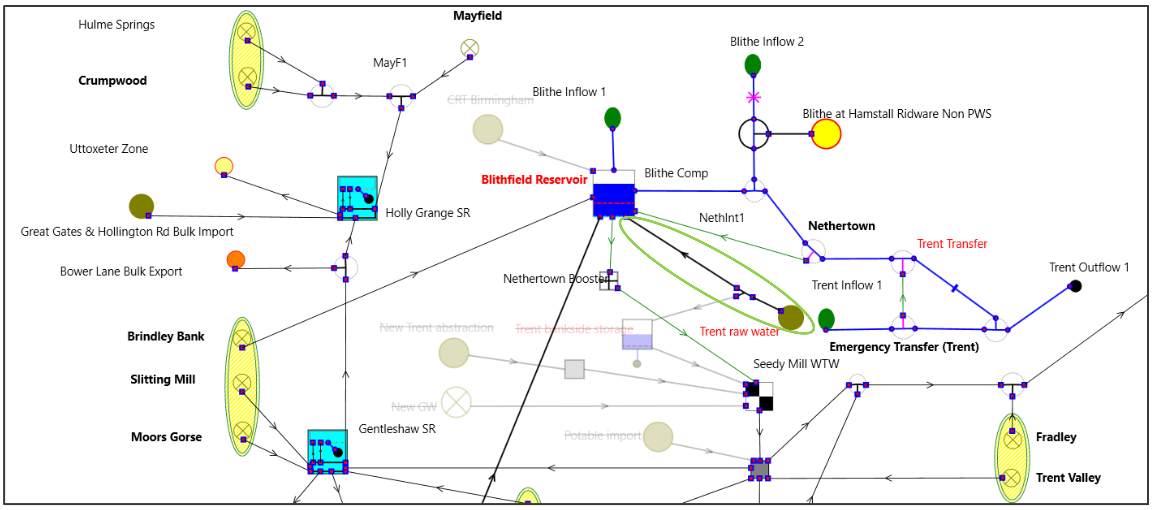

Figure 3: Option 2.1.1.1 (circled in green) implemented in Aquator XV.

Component	Custom VBA	Value	Action
BS6	WRMP24 Options (VBA).2.1.1.1 40 Ml/d new sw abst R.Trent to Blithfield Reservoir	Boolean	Activates option when box is checked
BS6	WRMP24 Options (VBA).2.1.1.1 40 Ml/d new sw abst R.Trent to Blithfield Reservoir max supply	40 Ml/d	Changes the max supply of the bulk supply to 40 Ml/d

Option 6.1.1 Trent

New abstraction (40 Ml/d) on the River Trent to go into Seedy Mill WTW with a 14-day bankside storage reservoir.

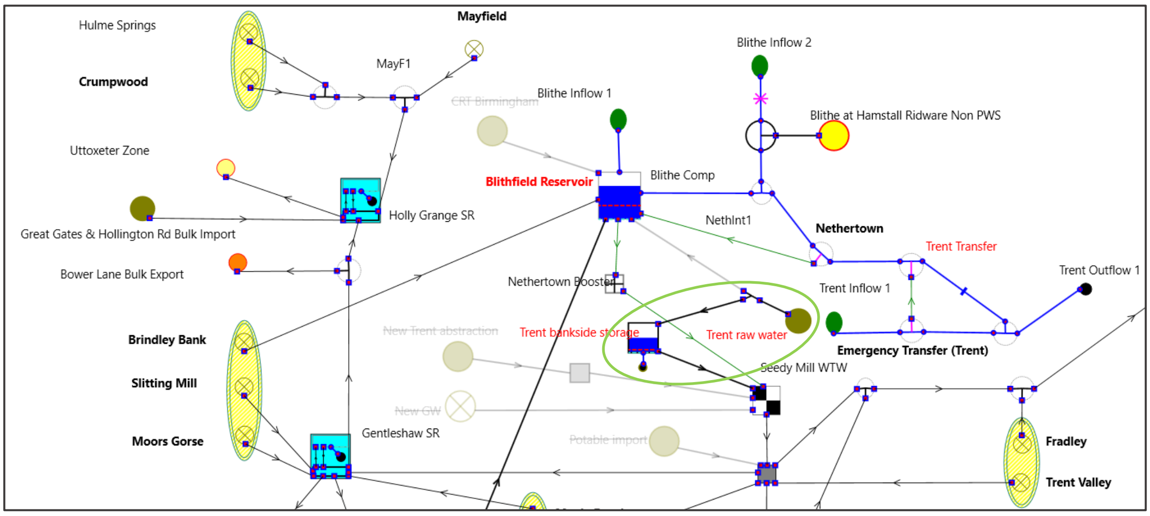

Figure 4: Option 6.1.1 (circled in green) implemented in Aquator XV.

Component	Custom VBA	Value	Action
BS6	WRMP24 Options (VBA).6.1.1 Trent 40 Ml/d – new sw intake with 14 day bankside storage and treatment works	Boolean	Activates option when box is checked
BS6	WRMP24 Options (VBA).6.1.1 Trent 40 Ml/d – new sw intake with 14 day bankside storage and treatment works max supply	40 Ml/d	Changes the max supply of the bulk supply to 40 Ml/d
RV15	WRMP24 Options (VBA).6.1.1 Trent 40 Ml/d – new sw intake with 14 day bankside storage and treatment works TWL volume	8052 Ml	Sets volume of bankside reservoir to 8052 Ml

Option 6.1.3 Trent

New abstraction (70 Ml/d) on the River Trent to go into Seedy Mill WTW with a 14-day bankside storage reservoir.

