Technical Note

Project:	SES Water Drought Plan Support		
Subject:	Groundwater Drought Action Trigger Levels		
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Document history

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1. Introduction

Drought action trigger levels are a critical tool that SES Water uses to manage its actions during drought and ensure sufficient water supply to customers. SES Water uses a combination of groundwater and surface water action triggers. This technical note concerns the Drought Plan 2021 (DP21) revision to the groundwater triggers.

In previous drought plans, SES Water used Well House Inn (WHI) observation borehole (OBH) as its reference borehole and generated trigger levels from historical and stochastic groundwater levels. WHI is located in the North Downs unconfined Chalk aquifer and has a long, relatively continuous data record since the 1940s. Until recently, it was one of the national 'index boreholes' used by the Environment Agency to monitor regional aquifer groundwater level trends. However, it was observed that the rate of groundwater level recession in WHI was not as great during extreme droughts as expected, and therefore there was concern that it was not representative of drought recession in the wider aquifer. The Environment Agency has now moved its long-term North Downs Chalk monitoring to the nearby Chipstead OBH (ref TQ25/86). This borehole shows very good correlation with WHI under most conditions but exhibits greater recession during extreme drought. The problem with the Chipstead OBH groundwater level record is that, until 2017 when it was lowered, it appears that the Environment Agency's telemetered level logger was dewatered during the two most severe groundwater droughts since monitoring commenced (2005/06 and 2011/12) and the manual dip record during these periods is insufficient to confirm the bottom of the recession.

Despite these data limitations, an Atkins review of WHI and Chipstead recommended that SES Water follows the Environment Agency and adopts Chipstead OBH as its drought action trigger borehole (Atkins, 2021b). However, as the logger is only 2.08 m lower than the lowest historical dip (44.57 m on 27/01/2006, pers. comm, Lizzy Bunker, EA, 12 Oct 2020), it is strongly recommended that the logger depth in the borehole is lowered to ensure it captures the full drought recession of any future, more extreme droughts.

The same review also considered the potential to establish a reference borehole in the Lower Greensand aquifer. Although SES Water has several groundwater abstraction sources in the Lower Greensand aquifer, drought action triggers for these sources are currently determined from the groundwater level condition in the Chalk reference borehole. Whilst the Lower Greensand has different properties to the Chalk, and therefore may respond differently, SES Water's deployable outputs (DO) from the sources in the Lower Greensand were, historically, largely insensitive to groundwater level conditions. However, in the WRMP24 DO assessment it was identified that two sources, representing 16% and 11% of the Lower Greensand minimum DO (MDO) and peak DO (PDO) respectively, are hydrogeologically constrained i.e. sensitive to drought groundwater level. A review into the alternative OBH options identified Riverhead OBH (ref TQ55/1) as the best reference borehole for the Lower Greensand, although it was noted that the historical OBH record for this borehole is complicated by large abstraction reductions from the surrounding public water supply sources.

This technical note sets out proposed new SES Water drought action trigger levels for Chipstead and Riverhead OBH. It also presents equivalent revised triggers for WHI to enable a comparison with DP19 to understand how the trigger levels have changed.

2. Trigger levels and Levels of Service (LoS)

Drought action triggers are used to help identify what action needs to be taken through the various stages of a drought. These drought actions take the form of both supply side actions, such as drought permits / orders, and demand side actions, such as demand restrictions including Temporary Use Bans (TUBS) and Non-essential use bans (NEUBS).

The recent Drought Planning guidance (Environment Agency, 2020) clearly links drought severity with the actions that should be taken. In addition to this, SES Water has introduced an additional trigger called Level 0, representing 'environmental stress'. This has been established to allow groundwater levels to fall a defined amount below the mean before a drought action is triggered. SES Water has also retained its old subdivision of Level 3, splitting out the more severe actions associated with the final steps prior to emergency drought orders (Level 3b) from the more frequent NEUBS (Level 3). **Figure 2-1** shows an example trigger curve and its linkages to the drought actions (both supply and demand side actions).

Levels of Service (LoS) are effectively a standard of service the Company aims to provide to customers in relation to demand restrictions. It is necessary that the drought action trigger levels are set such that the frequency they are breached aligns to SES Water's LoS. Since demand restrictions are implemented on a precautionary basis, prior to the ultimate severity of an ensuing drought event becoming known, the frequency of implementing demand restrictions will be higher than the drought severity to which the Company has designed resilience to. The LoS have not been changed from previous plans and are as follows:

- TUBS no more frequent than 1 in 10 years on average
- NEUBS no more frequent than 1 in 20 years on average
- Emergency drought measures no more frequent than 1 in 200 years on average

Target drought action trigger levels have therefore been assigned with the approximate annual breach return periods:

- Level 0 – 1 in 4,
- Level 1 – 1 in 8,
- Level 2 – 1 in 10,
- Level 3 – 1 in 20,
- Level 3b – 1 in 50,
- Level 4 – 1 in 200

