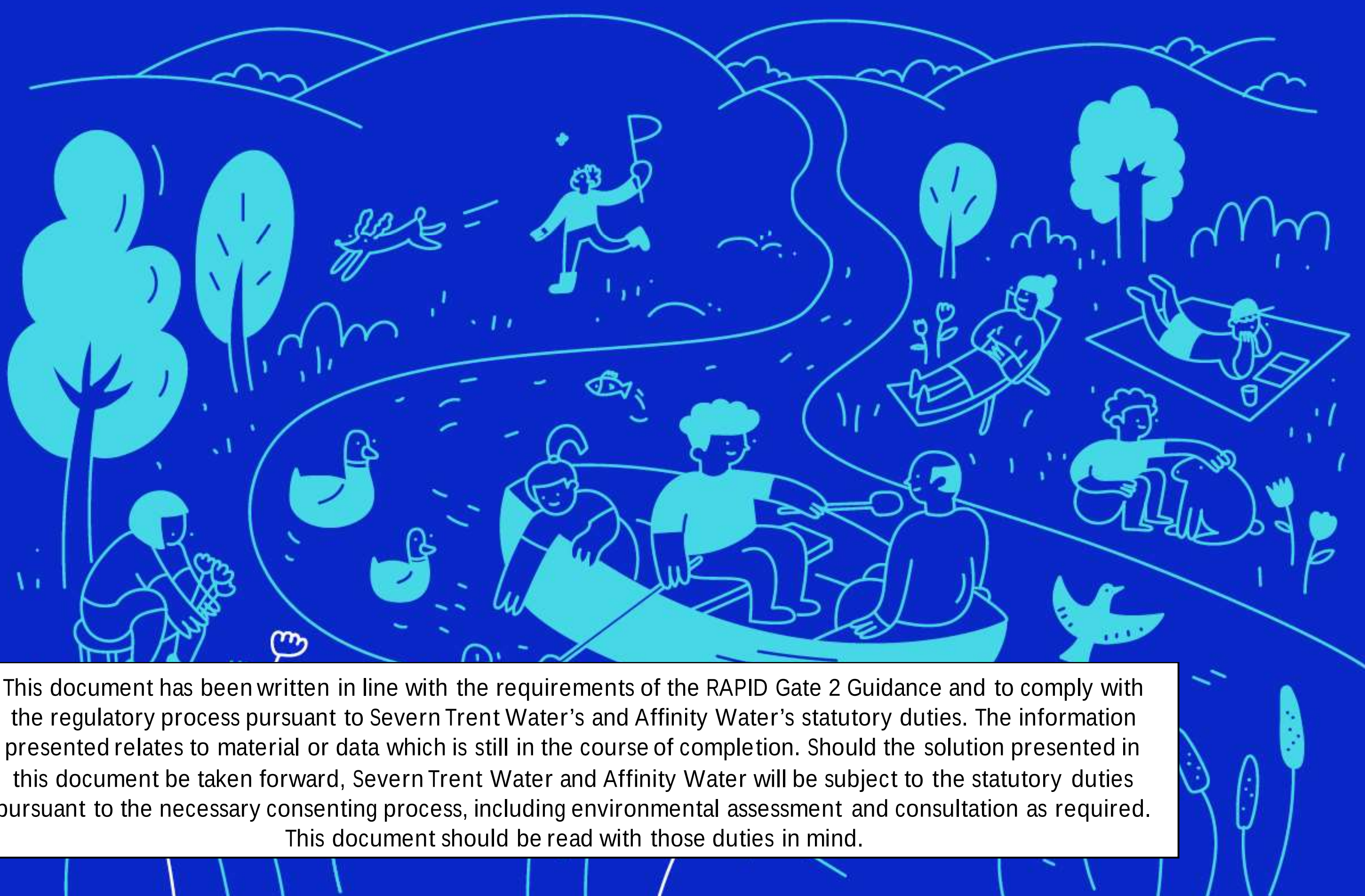
Affinity Water

Capacity Needs and Utilisation Profile for Strategic Options



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Introduction and Technical Background

This technical note provides a summary of the approach, modelling and assumptions used to generate both the capacity requirements and utilisation profile for Affinity Water when considering large scale new surface water developments. It utilises the Pywr water resources platform to consider the demand profiles that are generated when 50Ml/d, 100Ml/d or 200Ml/d of new resource is introduced into the system, primarily to replace groundwater sources that are lost through the Environmental Destination scenarios.