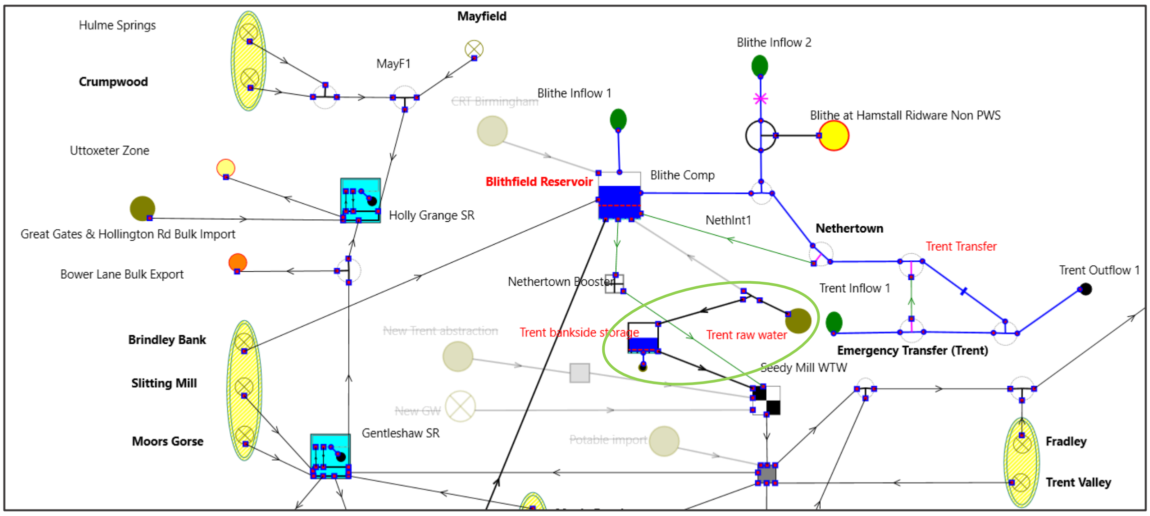

Figure 5: Option 6.1.3 (circled in green) implemented in Aquator XV.

Component	Custom VBA	Value	Action
BS6	WRMP24 Options (VBA).6.1.1 Trent 70 – new sw intake with 14 day bankside storage and treatment works	Boolean	Activates option when box is checked
BS6	WRMP24 Options (VBA).6.1.1 Trent 70 – new sw intake with 14 day bankside storage and treatment works max supply	70 Ml/d	Changes the max supply of the bulk supply to 70 Ml/d
RV15	WRMP24 Options (VBA).6.1.1 Trent 70 – new sw intake with 14 day bankside storage and treatment works TWL volume	14090 Ml	Sets volume of bankside reservoir to 14090 Ml

Option 7.5.1a Vyrnwy

Raw water transfer from UU to Hampton Loade via River Severn. (15, 30, 45 & 75 Ml/d for a, b, c & d respectively).

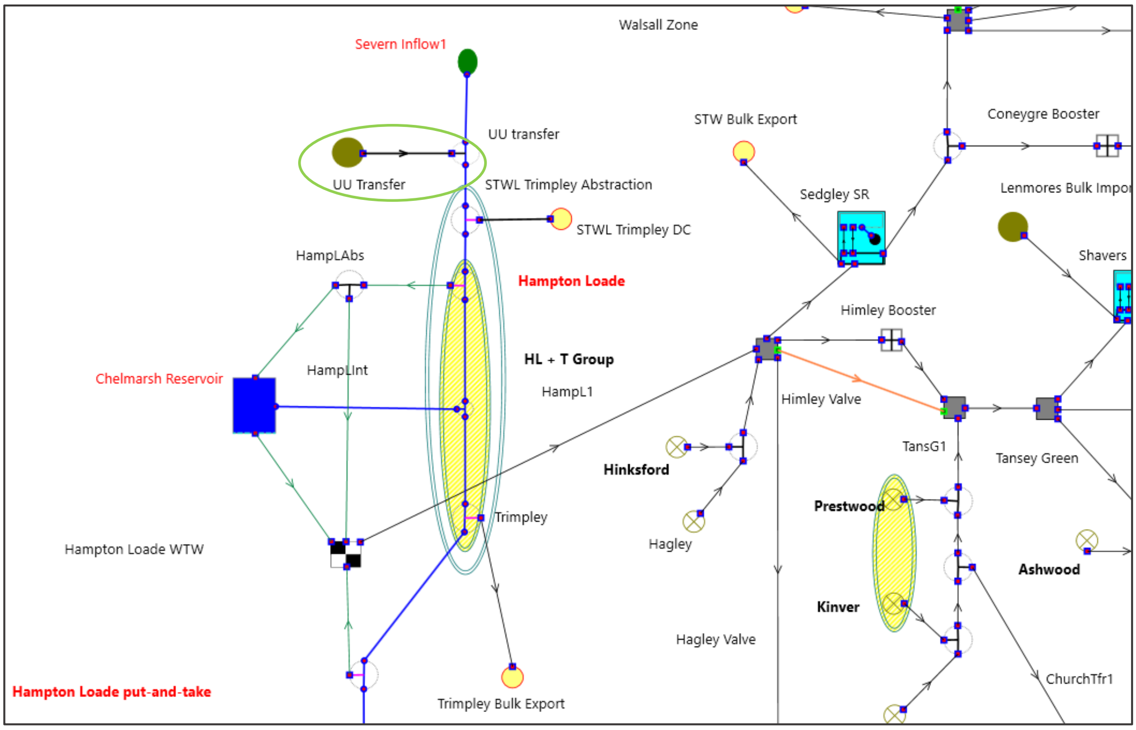

Figure 6: Option 7.5.1 (circled in green) implemented in Aquator XV.

