Groundwater resilience to drought in Scotland: Initial analysis of long-term groundwater level trends and geophysical surveys

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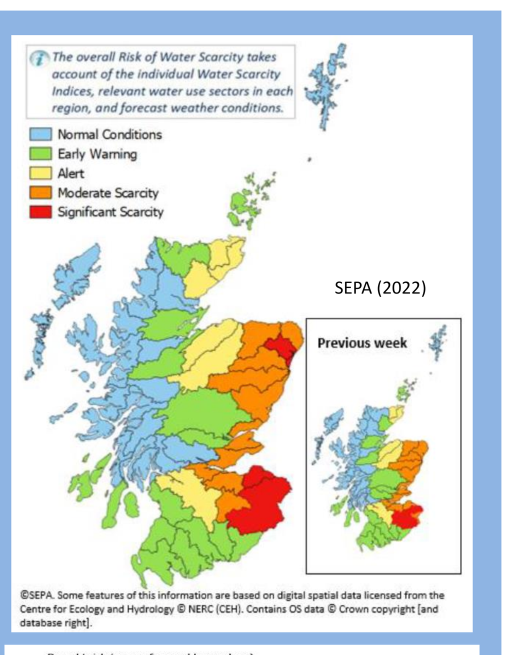
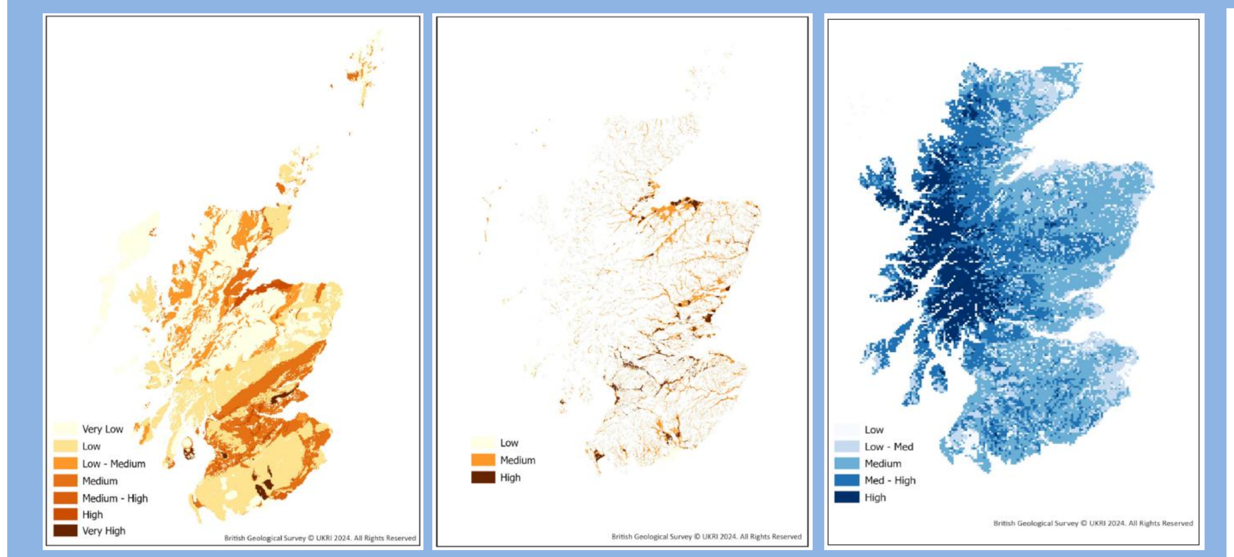
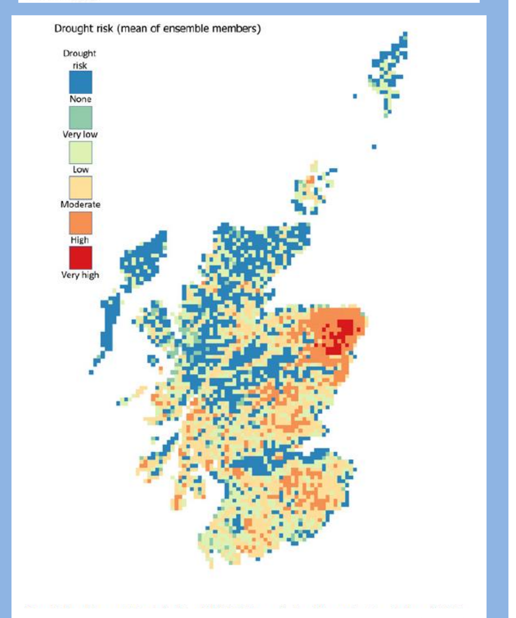
Introduction

