2027 DRAFT Drought Plan

Appendix N

Drought Response Surfaces

APPENDIX N Drought Response Surfaces

N1 Overview of Drought Response Surfaces

Drought Response Surfaces (DRS) are a method of assessing the type, duration, and timing of drought to provide further information in assessing what droughts are most critical for a given Water Resource Zone (WRZ). We have included an assessment of the risk of potential shortfall in water resources for each WRZ as outlined in Drought Vulnerability Framework1.

N1.1 Interpreting drought response surfaces

A drought response surface shows how different combinations of drought duration (X-axis, in 6-month bands) and rainfall deficit (Y-axis, % of long-term average in 5% increments) affect system risk. Short, lower intensity droughts appear in the top-left; longer, high intensity droughts appear in the bottom-right. A sample drought response surface (DRS) is shown in Figure N1.

The colour of each cell indicates the severity of impact (Z-axis), expressed here as the number of days emergency restrictions would be needed.

- Green = no emergency restrictions expected
- Red = long periods of emergency restrictions
- Grey = unrealistic or uncertain drought conditions

Black points show historical drought events, with an additional triangular point showing the recent 2022 and 2025 events for context. While curved probability lines indicate the likelihood of different duration–deficit combinations. Because durations are grouped into 6-month intervals, transitions across boundaries (e.g., 6 to 12 months) do not represent intermediate durations such as 9 months.