Component	Custom VBA	Value	Action
BS7	WRMP24 Options (VBA).UU – *x* Ml/d raw water transfer to Hampton Loade via River Severn max supply	x Ml/d	Sets max supply of bulk supply to x Ml/d

Option 7.5.1b Vyrnwy

Identical to option 7.5.1a except for the maximum bulk supply value, which under this option is 30 Ml/d

Option 7.5.1c Vyrnwy

Identical to option 7.5.1a except for the maximum bulk supply value, which under this option is 45 Ml/d

Option 7.5.1d Vyrnwy

Identical to option 7.5.1a except for the maximum bulk supply value, which under this option is 75 Ml/d

Option 2.2.1.1 Blithfield

Raise the level of Blithfield reservoir by 1m (3180 Ml), by maintaining the same absolute volume for control curves.

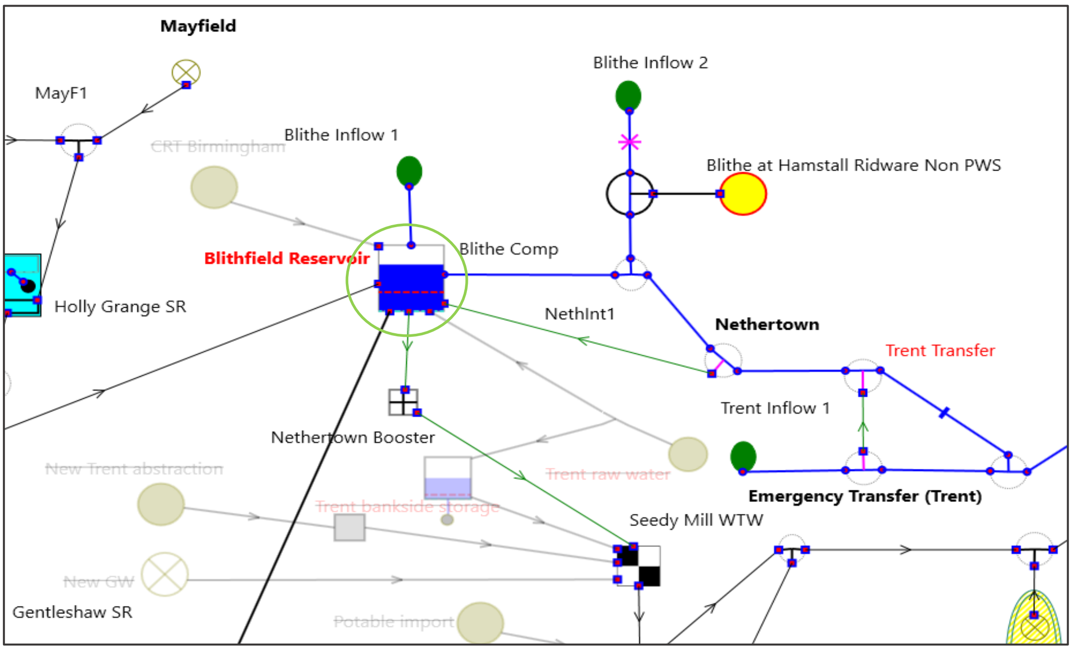

Figure 7: Option 2.2.1.1 (circled in green) implemented in Aquator XV.

Component	Custom VBA	Value	Action
RV1	WRMP24 Options (VBA).2.2.1.1 Blithfield Reservoir – 1m raising	Boolean	Activates option when box is checked
RV1	WRMP24 Options (VBA).2.2.1.1 Blithfield Reservoir – 1m raising TWL volume increase	3180 Ml	Increases the volume of the reservoir by 3180 Ml

Option 2.2.2.1 Blithfield

Identical to option 2.2.1.1 except for the level being raised by 2m (6600 Ml)

Option 2.3.1 Chelmarsh

Increase the volume of Chelmarsh reservoir, by 3060 Ml by maintaining the same absolute volume for control curves.

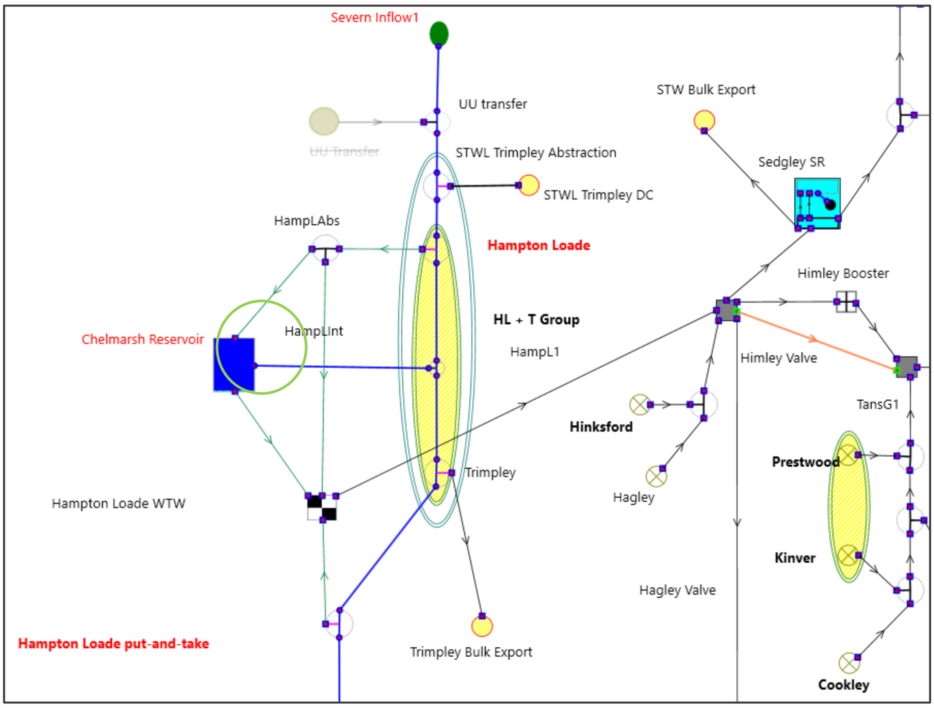

Figure 8: Option 2.3.1 (circled in green) implemented in Aquator XV.