Drought induced water scarcity in eastern Scotland is becoming more frequent and more severe with climate change. Our work looks at how groundwater levels have responded to past events, how well construction and completion across aquifers effect observations, and how these groundwater resources can be used to increase resilience and mitigate the impacts of drought on private water users.





From L to R: Bedrock and superficial aquifer storage maps, along with potential groundwater recharge. Recharge estimates produced by BGS using eFLAG modelling CEH Dataset (Glendell et al, 2024)

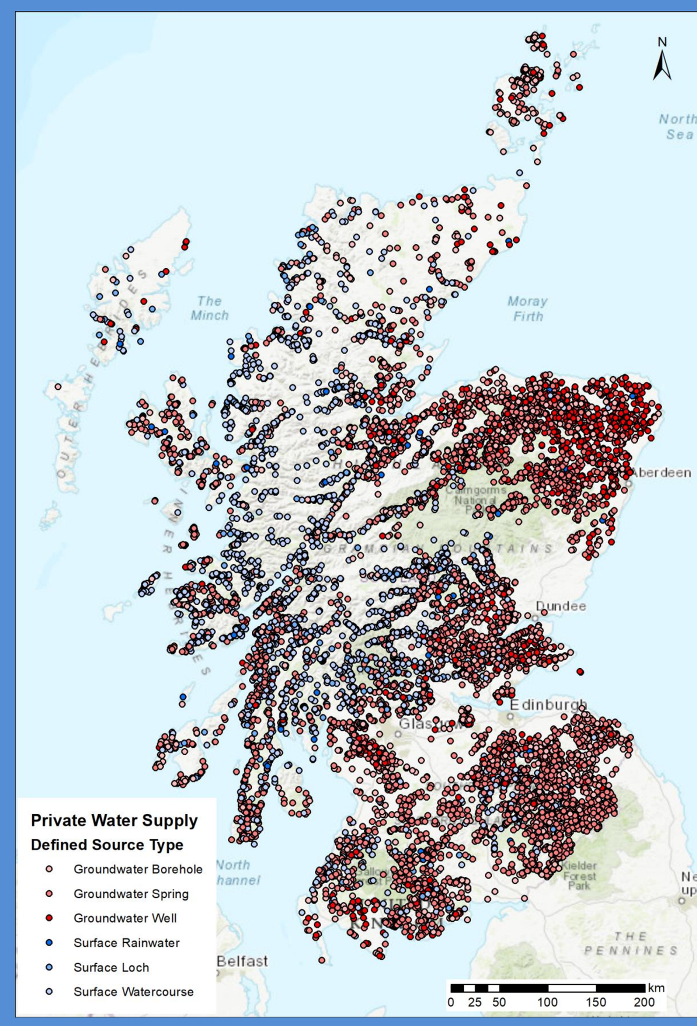


Rivington et al (2020)

Methods

Analysis of groundwater levels from SEPA boreholes can be used to quantify long term groundwater trends and assess site properties that may be more resilient to climate change based on observed response to drought events. Groundwater level response to annual recharge or drought events can be compared across different recharge regimes or aquifers with different storage properties. Characterising the response across hydrogeological settings, supported by geophysical surveys, along with quantifying long-term trends in existing SEPA data will support new monitoring initiatives focused on private water supplies (PWS) in eastern Scotland.