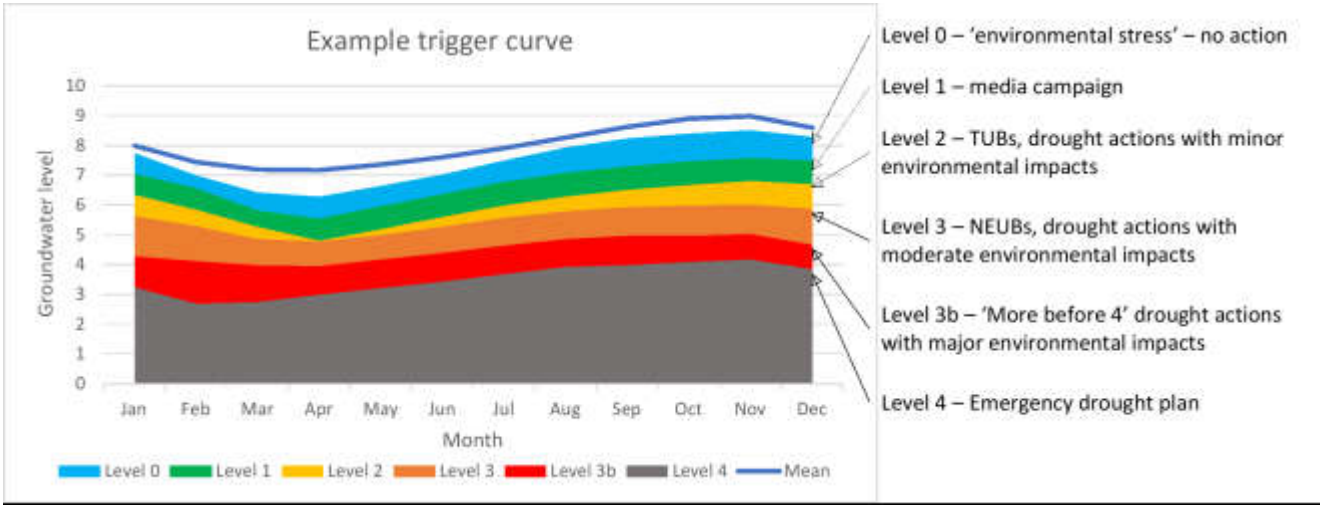

Figure 2-1 - Example trigger curve with associated actions

3. Well House Inn OBH

Drought Plan 2019 trigger levels

The trigger levels at WHI were updated in DP19 with the intention of aligning with the drought action frequency presented in **Table 3-1**. The assessment undertook frequency analysis on the groundwater level output from the WHI lumped parameter model using the full 15,000 year stochastic data that were being used for WRMP19 planning. From this, monthly groundwater levels reflective of a variety of drought severities were generated. However, there does not appear to have been a reconciliation back to the historical data or the LoS. As a result, the long term mean monthly groundwater level generally fell within the Zone 2 trigger band and were always within the Zone 1 or below (**Figure 3-1**). Not taking into account data from other trigger locations, this implies that media campaigns and TUBs would be in force more often than not which is not appropriate and not aligned with SES Water's LoS.

It is also noted that the DP19 assessment of the drought triggers under different drought severities did not consistently use the new DP19 triggers, but also referred back to DP14 triggers.

Table 3-1 – Basis of WRMP19 drought triggers

Drought severity return period	Zone	Response
1 in 2 to 1 in 4	1	Media campaigns
1 in 4 to 1 in 20	2	TUBS
1 in 20 to 1 in 50	3	NEUBS
1 in 50 to 1 in 200	3b	Additional drought actions
Less frequent than 1 in 200	4	Emergency restrictions

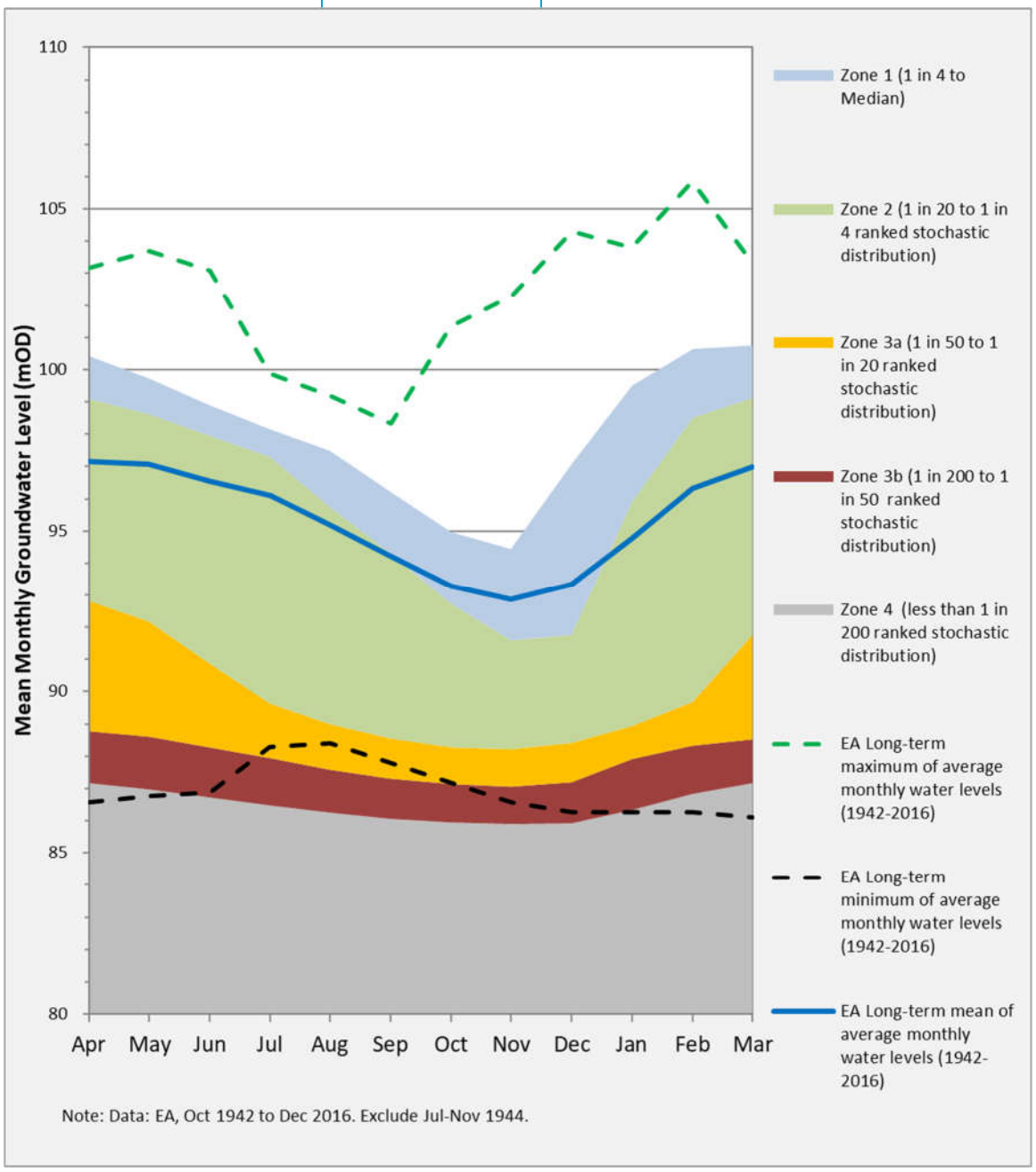

Figure 3-1 – WHI DP19 triggers (Figure 2.1 from SES Water's DP19)

WHI Equivalent Proposed Drought Plan 2021 trigger levels

The WHI equivalent to the Chipstead proposed new drought plan triggers have been developed from the 2020 updated WHI lumped parameter model and the WRMP24 stochastic dataset of 19,200 years. Stochastic analysis has been undertaken using the monthly average groundwater levels calculated from the original daily data.