Component	Custom VBA	Value	Action
RV2	WRMP24 Options (VBA).2.3.1 Chelmarsh Reservoir – 2m raising	Boolean	Activates option when box is checked
RV2	WRMP24 Options (VBA).2.3.1 Chelmarsh Reservoir – 2m raising TWL volume increase	3060 Ml	Increases the volume of the reservoir by 3060 Ml

Option 2.3.2 Chelmarsh

Identical to option 2.3.1 except for the volume being increased by 6120 Ml

Option 1.1.7 Shenstone

GW enhancement of Shenstone BH to connect to more areas in the system at all points (not just peak and drought scenarios).

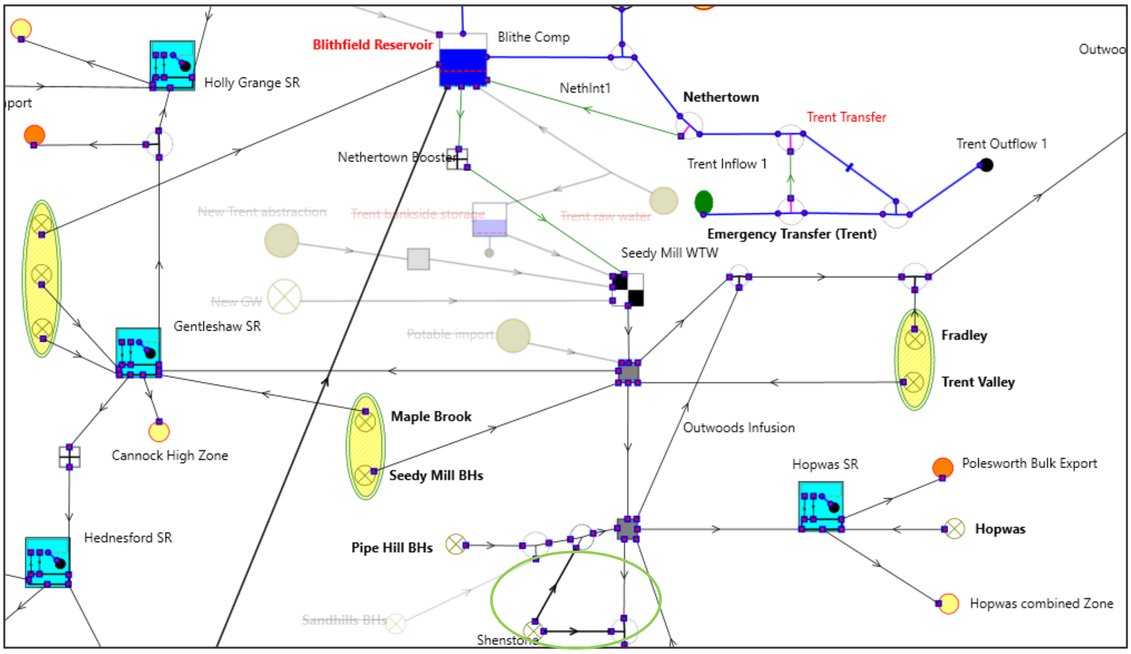

Figure 9: Option 1.1.7 (circled in green) implemented in Aquator XV.

Component	Custom VBA	Value	Action
GW15	WRMP24 Options (VBA).1.1.7 New BH SSPW	Boolean	Activates option when box is checked
GW15	WRMP24 Options (VBA).1.1.7 New BH SSPW Max supply amount	4.9 Ml/d	Changes the max supply of the groundwater to 4.9 Ml/d

Option 1.1.9 Warton

New GW source and treatment works in the Warton Unit.

