

APPENDIX I. EXCEPTIONAL SHORTAGE OF RAINFALL CASE

This appendix presents the Exceptional Shortage of Rainfall case report. This report is currently presented as a template, [xxxxx] indicates non-generic text that needs to be amended with relevance to the specific ESoR analysis. This type of analysis will be used in the event of a drought when there is a need for a drought permit application as part of the Statement of Needs. The 1976 drought is used as an example to show the type of analysis that will be carried out and how it will be presented.

1. Introduction

Portsmouth water has undertaken an exceptional shortage of rainfall (ESoR) assessment as evidence of the need for a drought permit for [xxxxxxx]. The evidence and case put forward for the ESoR has been conducted under Environment Agency guidance¹. Given that there is no prescriptive method or set definition for assessing an ESoR, this document outlines:

- The period and duration of relevant metrics for ESoR analyses
- The range of methodologies employed for analyses
- Presentation of analyses, defining the current drought period relative to previous droughts and long-term average (LTA) conditions by evaluating:
 - Percentage deviation from LTA across relevant drought metrics
 - Ranking and graphical representation of return periods for relevant drought metrics and Standard Precipitation Indices (SPI)
 - Graphical representation of cumulative rainfall and cumulative rainfall deficit

2. Assessment

2.1. Rainfall data

For the ESoR assessment, Portsmouth Water have used HadUK aerial rainfall for Portsmouth Water's water resource zone (WRZ), supplied by Defra as per Environment Agency requirements. As Portsmouth Water have only one WRZ, this represents one geographical area (see section 2.3 for geographical extent of analysis). Use of aerial rainfall provides an advantage over individual rain gauge datasets as uncertainty associated with individual gauges is reduced.

The case for ESoR is made for the period of xxxx to xxxx [To prevent a delay in the application, the end can be extended by quantitative weather forecast data up to 15 days ahead to enable a full month to be analysed]. The start date corresponds with when the rainfall deficit begins to impact upon the water resource situation, as is demonstrated in subsequent analysis in section 2.4. The end date stated is the date of drought permit application, when drought triggers within the Drought Plan have been crossed. The period of analysis has been agreed upon with the Environment Agency hydrologist, the Area Drought Coordinator and water company lead (OCS) prior to analysis, and is shown on Figure 2-1, including the period of record 1891 to present day [Confirm action has been taken]. Long term average (LTA) precipitation values and drought metrics have been determined using the period of 1891 to present day (specify end date).

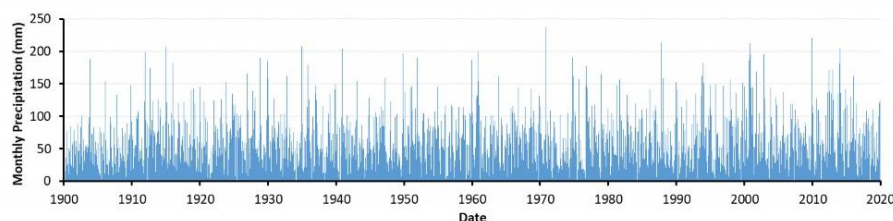


Figure 2-1 - Monthly rainfall data used within ESoR analysis 1891-2019.

¹ Environment Agency, March 2021. Drought permits and drought orders. Supplementary guidance from the Environment Agency and Department of Environment, Food and Rural Affairs

Update the rainfall plot to include most recent rainfall and since 1891 or selected period of analysis