Initial monthly groundwater level statistics were generated in three ways (percentile, assuming a normal distribution and ranked frequency analysis) with target monthly frequencies relating to the LoS. The annual frequency of breaching the triggers was calculated and compared to the LoS. The target *monthly* frequencies were then adjusted until the *annual* LoS requirements were met. In calculating the annual frequency of breaches, it was assumed that any drought spanning more than 12 months (i.e. greater than a year in duration regardless of which month the drought started in) would be counted as a multiple event. This is in accordance with the methodology applied by WRSE (pers. comm., Alison Murphy, SES Water, Jan 2021). It was also assumed that there needed to be an eight-month interval before the trigger could be breached again to count as two breaches. The purpose of this latter assumption was to prevent recording multiple breaches being recorded where the groundwater level hovers around the trigger level where in reality the prevailing drought action would probably remain in force until groundwater levels had clearly recovered above the trigger level. It is noted that WRSE has not determined a prescribed interval between droughts and therefore this may generate slight discrepancies in drought frequency calculation.

Unsurprisingly, the monthly trigger values generated using the percentile and ranked frequency analysis approach generated almost identical results. Greater deviation was seen with the normal distribution approach, reflective of the deviation away from a normal distribution at the extreme conditions. The final proposed triggers have been developed using the percentile approach. These are presented in **Figure 3-2** alongside the mean, minimum and historical observed groundwater level (1942 – 2012).

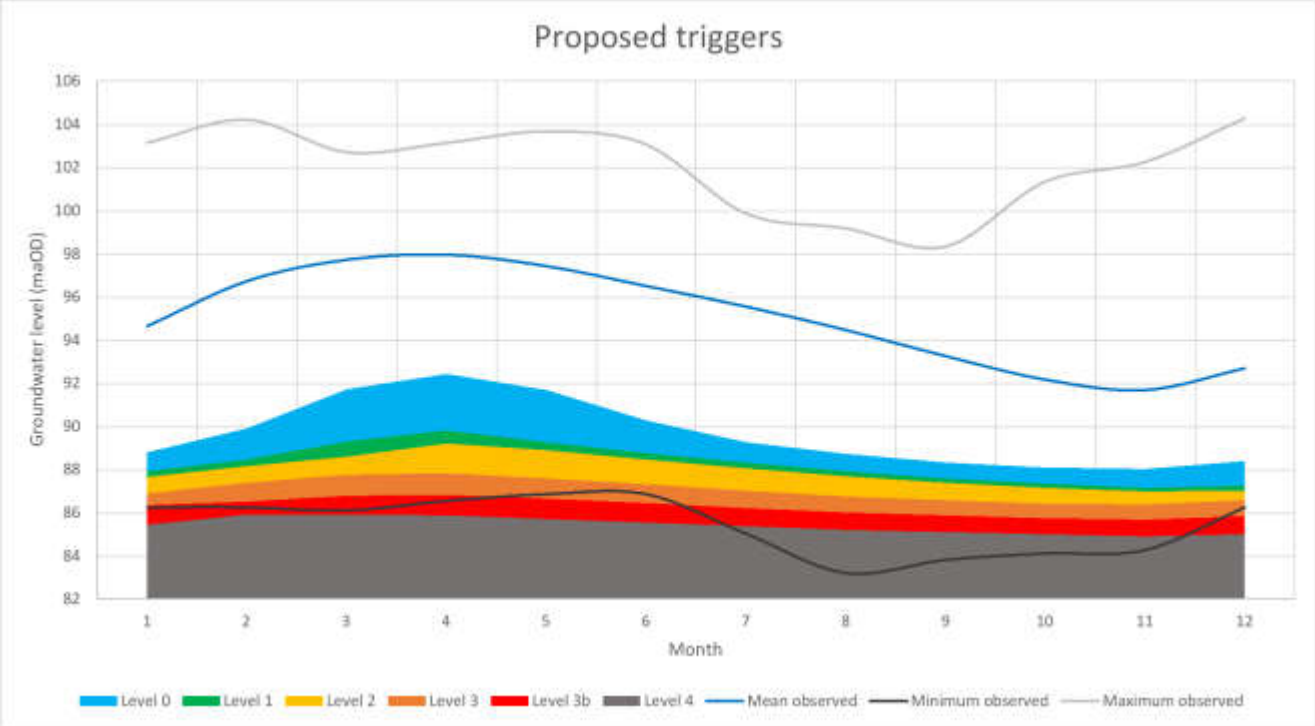

Figure 3-2 - Proposed WHI triggers

Figure 3-3 compares the WHI equivalent of the proposed triggers with those from DP19 (as shown on **Figure 3-1**). The most obvious point to observe is the significant lowering of the groundwater level triggers. This is partly due to the change in levels described above; previously, any reduction below the mean groundwater level resulted in zone 1. However, the difference is also considered to be due the monthly frequency values now being based upon returning the specified annual LoS. The seasonality is fairly similar, with less seasonality associated with the more extreme drought levels.