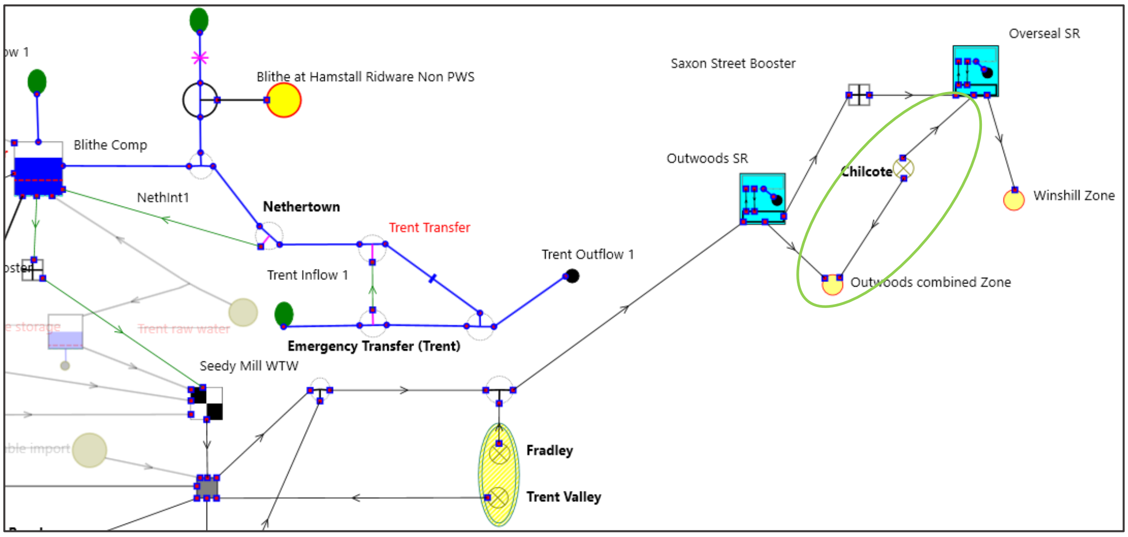

Figure 10: shows Option 1.1.9 (circled in green) implemented in Aquator XV.

Component	Custom VBA	Value	Action
GW9	WRMP24 Options (VBA).1.1.9 New groundwater source and treatment works in Warton Unit.	Boolean	Activates option when box is checked
GW9	WRMP24 Options (VBA).1.1.9 New groundwater source and treatment works in Warton Unit. max supply increase	2.5 Ml/d	Increases the value of the max groundwater supply by 2.5 Ml/d

Option 1.1.1.10 Sandhills

New GW source at Sandhills.

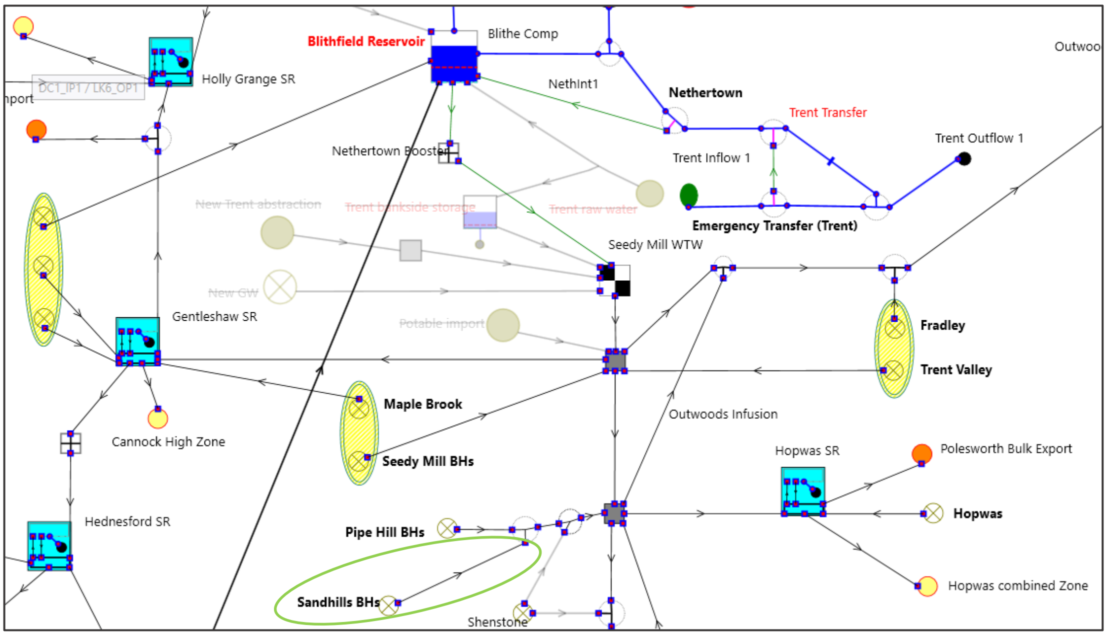

Figure 11: Option 1.1.1.10 (circled in green) implemented in Aquator XV.

Component	Custom VBA	Value	Action
GW14	WRMP24 Options (VBA).1.1.1.10 SAPW BH and upgrade treatment	Boolean	Activates option when box is checked
GW14	WRMP24 Options (VBA).1.1.1.10 SAPW BH and upgrade treatment Max supply amount	4.9 Ml/d	Changes the max supply of the groundwater to 4.9 Ml/d

Option 1.4.5 Coven

New GW source and treatment works in the Coven Unit.

