Exceptional Shortage of Rain case

Colliford Water Resource Zone: Colliford Lake and Stannon Lake

On behalf of South West Water

SEPTEMBER 2022

Version Control

Issue	Revision No.	Date Issued	Author	Checker	Reviewer	Comments
1	P01	13/09/22	Sarah Demetriou	Matt Langdon	Marcus Adams	
2	P02	20/09/22	Sarah Demetriou	Matt Langdon	Neil Evans	Updates following client feedback
3	P03	28/09/22	Elliot Blount-Powell	James Fidal	Matt Langdon	Updates to include September rainfall data
4	P04	30/09/22	James Fidal	Matt Langdon	Neil Evans	Updates following client feedback
5	P05	06/10/22	James Fidal	Matt Langdon	Neil Evans	Updates to respond to EA comments

Contents

Tables

Figures

1 Introduction

1.1 Aims

An Exceptional Shortage of Rain (ESoR) assessment has been undertaken by Arcadis on behalf of South West Water (SWW) as evidence of the need for a drought permit for both Stannon Lake and Colliford Lake (Stannon Lake Drought Permit Application 2022 and Colliford Lake Drought Permit Application 2022). This document sets out the case for an ESoR, following the Environment Agency (EA) Hydrological guidance for the assessment of an Exceptional Shortage of Rain[1].

1.2 Approach

1.2.1 Background

This analysis covers the Colliford Water Resource Zone (WRZ). The Zone has several water sources which can be used conjunctively to meet the needs of customers, whilst protecting the environment. To understand the challenge faced across these multiple sources it is appropriate to conduct rainfall analysis at a zonal scale. This ESoR assessment therefore covers both Colliford Lake and Stannon Lake.

1.2.2 Rainfall data

Areal rainfall data has been used to undertake all analyses carried out as part of this assessment. Rainfall data has been provided by the EA for the catchment area outlined in Section 1.2.4. The data includes the Met Office HadUK dataset[2] from January 1891 to December 2020 and the EA Daily Rainfall Tool (DRT) dataset[3] from January 2021 to end of August 2022 in monthly totals for the geographical extent of analysis.

To extend the analysis period to the end of September, a combination of recorded daily totals and forecast data has been used to create a monthly total for September. The EA ESOR guidance states that quantitative rainfall forecasts can be used to extend the period of analysis up to 15 days ahead to enable a full month to be analysed. Measured daily rainfall totals have been provided by the Environment Agency for the period 1st to 18th September and forecast data from MeteoGroup/DTN has been acquired from 19th to 30th September. A summary of the cumulative totals for each data source is given in Table 1-1.

The forecast data provided by MeteoGroup/DTN is provided as gridded data with a spatial resolution of 4.2km (each grid cell is 4.2km by 4.2km) with rainfall depths provided at 6-hour intervals, see Figure 1-1 below for more details. 172 grid cells covering the Colliford WRZ were selected based on whether the cell centre was located within the WRZ. This means that some of the selected cells along the boundary of the WRZ partially cover an area outside of the WRZ; however, there are also some cells along the boundary that were not selected. An auditable and repeatable approach of taking the mean rainfall depth for each 6-hour period from the 172 grid cells was adopted without any weighting for partial cells. Any potential source of uncertainty associated with this is considered in Section 2.4.

[1] Environment Agency, March 2021, Hydrological guidance for the assessment of an Exceptional Shortage of Rain (ESoR).
[2] Contains public sector information licensed under the Open Government Licence v3.0
[3] Contains Environment Agency information © Environment Agency and/or database right

