

*Water Resources Research*

Supporting Information for

**Groundwater Responses to Deluge and Drought in the Fraser Valley, Pacific Northwest**

A. H. Nott<sup>1</sup>, D. M. Allen<sup>1</sup>, and W. J. Hahm<sup>2</sup>

<sup>1</sup>Department of Earth Sciences, Simon Fraser University, Burnaby, BC, Canada. <sup>2</sup>Geography Department, Simon Fraser University, Burnaby, BC, Canada.

**Contents of this file**

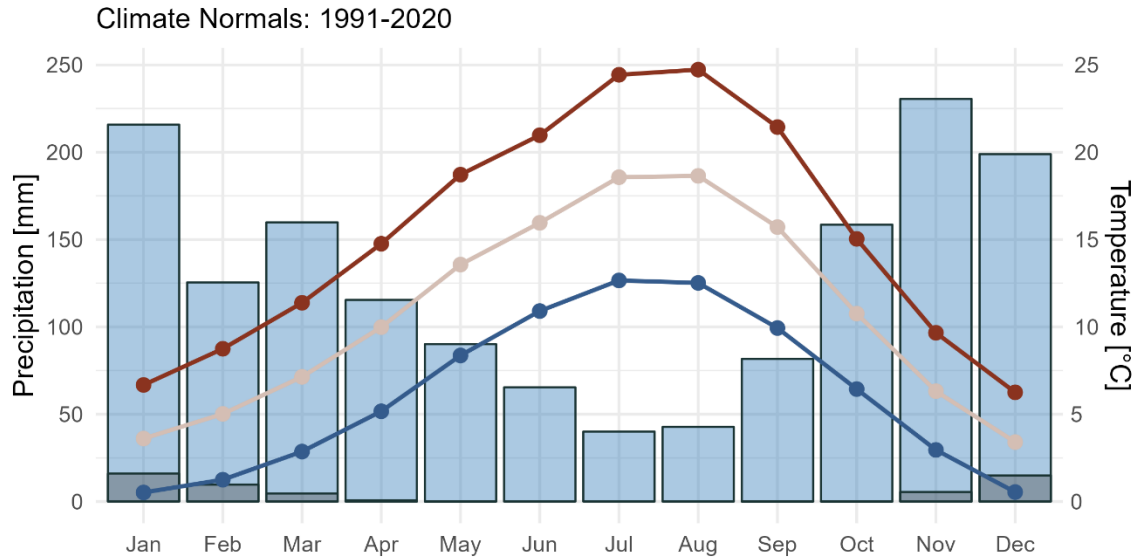
Figures S1 to S22  
Table S2

**Additional Supporting Information (Files uploaded separately)**

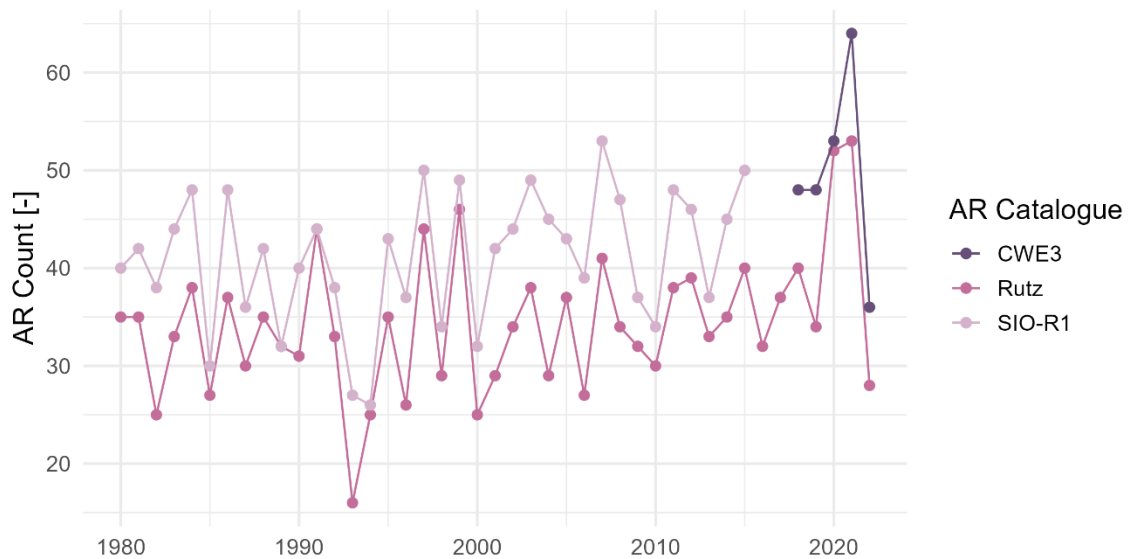
Table S1 is provided as an Excel spreadsheet in the linked hydroshare repository, <http://www.hydroshare.org/resource/d77f11c4ff8245d498faf7b924fe028a>.

**Introduction**

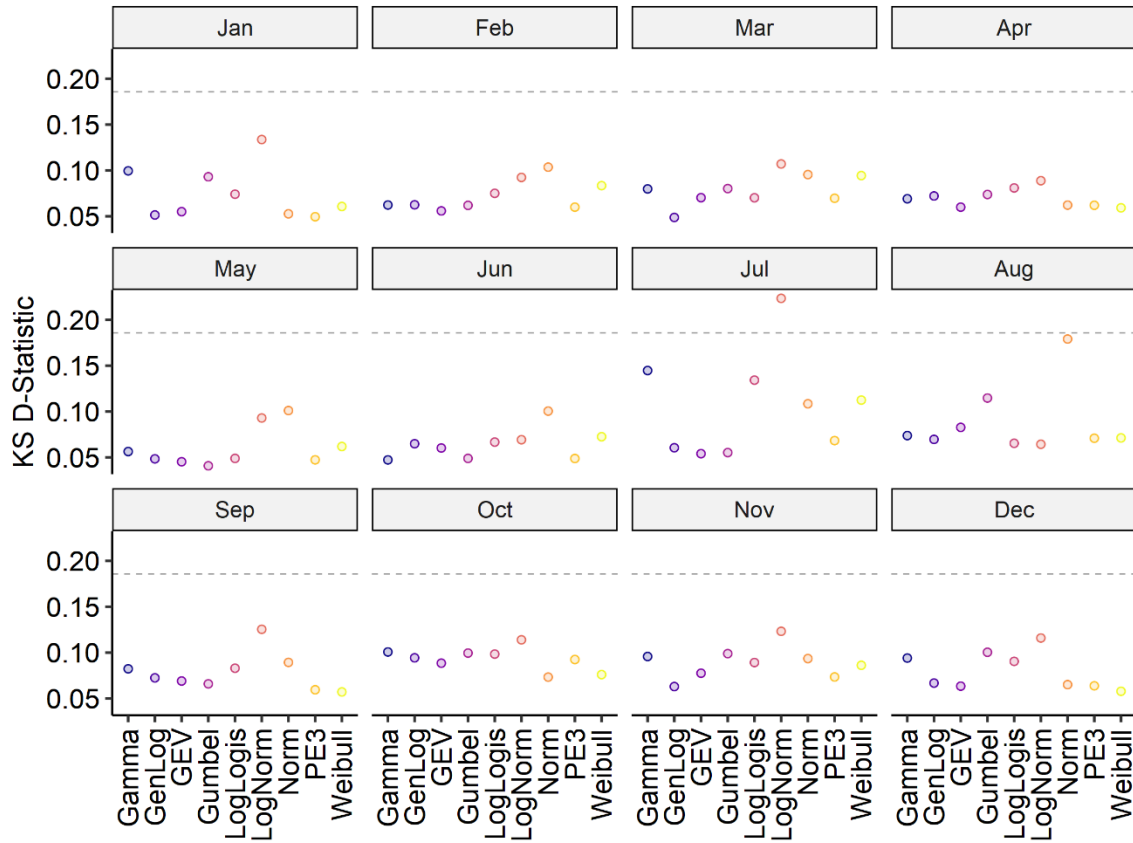
This document contains supplemental figures (S1 to S22) and Table 2 as referred to in the paper.