Because the Affinity Water system does not contain any significant raw water storage, the calculation of Deployable Output is complex and reflects three possible modes of system failure that can occur in a drought year:

1) Failure during autumn minimum groundwater periods where groundwater levels become so low that they are unable to maintain outputs even though demand is only running at seasonally low levels.
2) Failure during the peak week demand period, where the 7 day abstraction stress on borehole sources is sufficient to cause a transient drawdown to below operationally suitable levels (referred to as 'Deepest Advisable Pumped Water Levels (DAPWLs)).
3) Failure during extended summer demand periods, where prolonged higher rate abstraction from groundwater sources caused by summer demand increases causes boreholes to draw below DAPWLs.

The 'Average Deployable Output' (ADO) that is generated by the water resources assessment is a single figure that captures all of these complexities into a single representative value that can be used in investment modelling. **As detailed within the UKWIR Manual of Source Yields, the ADO is equal to the annual average level of *demand* that the water resource system can manage to supply under the design drought condition without any of the above failure modes occurring.**

The baseline DO modelling carried out for Affinity Water's dWRMP24 showed that the third failure mode tends to act as the constraint on ADO. This has implications for both the capacity requirements of new schemes, and the nature of operational utilisation of those schemes. These implications are conceptually illustrated in Figure 1 below.

As shown, because demand will be higher during the summer critical period, achieving a given ADO requires that the capacity of a new scheme is higher than the ADO. The ratio of scheme capacity to ADO will tend to reflect the ratio of average annual demand:summer period demand, although the presence of licence constrained sources complicates this relationship.

Similarly, because the point of failure tends to be during the summer, there is spare capacity in existing sources outside of that summer period. This spare capacity can be utilised when demand increases or supply is lost, which means that *new* sources of water only tend to have to be fully utilised during the summer. Both of these factors are quantified for new strategic options within this technical note.

Figure 1 ***Illustration of Supply/Demand Stress and Need in the Affinity Central System***

Methodology, Key Assumptions and Input Constraints

Scheme Capacity Requirements

The evaluation of capacity requirements was carried out using the three assessment steps shown below. The methodology used to configure and run the baseline Deployable Output assessment within Pywr is covered in a separate Deployable Output technical note. The methodology described here uses the same model and approach for calculating DO, but with specific configurations and assumptions.

1. Set up Pywr model to reflect the required operational scenario [incorporate preferred Environmental Destination scenario]. Calculate the baseline ADO using the 'Scottish Method'.

2. Add the Strategic Option at a fixed capacity [50 or 100Ml/d], used as the preferred source.

3. Re-run the Pywr model to generate the ADO with the strategic option included.

The requirements associated with each stage of the analysis are described in the sections below.

Step1 : Pywr Model Setup

The Affinity Water Central Region Pywr model was configured to provide a baseline assessment of system DO using the following key assumptions:

1) The standard 2018 demand profile and demand savings were used, along with the WRSE stochastic groundwater data set (400*48 years).
2) The 'Company Alternative' Environmental Destination scenario used in the WRSE Jan 22 emerging plan was incorporated by reducing or turning off the relevant groundwater sources. This reduced the effective 1 in 200 year MDO capability within the model by approximately 128Ml/d compared with the 2025 position.
3) Other key assumptions were retained as per the baseline WRSE DO model.

The model was run using the standard 5 step approach developed for WRSE and WRMP24, generating a baseline 1 in 200 year level of DO. The resulting absolute demand timeseries for that level of DO was recorded for WRZs 1 – 5 and used in the subsequent steps.

Step 2 : Add the Strategic Option

As the Pywr model is set up on a Water Resource Zone basis, incorporating the new strategic source of surface water was very straightforward. The new resource was added as a fixed capacity scheme, incorporated into the model supplying the appropriate WRZ. For this run, the new source was used preferentially to existing sources, to ensure that the DO benefits were maximised.

Step 3 : Re-Run ADO Evaluation

The 5 step process was then re-run to generate the new ADO with the option included, based on the 'Scottish Method'.

Scheme Utilisation

The methodology involved 4 stages of analysis, as summarised below.