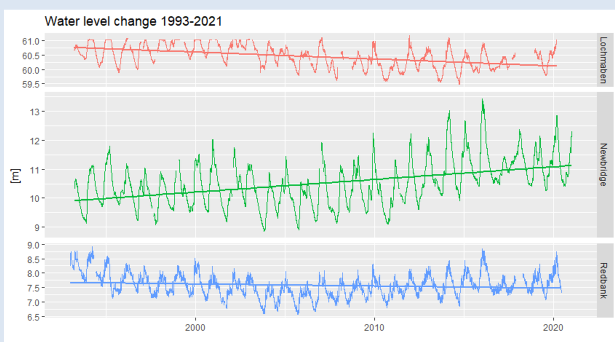
Examples of water supply source types. From L to R: Borehole, spring box, surface water collection



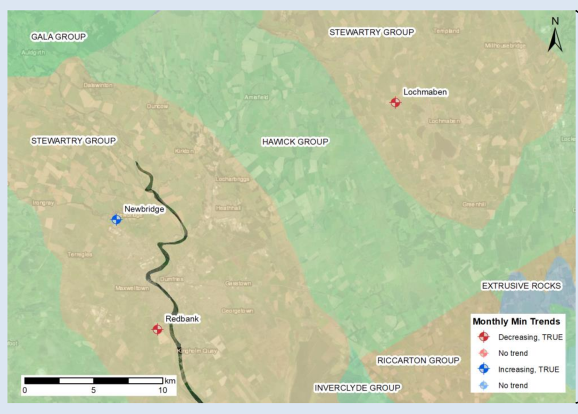
Data from DWQR (2024)

Results

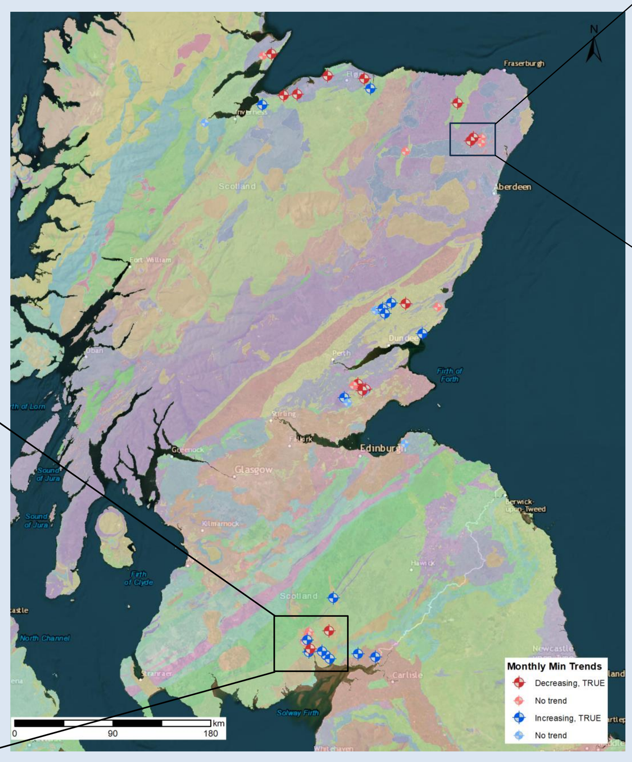
Monthly, minimum measured groundwater levels were were used to determine multi-year trend direction and magnitude at SEPA monitoring boreholes with sufficient data records. Trends vary within geologic units and recharge regimes showing potential effects of borehole construction and completion and highlighting the importance of understanding the greater hydrologic setting. Daily groundwater levels are used to understand event response.