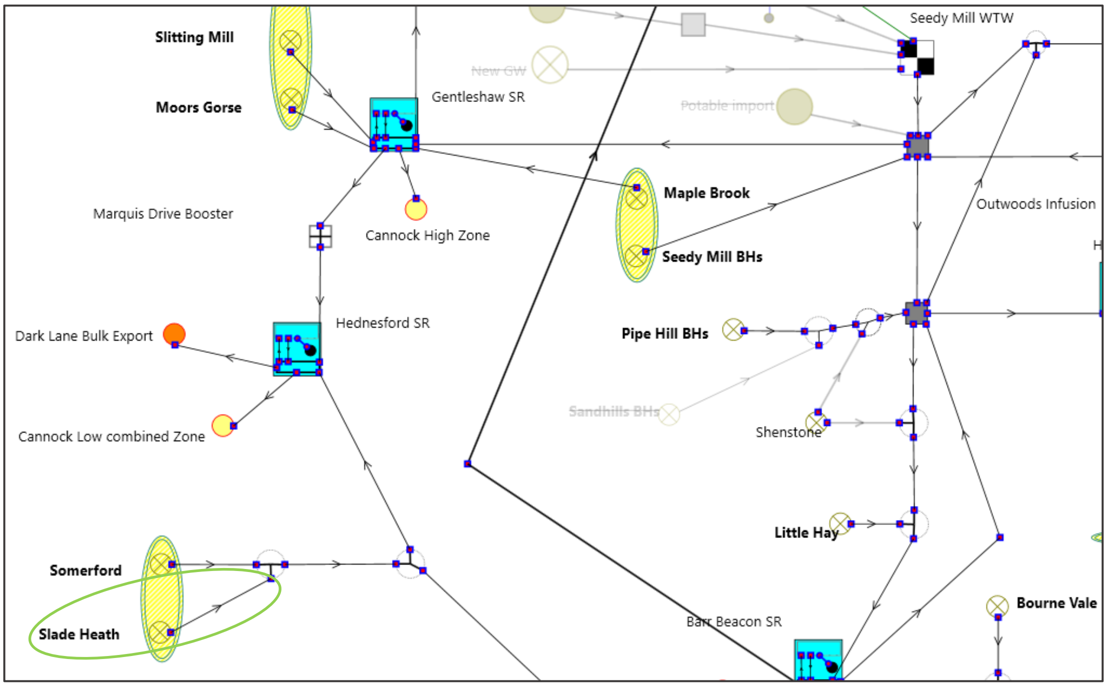

Figure 12: Option 1.4.5 (circled in green) implemented in Aquator XV

Component	Custom VBA	Value	Action
GW20	WRMP24 Options (VBA).1.4.5 Coven unit – new gw source and treatment works	Boolean	Activates option when box is checked
GW20	WRMP24 Options (VBA).1.4.5 Coven unit – new gw source and treatment works max supply increase	3 Ml/d	Changes the max supply of the groundwater to 3 Ml/d

Option 7.1.2.1 CRT

CRT transfer from Birmingham to Blithfield reservoir via the canal network.

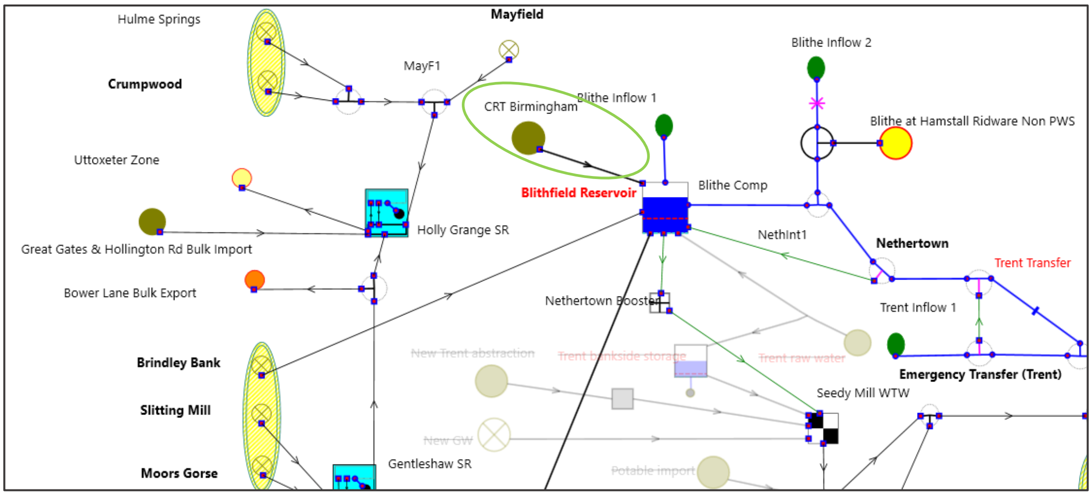

Figure 13: Option 7.1.2.1 (circled in green) implemented in Aquator XV.

Bulk supply (BS5) with a max supply of 5 Ml/d is enabled along with the link (LK235) connecting it to Blithfield reservoir, when option is selected via the OptionsSelector form.

Option 8.3.1 Burton-upon-Trent

Burton-upon-Trent new surface water reservoir.

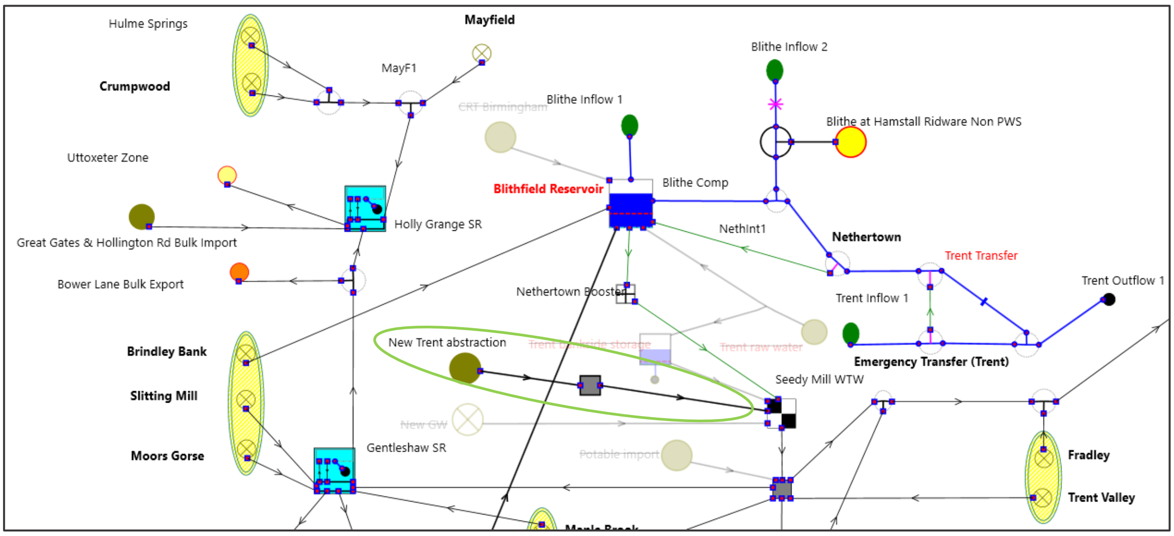

Figure 14: Option 8.3.1 (circled in green) implemented in Aquator XV.