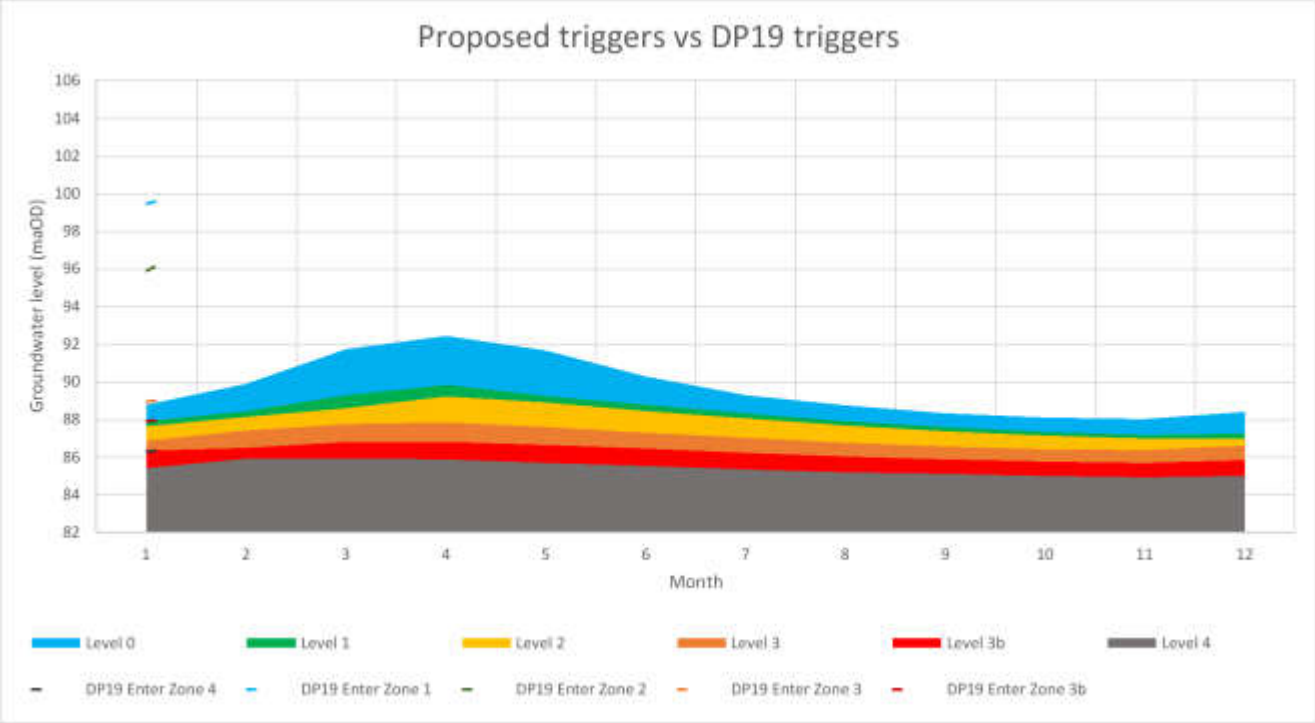

Figure 3-3 - Proposed WHI triggers vs DP19 triggers

Figure 3-4 overlies the historical record onto the proposed WHI equivalent of the drought triggers. In general, over the 70-year period, the triggers are breached with the expected frequencies; *Level 0* is entered 1 in 3 years, *Level 1* is entered 1 in 5, *Level 2* is entered 1 in 9, *Level 3* is entered 1 in 14 and *Level 3b* 1 in 70. Level 4 is breached once in 1944, although it is noted that WRMP19 concluded that this recession was spurious and considered unrepresentative of natural recession.

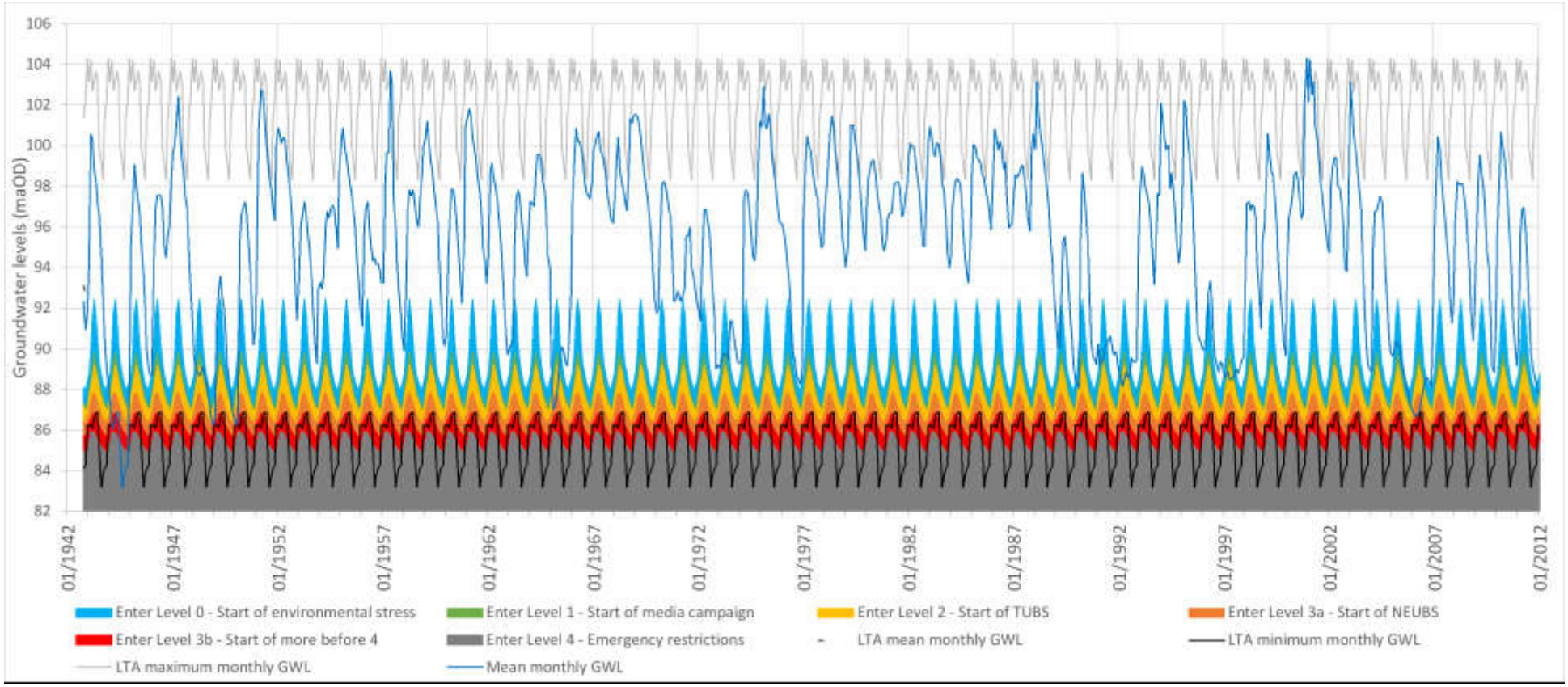

Figure 3-4 - Proposed WHI triggers vs historical record

LTA: 1942 - 2012

4. Chipstead OBH

Trigger levels for Chipstead OBH have been generated using the same methodology as for WHI: using the Chipstead lumped parameter model and statistically analysing the full 19,200 year record. The proposed triggers are presented in **Figure 4-1** alongside mean, minimum and historical observed groundwater levels (2002-2020).

The proposed triggers at Chipstead are lower than those at WHI. This is expected given the understanding that WHI underestimates the groundwater recession. The shape of the triggers is otherwise similar. The minimum observed groundwater level line is skewed in months 1-5 due to groundwater levels falling below the transducer during extreme droughts.