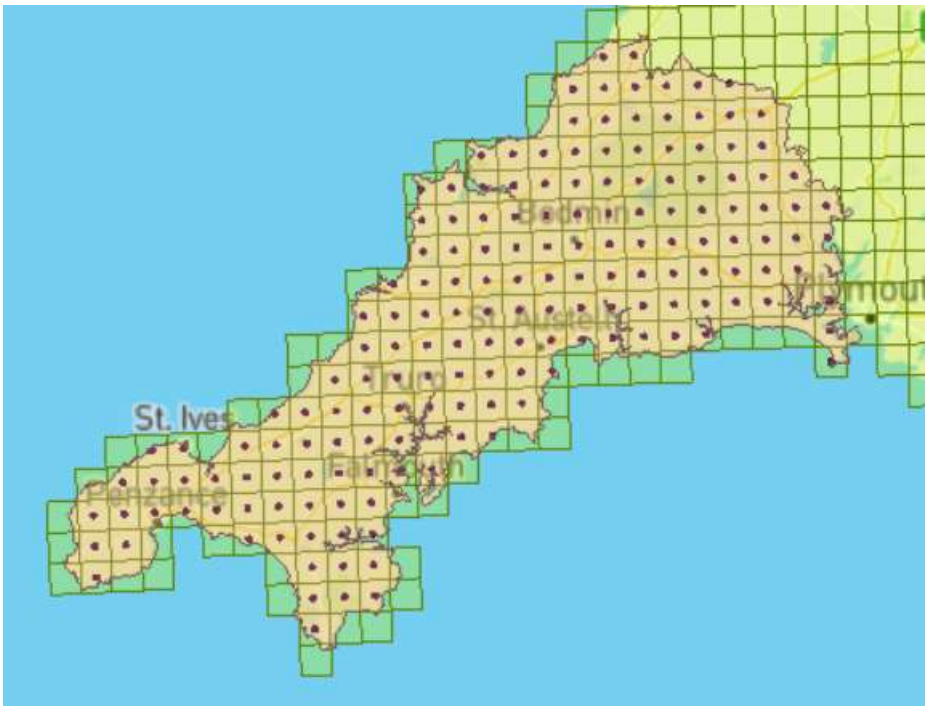

Figure 1-1 Map of Colliford WRZ with MeteoGroup/ DTN forecast data grid squares

Table 1-1: Summary of recorded and forecast data for September 2022

Source of Data	Start of Period	End of Period	Cumulative rainfall (mm)
EA DRT (recorded)	01/09/2022 09:00 GMT	19/09/2022 09:00 GMT	88.1
MeteoGroup/DTN Forecast	19/09/2022 09:00 GMT	01/10/2022 09:00 GMT	30.0
		TOTAL	**118.1**

As the hydrological day begins and ends at 09:00 GMT in the UK, the recorded data available covers up to 09:00 GMT on 19/09/2022. As such, the forecast data needs to cover from 09:00 GMT on 19/09/2022 until 09:00 GMT on 01/10/2022. The forecast data is provided at 6-hour intervals spanning 00:00-06:00, 06:00-12:00, 12-00-18:00 and 18:00-00:00 (GMT), so a proportion of the forecast data is needed to cover the first and last 3 hours of the hydrological day (see Figure 1-2 for context).

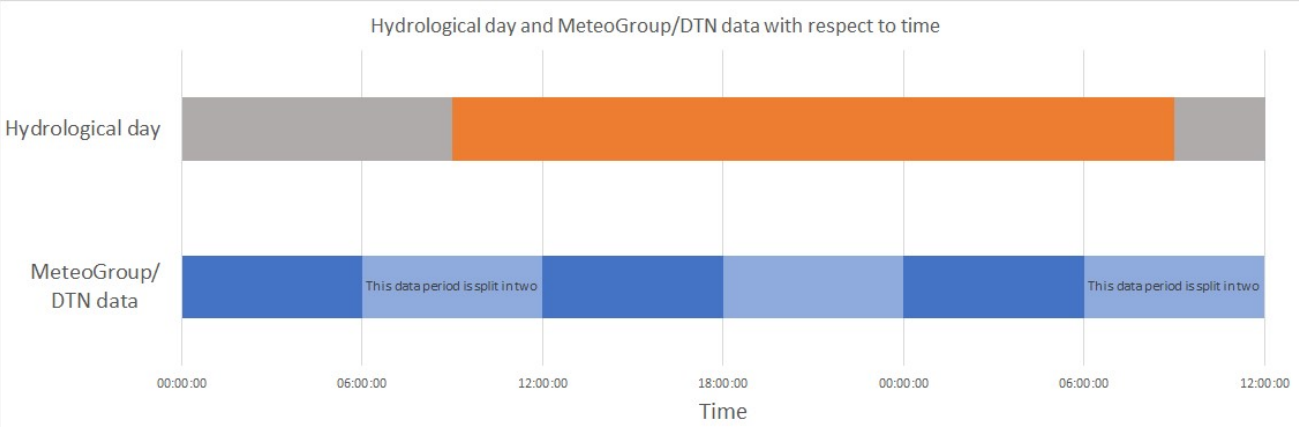

Figure 1-2: Visualisation of hydrological day and the MeteoGroup/DTN forecast data.

Since only a cumulative forecast rainfall depth is required, apportioning of rainfall depths only needs to be done for the first (19/09/2022 06:00-12:00 GMT) and last period (01/10/2022 06:00-12:00 GMT). The calculation is summarised in Table 1-2 and it has been assumed that rainfall is evenly distributed across the 6-hour period; therefore, half of the forecast rainfall from the two periods is added to the cumulative rainfall to generate a monthly total. This assumption results in a potential uncertainty of ±0.6mm and the implications of this are considered in Section 2.4.