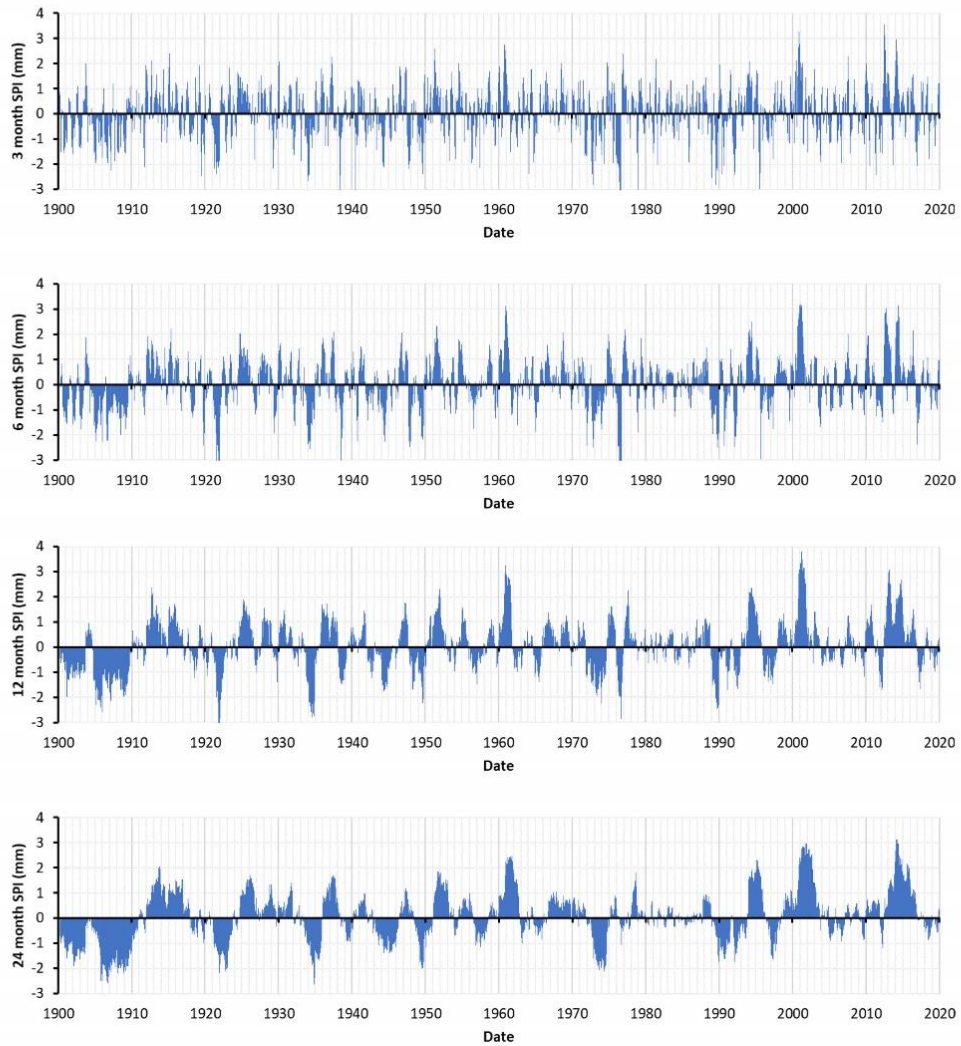


Figure 2-2 - Monthly rainfall SPI data (calculated over 3 months, 6 months, 12 months and 24 months) used within ESOR analysis 1891-2019.

Update SPI rainfall plot to include most recent data

2.2. Geographical extent of analysis

The ESOR assessment has been conducted for the area of Portsmouth Water's water resource zone (WRZ; Figure 2-3). As our only WRZ, the assessment aligns with our catchment and supply area.

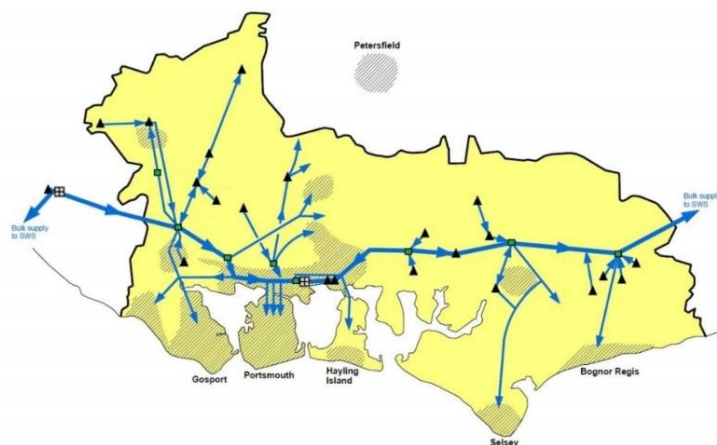


Figure 2-3 - Map of Portsmouth Water Strategic Water Resource Zone and the area of analysis for ESoR.