Component	Custom VBA	Value	Action
BS9	WRMP24 Options (VBA).8.3.1 Burton-upon-Trent new surface water reservoir	Boolean	Activates option when box is checked
BS9	WRMP24 Options (VBA). 8.3.1 Burton-upon-Trent new surface water reservoir max supply	7 Ml/d	Changes the max supply of the bulk supply to 7 Ml/d

Service reservoir (SR31) is also enabled with a capacity of 500 Ml along with the links (LK245 & LK246) connecting the bulk supply (BS9) to Seedy Mill WTW (WW1).

Option 8.1.1 Burton-upon-Trent

Third party potable import in Burton-upon-Trent.

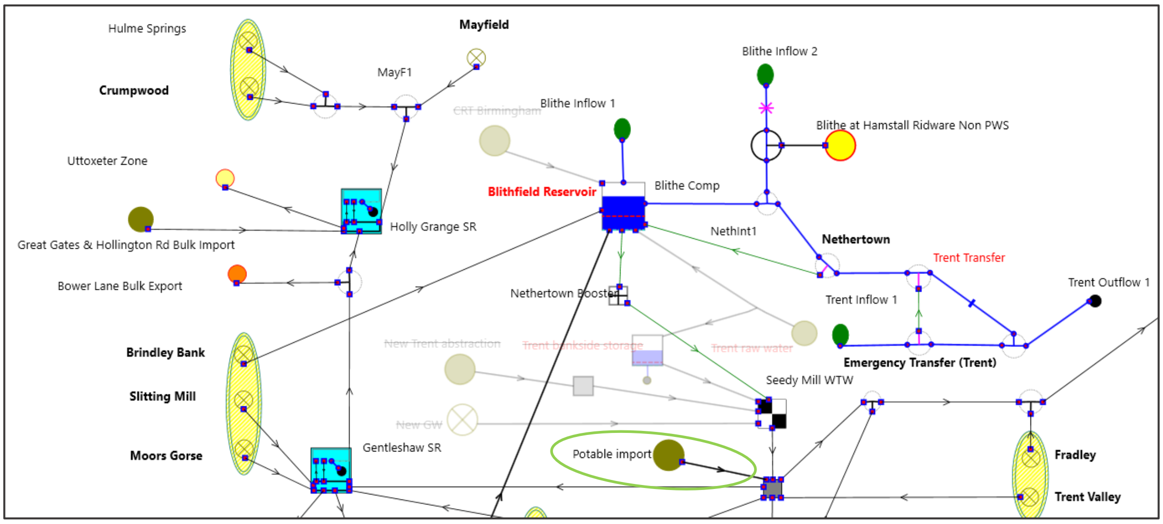

Figure 15: Option 8.1.1 (circled in green) implemented in Aquator XV.

Component	Custom VBA	Value	Action
BS8	WRMP24 Options (VBA).8.1.1 Third party potable import in Burton-upon-Trent	Boolean	Activates option when box is checked
BS8	WRMP24 Options (VBA).8.1.1 Third party potable import in Burton-upon-Trent max supply	1.2 Ml/d	Changes the max supply of the bulk supply to 1.2 Ml/d

Option 8.1.5 Burton-upon-Trent

New Burton-upon-Trent GW source to Seedy Mill WTW.

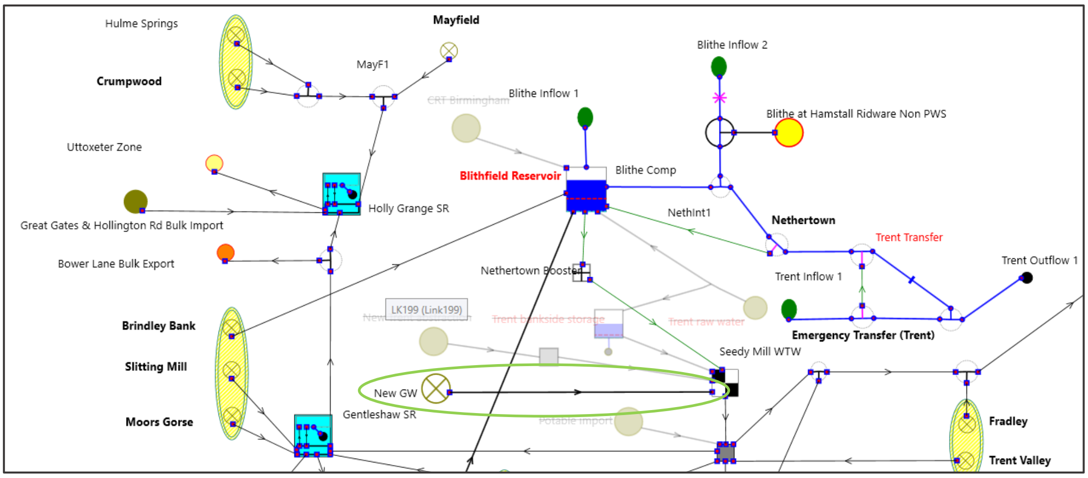

Figure 16: Option 8.1.5 (circled in green) implemented in Aquator XV.