Table 1-2: Apportioning of forecast rainfall

Forecast Period		Forecast Rainfall (mm)	Required Period		Apportioned Rainfall (mm)
Start	End		Start	End	
19/09/2022 06:00 GMT	19/09/2022 12:00 GMT	<0.1	19/09/2022 09:00 GMT	19/09/2022 12:00 GMT	0.0
01/10/2022 06:00 GMT	01/10/2022 12:00 GMT	1.2	01/10/2022 06:00 GMT	01/10/2022 09:00 GMT	0.6

1.2.3 Period of analysis

The main period of analysis spans the start of November 2021 to the end of September 2022. As illustrated in Figure 1-3, the net storage of the Colliford Lake was only at 80% following winter 2021/22. Following consultation with the Environment Agency, we have followed their recommendation[4] to begin the analysis in November 2021 as this is the date at which the reservoir storage crossed the pumped storage curve and could therefore be considered no longer normal for the time of year.

The purpose of this assessment is to determine whether the reservoir not reaching capacity in early 2022 and the steep continuous decline since April, to the current 22% capacity, is a result of an ESoR for this 11 month period.

[4] Email dated 08/09/2022 from Kate Bowers.

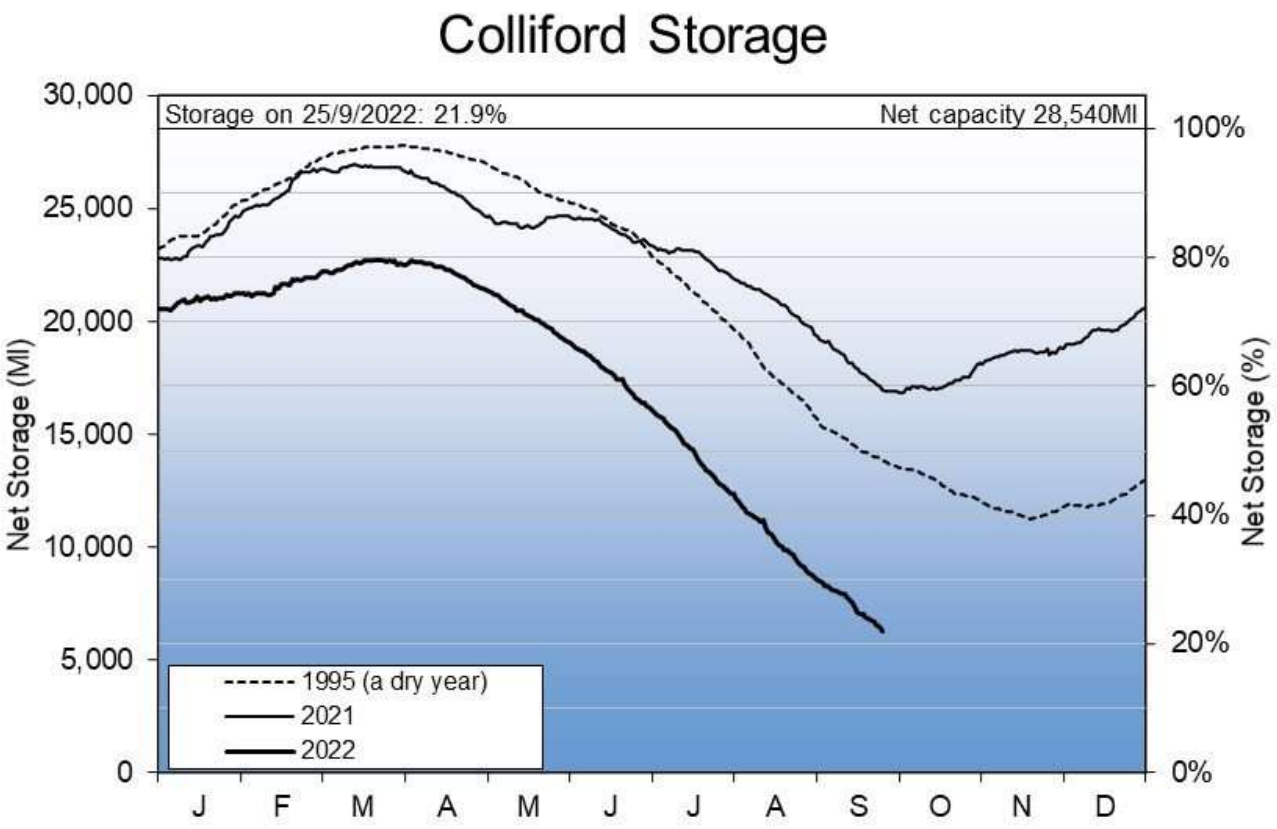

Figure 1-3: Storage for the Colliford Lake for 2022 (thick line) compared to 2021 (thin line) and a known dry year in 1995 (dashed line).