2.3. Technical rainfall analysis methods

The assessment completed by Portsmouth Water uses the following technical analysis methods outlined in Table 2-1.

We have employed methods of analysis proposed by the EA including ranking of droughts, graphical representation of cumulative rainfall and deviations from the long-term average (LTA). We include SPI metrics for 3 months, 6 months, 12 months and 24 months, and have also defined a range of drought metrics based upon different lengths (3 months up to 36 months) and seasonal focus (targeting winter drought or summer drought). As the ESoR identifies a shortage of rainfall over the period of xxxx to xxxx, the relevant metrics for this period of interest are xxxx and xxxx (e.g. winter drought 3 month end 12, 6 month end 3, SPI3). It is important to report upon appropriate drought metrics as drought conditions can transpire over different periodicities and intensities. The selected drought metrics of xxxx and xxxx for this ESoR associated with the period of analysis have been agreed upon with the EA, prior to commencing this analysis [confirm this action has been taken].

Table 2-1. Methods and input data for exceptional shortage of rainfall technical analysis

Method	Data/ Drought Metric/ Index	Rationale for analysis
Percentage deviation from the long-term average (LTA) rainfall	<p>[Amend to selected metric and omit/add other metrics as relevant]</p> <p>3 month, end 12 precipitation drought metric</p> <p>(LTA calculated from 1891 to 2021)</p> <p>(other options explored: 12 month, end 12;</p>	<p>Simple method for comparing current rainfall against expected rainfall. Method is insufficient evidence for ESoR if used in isolation.</p> <p>EA recommended LTA for standard periods of:</p> <p>1961-1990²</p> <p>1971-2000</p> <p>1981-2010</p> <p>And full record period of 1981-present day</p> <p>Probability ranking of rainfall can then be applied to determine whether current conditions are exceptionally</p>

² Baseline used by EA

	12 month, end 9; 6 month, end 9; 18 month, end 9; 24 month, end 12; 36 month, end 12)	low, notably low, below normal, normal or above normal based on percentage thresholds, as an essential component of the ESoR analysis.
Cumulative rainfall plots, highlighting 3 driest years and the period of interest	Monthly rainfall for 6 month period (July to Dec) across all years (1891 to 2021)	Extension of percentage deviation from LTA method, visualisation of the cumulative deviation through time and evidencing the initiation and ending of the drought period.
Rainfall ranking and return periods	3 month, end 12 precipitation drought metric (other options explored as indicated above)	Ranking method used by EA - compares the current dry period against the historic record to understand the severity of the event by determining how many years were drier since 1891. Requires hydrological justification for period used. Return period, event probability or 'frequency analysis' not essential component of ESoR and requires robust analysis and fitting to a statistical distribution, but return period plots using a cumulative distribution function provide a visualisation of event ranking.
Rainfall ranking and return periods	SPI (3 month, 6 month, 12 month, and 24 month) across all years (1891 to 2021)	Internationally recognised method and statistical indicator for cumulative rainfall deviation from the climatological average, recommended by EA for use in ESoR. Requires hydrological justification for period used.
Groundwater levels compared against historical drought years	Groundwater levels timeseries	Important for Portsmouth Water as public water supply sources are all groundwater based and with no significant raw water storage. Recharge of groundwater over the winter period is therefore very important.

2.3.1. Cumulative rainfall plots

Cumulative rainfall over 24 months indicates deviation from the LTA (1891-2019) in **January 1976**, with increasing departure until **September 1976** (Figure 2-4). This is the recommended and agreed upon period of analysis for this ESoR.