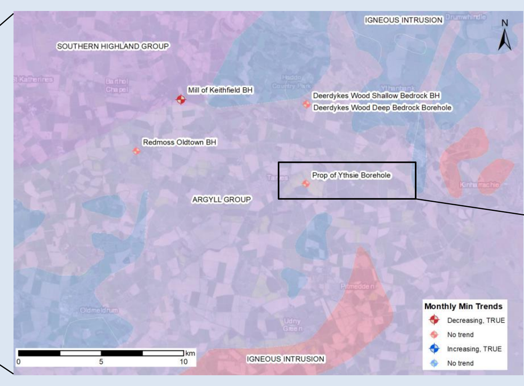


Although all three boreholes appear to be completed within the same sandstone aquifer, the long-term trends differ in direction along with annual amplitude of water level change.

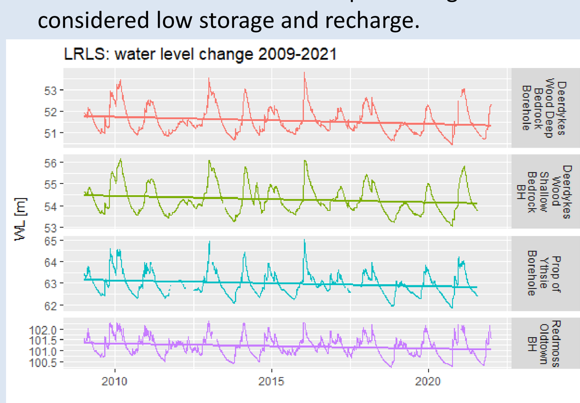


Subset of SEPA boreholes representing an area of high storage and recharge.

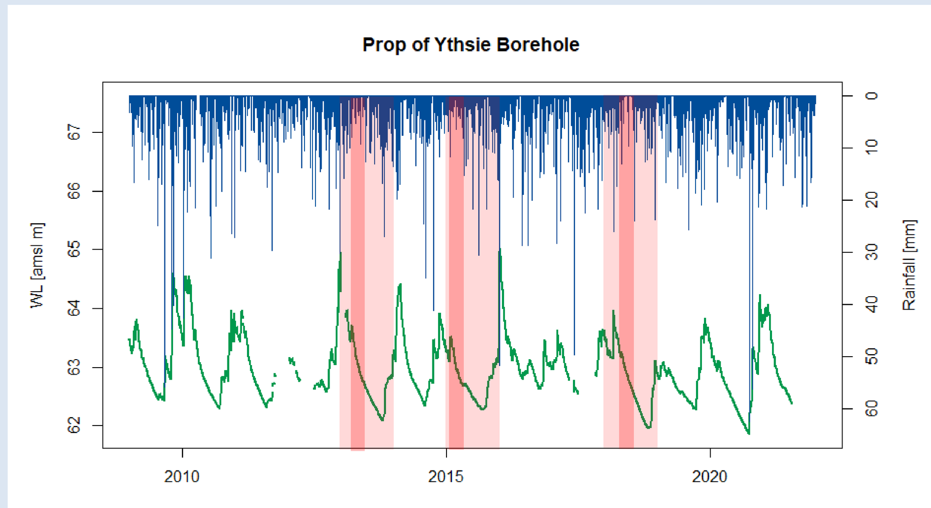




Subset of SEPA boreholes representing an area considered low storage and recharge.