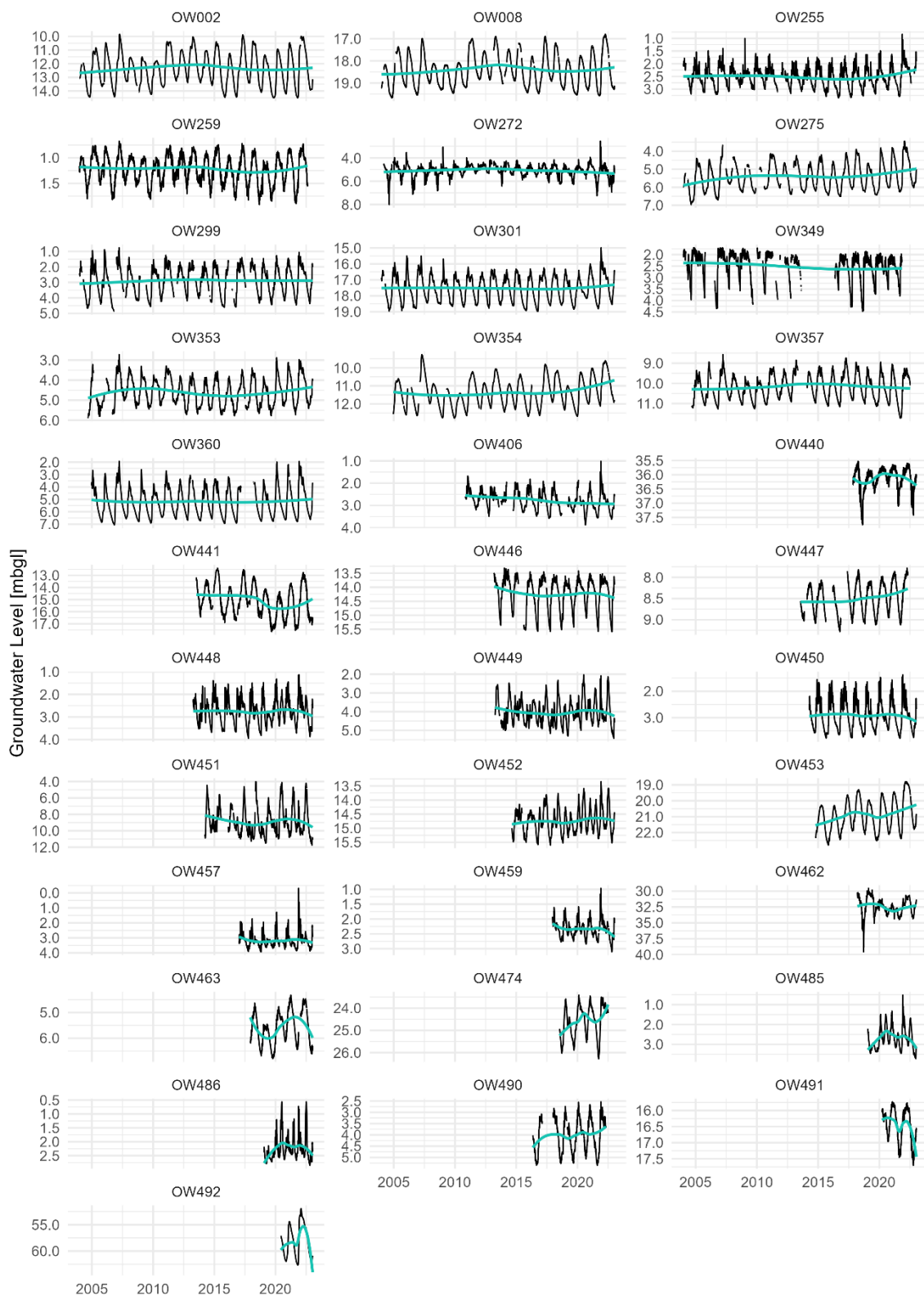
**Figure S1.** Climate normals at the Abbotsford Airport Climate Station **EC1100030/31** (ECCC, 2023) from 1991 to 2020. Monthly maximum (red line), mean (beige line), and minimum (blue line) temperatures. Monthly mean precipitation (blue bars) and snow (dark blue bars).



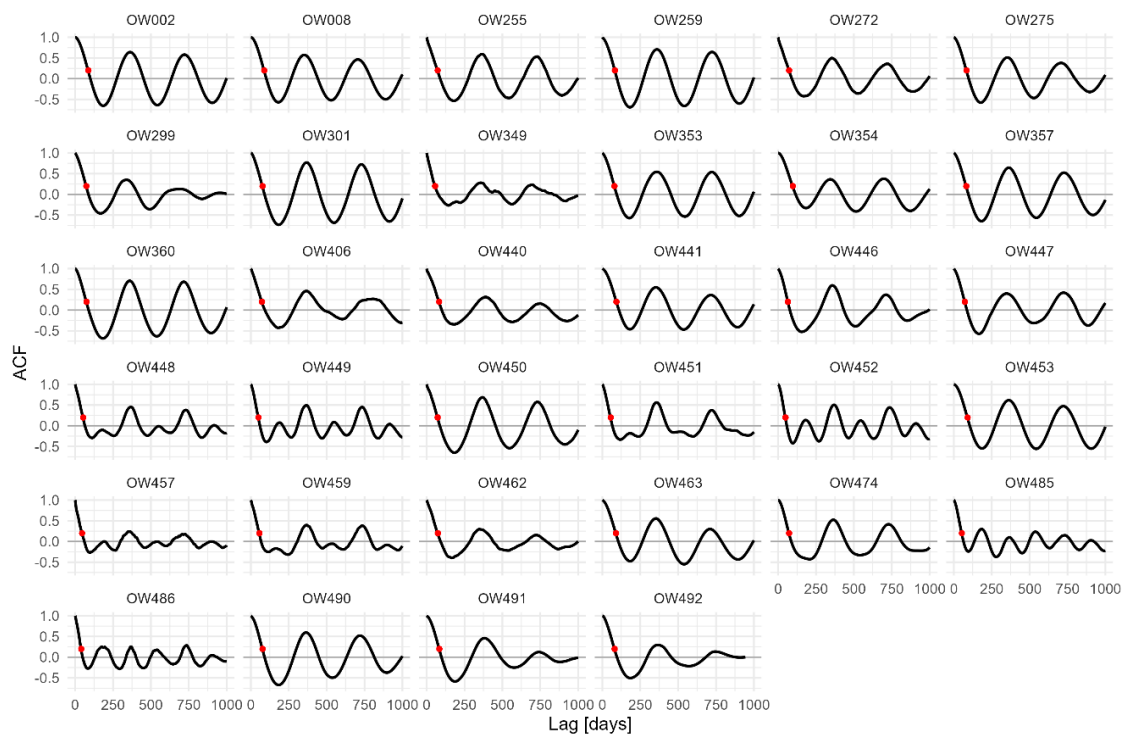
**Figure S2.** Annual count of landfalling ARs in the study area (see Figure 1) from three AR catalogues: (1) Center for Western Weather and Water Extremes (CW3E) observations, (2) Cropped and resampled Rutz et al. (2014) catalogue, and (3), cropped and resampled Gershunov et al. (2017) SIO-R1 catalogue.



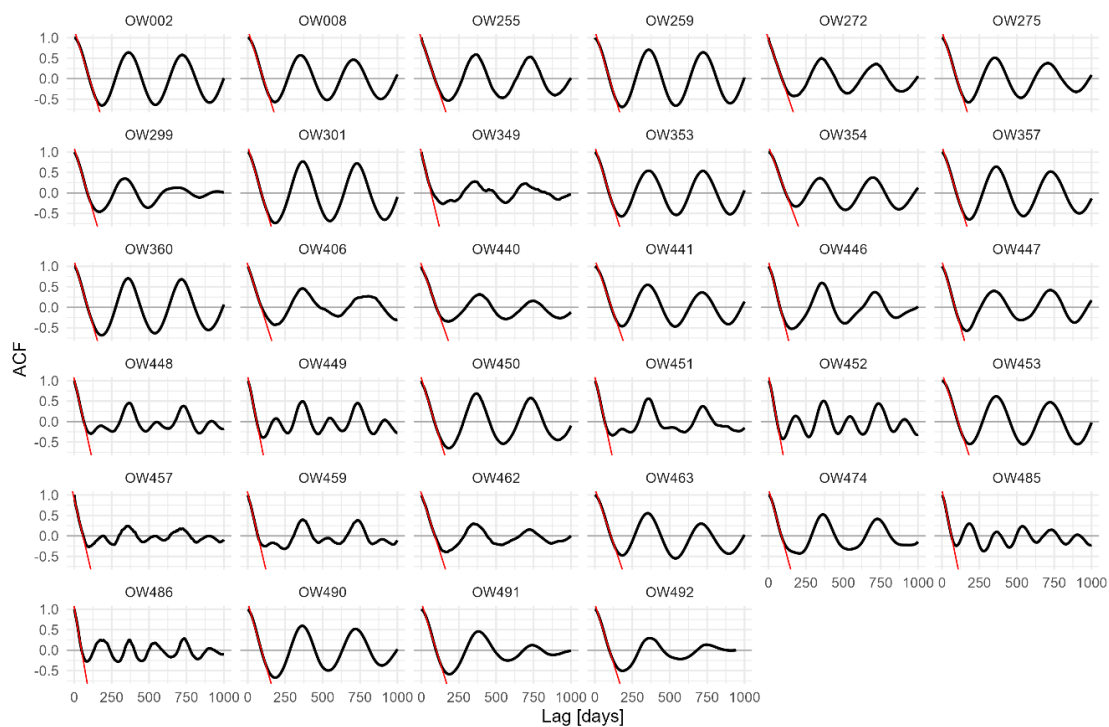
**Figure S3.** Kolmogorov-Smirnov goodness-of-fit D-statistic for select distributions used in computing the SPI. The Pearson Type-3 (PE3) is selected in this study as it is the most consistent distribution with a low variability in the D-statistic. The dashed grey line represents the D-critical statistic (0.18) for which the empirical data no longer fit the tested distribution.