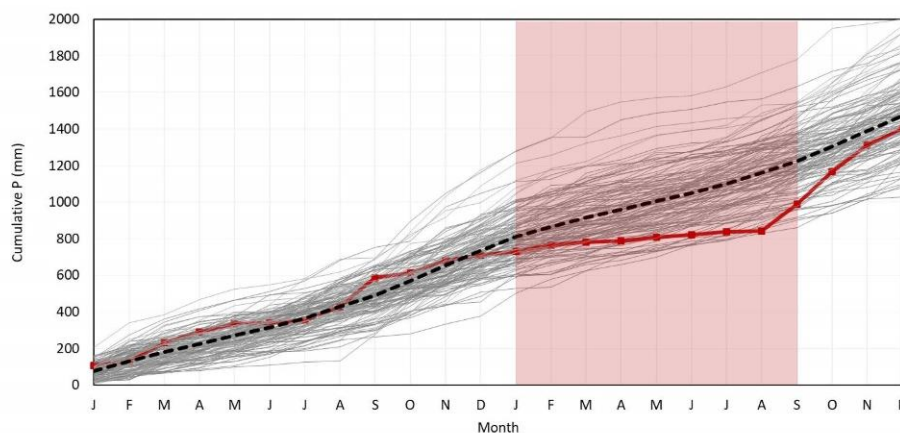


Figure 2-4 - 24 month cumulative rainfall plot. Black dashed line signifies the LTA, the red line indicates the period of interest. The red box delineates the period of analysis, as inferred from this figure.

2.3.2. SPI

SPI values calculated relative to 3 month, 6 month, 12 month and 24 month climatological averages indicate extremely dry conditions (< -2) for the period of xxx to xxxx for SPI3, xxx to xxxx for SPI3, and xxx to xxxx for SPI12 (Figure 2-5).

Ranking of SPI6 metrics indicates that the 3 driest SPI values on record occurred within the period of analysis (June to August 1976, Figure 2-6, Table 2-2). This includes an extremely dry SPI6 value of -4.36 in August 1976.

[Add more details if necessary]

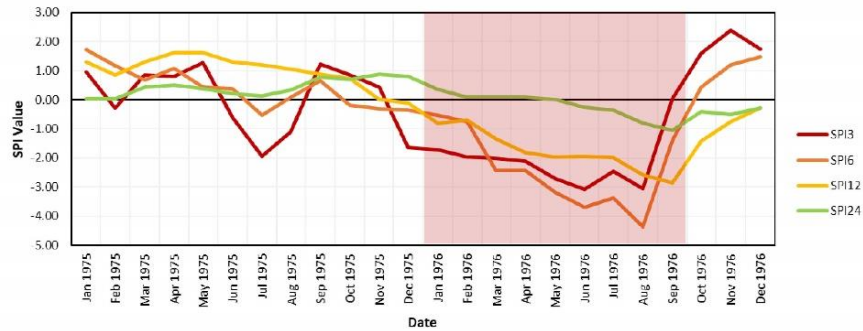


Figure 2-5 – SPI timeseries plot for the period of interest. The red box delineates the period of analysis, as inferred from this figure and previous analyses (Figure 2-4).