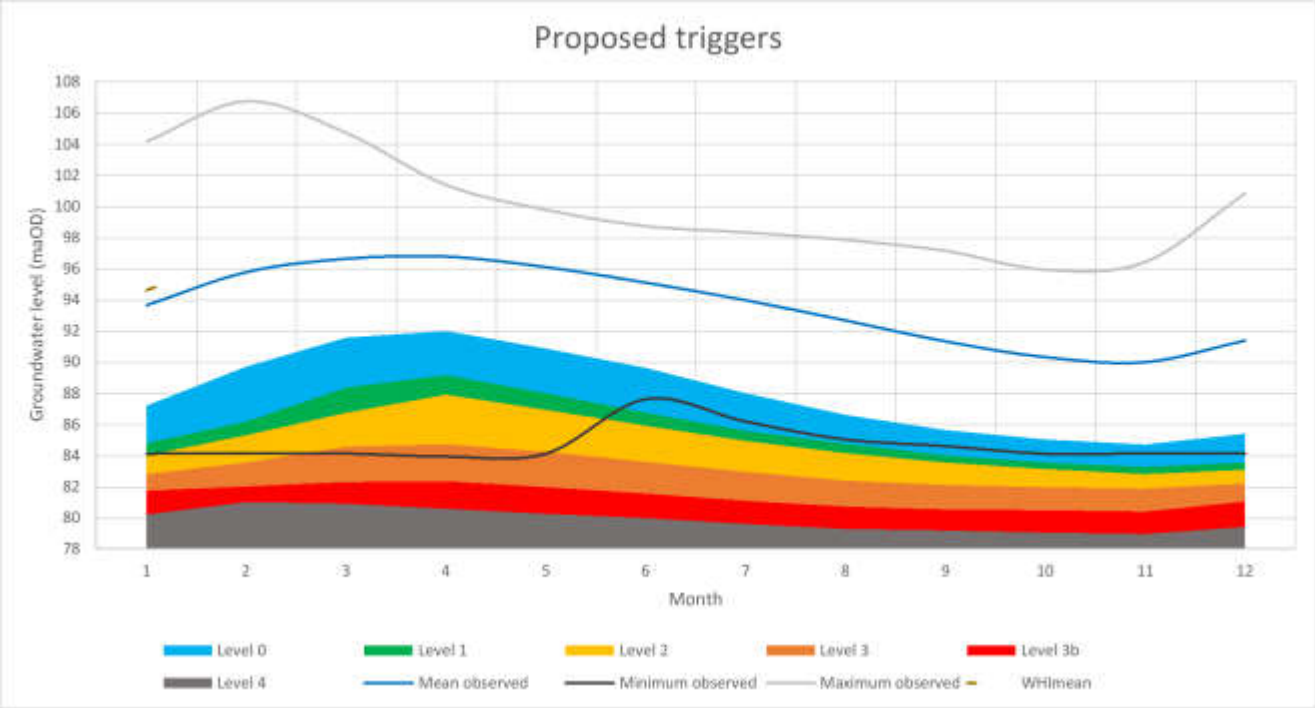

Figure 4-1 - Proposed Chipstead triggers

Figure 4-2 overlies the historical record onto the proposed drought triggers. The apparent truncation of levels due to levels falling below the transducer is evident in both the 2005-06 and 2011-12 droughts. If the potential recession is visually extrapolated, the levels are breeched with an approximate return frequency comparable to the target frequencies: *Level 0* is entered 1 in 4 years, *Level 1* is entered 1 in 9, *Level 2* is entered 1 in 9, and *Level 3* is entered 1 in 18 years. Neither Level 3b nor Level 4 are triggered in this short 18-year record. This aligns with the WRMP19 conclusion that the drought of 2005-2006 corresponded to a 1 in 35 yr return period.

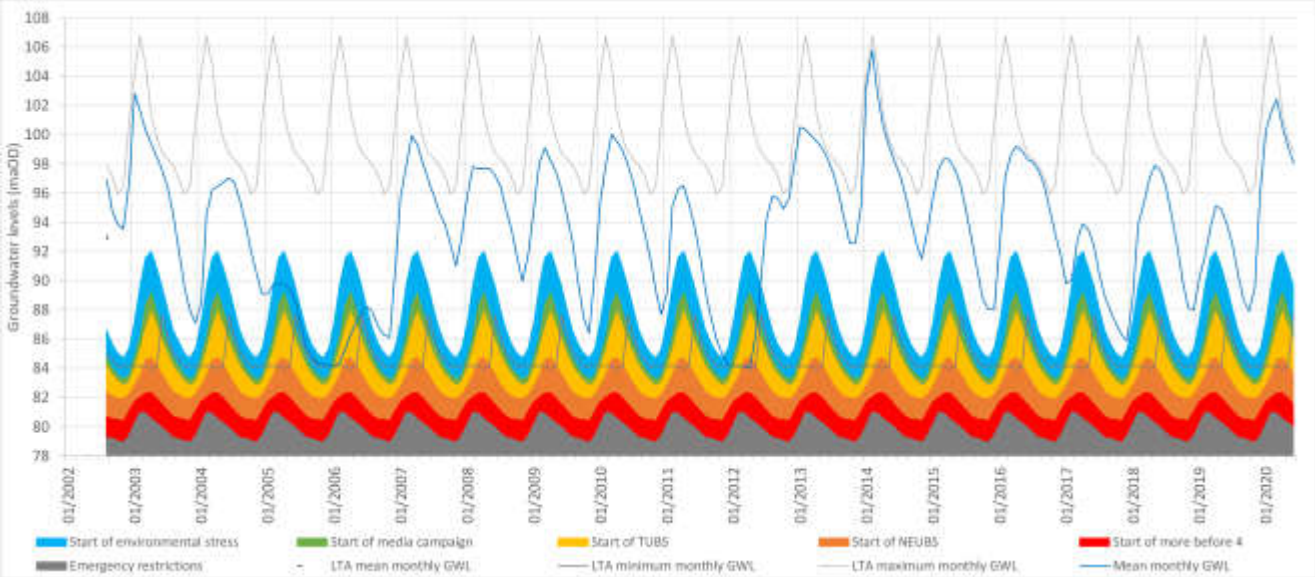

Figure 4-2 - Proposed Chipstead triggers vs historical record

LTA; 2002 - 2020

Figure 4-3 plots two examples of stochastically generated 7-year groundwater level periods spanning 1 in 200-year and 1 in 500-year annual groundwater level minimum events against the proposed triggers. The traces have been plotted on an arbitrary x axis from 1953 to 1960 to allow for comparisons between the traces (i.e. these are not historical simulations for this period).

The figure demonstrate that droughts may be of different character and duration even if the drought severity is the same. The Level 4 trigger threshold has been set at a 1 in 200-year return period, with the result that example droughts just brush this threshold. In contrast the 1 in 500-year droughts dip more significantly into level 4.