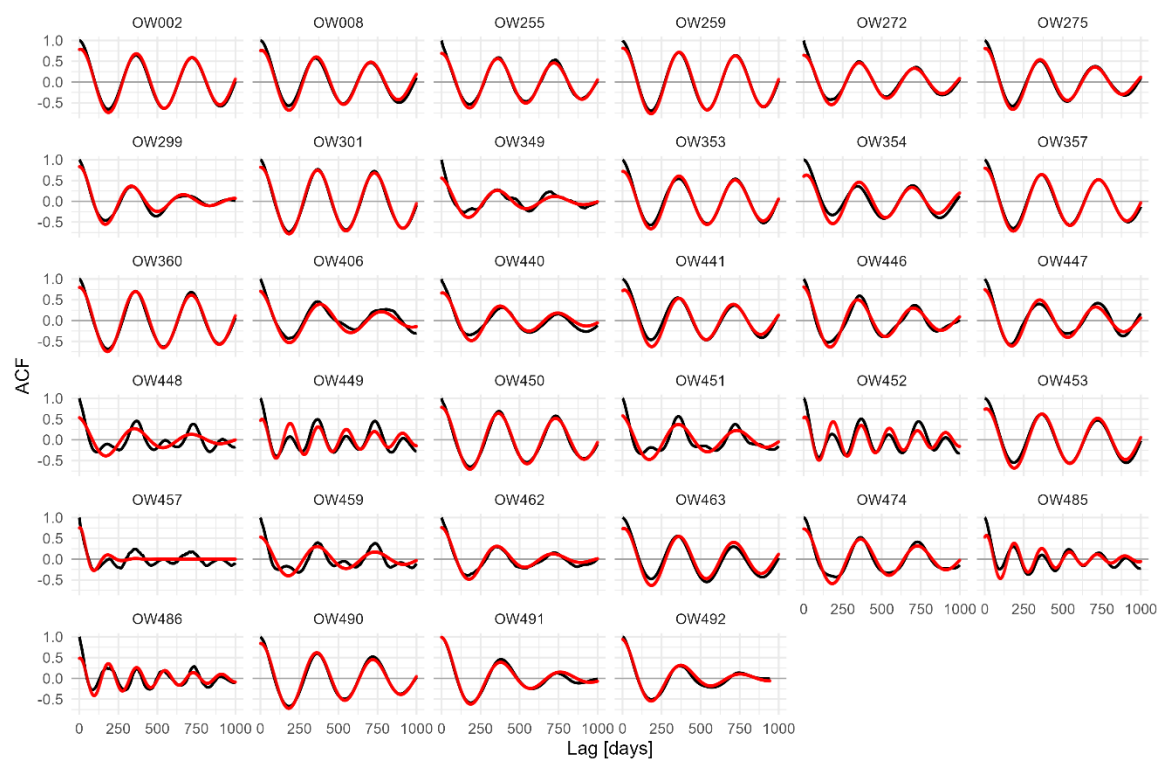
**Figure S4.** Groundwater monitoring well level data with a loess smoothing line in teal.



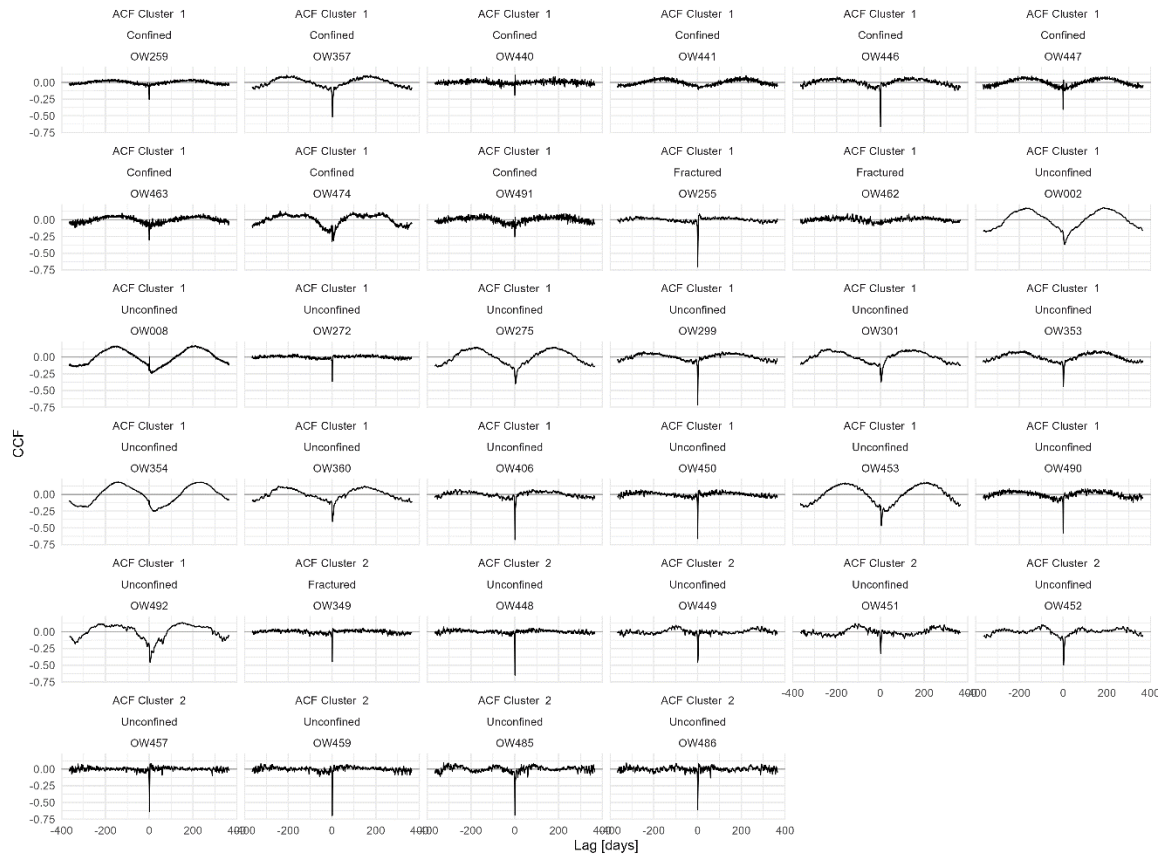
**Figure S5.** Decorrelation lag time (red dot) of the ACF for each well.