[1] https://ukwir.org/drought-vulnerability-framework-0

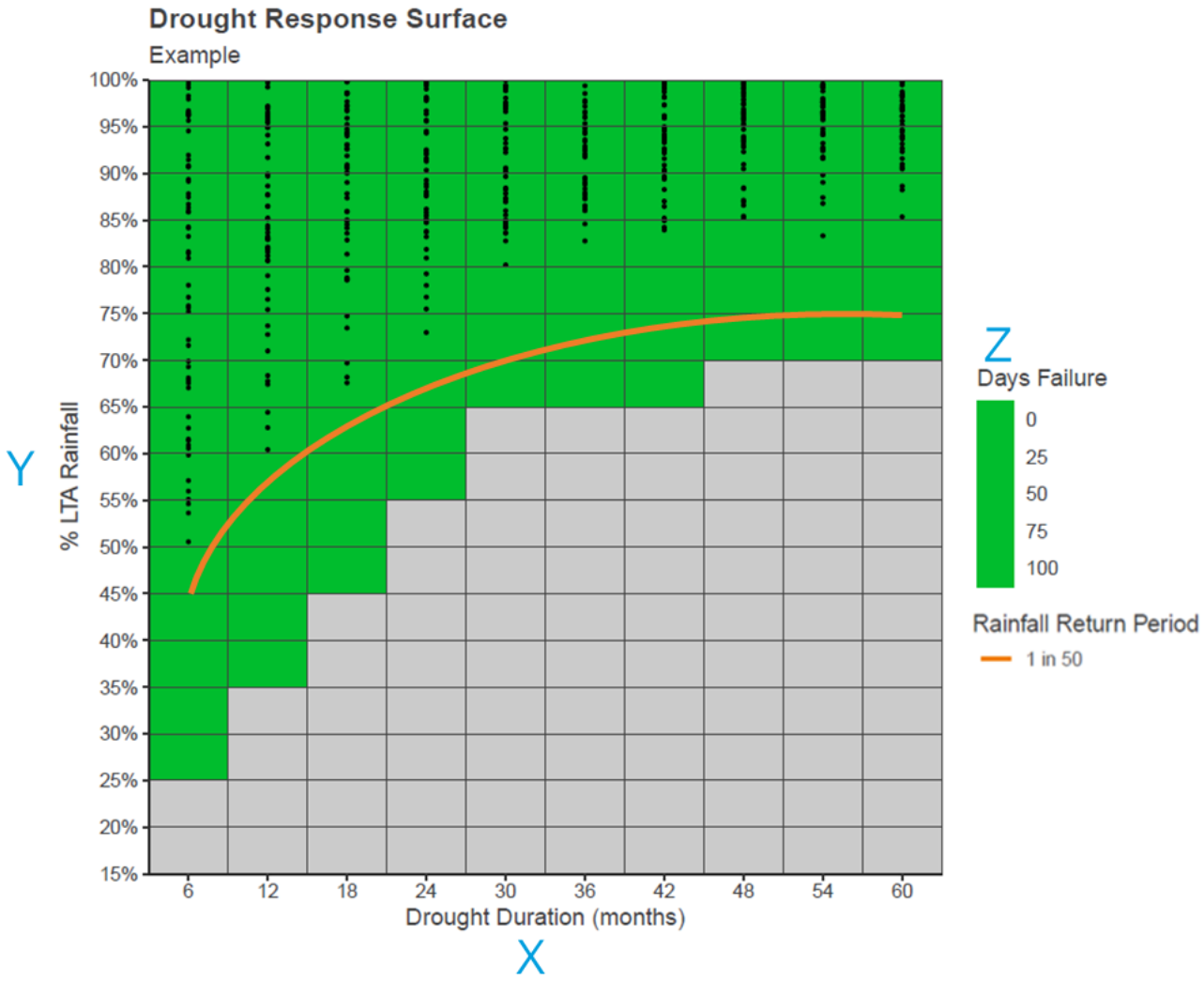

Figure N1 Example Drought Response Surface

N2 Drought Response Surfaces for each WRZ

N2.1 London

London DRS is built using long-term stochastic weather data, allowing us to test a wide range of realistic and extreme droughts. Pwyr modelling carried out for WSRE regional plan and WRMP24 and was used to produce the DRS using Calculation Approach 1a in the UKWIR Drought Vulnerability Framework. The DRS is provided in Figure N2.

For each simulated year, rainfall deficits and aggregated reservoir storage levels were matched to the number of days London would cross Level 4 on the LTCD. These results were averaged within each DRS cell.

The results show that London generally doesn't cross level 4 in droughts up to around a 1-in-200-year severity. Vulnerability increases for droughts lasting 1 to 3 years with less than 75% of average rainfall; for example, an 18 month drought with 45 to 50% rainfall could lead to around six months of emergency restrictions. An isolated 42 month with 80 to 85% rainfall result is considered an artefact of the method rather than a real vulnerability.
This DRS appears more pessimistic than the Severe Drought Assessment because it classifies drought severity by rainfall alone, rather than system response (storage). DRS results are also sensitive to the use of mean values, which can be skewed by a small number of severe events, and they cannot distinguish between different drought sequences that produce the same overall rainfall deficit.