The full historical record (1891-2022) has been used for comparison when carrying out the analysis for this assessment, in keeping with the guidance, to ensure a large span of analysis. By using a long historical record of available observational data, this minimises associated uncertainties when comparing the period of analysis to previous historical droughts.

1.2.4 Geographical extent of analysis

As discussed above, given the water supply network connection between Stannon Lake and Colliford Lake and the significant reliance of the Colliford WRZ on water stored within the Colliford Lake, one ESoR assessment, covering the full WRZ (over 3,000km^2), will be used to support both drought permit applications. The WRZ and its relation to the natural drainage catchments is shown in Figure 1-4.

This approach was agreed with the hydrology team at the Environment Agency.

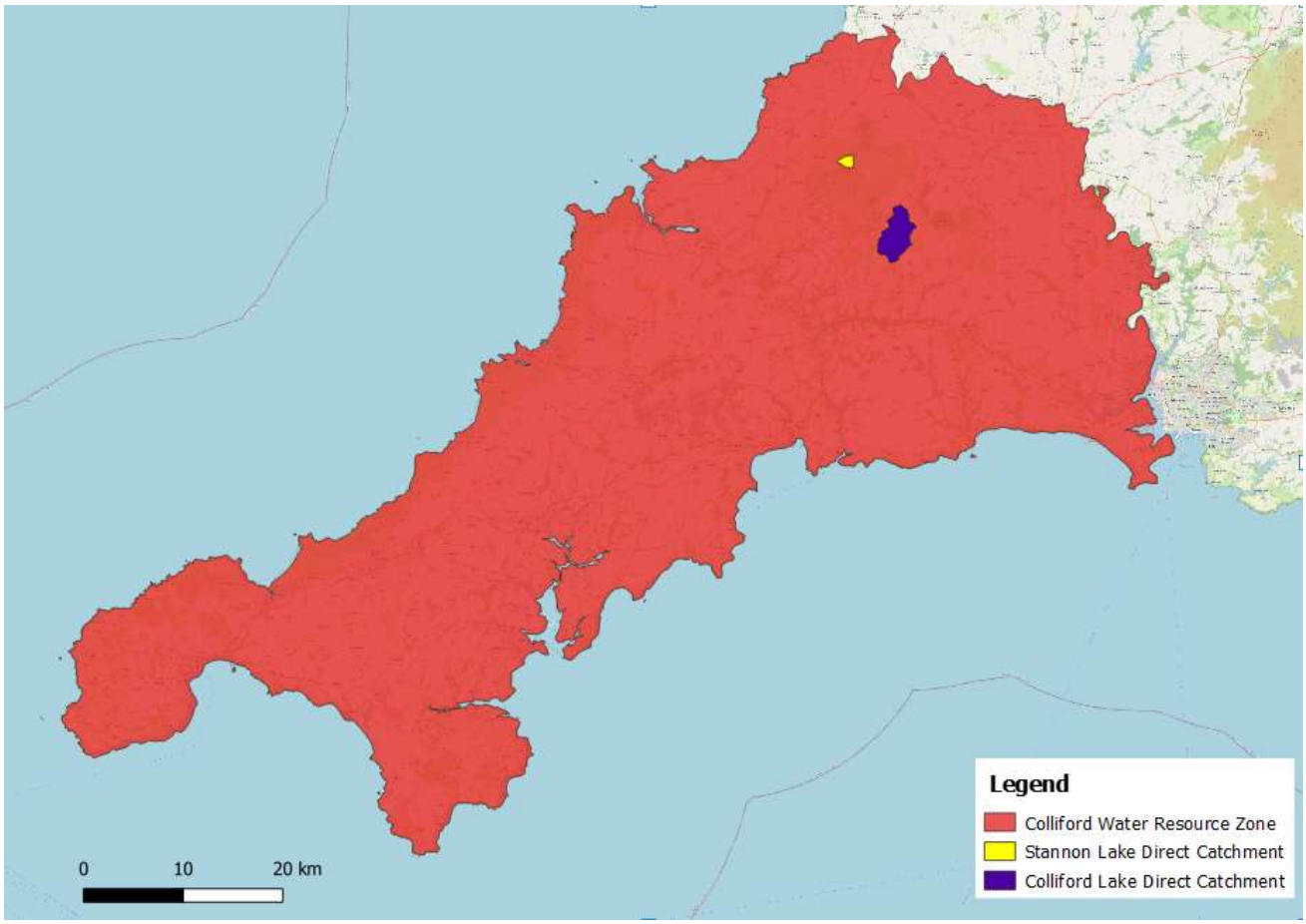

Figure 1-4: Colliford Water Resource Zone and Catchment Boundaries for Stannon Lake and Colliford Lake. Contains OS data © Crown copyright and database right (2022).