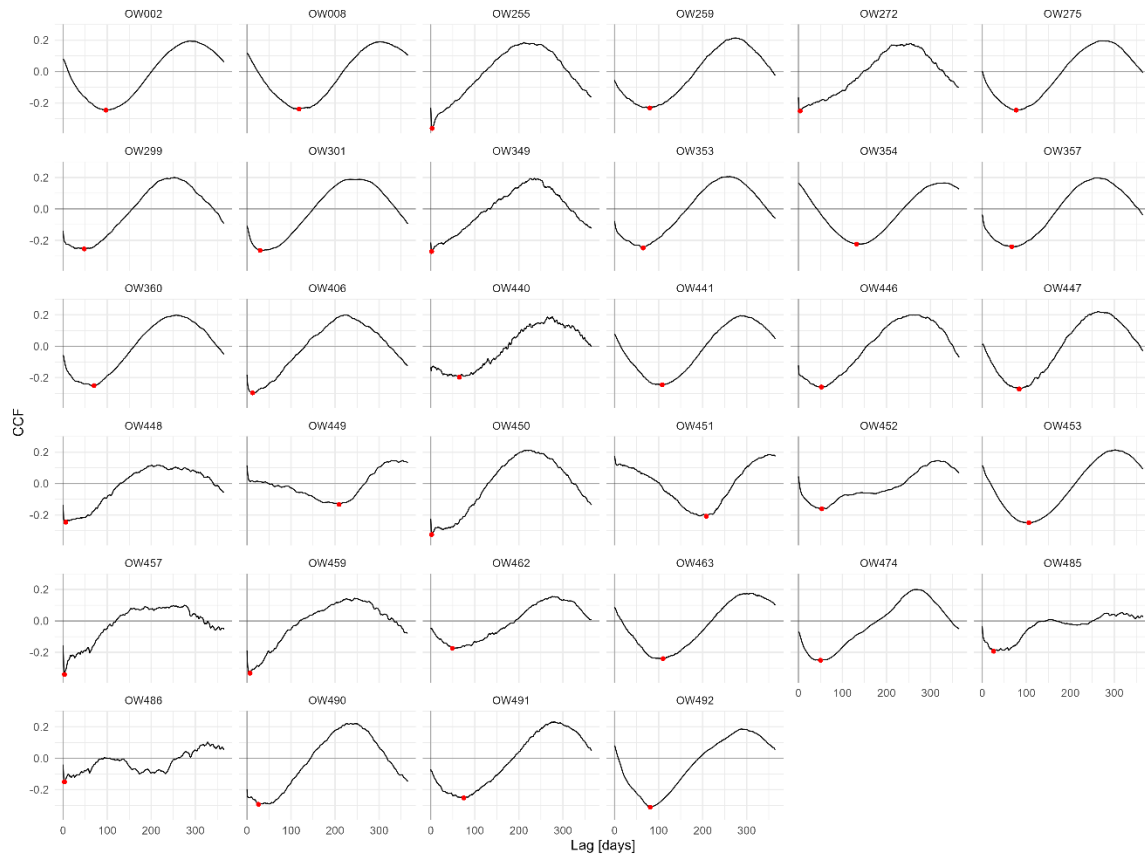
**Figure S6.** Linear decay rate (red line) at early lag times of the ACF for each well.



**Figure S7.** Damped decay sinusoid function fit to the ACF for each well.

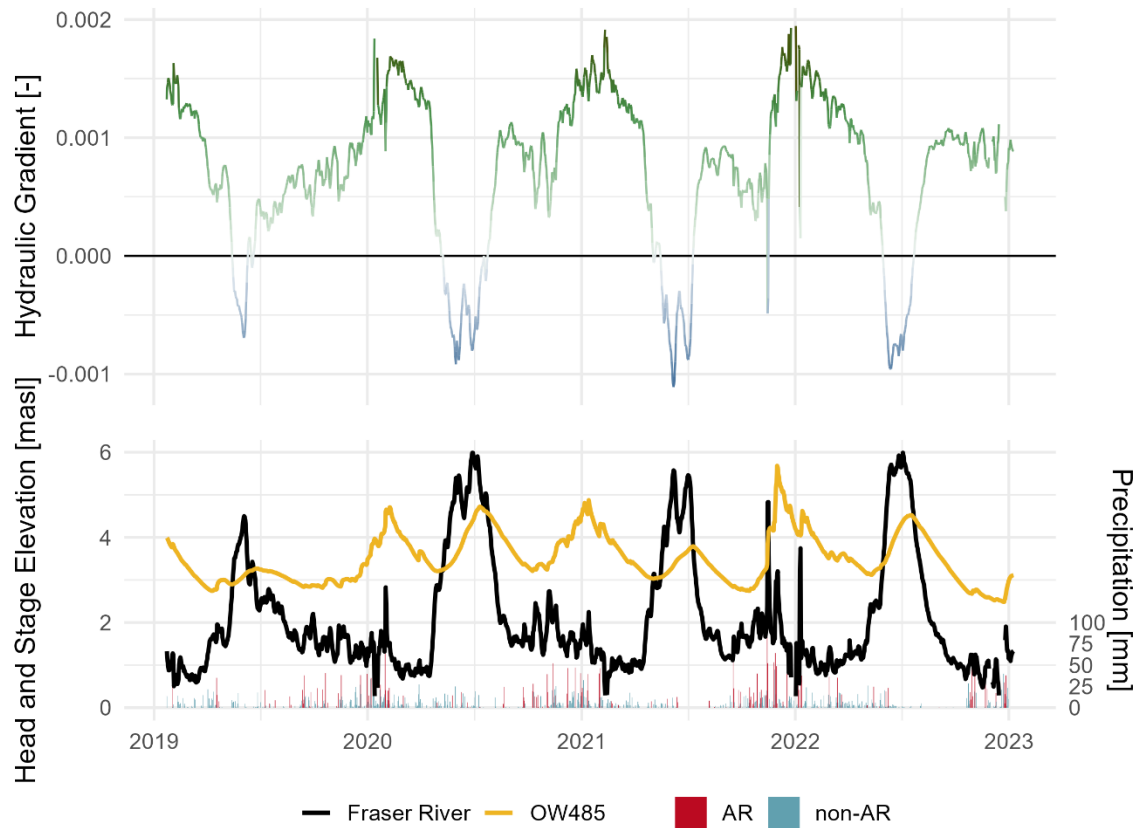


**Figure S8.** Daily groundwater level rates of change (ROC) cross-correlated with daily precipitation to a maximum lag of 365 days.

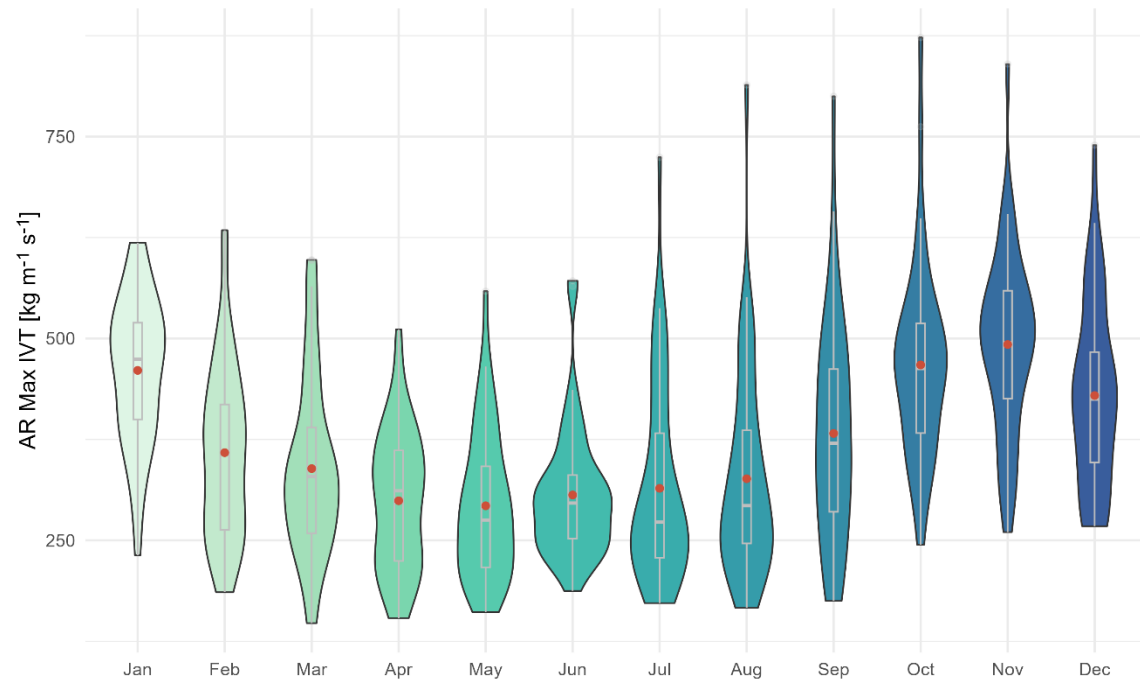


**Figure S9.** Daily groundwater level cross-correlated with daily precipitation to a maximum lag of 365 days. The red dot shows the lag time for the minimum correlation values.