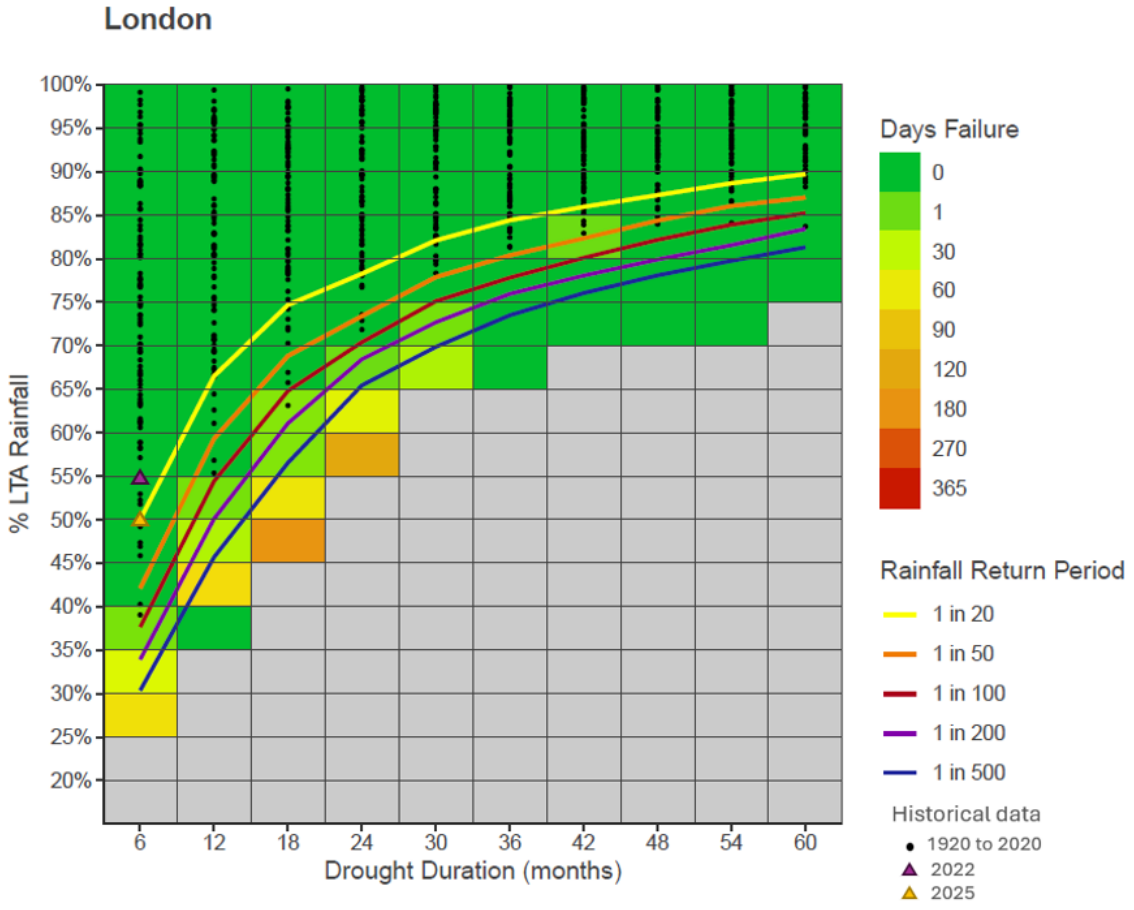

Figure N2 London Drought Response Surface

N2.2 Swindon and Oxfordshire (SWOX) WRZ

The SWOX drought response surface (Figure N3) uses the same methodology as London. It shows that SWOX generally avoids crossing level 4 in droughts up to around a 1 in 200-year severity. More extreme droughts could lead to more drought measures being required. This aligns with previous assessments: SWOX would avoid crossing level 4 in a 1976 type event, but a longer event

would require additional measures to avoid emergency restrictions. The DRS also highlights that SWOX is particularly vulnerable to droughts lasting 12 to 18 months with rainfall below ~60% of the long-term average.