1.2.5 Soil moisture deficit

Whilst this ESoR is primarily exploring the amount of rainfall that falls within the water resource zone, the impact the lack of rainfall has had on the soil moisture deficit (SMD) and consequently on runoff and reservoir refill for the analysis period will also be considered and presented. Soil moisture deficit charts are produced by the EA using raw MORECS SMD data. These charts are produced monthly during routine water situation reporting but are produced on a weekly basis during drought conditions[5].

1.2.6 River flow levels

River flow levels are a good indication of the impact that rainfall is having within a catchment when compared with average flows for that time of the year and the SMD. Alongside this, some river systems within Colliford WRZ require supply releases from reservoirs to support downstream abstractions and meet water supply needs. River flow levels will be considered and presented within this ESoR case. SWW has provided Arcadis with hydrographs produced for their weekly water situation report, based on EA data.

[5] Email dated 14/09/2022 from Kate Bowers.

1.2.7 Technical rainfall analysis methods

The following technical rainfall analysis methods have been carried out as part of this assessment for the geographical area and period of interest as described above. The methods have been chosen as they are deemed “essential” in the decision making of whether the period has experienced an ESoR:

- Standard Precipitation Index (SPI)
- Ranked Cumulative Rainfall Totals
- Rainfall Probability Bands

The methodology and findings from these analysis methods are described in Section 2.

2 Assessment

2.1 SPI

SPI values have been calculated for the geographical area of interest (Colliford WRZ) using the EA Standardised Precipitation Index tool[6] for the full period of record (1891-2022) and for the period of analysis (November – September). The results for the full period of record are presented in Figure 2-1 allowing for comparison of the 2021/22 period of analysis to the historical record.

An SPI value of -1.753 has been calculated for the analysis period in 2021/22. The UK Centre for Ecology and Hydrology (UKCEH) classifies an SPI value between -1.5 and -1.99 as "**Severely Dry**" and comparison to the full period of record shows that this is the tenth lowest SPI value recorded.