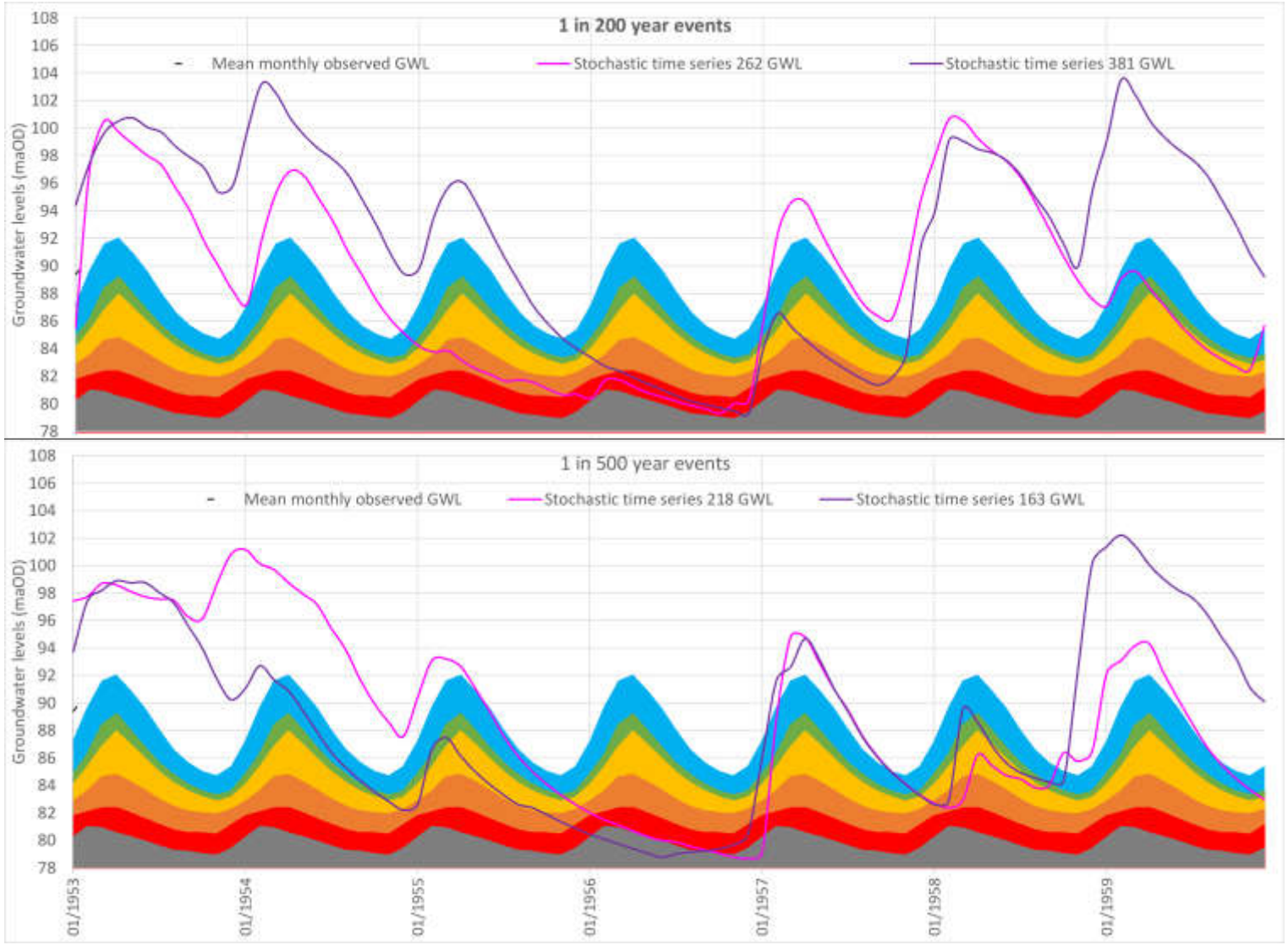

Figure 4-3 - Chipstead triggers vs example 1 in 200 and 1 in 500 year events

5. Riverhead OBH

Trigger levels for Riverhead OBH have been generated using the same methodology as for WHI and Chipstead: using the Riverhead lumped parameter model and statistically analysing the full 19,200 year record. The proposed triggers are presented in **Figure 5-1** alongside mean, minimum and historical observed groundwater levels (1965 – 2016).

Atkins, 2021, noted that there was low confidence in the Riverhead lumped parameter model. Whilst the model was able to generate a reasonable calibration to data after 1998, it was unable to replicate the lower groundwater level recessions observed during the 1990s droughts. It is unclear if this is due to abstraction impact as prior to 1997 there was significantly more abstraction from Thames Water's adjacent Sundridge and Brasted sources. However, various abstraction impact investigations have been inconclusive as to the impact these sources had on groundwater levels.

The poor calibration of the Riverhead lumped parameter model to the observed levels in the 1990s drought is responsible for the minimum observed groundwater level line on **Figure 5-1** sitting firmly within the Level 4 trigger zone. However, excluding these uncertain data results in a minimum water level trace that is closer to that expected.

The proposed Riverhead triggers are therefore presented with caution, and it is expected that they may need to be revised once they have been operationally tested. However, despite this uncertainty, these triggers are regarded as an improvement to SES Water's overall plan; previous plans did not have a reference borehole in the Lower Greensand, and whilst many of SES Water's sources from this aquifer are insensitive to groundwater level change, this is not the case for all.

In comparison to the Chalk OBH reference boreholes, the triggers developed for Riverhead OBH are relatively insensitive to seasonality. This is reflective of the higher storage in the Lower Greensand aquifer and thus smaller range in annual groundwater level fluctuation.