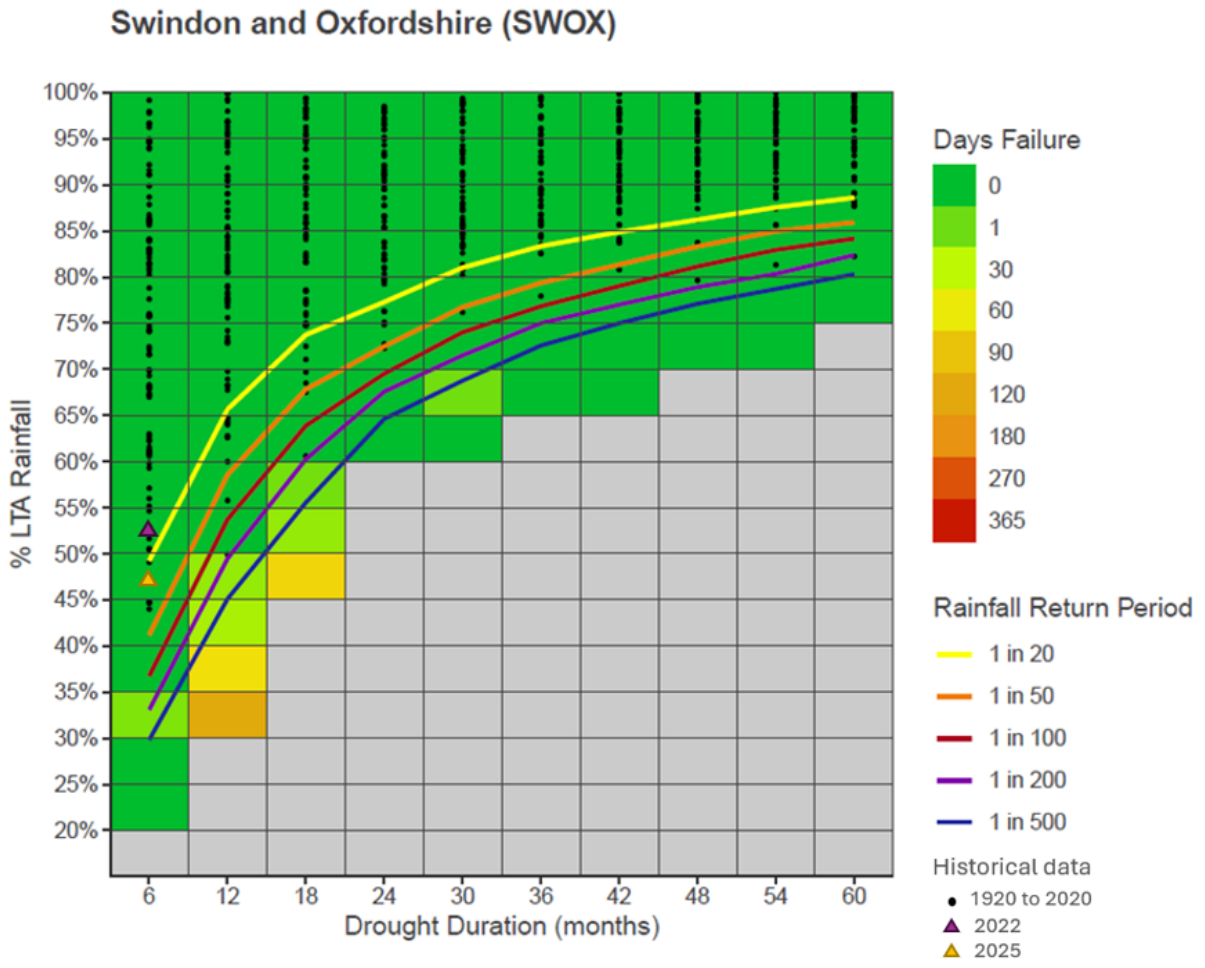

Figure N3 SWOX Drought Response Surface

N2.3 Kennet Valley

The Kennet Valley DRS (Figures N4a and N4b) was developed using Calculation Approach 1b and 4b in the UKWIR Drought Vulnerability Framework. The yield of our KEN_0002 surface water source (run of river) was determined for each year in the stochastic series (using river flows from the same Pywr modelling used for the London and SWOX DRS analysis). An appropriate stochastic rainfall dataset was used to classify years in the stochastic record to boxes on the DRS. For WRMP24, flows in the River Kennet were re-assessed and quantile mapping of flows applied to improve the estimation of lower flows. A stochastic dataset of yields was also produced for KEN_0004 and combined with the stochastic rainfall data as above.

Approach 4b was applied for other sources within the Kennet Valley WRZ. This approach involves determining a statistical relationship between rainfall over a given duration and groundwater levels, and then applying these relationships to determine groundwater levels, and so yield, that may be anticipated for different drought durations and severities.
Our analysis using approaches 1b and 4b resulted in yields for each source being determined for each DRS cell. The sum of surface and groundwater yields were used to determine the total yield for the WRZ in each cell. This was compared to an appropriate demand figure (to give an indicative supply-demand balance for each DRS cell) and a calculation applied to determine if, and for how long, emergency restrictions might be required for.