1. Set up Pywr Model to reflect the required operational scenario [incorporate preferred Environmental Destination scenario]
2. Include new strategic resource and run Pywr Model at the increased DO position[demand set at revised baseline DO plus 50, 100 or 200Ml/d] to generate raw utilisation profiles.
3. Modify profiles to reflect operationally realistic utilisation
4. Generate utilisation versus return period profile (either isolated or coherent with donor systems).

Step1 : Pywr Model Setup

This step was the same as the scheme capacity assessment described above.

Step2 : Include SRO and Re-Run

For the utilisation analysis the strategic resource was added in the same way as the capacity analysis, but in this case with an unlimited capacity but as the least preferred source of water (i.e., the system could draw on it as much as required, albeit as the source of last resort). The model was then run at a single demand value, equal to the baseline plus either 50, 100 or 200Ml/d ADO.

Step 3 : Modify Profiles to Reflect Operational Reality

Because the drought vulnerability in the Affinity Water system relates to groundwater, there is uncertainty in the performance and availability of groundwater during drought events. Although new sources are relatively expensive, they would be managed pro-actively to avoid unexpected problems and failures of groundwater. It is therefore proposed that operations of new sources would incorporate three key principles:

1. The groundwater recession during the drought and the design demand profile (calendar year 2018 with TUBs and NEUBs in place as relevant) would be used to forecast the expected need, with operation during June to August inclusive set to equal to maximum sustained demand requirement that might be expected.
2. New sources would be ramped up and ramped down in relation to the summer need during May and September in a controlled and pro-active fashion.
3. Sources with annual volumetric constraints that are capable of pumping at higher rates during peak times, such as the Blackford Group and the existing Anglian Water import transfer, would be operated at increased rates during the summer, but this would be moderated to ensure that annual allowances were not exceeded towards the end of the rolling 12 month period.

The raw model outputs generated during Step 2 were therefore modified so that:

1) Abstraction from the new source during June to August was set to the maximum 30 day value recorded by the model for that period.
2) Utilisation during May and September was set to half the difference between the lower autumn to spring period and the summer period calculated above.
3) As the model was configured so that the new sources were used last in the optimisation, this typically meant that existing volumetric licences ran out in March of the following year (as the licences are managed in Pywr on a March-April basis). This meant that a large 'spike' of usage for the new source was typically generated in that period. This volume represents under-utilisation of existing licence during the summer event if the system is operated pro-actively, so it was re-apportioned to the May to October period for the previous year.

These modifications were applied to the timeseries of monthly utilisation profiles generated for the full stochastic data series in Step 2.

Finally, it is very unlikely that the Affinity Water SROs proposed could be operated on a complete on/off basis during the year. A second timeseries was therefore generated for a 'minimum turnover' case, where scheme utilisation could not reduce below 25% of the claimed ADO for the scheme.

Step 4 : Generate Utilisation versus Return Period Curves

The rate of change of Deployable Output with drought severity is not particularly steep for Affinity Water. At the same time, the lack of storage means that TUBs and NEUBs tend to have a large influence on the utilisation during summer. That means the need during summer can drop significantly once the TUBs threshold is passed (i.e. for droughts just greater than 1 in 10 years), up to the point that the deteriorating groundwater capability results in a supply/demand situation that is actually worse than dry weather demand events where TUBs and NEUBs are not in place.

It is therefore important for Affinity Water to understand the relationship between annual utilisation and frequency. This was achieved by a simple percentile analysis of all of the years within the stochastic sequence to understand the relationship between frequency and annual average utilisation for a given scheme size. This was done for the 'operationally realistic' utilisation timeseries, with and without the minimum utilisation constraint outlined in Step 3.

Results and Discussion

Scheme Capacity Requirements

The analysis was based on a 'nominal' SRO that is able to send water to any of WRZs 1-5. The analysis of DO benefits for a 50, 100 and 200 Ml/d capacity schemes are provided below:

Transfer capacity	DO Increase	Efficiency
0	0	
50	43	87%
100	85	85%
200	183	91%

This result is as expected. With TUBs and NEUBs in place, the 30 day rolling average demand during a 'dry year' (2018) summer is around 10% - 14% higher than the annual average (depending on when the TUBs and NEUBs are introduced within the year). An effective DO that is 9% to 15% lower than the capacity is therefore as expected.