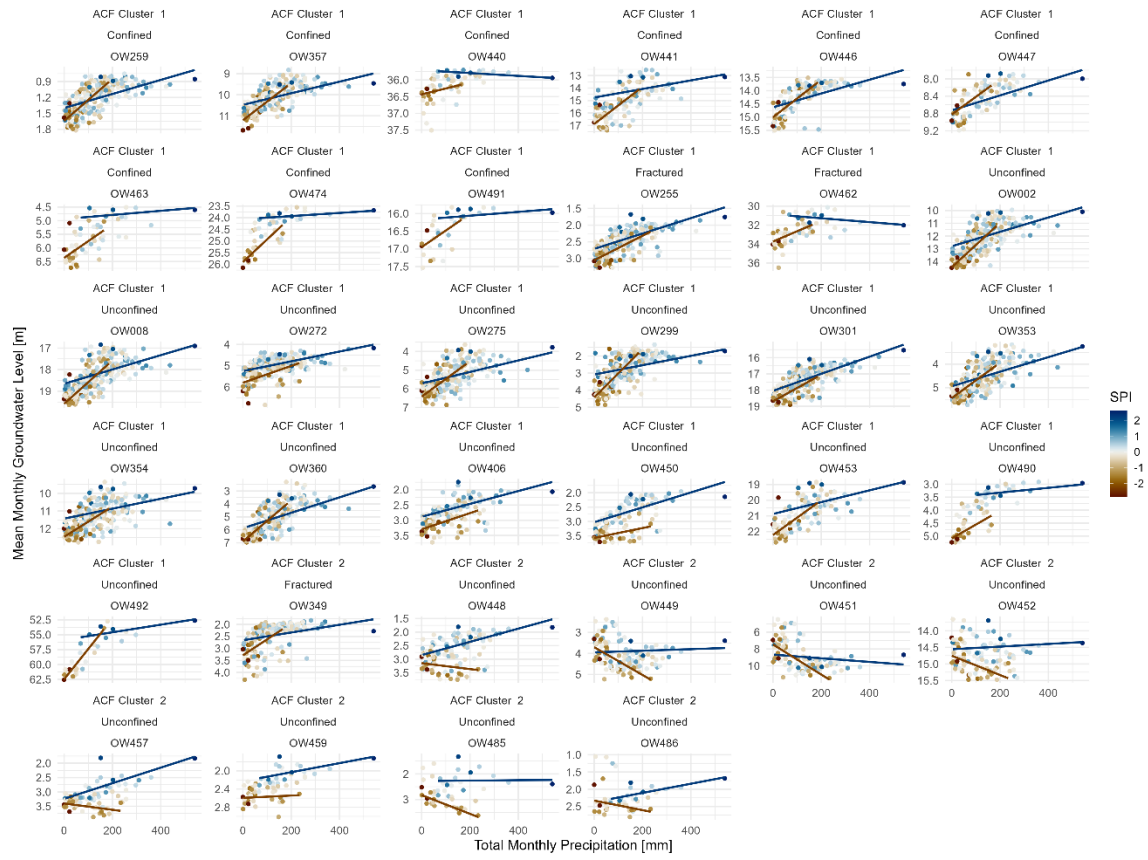




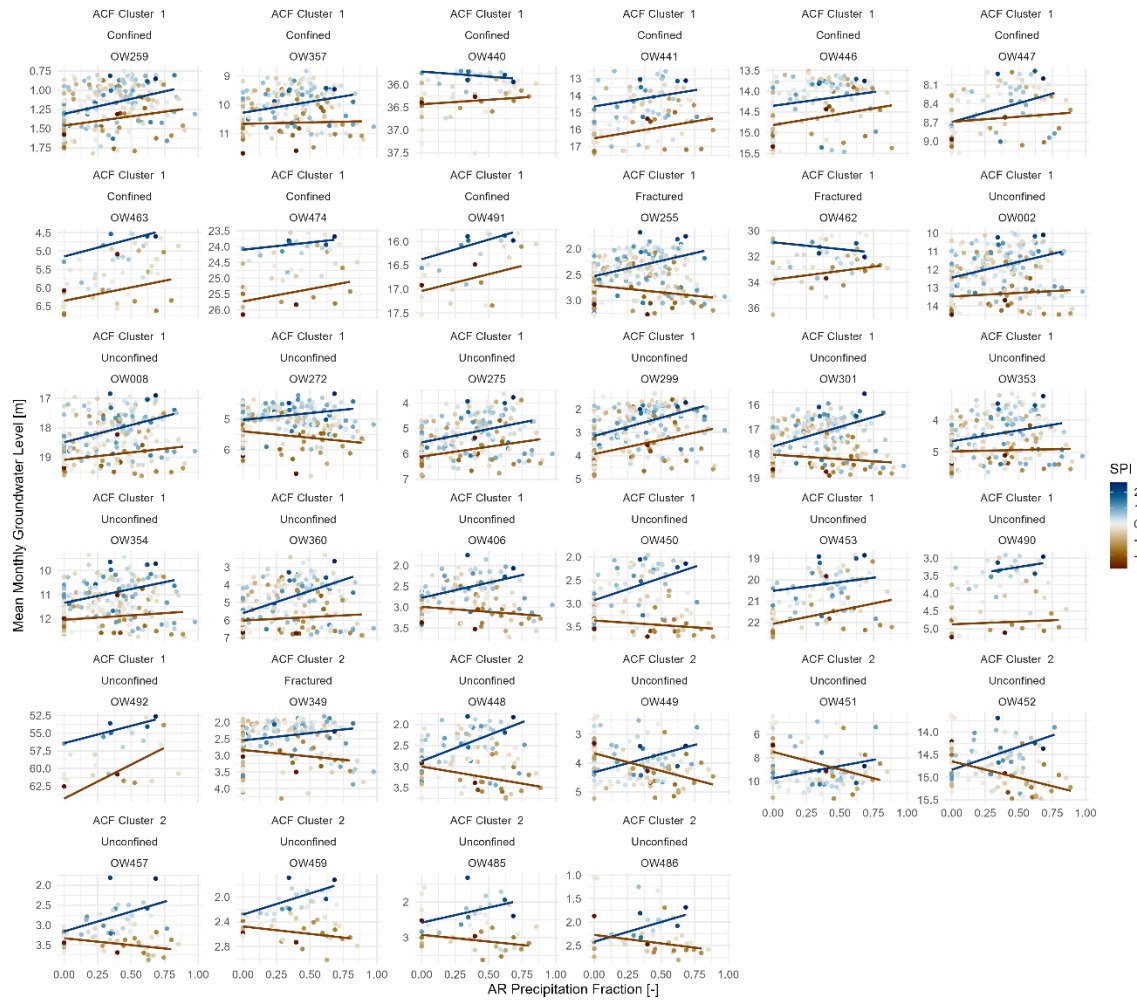
**Figure S10.** Top: Hydraulic gradient between the Fraser River and OW485. A negative (positive) gradient denotes stream (aquifer) to aquifer (stream) exchange; hence, groundwater is being recharged (discharged). Bottom: Head and stage elevation for OW485 and the Fraser River, respectively. Precipitation is split into AR and non-AR events.



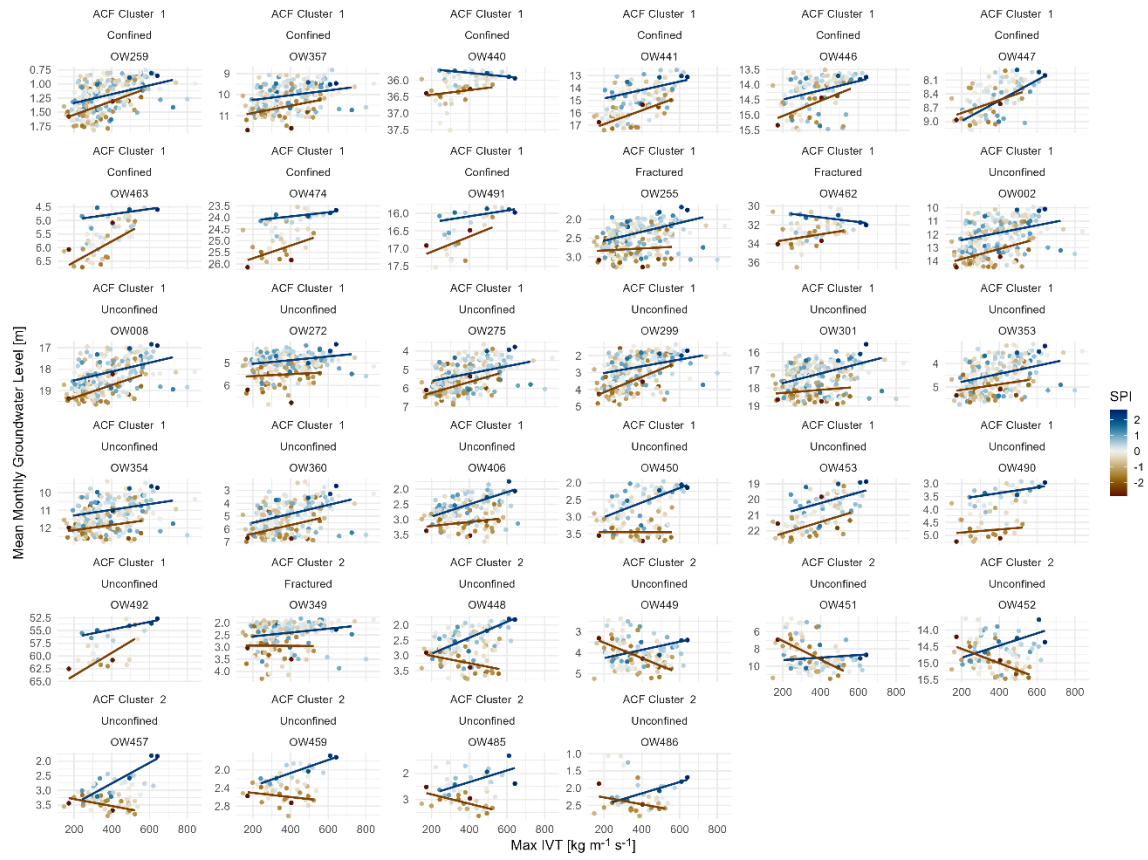
**Figure S11.** Maximum AR intensity averaged by month.