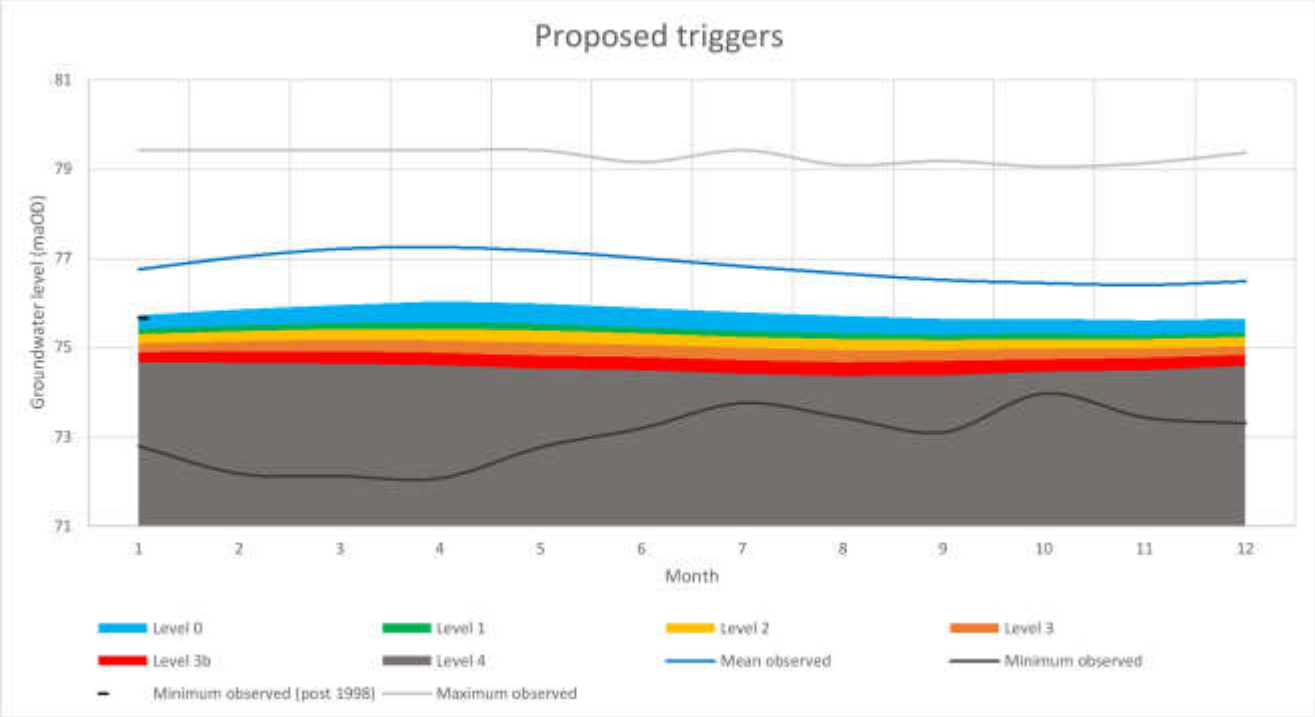

Figure 5-1 - Proposed Riverhead triggers

Figure 5-2 and **Figure 5-3** overlay the Riverhead OBH historical record on to the proposed drought triggers for the Lower Greensand sources. **Figure 5-2** plots the full historical record, whilst **Figure 5-3** plots the period post 1998, the period to which the Riverhead lumped parameter model was calibrated.

When considering the full record, the initial drought action zones are entered at approximately the Company's target LoS frequencies. However, the more severe drought action triggers are breached more frequently than their target LoS. This is as expected given that the Riverhead lumped parameter model, which was used to

generate the stochastic groundwater levels that the triggers are based on, was unable to represent the periods of particularly low observed groundwater levels in the 1990s. As noted above, it is unclear if this observed response is due to historical abstraction rates.

When excluding the early data (pre 1998) the more severe drought action zones still appear to be triggered too frequently (e.g. Levels 3, 3b and 4s are all breached 1 in 2 yrs). However, the statistics are influenced by the short record duration combined with the inclusion of the 2006 drought, which was estimated in the WRMP19 to have a return period of 1 in 175 years. It is therefore appropriate that the level 3b trigger (but not level 4) is breached in this drought year.

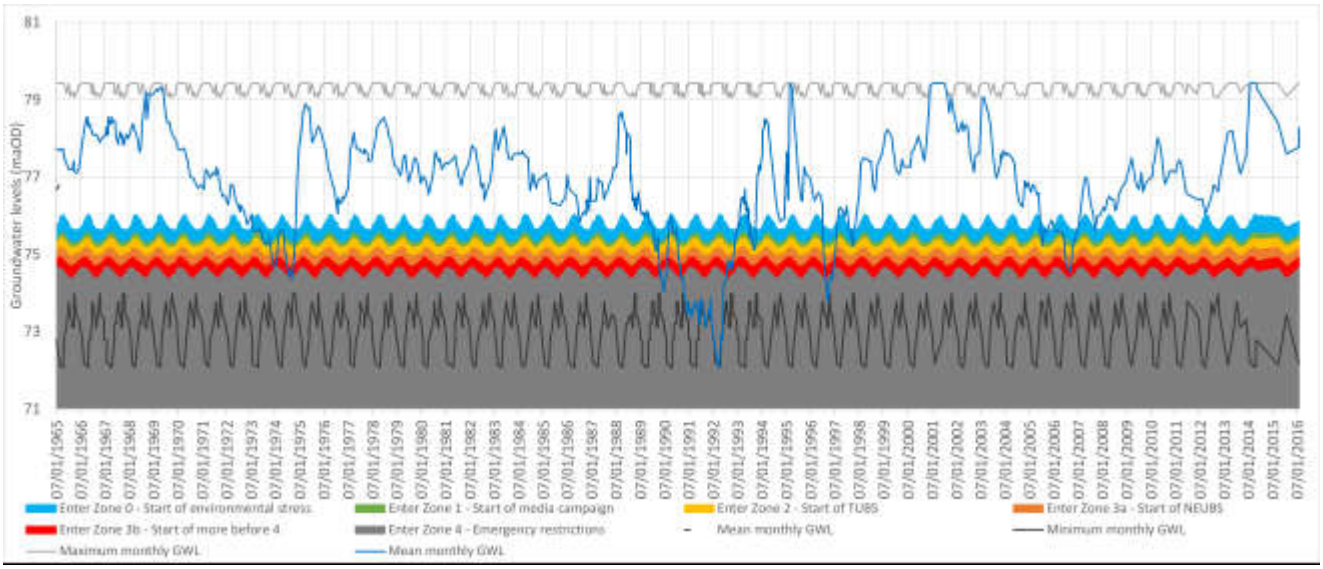

Figure 5-2 - Proposed Riverhead triggers vs historical record (full record)