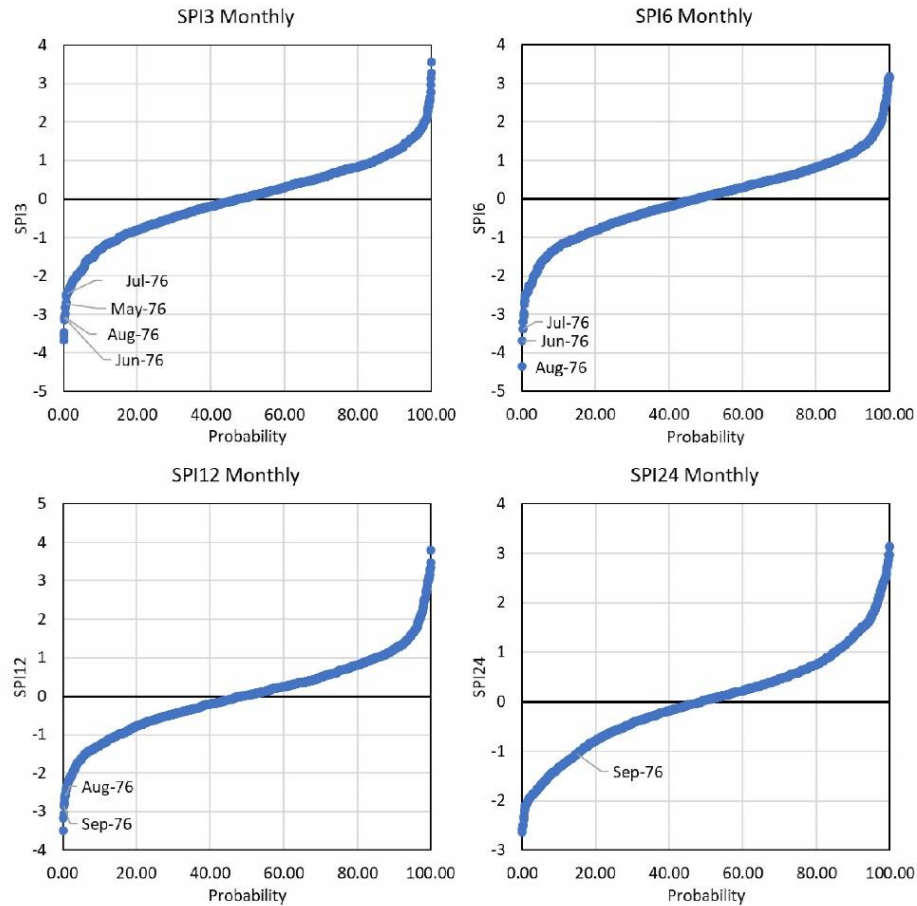


Figure 2-6 – Ranking of SPI values for 3, 6, 12 and 24 month SPI metrics. The period of analysis (1976) is labelled within each plot, and associated ranks and values are reported in Table 2-2 with the top 10 driest events.

Table 2-2. Top 10 ranked SPI metrics. Values occurring within the period of analysis are highlighted in red. Where the period of analysis does not rank within the top 10, the highest rank for that period is given.

Rank /1548 Months	SPI3		SPI6		SPI12		SPI24	
	Year	Value	Year	Value	Year	Value	Year	Value
1	Apr 1938	-3.66	Aug 1976	-4.36	Dec 1921	-3.49	Oct 1934	-2.63
2	Nov 1978	-3.55	Jun 1976	-3.69	Oct 1921	-3.16	Sep 1906	-2.57
3	May 3793	-3.47	Jul 1976	-3.37	Nov 1921	-3.06	Dec 1905	-2.51
4	Jun 1940	-3.14	Jul 1921	-3.37	Sep 1976	-2.85	Aug 1906	-2.50

5	Jun 1976	-3.08	Oct 1921	-3.19	Jan 1922	-2.83	Oct 1905	-2.49
6	Aug 1976	-3.07	May 1976	-3.18	Jul 1934	-2.80	Nov 1934	-2.38
7	Jun 1995	-2.98	Nov 1921	-3.06	Oct 1934	-2.74	Oct 1906	-2.33
8	Oct 1972	-2.83	Jul 1938	-3.02	Sep 1934	-2.65	Jul 1906	-2.31
9	Jul 1989	-2.81	Aug 1995	-2.96	Aug 1976	-2.59	Nov 1905	-2.23
10	May 1976	-2.72	Feb 1971	-2.74	Jun 1934	-2.59	Feb 1908	-2.21
231	-	-	-	-	-	-	Sep 1976	-1.05

2.3.3. Deviation from long term average (LTA)

[Amend/add more detail as necessary]

Monthly rainfall expressed as a percentage of the LTA (Figure 2-7) indicates extremely low (<65% of LTA) from October 1975 to August 1976, with below normal (<90% of LTA) rainfall in November 1975. The period of analysis concludes with above normal rainfall in September 1976.

Consideration of a suite of drought metrics, calculated over a range of durations and starting dates emphasises the impact of the temporal distribution of rainfall on drought conditions, and demonstrates the importance of selecting appropriate metrics for ESoR analysis (Figure 2-8). Short drought metrics (12 months and 9 months) that conclude at the end of the period of analysis (September 1976) indicate extremely low rainfall, at xx% of LTA for 12end9 and xx% for 9end9. These selected metrics are important for the water resources management of Portsmouth water because [add justification for metrics. i.e. they haven't been selected because they make the best case for the ESoR, but because they are important for water resource management because] and have been considered in further detail in section 2.3.4.

