Technical Note

Project:	SES Water Drought Plan		
Subject:	Bough Beech Drought Triggers Update		
Author:	Tom Gribbin		
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Distribution:	Alison Murphy	Representing:	SES Water

Document history

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Client signoff

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1. Background

Bough Beech reservoir is a winter refill reservoir, important for local supply and capable of supporting the wider network when storage is favourable. SES Water uses drought trigger levels on Bough Beech, in conjunction with information about groundwater levels at the Chipstead observation borehole, to determine appropriate actions in the event of a drought.

Previously, the Bough Beech standalone Aquator model used the available historical record for determining deployable output (DO) and tested the impact of more extreme events using short replicates sampled from a long stochastic timeseries. However, the recommended methodology for determining 1-in-200 or 1-in-500 year DO has been updated, and the simulation of the full stochastic inflow series (19,200 year timeseries) is now required. Initial testing has shown that the Level of Service (the frequency with which temporary use bans (TUBs) and non-essential use bans (NEUBs) are triggered) provided by the current triggers is not suitable when DO is assessed using the updated methodology.

The rapid speed of the recently updated Bough Beech standalone Pywr model allows various new curve options to be tested using the new DO methodology. The optimal set of drought triggers will:

- Meet the company's stated Level of Service at the reported DO demand.
- Enable SES Water to implement actions early enough to reduce the likelihood and duration of severe events.
- Allow sufficient time between triggers for agreed actions to be implemented.
- Be operationally feasible to implement.

Whilst trade-offs exist between these objectives (for example, earlier implementation of trigger actions increases resilience but reduces the Level of Service), the chosen trigger curves must meet all these objectives independently.

2. Approach

Previously, the shape of the trigger curves was based on the mean monthly storage (MMS) at Bough Beech over the period April 1996 to March 2011. Deriving the curve shape in this way using observed data helps to ensure that operationally sensible curves are generated, because the actual refill/emptying dynamics of the reservoir are taken into account.

To update the trigger curves for this Drought Plan, a more recent series of observed storage at Bough Beech from 1995-2020 was used to calculate an updated profile for the MMS and the 95th percentile mean monthly storage (MMS-95). Whilst the MMS-95 will more closely follow the Bough Beech storage dynamics of the worst events that occurred during this period, curve sets based on both the MMS and the MMS-95 were tested in the model because in the context of the stochastics either could provide an acceptable solution. These curves are shown in Figure 2-1.