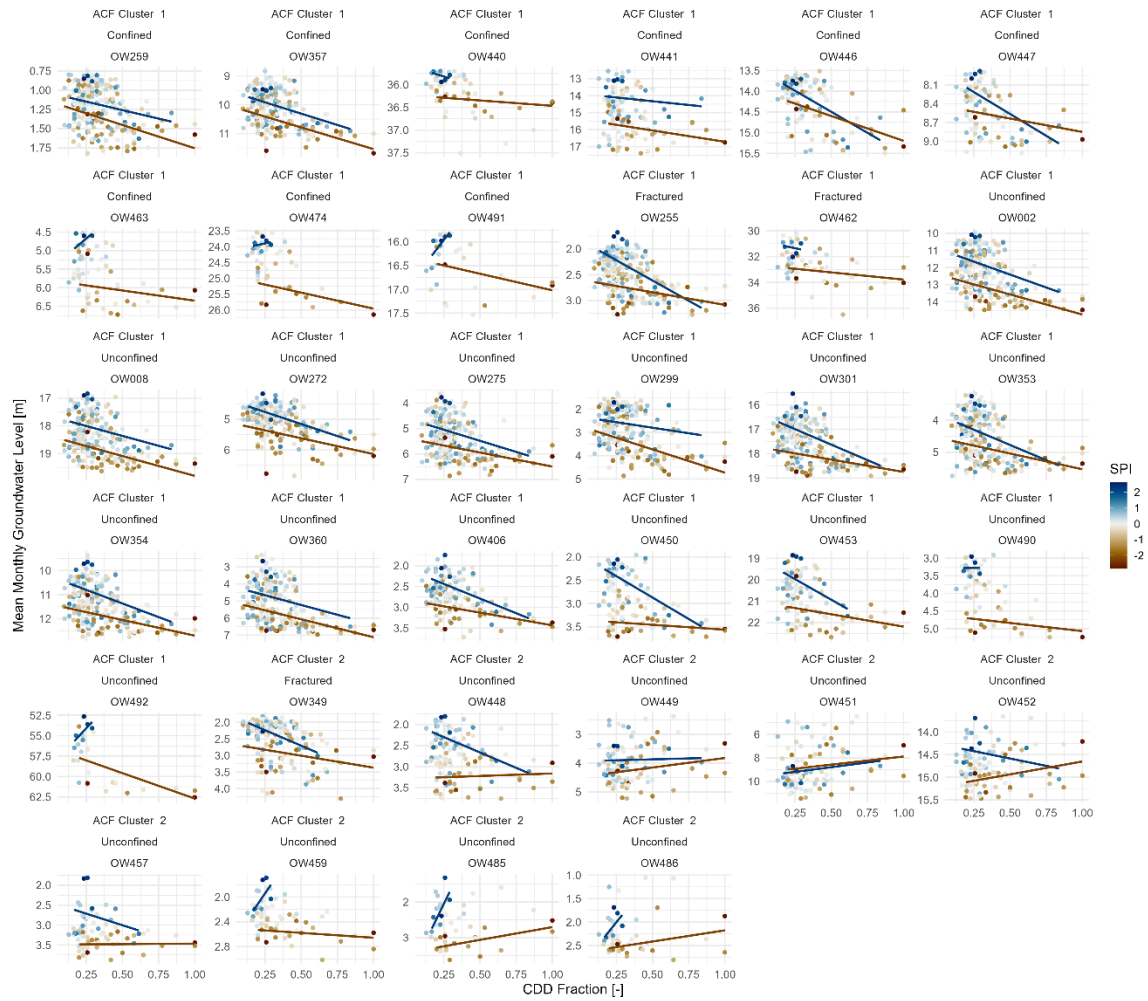
**Figure S12.** Total monthly precipitation as a function of mean monthly groundwater levels.



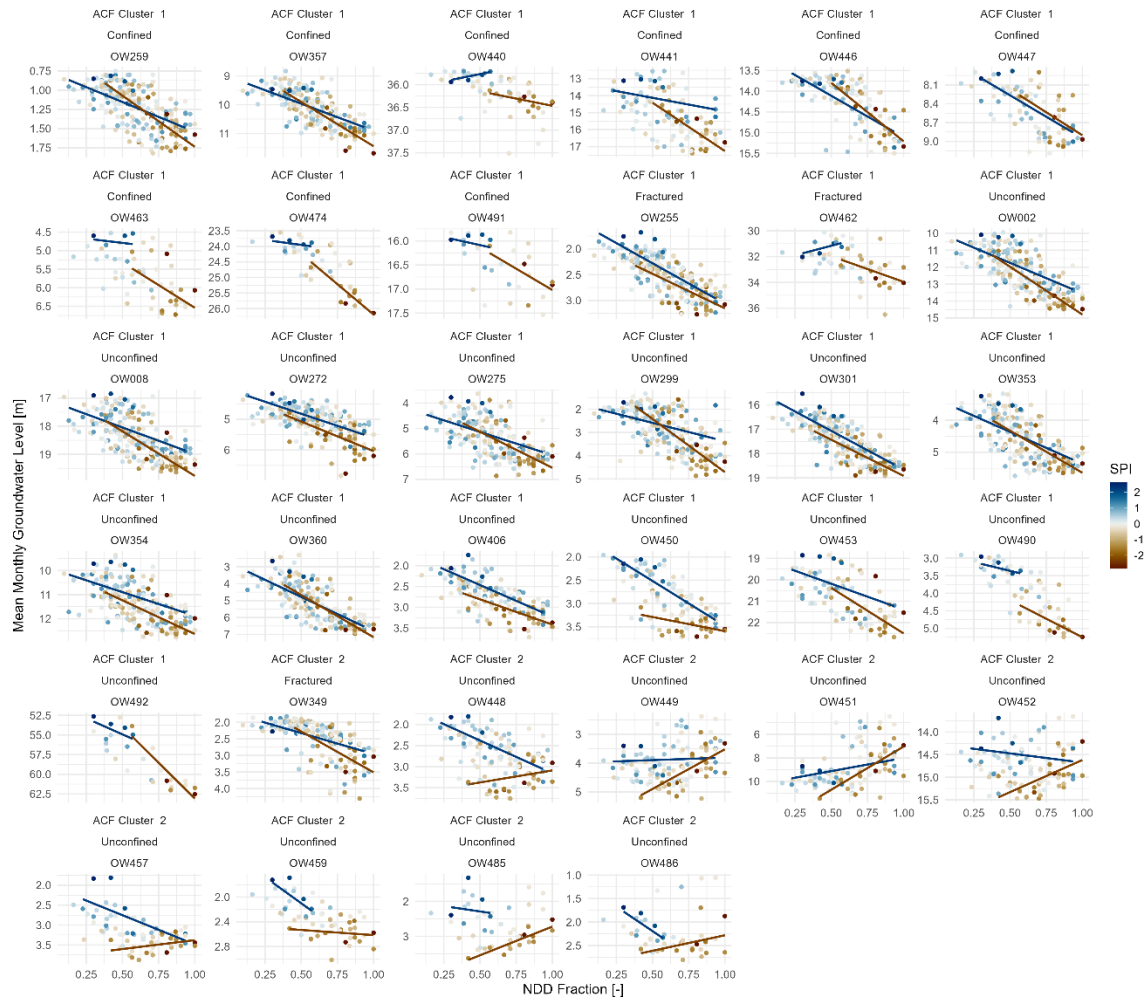
**Figure S13.** AR fraction of precipitation as a function of mean monthly groundwater levels.