Component	Custom VBA	Value	Action
GW30	WRMP24 Options (VBA).8.1.5 New Burton-upon-Trent GW source with licence trade	Boolean	Activates option when box is checked
GW30	WRMP24 Options (VBA).8.1.5 New Burton-upon-Trent GW source with licence trade max supply	2.5 Ml/d	Changes the max supply of the groundwater to 2.5 Ml/d

Option 1.1.1 Kinver

New GW source at the Kinver site.

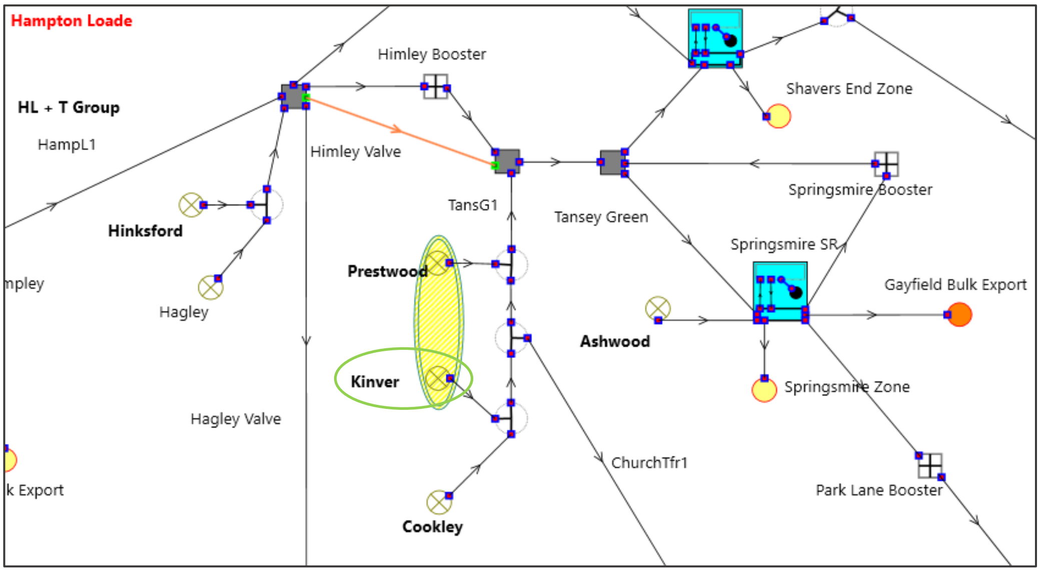

Figure 17: Option 1.1.1 (circled in green) implemented in Aquator XV.

Component	Custom VBA	Value	Action
GW24	WRMP24 Options (VBA).1.1.1 New BH KIPW1	Boolean	Activates option when box is checked
GW24	WRMP24 Options (VBA).1.1.1 New BH KIPW1 Max supply amount	18 Ml/d	Changes the max supply of the groundwater to 18 Ml/d

Option 1.1.3a/b Hinksford

Increase GW production at Hinksford BH.

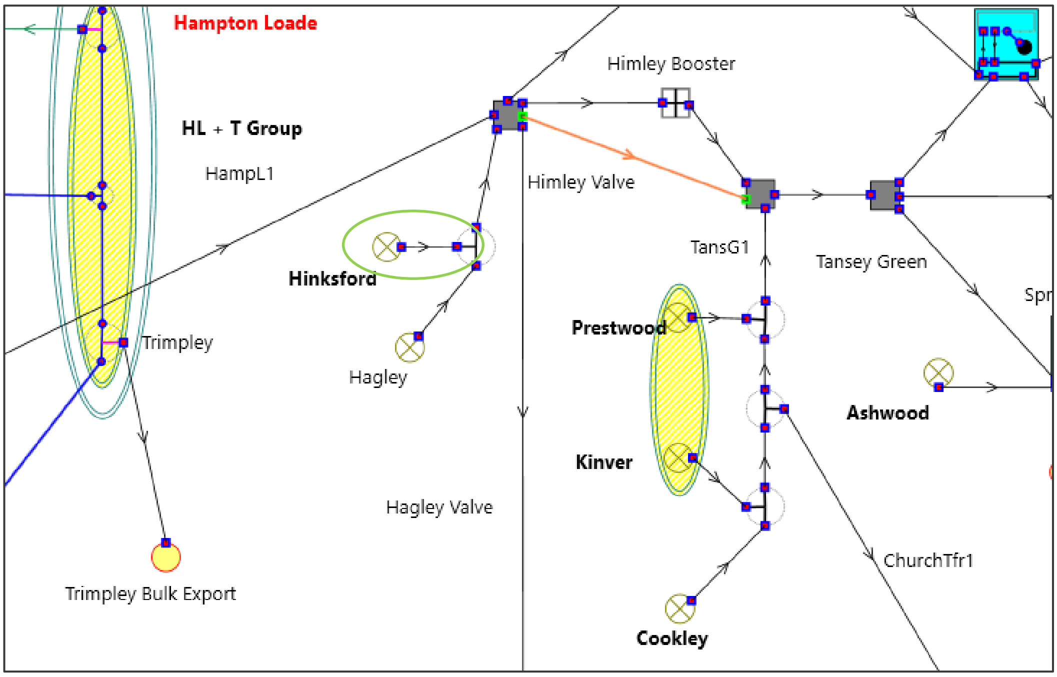

Figure 18: Option 1.1.3a/b (circled in green) implemented in Aquator XV.

Component	Custom VBA	Value	Action
GW21	WRMP24 Options (VBA).1.1.3a/b New BH HIPW	Boolean	Activates option when box is checked
GW21	WRMP24 Options (VBA).1.1.3a/b New BH HIPW max supply increase	6.5 Ml/d	Increases the value of the max groundwater supply by 6.5 Ml/d

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