LTA: 1965: 2016

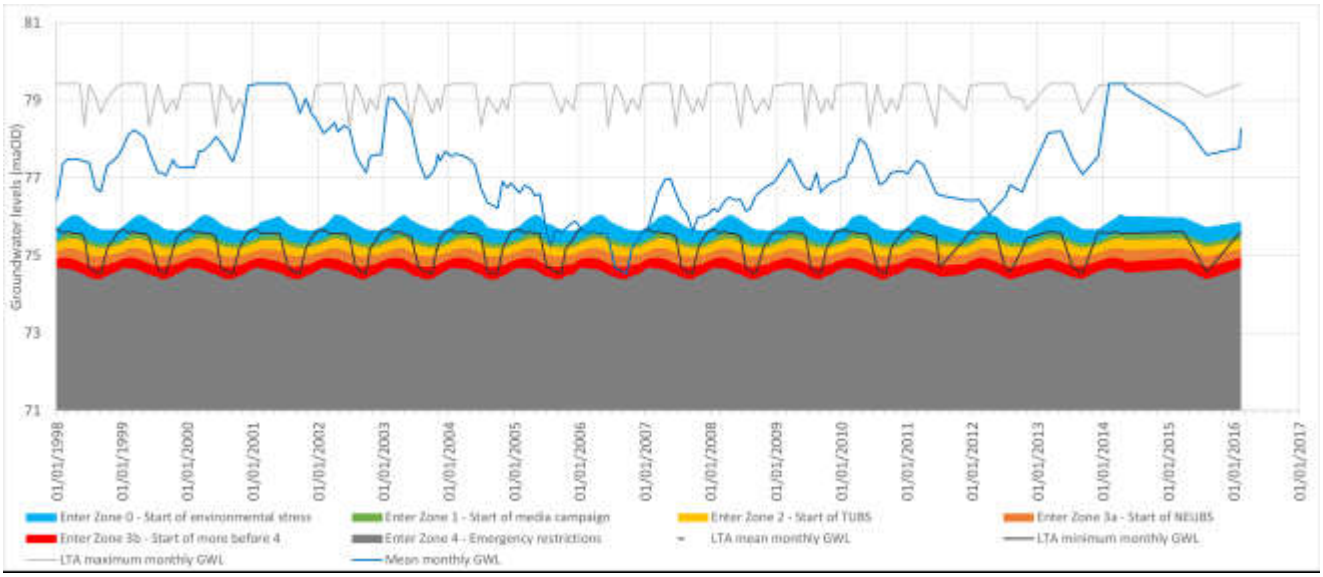

Figure 5-3 - Proposed Riverhead triggers vs historical record (post 1998)

Two examples of 1 in 200-year and 1 in 500-year groundwater level minima stochastic traces have been plotted against the proposed Riverhead OBH triggers in **Figure 5-4**. These traces have been plotted on an arbitrary x axis from 1953 to 1960 to allow for comparisons between the traces (i.e. these are not historical simulations for this period). Note both stochastic timeseries IDs 243 and 140 occur towards the end of the record, and as such the full recovery is not captured.

The Level 4 trigger threshold has been set at a 1 in 200-year return period, with the result that example droughts just brush this threshold. The 1 in 500-year drought dip slightly further into level 4, but as noted in

Atkins 2021, the difference between a 1 in 200 and 1 in 500-year groundwater level at Riverhead is small (12 cm).

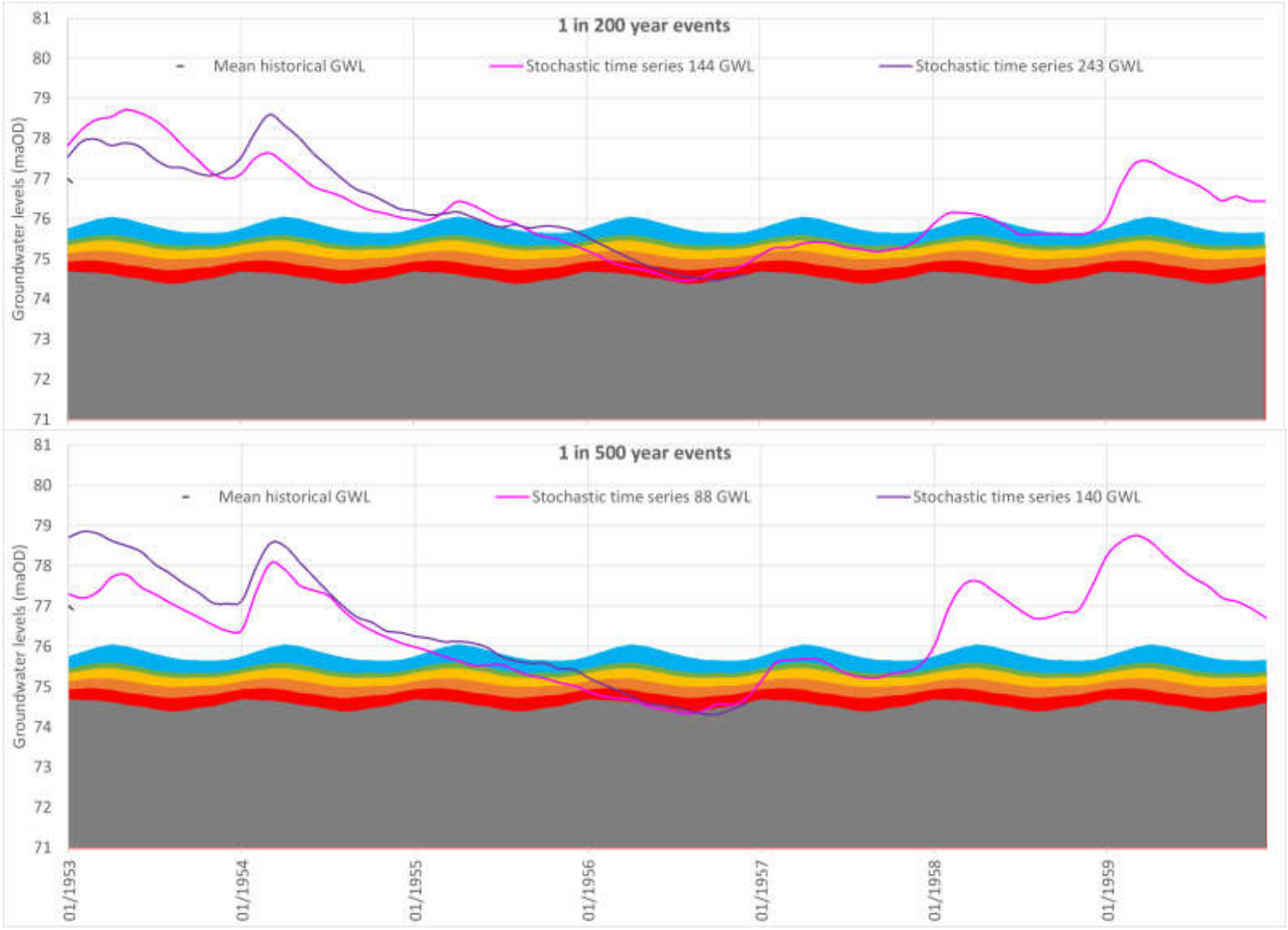

Figure 5-4 - Riverhead triggers vs example 1 in 200 and 1 in 500 year events

6. References

Environment Agency, 2020, Water Company Drought Plan guideline (Version 1.2)
Atkins, 2021, Groundwater deployable output review (draft)
Atkins, 2021b, Drought plan - OBH review (draft)