Two KEN_0006 scenarios were considered:

1. Using the current trigger for KEN_0006 – London's reservoir storage falling below Level 2 on the LTCD (Fig N4a)
2. Using a potential trigger for KEN_0006 based on low flows in the River Kennet (Fig N4b)

The difference between these two figures indicates that there would be benefit for the Kennet Valley WRZ in introducing a river Kennet based trigger for KEN_0006. Such a trigger would require agreement with the Environment Agency. Peak (i.e. ending in August) and average DRSs were produced. As well as these two versions, DRSs were plotted for both the Peak period (defined as an event ending in August) and Annual Average, only the peak period scenario is presented here. Generally, for the Annual average scenario, there were few or no failures in both versions.

The Kennet valley DRS, Figure N4a, shows that would avoid crossing level 4 in a 1 in 500-year droughts of 2 years or more. We may be vulnerable to drought events of 1 in 100 year or worse severity lasting 1 to 1.5 years. Triggering of KEN_0006, or use of other drought permits, may be required should such an event occur. As with the London WRZ, this assessment is based on event severity being a function of rainfall, rather than river flows. Note this appears worse than previous assessments partly due to the improved estimation of lower flows. The river flows used in this assessment are lower and therefore produce lower yields at KEN_0002. Figure N4a suggests that under the new assessment of river flows, there would not be enough flow in the Kennet available to abstract at KEN_0002 for drought events of 12 to 18 months and a severity of more than 1 in 100 years. Our resilience to drought is significantly improved to most droughts less severe than 1 in 500 years with the KEN_0006 being able to be triggered by need in Kennet Valley. If London becomes more resilient to drought, the KEN_0006 is less likely to be triggered regardless of the potential drought risks in the Kennet Valley WRZ.

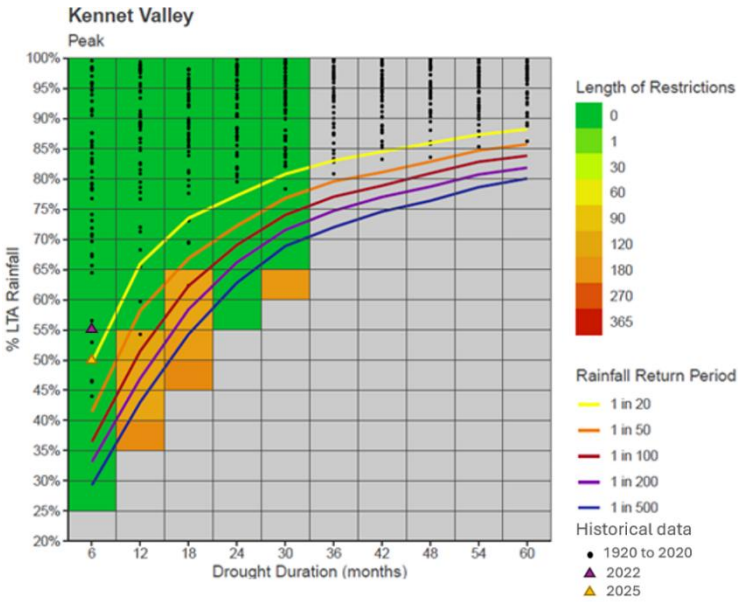

Figure N4a Kennet Valley Drought Response Surface with KEN_0006 triggered on London LTCD