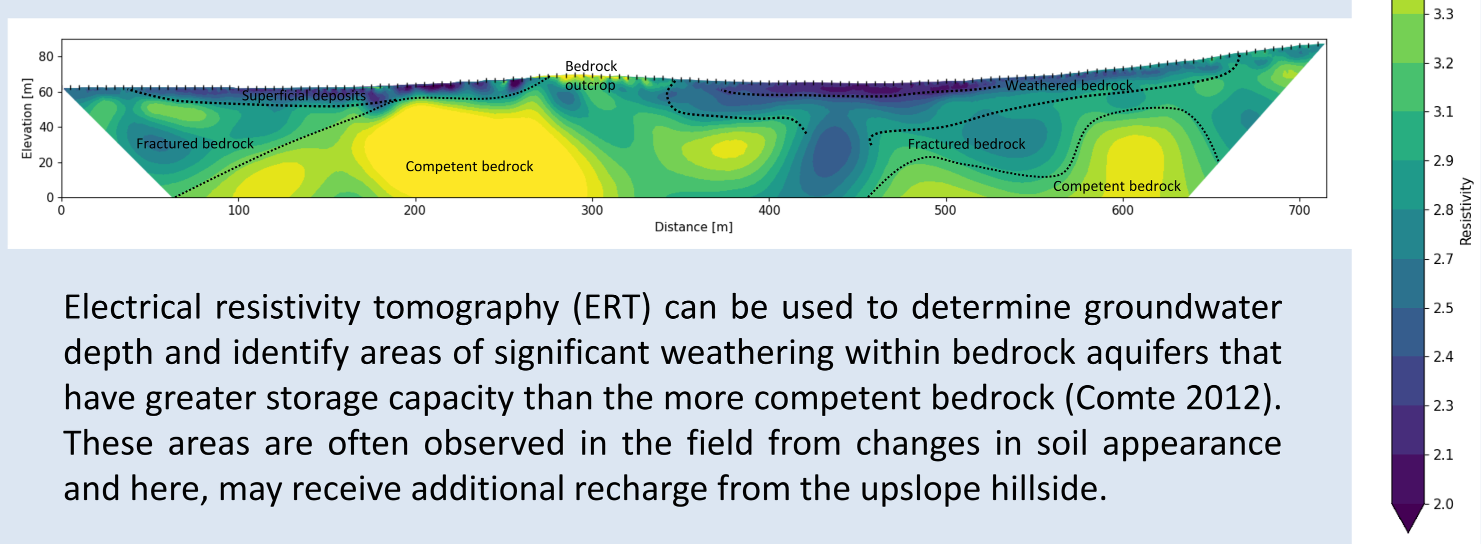
Boreholes here, within metasedimentary units trend in the same direction with similar groundwater event response.



Highlighted years 85% mean normal precipitation, drought events highlighted within.

In addition to identifying water level trends, geophysical surveys (ERT) have been completed to conceptualise the hydrogeologic setting and identify areas where significant weathering occurs at depth. Aquifers consisting of weathered bedrock are often utilised by PWS users but the storage potential is not well defined.