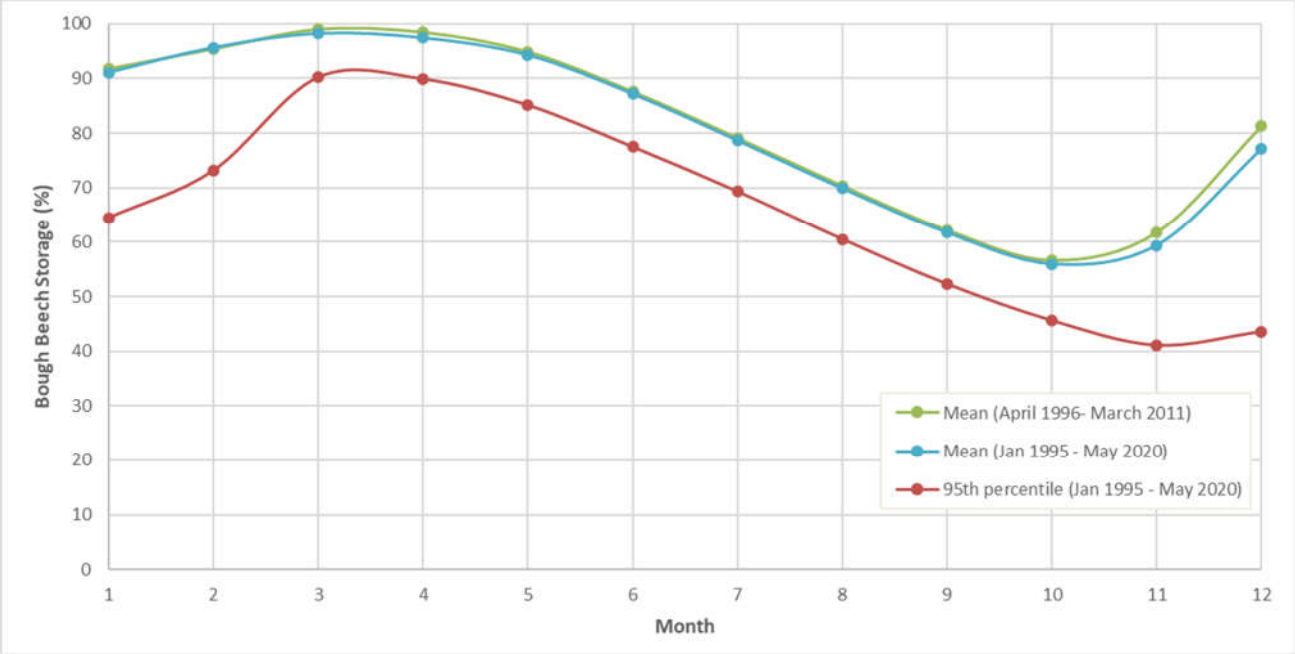

Figure 2-1 – Observed monthly storage profile recalculated based on latest available data (1995 - 2020)

The two curve profiles were shifted using various transformations and offsets, with each set tested in the Bough Beech model using a 'Scottish DO method'[1] with the full stochastic timeseries. Curves were further refined over a number of modelling iterations to take into account frequency of trigger crossings and timing constraints between triggers, with 15 sets of curves ultimately tested. The final agreed set is based on a transformation of MMS-95 and is shown in Figure 2-2 alongside an example based on MMS.

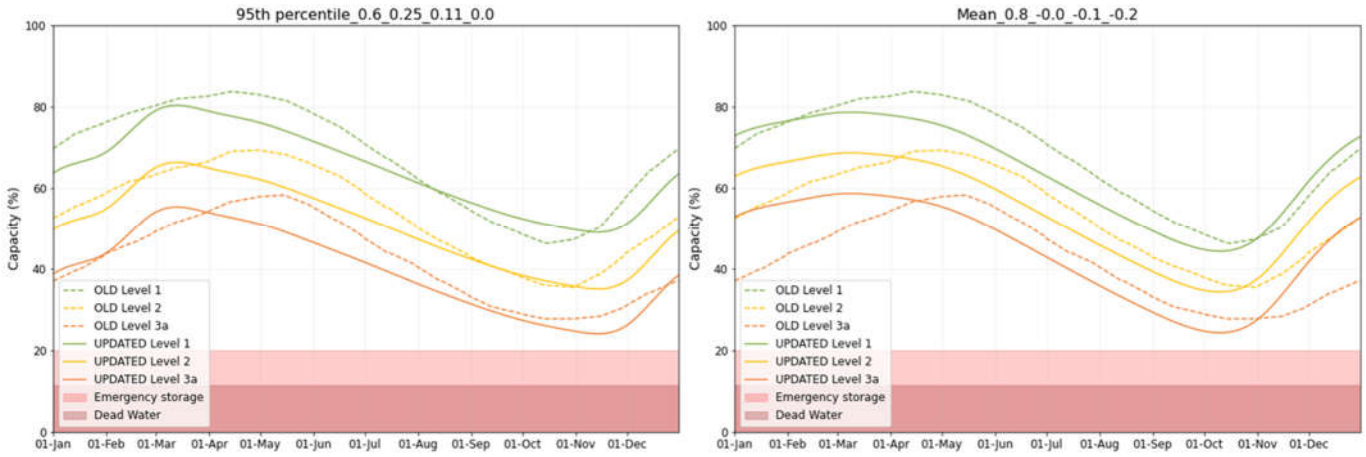

Figure 2-2 - Left: final chosen curve set based on MMS-95. Right: example alternative curve set based on MMS. Previous (Drought Plan 2019) triggers shown on both plots for context

[1] In the Scottish method a range of demands are tested to find the point at which each level of service is breached.

3. Results

Key information for the new curve set is provided below and compared to the previous triggers for context.

3.1. Deployable output

In the context of DO, the objective of moving the trigger curves would be to optimise DO when demand savings from TUBs and NEUBs are both off and on. Baseline DO should be reported in a Water Resources Management Plan with demand savings off, albeit that the benefit from demand savings is reported in some parts of the WRMP. However, it is important to ensure that when demand savings are on, the trigger curves aren't breached more frequently than the company's stated levels of service, as this would be the operational reality of the way in which the reservoir would function.