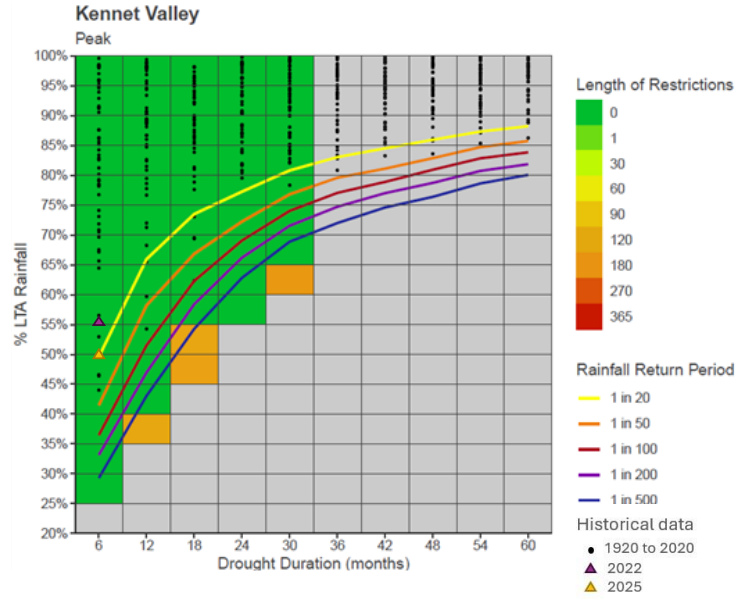

Figure N4b Kennet Valley Drought Response Surface with KEN_0006 triggered based on low flows in the Kennet

N2.4 Slough, Wycombe and Aylesbury (SWA)

The method used for producing the SWA DRS is similar to that of Kennet Valley – a combination of statistical estimations of groundwater levels and yields at a number of sites added to stochastic yield datasets for SWA_0001 and SWA_0006 sources.

The DRS for SWA, Figure N5, shows that we avoid crossing level 4 in droughts of up to 1 in 200 years but that beyond that there may be the requirement for drought permits during events of 30 to 36 months with less than 70% LTA rainfall. This reflects the potential vulnerability in the yields of a small number of sources, particularly SWA_0004 and SWA_0005. Sustainability reductions have been implemented at SWA_0005, therefore the yield is likely to be resilient to severe drought, and SWA_0004 is currently planned to be closed. It's also worth noting that sustainability reductions have been made at SWA_0003 & SWA_0007, and that SWA_0001 is currently disused (due to be brought back into service soon). SWA_0006 is a small source near the catchment divide and, if necessary, could be supported by tankering. In a severe drought we would have implemented demand management measures to suppress demand and so it is expected that the WRZ would avoid emergency restrictions due to severe drought because the majority of the zone's supply comes from Thames-side sources. If necessary, in a severe drought of greater than 1 in 100 or worse, the Drought Permit option at SWA_0005 could be used.