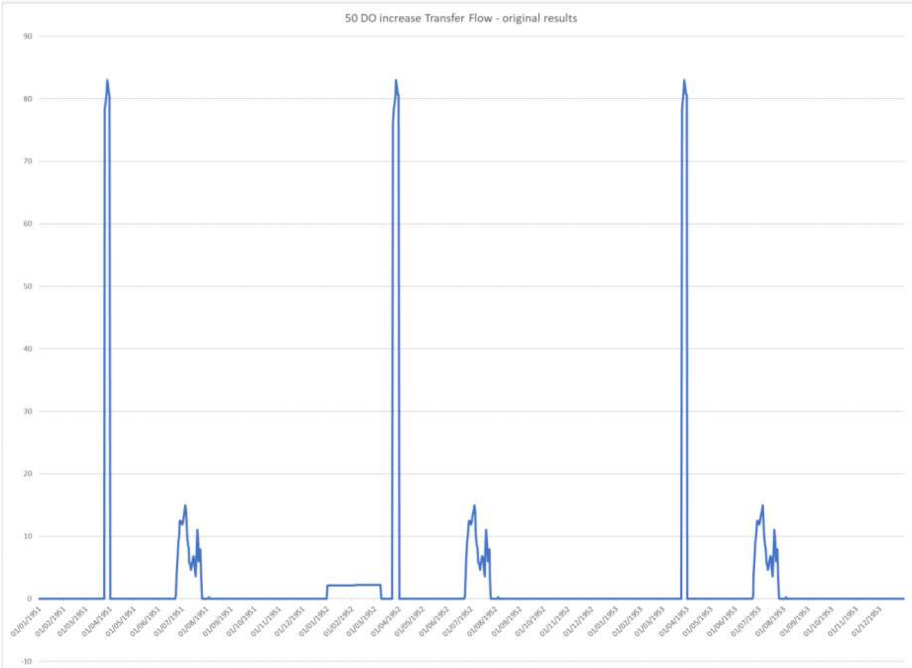
Because the above ratios work across WRZs 1-5, they apply to the DO capability of any of the strategic resource schemes.

Scheme Utilisation

Examples of the raw outputs for the scheme utilisation time series for the 50Ml/d DO increase is shown below.

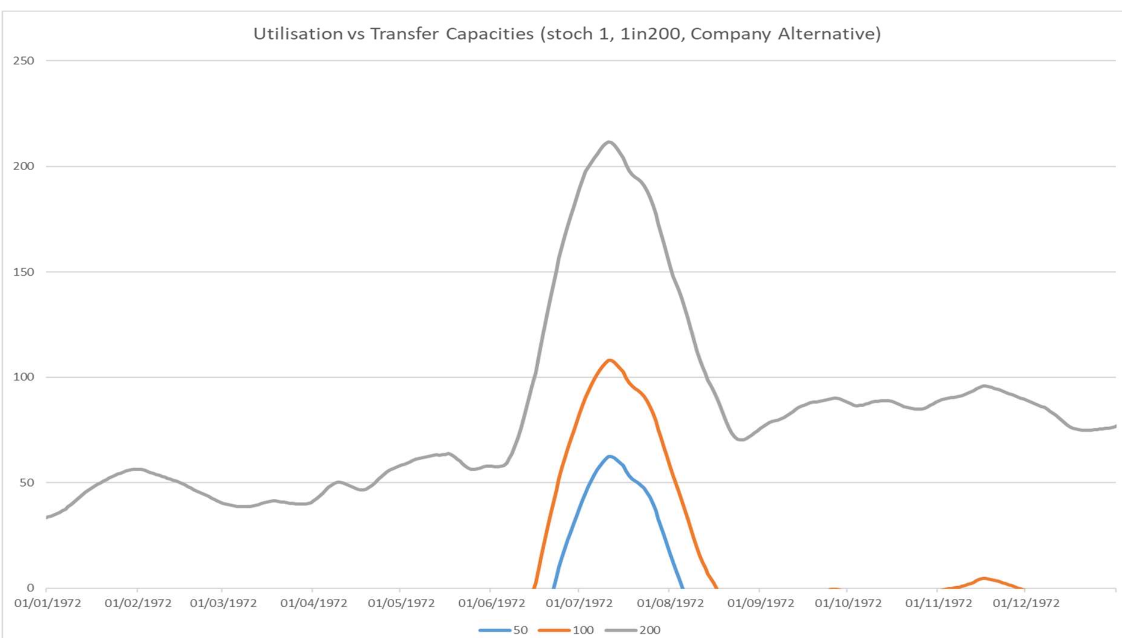
As shown, in a normal year with a dry year summer event the utilisation is very low and concentrated in the summer only, at around 30% of the DO increase. There is a large 'spike' which is caused by the model minimising use of the new source, which means some of the volumetric licences run out at the end of the year.