Table 3-1 shows that for both the previous triggers and the new triggers, when demand savings are not activated, the 1-in-200 year implementation of emergency drought orders (EDOs, Level 4 drought actions) occurs at a demand of 21.4 Ml/d. This demand level is the maximum demand that can be met by the reservoir before Level 4 is breached. The threshold demand for breaching TUBs (Level 2 drought actions) and NEUBs (Level 3a drought actions) is higher at 21.6 and 25.5Ml/d respectively. From the perspective of simply maximising DO and the impact of demand savings, the optimal triggers placement gives equivalent maximum demands for Level 2, Level 3, and EDOs.

At the 1-in-200 DO demand, a larger DO benefit from demand savings[2] can be reported with the new triggers compared to the old. When demand savings are enabled with the new triggers, 1-in-200 DO increases by 1.0Ml/d from 21.4Ml/d to 22.4Ml/d. At this demand, neither the Level 2 (TUBs) nor the Level 3 (NEUBs) Level of Service is breached.

However, with the previous triggers, the Level 2 (TUBs) Level of Service limited the 1-in-200 DO to 21.6 Ml/d when demand savings were on, which equates to a DO increase of only 0.2 Ml/d compared to the baseline.

Table 3-1 - Scottish DO assessment comparison between previous triggers and new triggers, with demand savings on and off

		Old triggers		New triggers	
Trigger crossing	Level of service (return period, years)	DS OFF - maximum demand (Ml/d)	DS ON - maximum demand (Ml/d)	DS OFF – maximum demand (Ml/d)	DS ON - maximum demand (Ml/d)
Level 2	1-in-10	21.6	21.6	22.9	22.9
Level 3	1-in-20	25.5	25.6	25.1	25.2
EDOs	1-in-200	21.4	22.4	21.4	22.4
EDOs	1-in-500	18.0	18.9	18.0	18.9

3.2. Timings between triggers

The triggers must be spaced far enough apart to allow sufficient time for SES Water to implement the drought management actions associated with each trigger zone as a drought progresses. Discussions with SES Water indicated that at least 3 weeks were required between Level 1 and Level 2, and at least 4 weeks between Level 2 and Level 3. The new curve set has brought the typical number of days between triggers closer to these limits but does not exceed them, as shown in Table 3-2 and described below.

For the new curve set the modal number of days between Level 1 and Level 2 has decreased by 8 days from 35 to 27 days. Similarly, the modal number of days between Level 2 to Level 3 has also decreased, from 41 to 31 days. The timing between Level 3 and Emergency Storage does not change significantly between the old and new curves. The time between Level 3 and Emergency Storage is significantly longer than the other

[2] Demand savings are the percentage reductions in demand associated with TUBs and NEUBs.

crossings because Level 3 crossings tend to occur in February-March when the Level 3 curve is considerably higher than emergency storage.

Figure 3-1 shows storage at Bough Beech during all Level 2, 3 and Emergency storage crossings in a full 19,200-year stochastic model run. The top row shows that for the majority of the Level 1-Level 2 crossings, storage recovers sufficiently after the crossings (around January-April) to prevent an Emergency Storage crossing the following summer. If an event reaches Level 3 (shown in the Level 2-Level 3 row in Table 3-2), the risk of the event going on to cross Emergency Storage increases. The extent (and water resources benefit) of SES Water's planned mitigation actions (demand restrictions) increases as an event progresses through the trigger levels to reflect this changing level of relative risk.

Table 3-2 - Days between trigger crossings in a stochastic run at a demand of 21.0Ml/d with demand savings enabled

	Old triggers			New triggers		
Trigger crossing	Mean no. of days	Median no. of days	Modal no. of days	Mean no. of days	Median no. of days	Modal no. of days
Level 1 – Level 2	35	33	35	36	29	27
Level 2 – Level 3	47	42	41	44	31	31
Level 3 – Emergency Storage	136	143	142	135	147	142

