Design of an experimental hydrological network to record and evaluate the differences in hydrological functioning across restored, unrestored and near-natural peatland

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Introduction

Approximately 70% of drinking water in Scotland is sourced from peat-dominated headwater catchments. Healthy peatlands provide high-quality water which requires minimal processing. However, many of Scotland's upland peatlands show extensive evidence of gully erosion (Figure 1). The consequences of peatland erosion include:

- The release of dissolved organic carbon (DOC) and particulate organic carbon (POC) in water supplies
- Increased risk of flooding
- Reduced biodiversity
- Carbon release into the atmosphere.

Figure 1. Eroded peatland. Balmoral Estate

The 1992 European Community Habitats Directive led to legislative protection for several UK peatlands, and peatland catchment planning is a requirement of the EU Water Framework Directive. Peatland restoration is an important aspect of Scottish Government's Climate Change planning, with a target of restoring 250 000 ha (41%) of degraded Scottish peatlands by 2030. Although there has been an increase in UK peatland restoration projects (and associated funding) relatively few studies have sought to understand and evaluate the effectiveness of restoring the underlying hydrology, including water table depth, runoff, flow patterns and water quality.

Here we propose an experimental design to monitor and record data from restored, unrestored and near-natural peatland micro-catchments, with a view to analysing and integrating the empirical data with that from modelling studies, so as to synthesise new understanding of the relationship between restoration measures and hydrological functioning and assess potential hydrological trajectories.

Methodology

Study site

The study site is an upland peatland in the Balmoral Estate, Scotland. The peatland, which is heavily eroded, is currently undergoing restoration by Scottish Natural Heritage (SNH). There are four zones (Blackburn Phases 1,2,3 and Blackhill 2015) designated for restoration, two of which - Blackhill 2015 and Blackburn Phase 1 - have already undergone treatment (Figure 2). The other two zones will be undergoing restoration in the coming year(s). There is an eddy covariance flux tower operated by the James Hutton Institute (JHI), sited in Blackburn Phase 3, at an elevation of 642 metres.

Hydrological monitoring

Sites will be chosen in the course of the experimental design phase using GIS and ground truthing to best match average slope, aspect and drainage. Hydrological head and water table depths will be continuously monitored using piezometers and dipwells. Each site shall have three piezometer nests arranged in a triangle, each nest consisting of a piezometer centred at 21cm, 48cm and 75cm below the peat surface. Two legs of each triangle will be located within 1 metre of a peat gully. Additionally, there shall be a dipwell at each nest to monitor average water table levels. The use and layout of the piezometers will enable modelling of hydraulic conductivity, hydraulic gradient, equipotential lines and direction of flow, both vertically and horizontally. Overland flow at each site will be measured with crest stage tubes. Eight V-notch weirs shall be installed at the micro-catchment outlets to measure discharge (Figure 3). All piezometer, dipwell, crest stage tube and weir data will be continually recorded using capacitive water loggers. Particulate organic compounds (POC) will be collected in the gullies with time-integrated mass flux samplers (TIMS). Hydrological modelling will be undertaken using a deterministic, physically-based, fully distributed modelling system. The coordinates of all monitoring equipment shall be measured to 1cm horizontal accuracy, 2cm vertical accuracy.

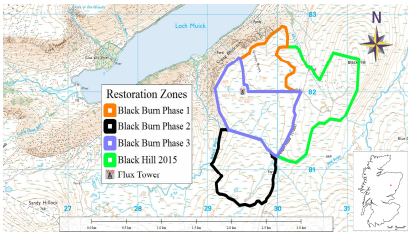

Figure 2. Balmoral study site showing restoration zones, (Reproduced by James Hutton Institute, © copyright and database right 2020. All rights reserved. Ordnance Survey Licence Number 100019294).

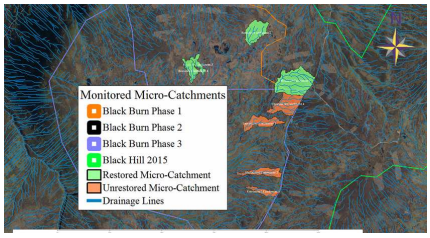

Figure 3. Aerial photograph showing micro- catchments to be monitored. © copyright Getmapping 2020.

Hydrological measurements and calculations shall be referenced against a fixed datum utilising peat depth survey data supplied by SNH, a high-resolution Digital Elevation Model, and high precision GPS data. Hydraulic conductivity at each piezometer nest will be measured using a) slug withdrawal tests and b) steady state constant head methods. The hydrological modelling will be undertaken using a deterministic, physically-based, fully distributed modelling system, employing lumped or semi-distributed sub-models where appropriate. Evapotranspiration data will be sourced from the JHI eddy covariance flux tower supplemented, where necessary, by the Meteorological Office Rainfall and Evaporation Calculation System (MORECS). All hydrological inputs and outputs including precipitation, surface and groundwater inflows, surface runoff, saturated and unsaturated runoff, storage, snowmelt, evapotranspiration, hydraulic head and hydraulic conductivity will be included.

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