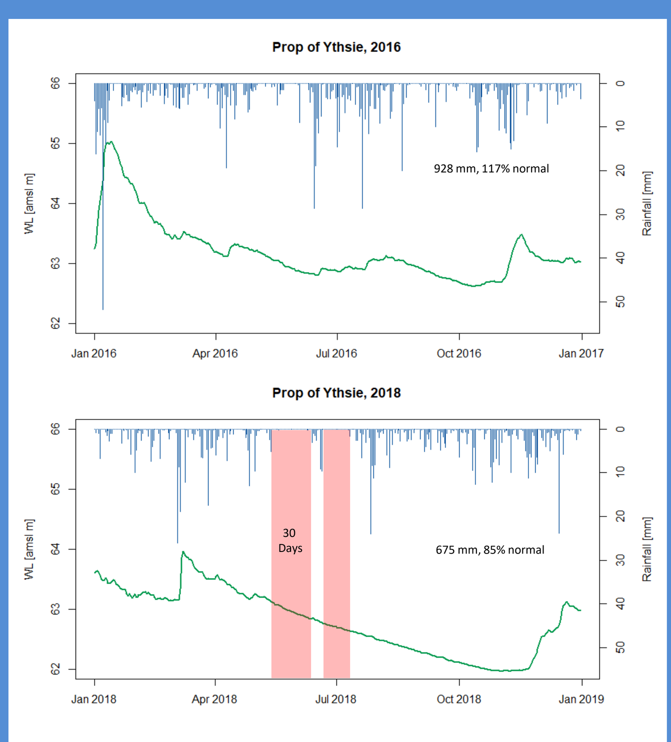
Prop of Ythsie ERT line



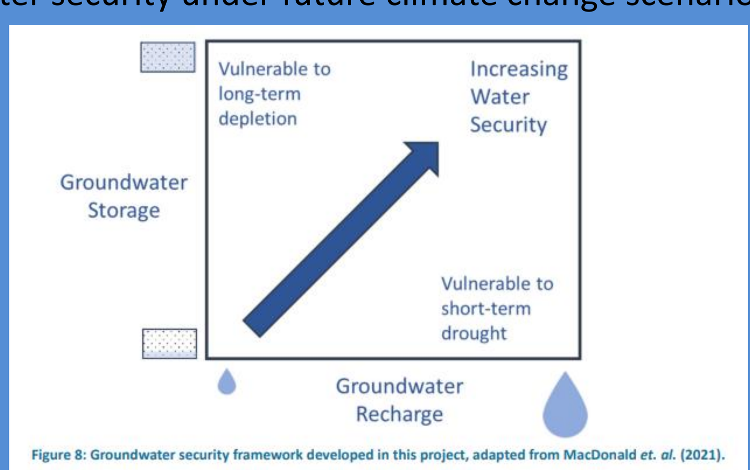
Electrical resistivity tomography (ERT) can be used to determine groundwater depth and identify areas of significant weathering within bedrock aquifers that have greater storage capacity than the more competent bedrock (Comte 2012). These areas are often observed in the field from changes in soil appearance and here, may receive additional recharge from the upslope hillside.

Conclusions

Understanding the drivers of past signals is key to predicting future groundwater response to climate change and drought and identifying areas of groundwater resilience.



Extended dry periods can influence infiltration rates and impact recharge to aquifers. It's necessary to understand groundwater level response under conditions of short-term drought, in addition to long-term trends, to develop a conceptual model of groundwater resilience and determine the role of groundwater in increasing water security under future climate change scenarios.



Glendell et al. (2024)

References

Comte, JC., Cassidy, R., Nitsche, J., Ofterdinger, U. Pilatova, K., and Flynn, R. (2012). *The typology of Irish hard-rock aquifers based on an integrated hydrogeological and geophysical approach.* Hydrogeology Journal (20): 1569-1588. https://doi.org/10.1007/s10040-012-0884-9.

DWQR (2024). *Private water supply sources.* Drinking Water Quality Regulator, June 2024: https://data.spatialhub.scot/dataset/private_water_supply_sources-dwqr. UK Open Government Licence v3.0 [Online].

Glendell, M., Blackstock, K., Adams, K., Brickell, J., Comte, JC., Gagkas, Z., Geris, J., Haro, D., Jabloun, M., Karley, A., Kuhfuss, L., Macleod, K., Naha, S., Paterson, E., Rivington, M., Thompson, C., Upton, K., Wilkinson, M., Williams, K. (2024). *Future predictions of water scarcity in Scotland: impact on distilleries and agricultural abstractors. CRW2023_05.* Centre of Expertise for Waters (CREW).

Rivington, M., Akoumianaki, I. and Coull, M. (2020). *Private water supplies and climate change: The likely impacts of climate change (amount, frequency and distribution of precipitation), and the resilience of private water supplies.* CRW2018_05. Scotland's Centre of Expertise for Waters (CREW).

SEPA 2022. *Water Scarcity Report, 1st September 2022.* September 2022: Strathallan House, Castle Business Park, Stirling, FK9 4T. [Online]

SEPA 2024. SEPA Time series data service (API). https://timeseriesdoc.sepa.org.uk/api-documentation/. UK Open Government Licence v. 3.0 [Online]

Acknowledgements

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