Figure 2 Raw Pywr Model Ouput for Utilisation of the 50Ml/d Scheme



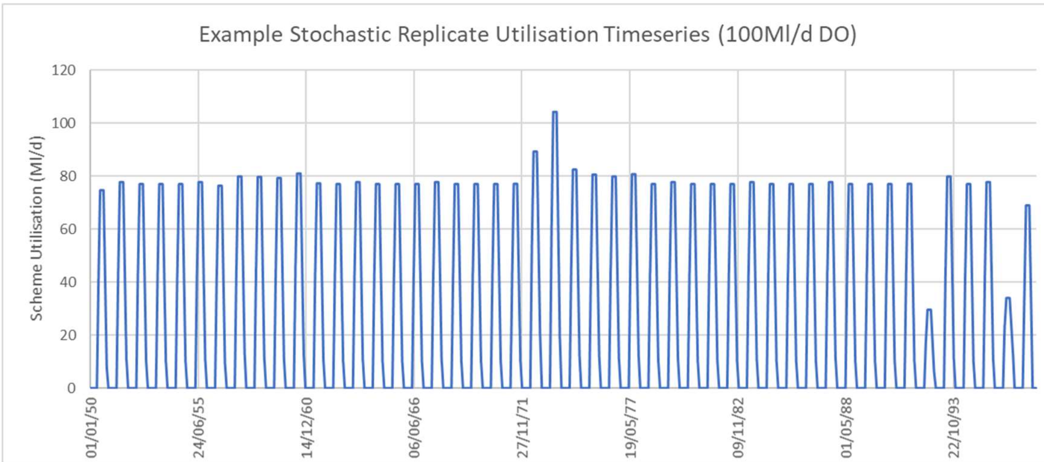
Once the licence 'spikes' were re-allocated to the summer period (as would actually happen), then for a design drought the utilisation was typically as shown in Figure 3 below. This shows that theoretical minimum usage outside of the summer period is effectively zero until circa 100Ml/d scheme DO, after which there is some 'baseload' requirement.

Figure 3 Apportioned Scheme Utilisation Profiles under the Design Drought Event



Once the 'operationally realistic' operational modifications are applied, then a utilisation timeseries as shown in Figure 4 is derived.

Figure 4 Example Operational Utilisation Timeseries for a 100Ml/d Strategic Scheme

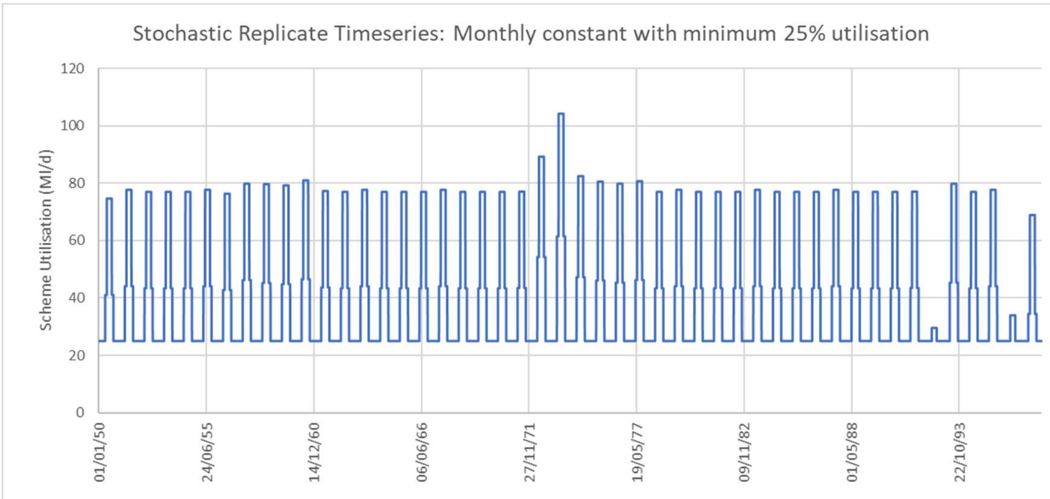


It should be noted that the above timeseries is for an example stochastic replicate (nominal years – the stochastic data runs multiple sets of 50 year 'what if' climate analysis), and *not* the historic record.