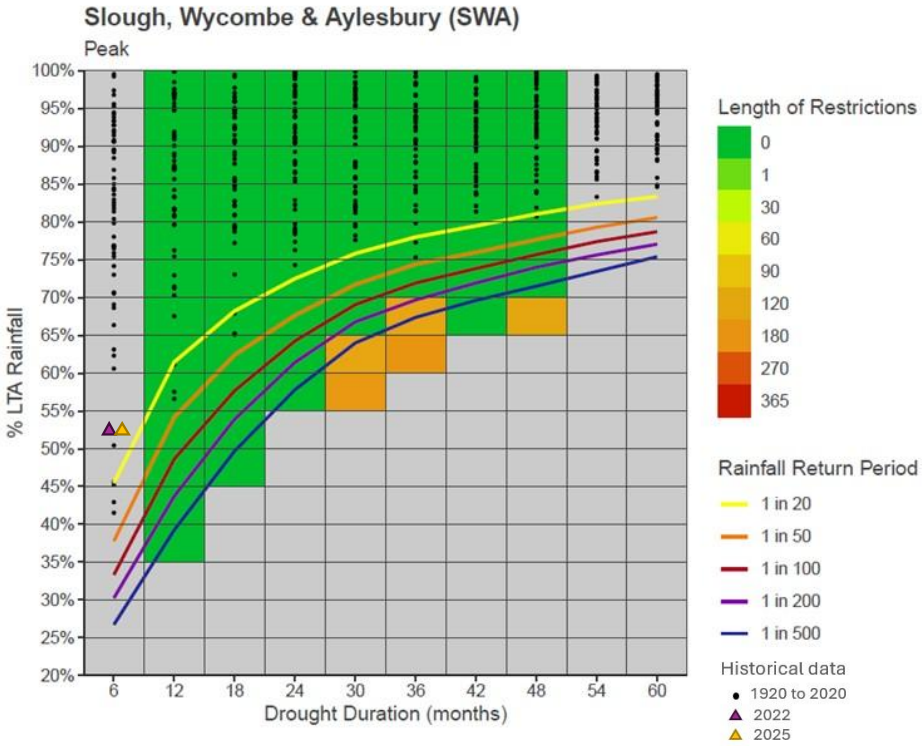

Figure N5 SWA Drought Response Surface

N2.5 Guildford

The Guildford DRS (Figure N6) shows that we avoid crossing level 4 in droughts up to at least a 1 in 500 year event. At this level of drought severity there is a high level of uncertainty but this view accords with our assessment of the drought resilience of the GUI_0006 source which is dependent upon flows in the River Wey being maintained at greater than 30 Ml/d.

The method used to produce this DRS is similar to that used for the SWA WRZ, whereby a combination of modelled flows using the stochastic record and statistically determined groundwater levels have been used to generate this surface.

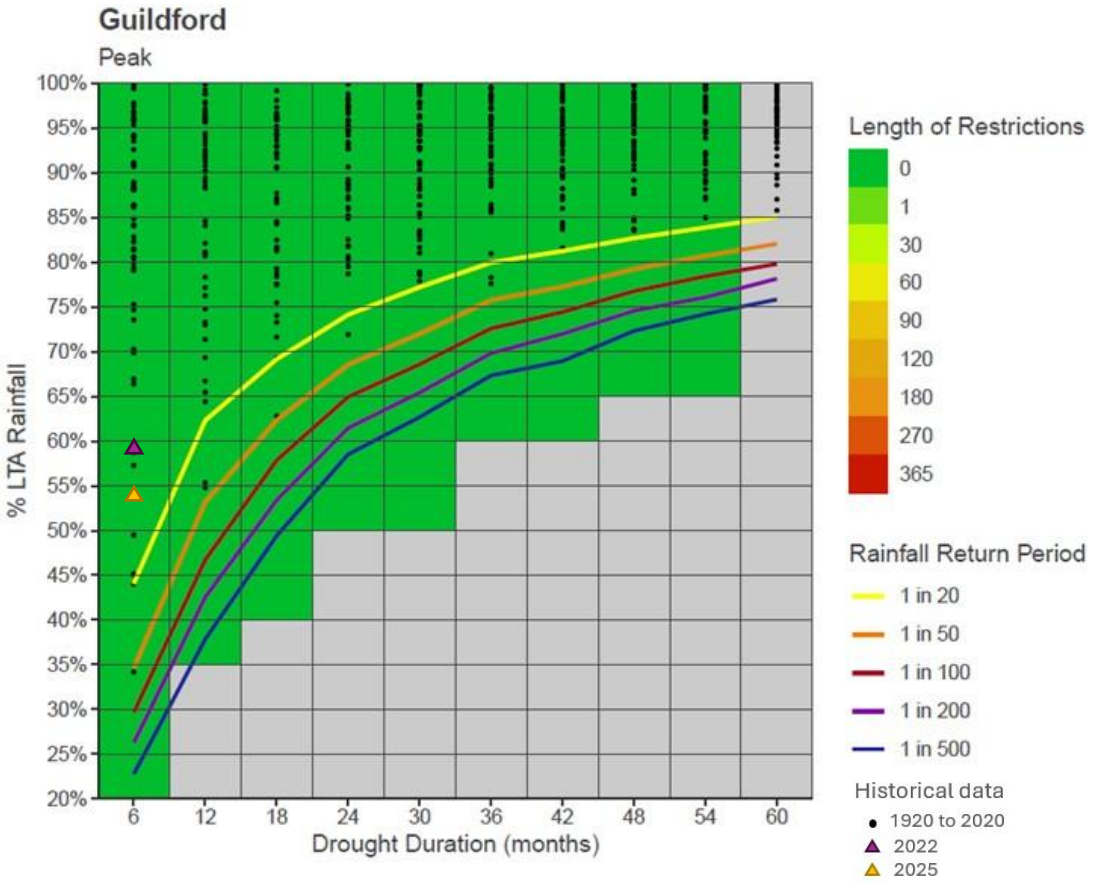

Figure N6 Guildford Drought Response Surface

N2.6 Henley

The Henley DRS (Figure N7) shows that we avoid crossing level 4 in droughts up to at least a 1 in 500 year event. At this level of drought severity there is a high level of uncertainty but this view accords with what is known about our Henley sources in that they are Thames-side groundwater sources and so have a high level of drought resilience.