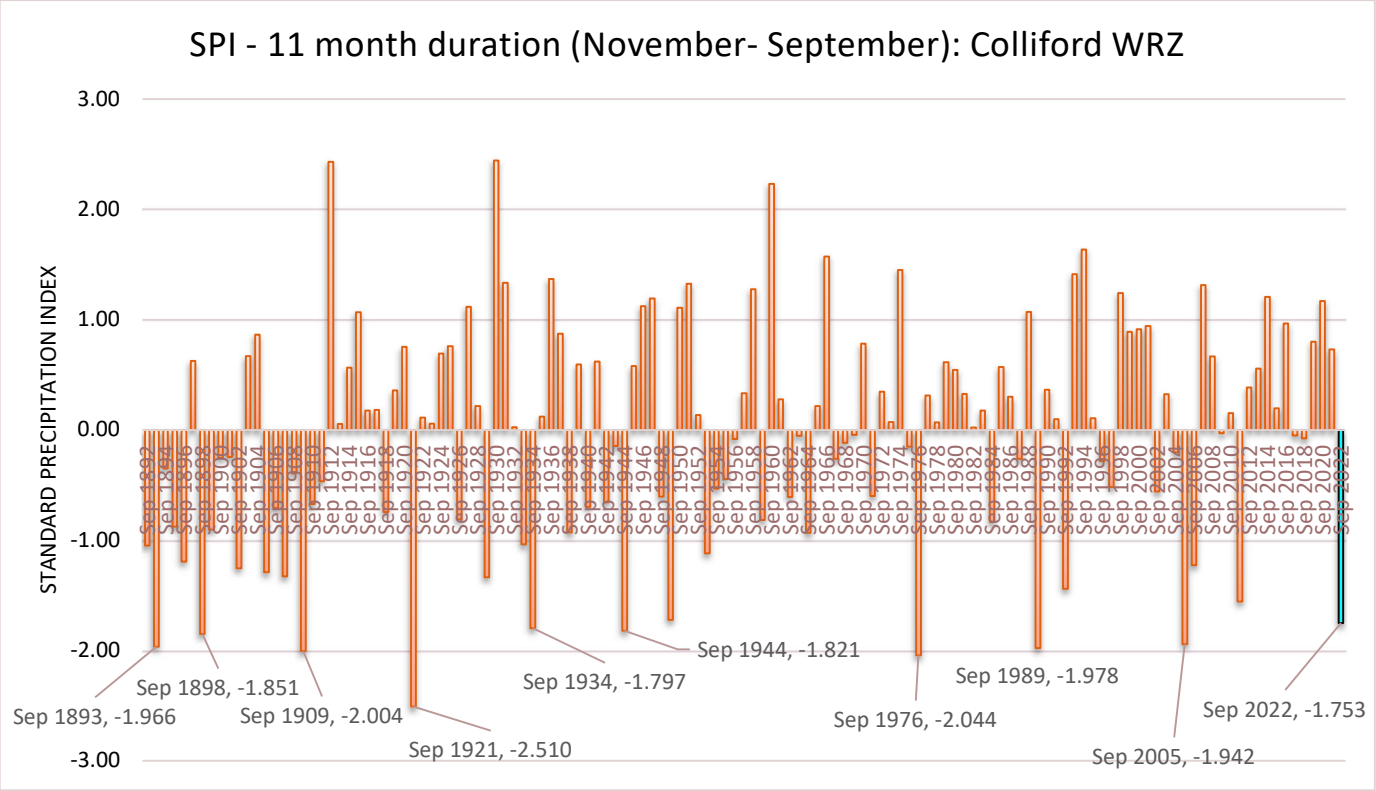

Figure 2-1: SPI values for the eleven months preceding September for the Colliford WRZ. The period of assessment is highlighted in blue

[6] Environment Agency, supplied August 2022, Environment Agency SPI Tool.pdf and Standardised Precipitation Index Rev B v2007_extended.xlsm. Provided under the Environment Agency Conditional Licence Contains Environment Agency information © Environment Agency and/or database right

2.2 Ranked Cumulative Rainfall Totals

The cumulative rainfall totals have been calculated for each available year (since 1891) for the period of analysis (November-September) and these have been ranked and are presented in Table 2-1. For comparison, the Long Term Average (LTA), calculated on the years 1961-1990, for the cumulative period has also been included.

The analysis period for 2021/22 is ranked as the tenth driest. Notable UK drought years, according to the EA drought response report[7] for the period 1967-2017 include: 1975-76, 1989-92, 1995-96, 2004-06 and 2010-12. The SWW Drought Plan[8] lists serious droughts as occurring in 1959, 1975-76, 1978, 1984, 1989 and 1995, thereby suggesting that these events impacted the southwest specifically, and potentially the area of interest.

The analysis period for 2021/22 has been ranked above (drier than) 1995, a noted drought year by the EA and SWW.

Table 2-1: Ranked 11-month cumulative rainfall totals up to September. The blue band highlights the period of analysis for this assessment

Rank (driest = 1)	Years	Cumulative Rainfall (mm) November – September
1	1920/21	701.2
2	1975/76	761.0
3	1908/09	766.3
4	1988/89	769.8
5	1892/93	771.3
6	2004/05	774.5
7	1897/98	786.8
8	1943/44	790.8
9	1933/34	794.1
10	2021/22	800.1
11	1948/49	804.4
12	2010/11	827.1
LTA	*1961-90*	*1076.5*

[7] Environment Agency, June 2017, Drought response: our framework for England
[8] South West Water, October 2018, South West Water Bournemouth Water Drought Plan

2.3 Rainfall Probability Bands

Rainfall probability ranking has been undertaken using the EA Monthly Rainfall Probability Ranking tool[9] for the geographical area of interest (Colliford WRZ) for the full period of record (1891-2022) and for the period of analysis (November - September).

A summary extract from the tool is given in Table 2-2 for the 2021/22 period of analysis. The 2021/22 period of analysis gives a cumulative total of 800.1mm, which is 75% of the LTA. This period is given a probability band of "Notably Low".

Table 2-2: Extract from the EA's Monthly Rainfall Probability Ranking tool for the Colliford WRZ.

11-month period ending	Cumulative Total (mm)	Band	% Long Term Average (LTA)
Sep-22	800.1	Notably Low	75%

2.4 Uncertainty associated with the rainfall data

The processing of the forecast data introduces a degree of uncertainty (besides the uncertainty in the forecast itself) through taking the mean of the selected grid cells and half of the 6-hourly depths at the start and end of the forecasted period, see Figure 1-2 for more details. The latter is easily quantified as ±0.6mm and would not affect the ranking and, therefore, is considered not to be significant.

The uncertainty from using an un-weighted mean of the grid cells is less straightforward to quantify. However, the forecast data constitutes only 3.7% of the cumulative rainfall total for the period of analysis. Additionally, the forecast total would have to change by 14-20% (4.3-6mm) to move the ranking down or up one, respectively. As such, the use of an un-weighted mean to account for grid cells partially in or outside the WRZ is considered unlikely to have a significant effect on the conclusions of this assessment.

2.5 Shorter duration analysis

Arcadis previously prepared an ESoR case with a 10-month duration for the month ending of August 2022. The same analysis from Sections 2.1, 2.2 and 2.3 was performed. The results of this gave:

- The SPI value for the period of analysis was -2.031 which indicates an "extremely dry" period, ranking it fourth lowest SPI since records began in 1891.
- The cumulative rainfall ranked this period as fourth driest since 1891, with it ranking higher than several known droughts (e.g.,1995).
- The rainfall probability ranking puts the period of analysis within the "Exceptionally Low" probability band at 69% of the LTA.