As expected, this shows that the majority of years are 'normal' with utilisation dictated by the level of demand. Five years show exceptional utilisation, three significantly below the 'normal' requirement and two significantly higher than the 'normal' requirement. The three years with reduced requirements represent events that are worse than 1 in 10, so have TUBs applied during the summer, but the droughts are not severe so the benefits of restrictions outweighs negative drought impacts on groundwater resources. The two remaining events are more severe, and the impact of drought outweighs the Tubs/NEUBs benefits.

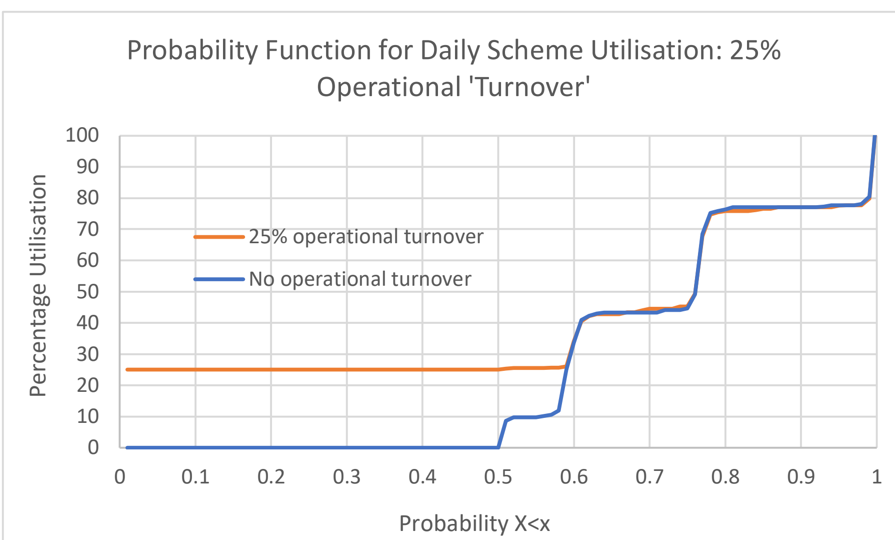
If a minimum engineering utilisation of 25% is imposed on the schemes, and operationally realistic constant values for May and September are imposed on the utilisation profiles, then the example timeseries is as shown in Figure 5 below.

Figure 5 Operational Utilisation Timseries with 25% Minimum Scheme Turnover



Based on the full stochastic analysis, the probability of expected daily usage of the scheme is as shown in Figure 6 below. This shows that outside of the May to September period, expected usage is likely to be dictated by operational turnover. During May to September the usage is a balance of groundwater level versus the demand management impacts of TUBs and NEUBs. Typical utilisation is in the order of 80% in summer, only increasing with significant droughts beyond 1 in 50 years.

Figure 6 Cumulative Probability Distribution fro Daily Scheme Utilisation



When these are transformed into annual average utilisation rates, then the corresponding cumulative probability plots for the two types of operation for a 100Ml/d scheme are as shown in Figure 7and Figure 8 below.

Figure 7 Cumulative Probability Curve for a Strategic Scheme without minimum Turnover