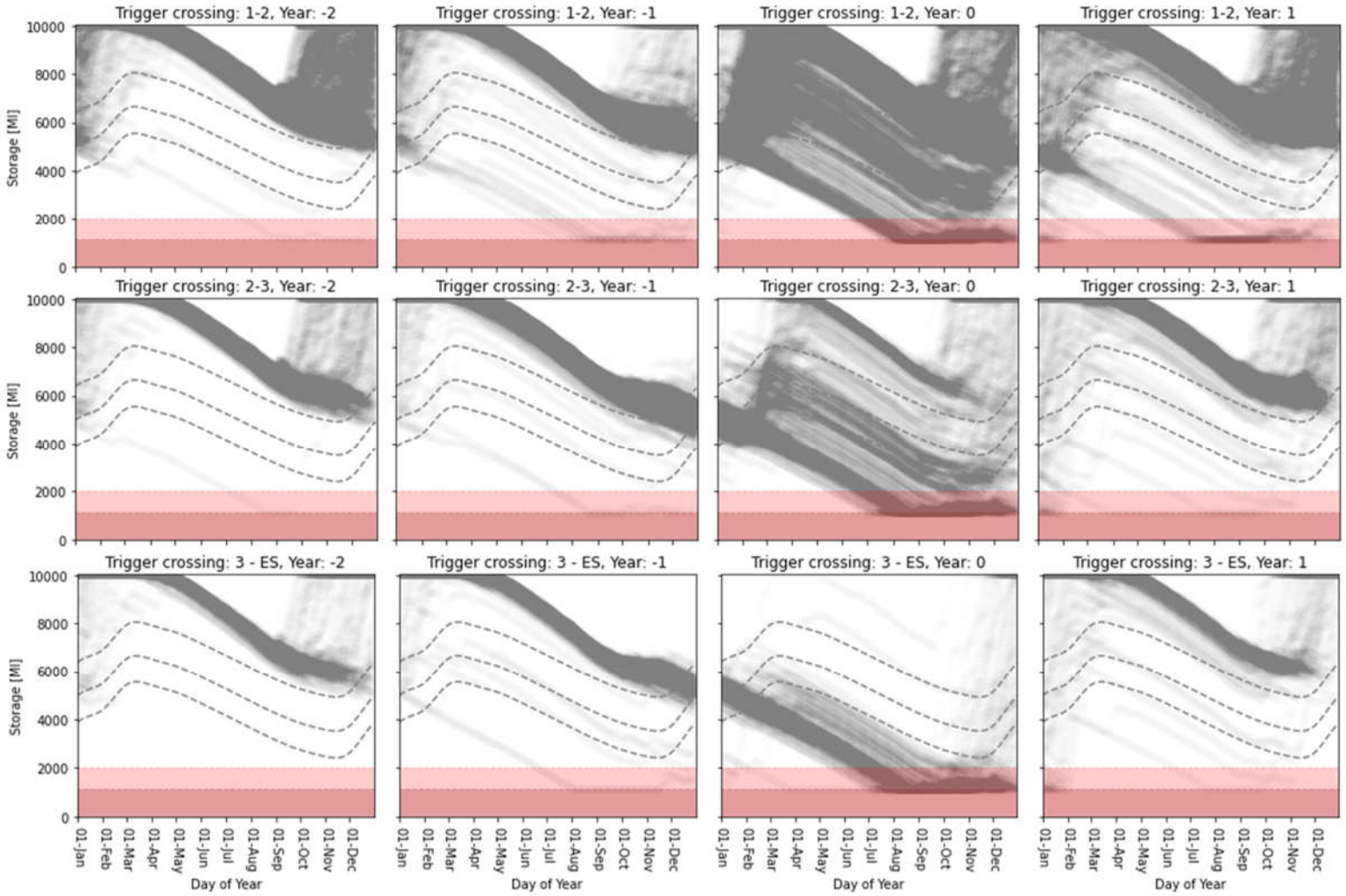

Figure 3-1 - Bough Beech drought events shown by trigger crossings. Top row: All Level 1 – Level 2 trigger crossings, Middle row: All Level 2 – Level 3 trigger crossings, Bottom row: All Level 3 – Emergency Storage crossings

4. Summary

The new curve set increases the 1-in-200 DO benefit gained from demand savings from 0.2Ml/d to 1.0 Ml/d. Whilst the new curves reduce the typical number of days between Level 1, 2 and 3 crossings, the minimum required timescales between levels that were suggested by SES Water are achieved. Figure 4-1 shows that had these triggers been used in the past, Level 1 is positioned sufficiently far below the long-term average (LTA) storage such that it is not crossed every year. The Level 1 trigger is crossed in 9 different years, and Level 2 in just 2 years out of the 25 in the observed historic record.