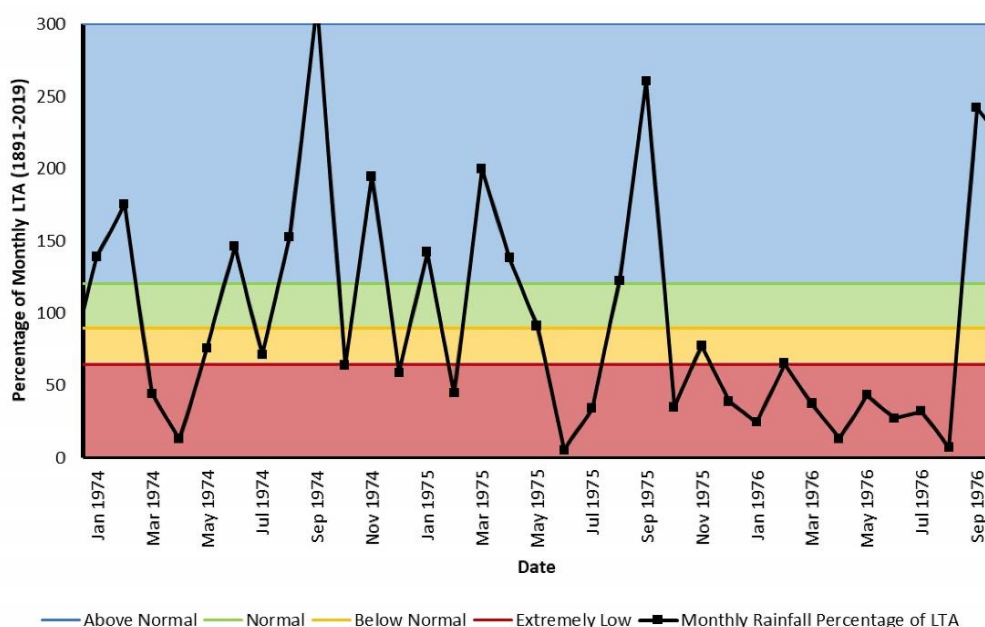


Figure 2-7 – Timeseries of monthly rainfall expressed as a percentage of monthly LTA (1891-2019). Values are then classified as above normal (>120%), normal (90-120%), below normal (65-90%) and extremely low (<65%).

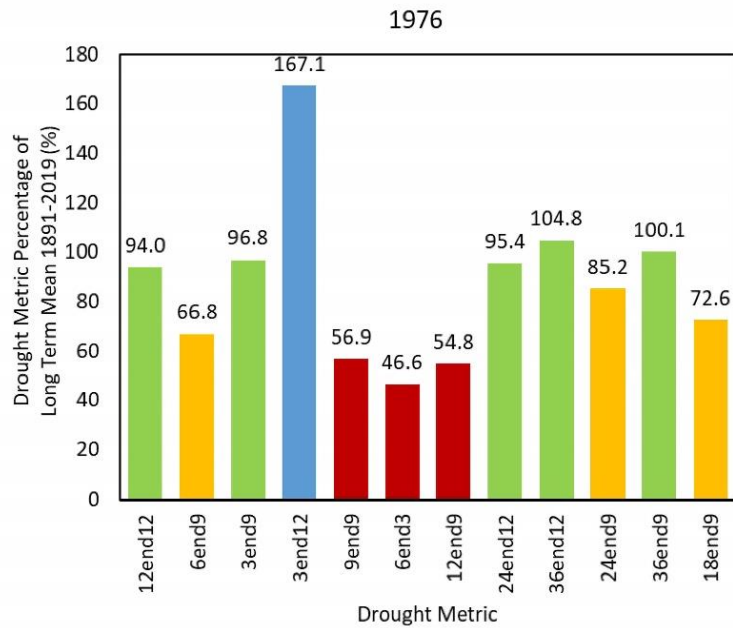


Figure 2-8 – Drought metric values as a percentage of LTA (1891-2019) for the period of analysis. Values are then classified as above normal (blue, >120%), normal (green, 90-120%), below normal (yellow, 65-90%) and extremely low (red, <65%). A full suite of metrics are presented to indicate the relevance of specific metrics due to the temporal distribution of rainfall.

2.3.4. Ranking of drought metrics

Ranking of relevant drought metrics indicates that the event within the period of analysis ranked first within the historic record for 12end9 and second for 9end9. This represents 55% and 57% of LTA respectively, equating to xxx mm deficit of rainfall or the period of January to September 1976.

Amend/add more detail as necessary.