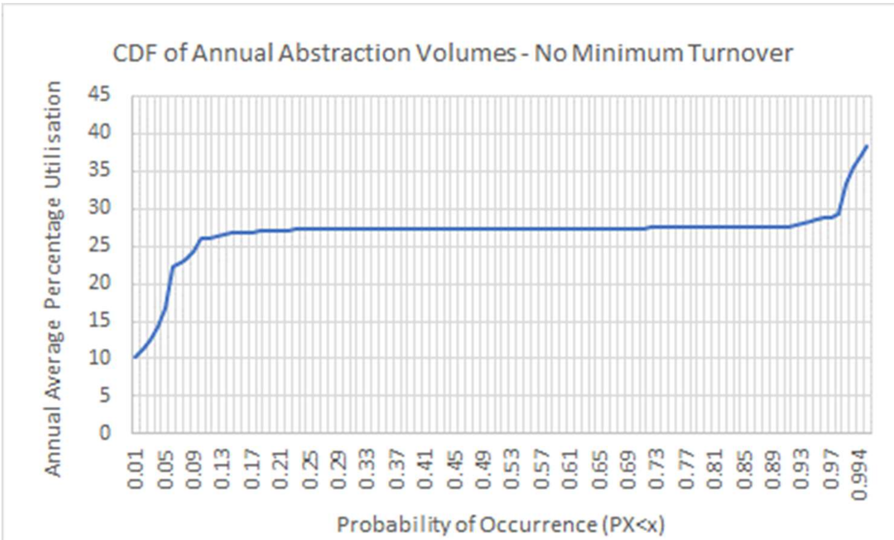
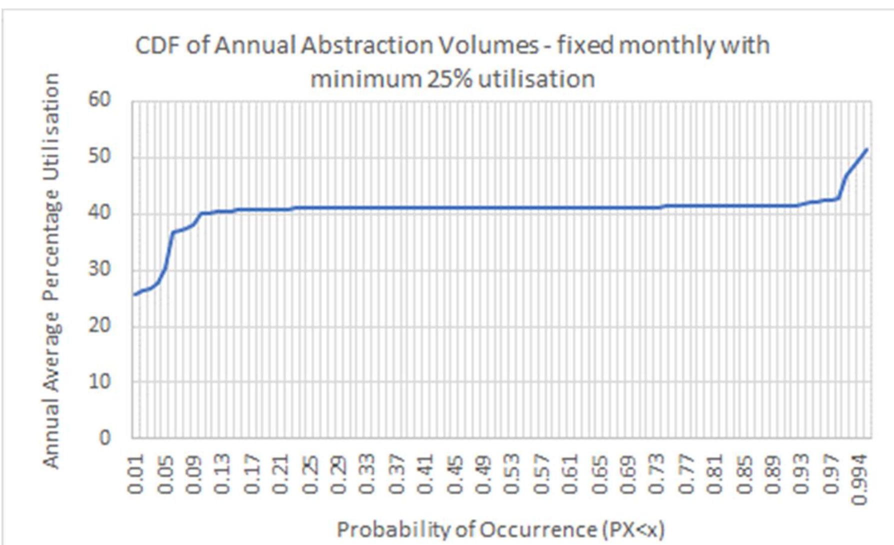


Figure 8 Cumulative Probability Curve for a Strategic Scheme with 25% Minimum Turnover



These figures demonstrate that normal 'dry year' utilisation (i.e., prolonged summer not associated with a groundwater drought) typically ranges from around 27% if no minimum 'turnover' use is applied, to just over 40% if a 25% operational minimum use is applied.

Most drought years will actually result in a reduction in overall utilisation due to Tubs and NEUBs, with only droughts worse than around 1 in 50 years generating a significant increase above a 'normal' dry year.

The 50Ml/d scheme will have a lower utilisation than the 100Ml/d scheme, but this is not significant as both behave in a similar fashion. Once schemes exceed 100Ml/d then the overall utilisation will begin to increase as a baeline load is introduced. However, as shown in Figure 3, the scheme baseload outside of the summer months will only just start to exceed 25% as the scheme approaches 200Ml/d DO.

Conclusions.

The analysis carried out draws the following three key conclusions, which should be used when considering the capacity requirements and utilisation schemes for the purposes of investment modelling and water resources analysis:

1. For the purposes of capacity planning, schemes should be sized at around 112% of the intended Deployable Output. This is without process losses, so raw water transfers are likely to be in the order of 115% of the required Deployable Output.

2. Scheme utilisation is heavily focused on summer for all schemes up to 100Ml/d Deployable Output under the 'company alternative' environmental destination scenario. Usage in the summer is typically around 80% during dry year demand events, increasing beyond this only during significant droughts (>1 in 50 years). The annual average take is around 27% of DO for a scheme that does not have minimum operational 'turnover' rate. This increases to just over 40% for a scheme with a 25% operational minimum turnover rate.

3. For the purposes of volumetric storage, even under severe droughts with a 25% operational minimum turnover, the required utilisation is very unlikely to exceed 50% of DO. A 100 Ml/d DO scheme therefore only requires (365*100/2) 18,250Ml per annum of water to support the scheme.