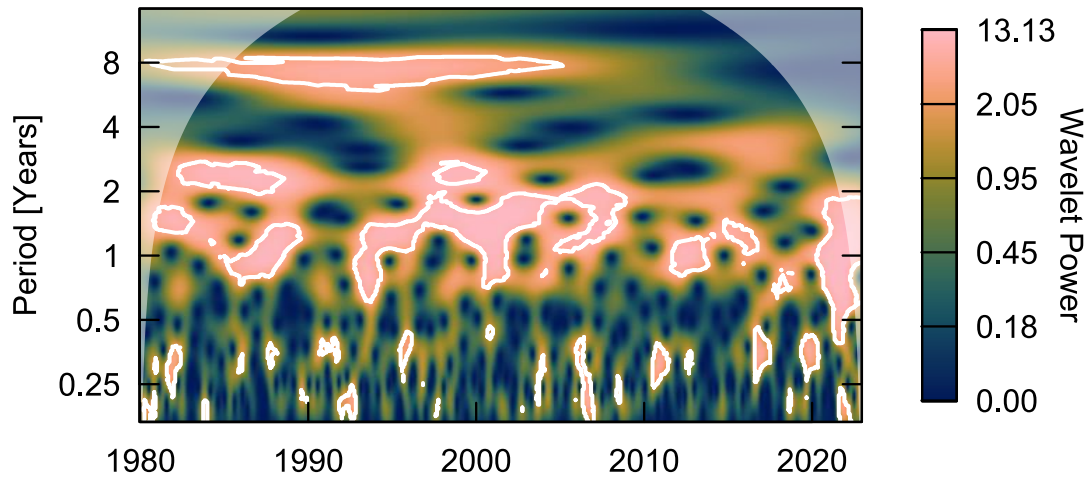
**Figure S14.** Maximum monthly AR IVT as a function of mean monthly groundwater levels.



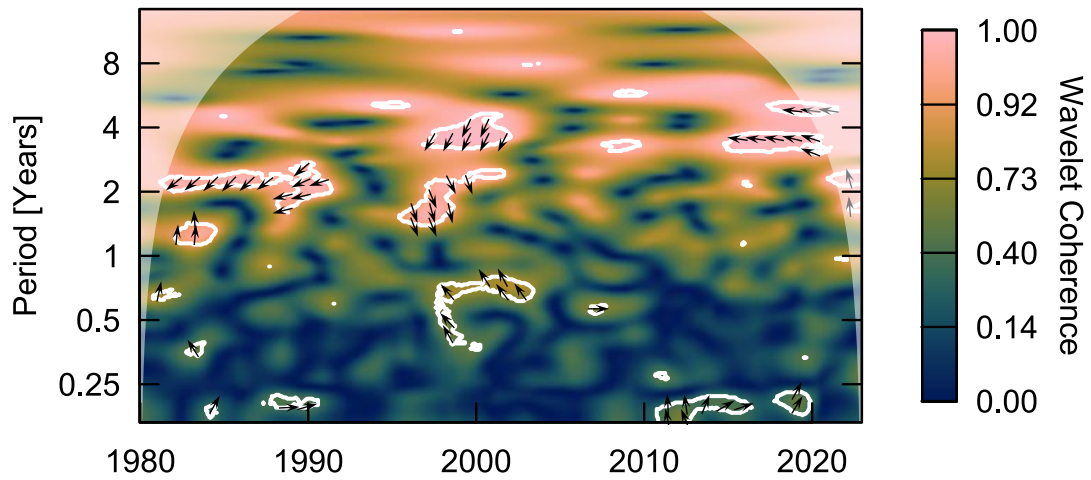
**Figure S15.** The fraction of consecutive dry days (CDD) in a month as a function of mean monthly groundwater levels.