[9] Environment Agency, supplied August 2022, Monthly Rainfall Probability Ranking Macro_r21-11a.xlsm. Provided under the Environment Agency Conditional Licence. Contains Environment Agency information © Environment Agency and/or database right

2.6 Soil moisture deficit

Figure 2-2 shows the areal average soil moisture deficit for all of Devon and Cornwall for the years 2022, 2021, 2018, the long-term average (1961-1990) and the historical maximum and minimum. It is shown that SMD levels have been consistently increasing since March 2022, in line with the exceptionally low rainfall, with a new historic maximum observed at the start of September. The SMD has decreased in the beginning of September in response to rainfall; however, it is still well above the long-term average. The new historic maximum SMD at the start of September indicates just how dry the soils were at that time and demonstrates why the September rainfall has had negligible impact on runoff and reservoir refill and, consequently, has been ineffective at reducing the risk to security of supply.

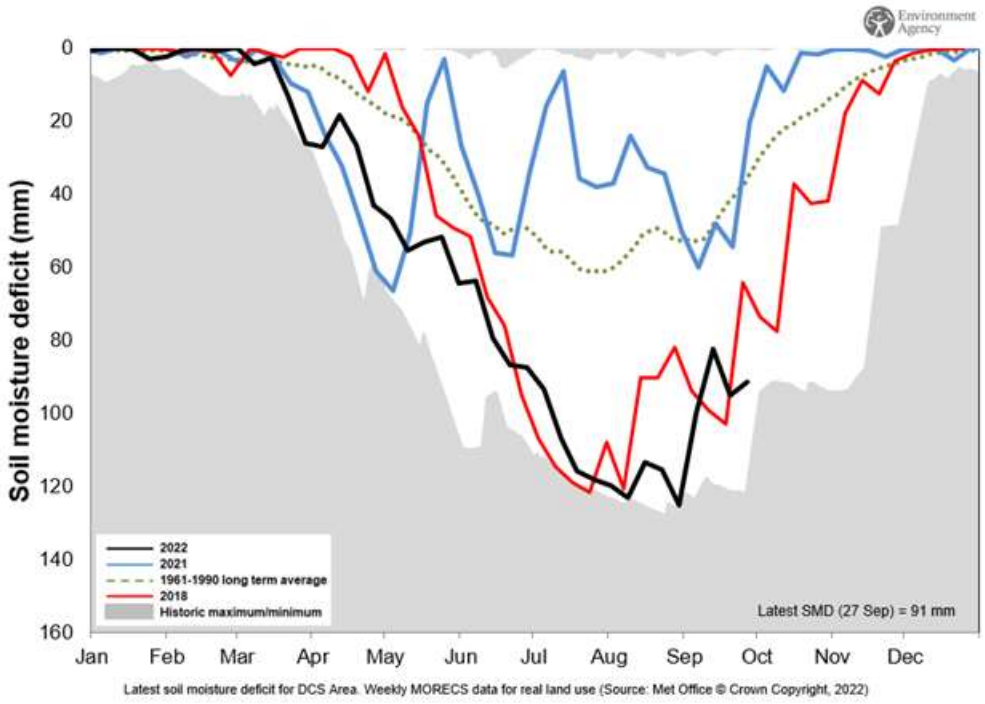

Figure 2-2: Soil Moisture Deficit for Devon and Cornwall.

2.7 River flows

Figure 2-3 shows the flow for the River Fowey at Restormel for years 2022 and 2021, as well as an average monthly flow (calculated on data from 1991-2020). Apart from a day or two in early June, river flow has remained consistently below average from mid-March 2022 until September. Since June, river flow has been below the prescribed flow which has meant SWW has needed to release water from Colliford Lake to meet the needs of Restormel WTW downstream. The short-term increase in flow in early September is generated by a rainfall event which is also shown in terms of temporarily reduced SMD in Figure 2-2, before SMD increases once more and river flow continues its downward trend. Until river flows have recovered sufficiently, SWW will still need to carry on releasing water from Colliford Lake and the storage will continue to decline.