The Henley DRS was produced solely using statistical analysis of groundwater levels (method 4b) under low probability rainfall events.

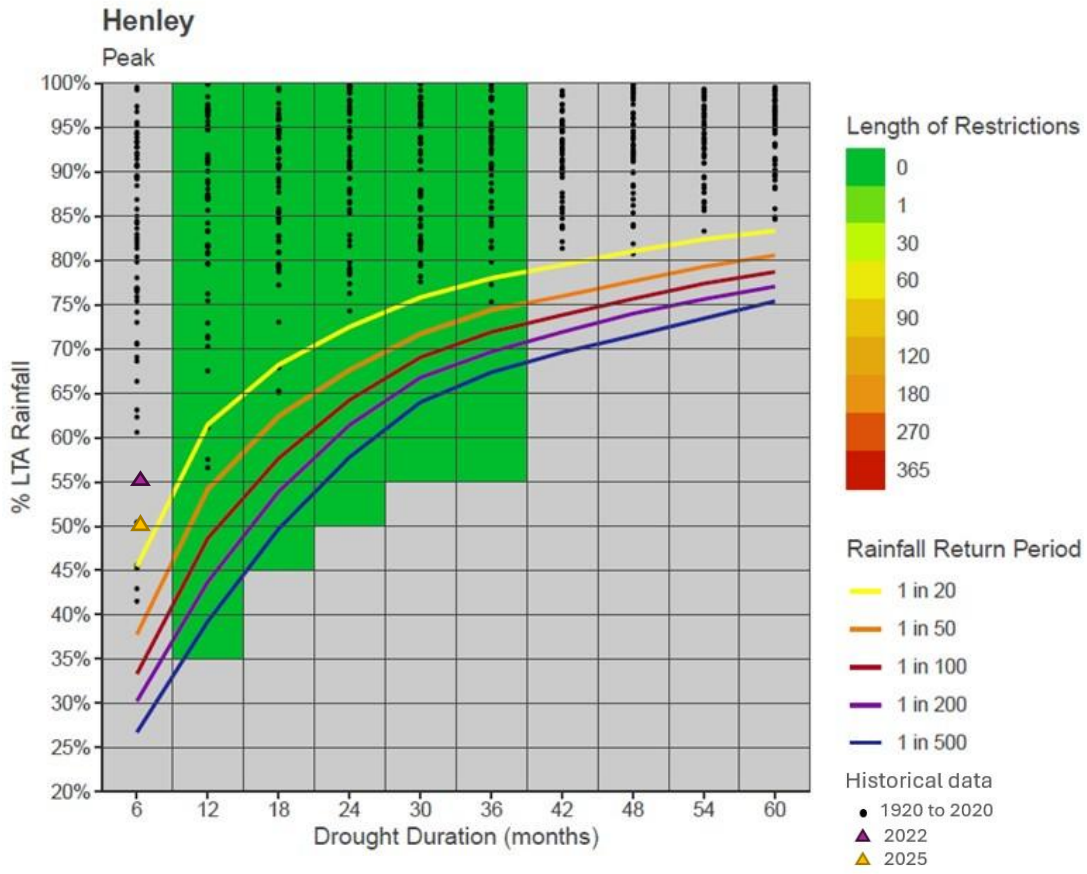

Figure N7 Henley Drought Response Surface

References

1. *UKWIR 2017, "Drought Vulnerability Framework", UKWIR Report Ref. No 17/WR/02/12*
2. *EA 2017, "Using the Drought Vulnerability Framework in Water Resources Management Plans"*