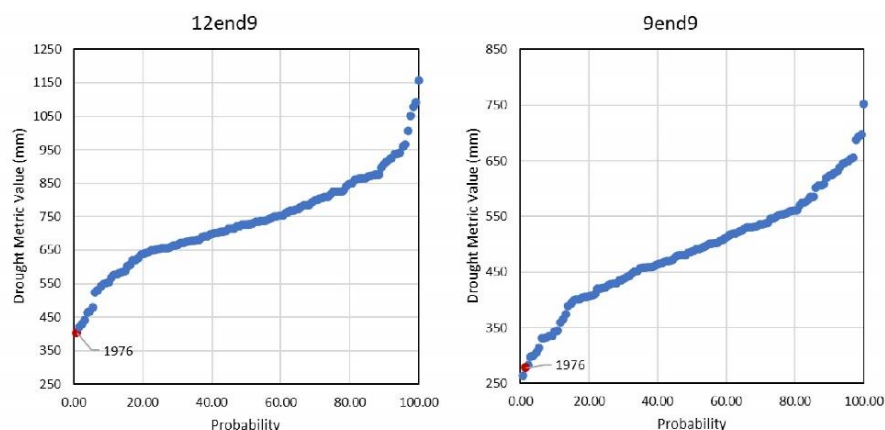


Figure 2-9 – Ranking of drought metric values for 12 months, end 9 and 9 months, end 9. The period of analysis (1976) is labelled within each plot, and associated ranks and values are reported in Table 2-3 with the top 10 driest events.

Table 2-3. Top 10 ranked drought metrics. Values occurring within the period of analysis are highlighted in red.

Rank /129 Years	12end9				9end9			
	Year	Drought Metric Value (mm)	Percentage of LTA 1891-2019	Percentage of LTA 1961-1990	Year	Drought Metric Value (mm)	Percentage of LTA 1891-2019	Percentage of LTA 1961-1990
1	1976	402.6	54.81	55.35	1921	264.4	54.13	54.06
2	1934	421.84	57.43	57.99	1976	277.7	56.85	56.78
3	1898	430.77	58.65	59.22	1949	282.91	57.92	57.85
4	1989	440.5	59.97	60.56	1898	296.91	60.79	60.71
5	1921	464.55	63.25	63.86	1929	299.71	61.36	61.28
6	1905	467.1	63.60	64.22	1938	305.77	62.60	62.52
7	1949	479.5	65.28	65.92	1989	313.4	64.16	64.08
8	1906	524.26	71.38	72.07	1907	330.45	67.65	67.57
9	1944	530.31	72.20	72.91	1944	330.93	67.75	67.67
10	1938	541.98	73.79	74.51	2003	332.5	68.07	67.99
LTA	-	-	734 mm	727 mm	-	-	488 mm	489 mm

2.4. Other meteorological and hydrometric measures

2.4.1. Groundwater levels

[Add text discussing groundwater levels]

[Insert a figure of groundwater levels]

Figure 2-10 – Timeseries of groundwater levels for the period of analysis in comparison to top 5 driest events.

3. Summary and conclusions

The analysis within this report employs a range of methodologies to evidence the ESoR and the need for the xxxxxx drought permit. We conclude that an exceptional shortage of rainfall occurred within the period of xxx to xxx based upon the following evidence:

- Cumulative rainfall plots indicate that a deviation from the LTA begins in xxxx, and trends towards the LTA in xxxx, which has been used as the period of analysis for this ESoR. This cooccurs with very dry SPI values (<-2 , [indicate a metric]) from xxxx to xxxx.
- Ranking of SPI metrics indicates that 3 months within the period of interest are within the top 10 driest events for SPI3 and top 3 driest events for SPI6 out of a record with a length of 1548 months. This includes an extremely dry SPI6 value of -4.36 in August 1976.
- Expressing monthly rainfall as a percentage of the LTA indicates predominantly exceptionally low ($<65\%$ of LTA) from October 1975 to August 1976, with below normal rainfall in November 1975.
- Twelve monthly of cumulative rainfall, concluding in September 1976 represents 54.8% of LTA and is ranked the driest event on record (1981-2019).
- Groundwater levels are ranked xxx in the historic record of xxxx to xxxx.

[Amend/add more detail as necessary]