**Figure S16.** The fraction of number of dry days (NDD) in a month as a function of mean monthly groundwater levels.

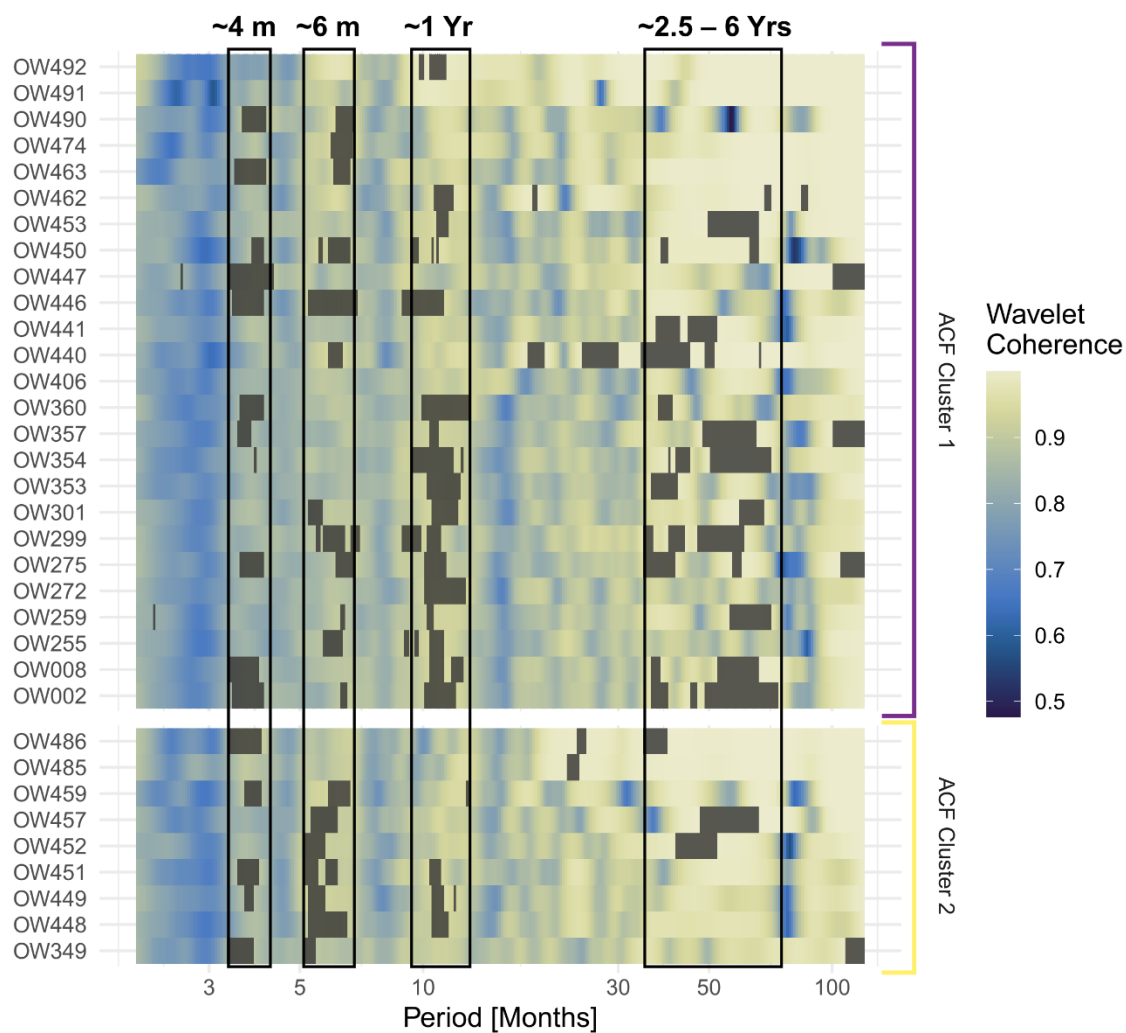


**Figure S17.** CWT for the SPI-6. Significant periods outlined in white.

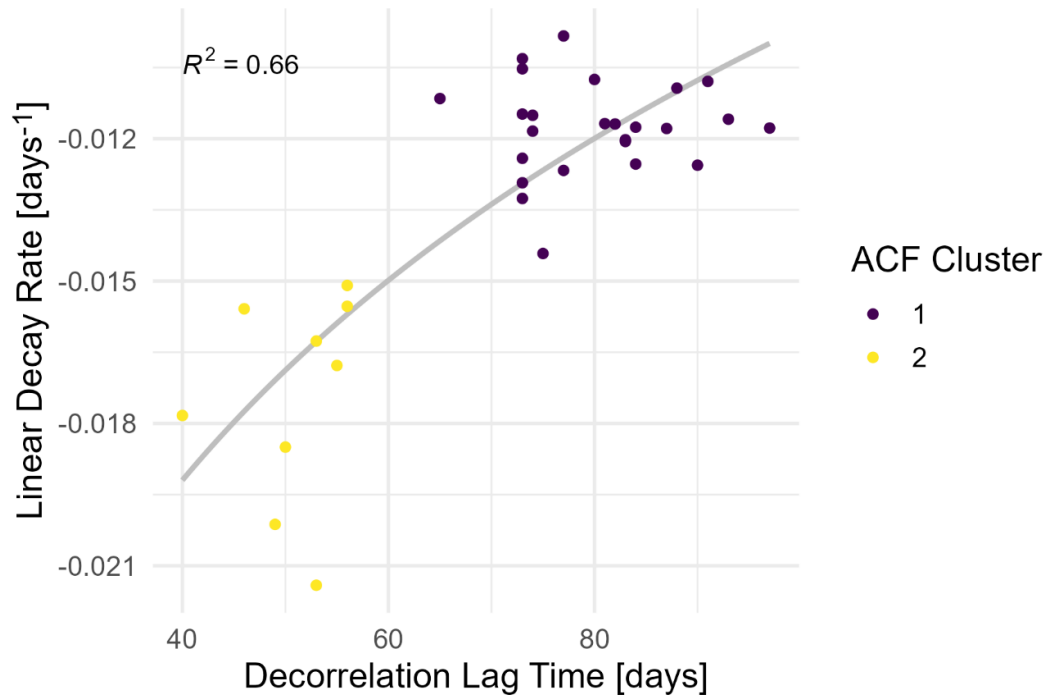


**Figure S18.** WTC between ONI and SPI-6. Significant periods outlined in white. Black arrows represent the phase lag between both signals.

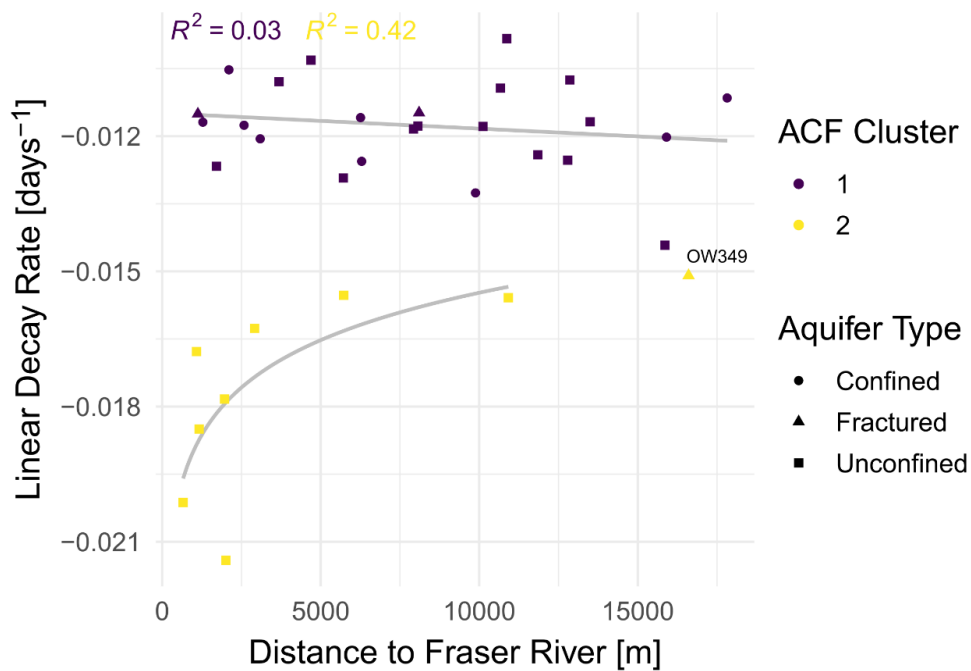




**Figure S19.** Wavelet coherence between the GWLs and ONI. Grey rectangles mark areas of significant coherence at a 5% significance level.

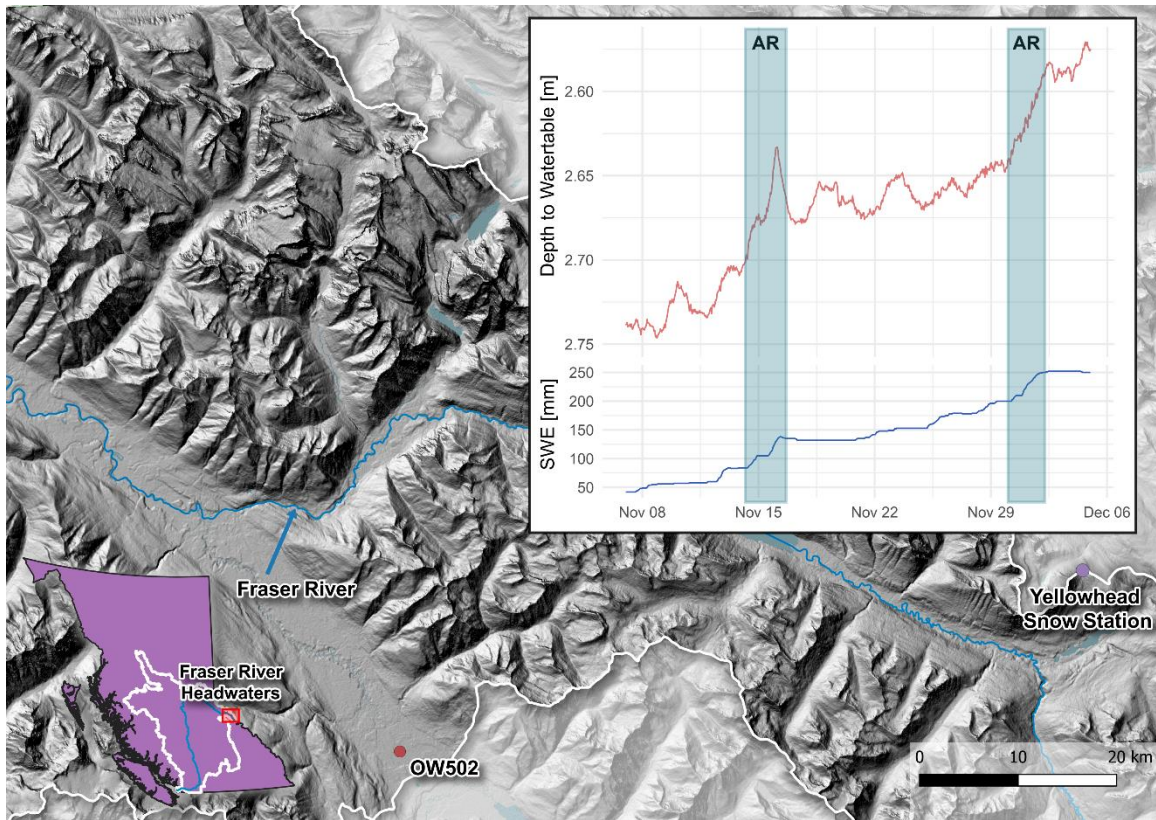


**Figure S20.** Linear decay rate as a function of the decorrelation lag time with a log<sub>10</sub> smoothing fit.



**Figure S21.** The linear decay rate fitted to the ACF as a function of well distance to the closest reach of the Fraser River. Linear and logarithmic regressions are fit to cluster 1

and 2 aquifers, respectively. OW349 is omitted, as it is not hydraulically connected to the Fraser River.



**Figure S22.** Headwaters of the Fraser River Basin (FRB) and the groundwater response in OW 502 and snow water equivalent (SWE) during the historic November 2021 ARs.

**Table S2.** Hydrometeorological summary of drought and deluge in the last decade. The long-term average is computed from 1980 to 2022. \*Major drought year. \*\*Major drought year interrupted by the strongest recorded AR in the Fraser Valley. \*\*\*Very wet winter.

<b>Year</b>	<b>Total Precipitation</b>	<b>AR Count</b>	<b>AR Fraction of Precipitation</b>	<b>Total NDD (Annual fraction)</b>	<b>Max CDD</b>
2013	1514	33	0.28	215 (0.59)	19
2014	1684	35	0.29	230 (0.63)	26
2015*	1289	40	0.44	241 (0.66)	32
2016	1588	32	0.31	207 (0.57)	24
2017	1645	37	0.40	214 (0.59)	29
2018	1505	40	0.42	217 (0.59)	29
2019	1212	34	0.44	244 (0.67)	21
2020	1694	52	0.42	215 (0.59)	25
2021**	1618	53	0.56	223 (0.61)	53
2022***	1311	28	0.44	233 (0.64)	77
<b>Long Term Averages</b>	<b>1542</b>	<b>34</b>	<b>0.37</b>	<b>216</b>	<b>26</b>