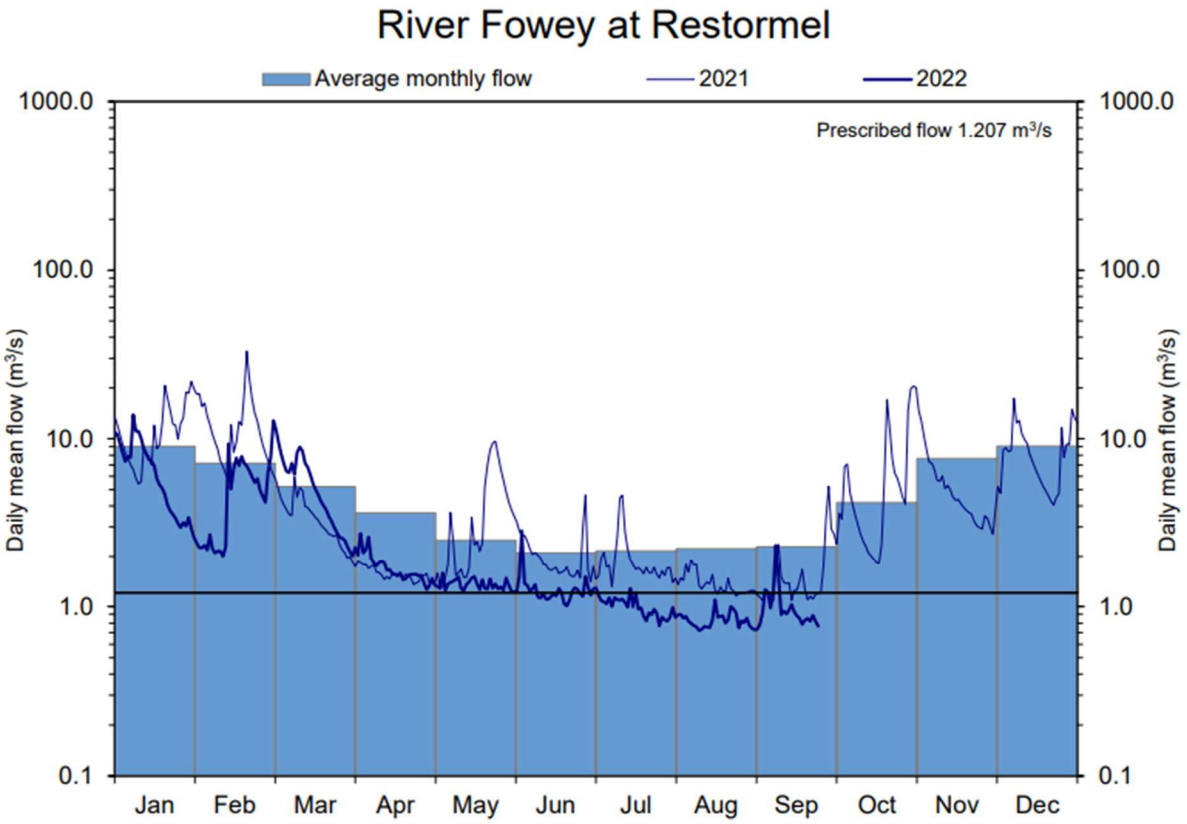

Figure 2-3: 2022 and 2021 River flow for River Fowey at Restormel from SWW's Water Situation Report.

3 Summary

An ESoR assessment is required to support the drought permit applications relating to Stannon and Colliford Lakes. A period of analysis (November 2021 - September 2022) has been recommended by the EA and agreed by SWW. This was determined by the storage curve for Colliford Lake; winter rainfall only filled the reservoir to 80% of capacity and since April 2022 there has been a steep decline in storage. This steep downward trend has continued until present.

Analysis using areal rainfall data for the geographical area of interest, as provided by the EA, has been carried out in accordance with the latest EA guidance and using EA tools, where available. Forecast rainfall data provided by MeteoGroup/DTN has been used to generate a total rainfall depth for September 2022.

The three key analyses used to support this ESoR assessment are: SPI, cumulative rainfall ranking and rainfall probability bands. The findings of the September results are given as follows:

- The SPI value for the period of analysis (-1.753) indicates a “severely dry” period, ranked within the ten lowest SPI values in a record starting in 1891;
- Ranked cumulative rainfall shows the period of analysis to be ranked tenth driest in a record starting in 1891 and ranked higher than a number of known drought events across the UK; and
- The rainfall probability ranking puts the period of analysis within the “notably low” probability band at 75% of the LTA.

The slightly shorter duration period (August month end) demonstrated an “extremely dry” SPI and “exceptionally low” probability band, clearly demonstrating an ESOR.

Adding the month of September 2022 into the analysis produces slightly less extreme results. Rainfall in September could be considered normal; however, this rainfall has had little impact on the WRZ with SMD levels only recovering slightly, and river flow levels only experiencing a singular, short-term, increase before returning to a low baseflow. Continued high SMD is resulting in a lack of runoff for reservoir refill and continued low river flows are necessitating supply releases from Colliford reservoir to meet the needs of Restormel WTW. This further evidence reinforces the demonstration of an ESoR, with SWW advising that the exceptionally low rainfall has been, and still is, critical to the water resource situation in Colliford WRZ.

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