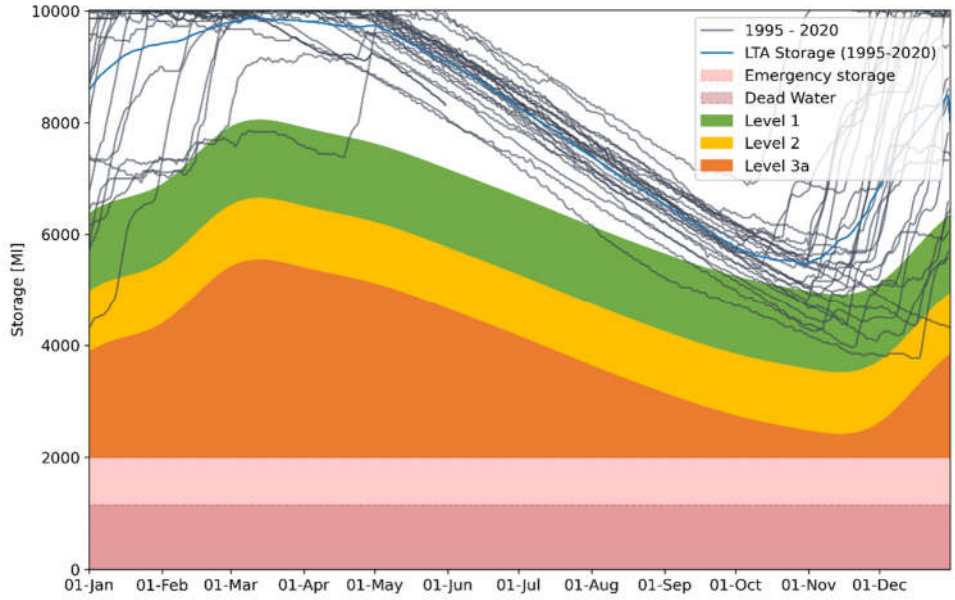

Figure 4-1 - Observed Bough Beech storage (1995 - 2020) against the new triggers

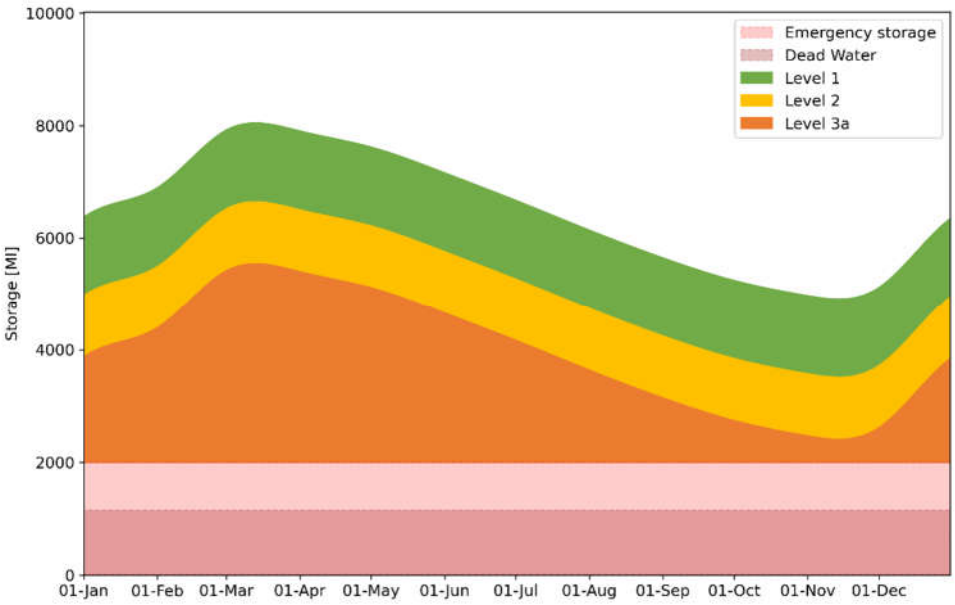

Figure 4-2 - New Bough Beech triggers