Geophysical Research Abstracts
Vol. 16, EGU2014-2253, 2014
EGU General Assembly 2014

What is baseflow? Integrating hydrometric and hydrochemical methods to assess dynamic groundwater contributions to montane streams under low flows

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We monitored changing groundwater-surface water interactions through an unusual prolonged dry spell in the Scottish Highlands in summer 2013. The period between May and September saw a 20 year return period drought, these changing hydrometric conditions were monitored in an intensively instrumented 3.2km2 catchment. This montane catchment is underlain by granite and metasediments and has extensive cover of diverse drift deposits.
The drought saw slight declines in soil moisture and groundwater levels in valley bottom wetlands but major, rapid declines on steeper upland slopes. This coincided with gradual declines in discharge, however the chemical composition of reducing stream flows showed marked temporal variation which differed spatially. Synoptic hydrogeochemical surveys were carried out on four occasions as flows declined. Each survey repeated sampling of 30 sites on the 3km long stream network as the catchment transitioned from wet to dry conditions. Samples were analysed for major anions, cations and water isotopes.
Initial surveys just after the last winter rain showed relatively homogenous stream chemistry, dominated by drainage from acidic peat soils in valley bottom areas. Stream chemistry became increasingly enriched with weathering-derived solutes (e.g. alkalinity, Ca, Mg etc.) as flows declined and groundwater contributions to flow increases. Repeat surveys showed an evolving chemistry of groundwater contributions as discharge from smaller shallower stores sequentially depleted. However, these changes showed marked spatial variability reflecting geochemical differences in the bedrock geology and the distribution of drift deposits. Importantly, much more dynamism was observed than previously thought with diverse montane groundwater bodies contributing to flows differentially during the recession. In addition, strong topographic shading in this montane catchment results in spatially variable radiation inputs and evapotranspiration. This is reflected in differences in Cl concentrations which show high groundwater inputs in the lower part of the catchment where ET is highest.

These integrated data have provided the basis for a new conceptual model of catchment groundwater-surface water systems. The new model encompasses this much more dynamic nature of baseflow reflecting the interactions of shallower and deeper stores with different chemical and isotopic composition. This is informing numerical model development using 2-D and 3-D configurations of the Hydrus model.