# Integrated River Evaluation for Management (IREM): A novel approach to understanding the role and impact of groundwater-surface water interactions on in-stream water quality

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## Integrated River Evaluation for Management (IREM)

- IREM is a novel approach to integrate factors affecting surface water (SW) and groundwater (GW) connections to better inform management interventions of local water resources impacted by multi-threats. This approach has been established to better manage water resources to meet standards (e.g. Water Framework Directive (WFD; 2000/60/EC); a holistic assessment of the system behaviour and connections is required to deal with contemporary fluvial challenges (Brunner *et al.*, 2017).
- IREM is an analytical tool that utilises desk- and field-based techniques to compile existing and empirical data in a Geographic Information (GIS) framework (Table 1).
- Here, we present the findings from a pilot test of IREM on the Herrington Burn (NE England).

*Table1: Example data sources used in IREM.*

| Surface | Subsurface |
|---|---|
| SW network, flow | Geology |
| Pollution sources – point and diffuse | Lithology, including superficial deposit thickness and composition |
| Land use – historic and contemporary | Worked mineral deposits, e.g. coal mining |
| Historical channel changes | GW quality |

## Pilot Test

- The Herrington Burn (catchment area: 13 km$^2$) is a heavily modified tributary of the Lumley Park Burn which flows into the River Wear (Figure 1). It is currently failing to achieve 'good' WFD status (Environment Agency, 2018).
- There are concerns regarding elevated nitrate concentrations in GW abstractions at the borehole marked on Figure 2. It was initially hypothesised that the nitrate source was attributable to the downwelling of poor-quality SW. Applying the IREM approach has shifted focus from the surface to the subsurface, facilitating a first-order, holistic assessment across the systems.

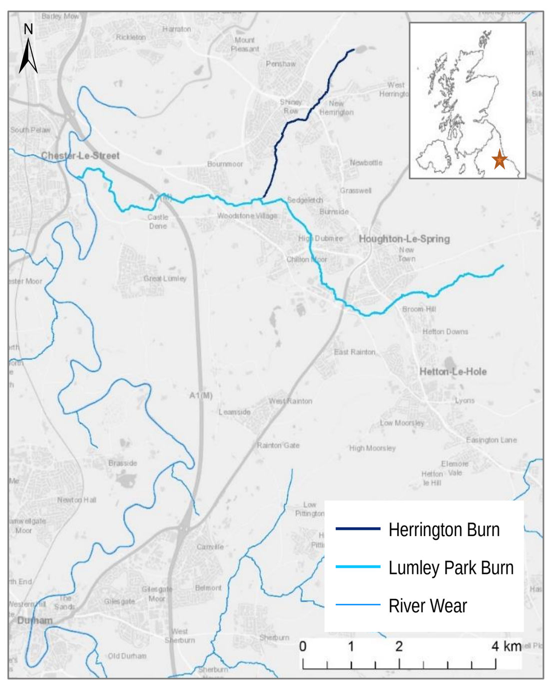


*Figure 1: The Herrington Burn, a tributary to the Lumley Park Burn and River Wear.*

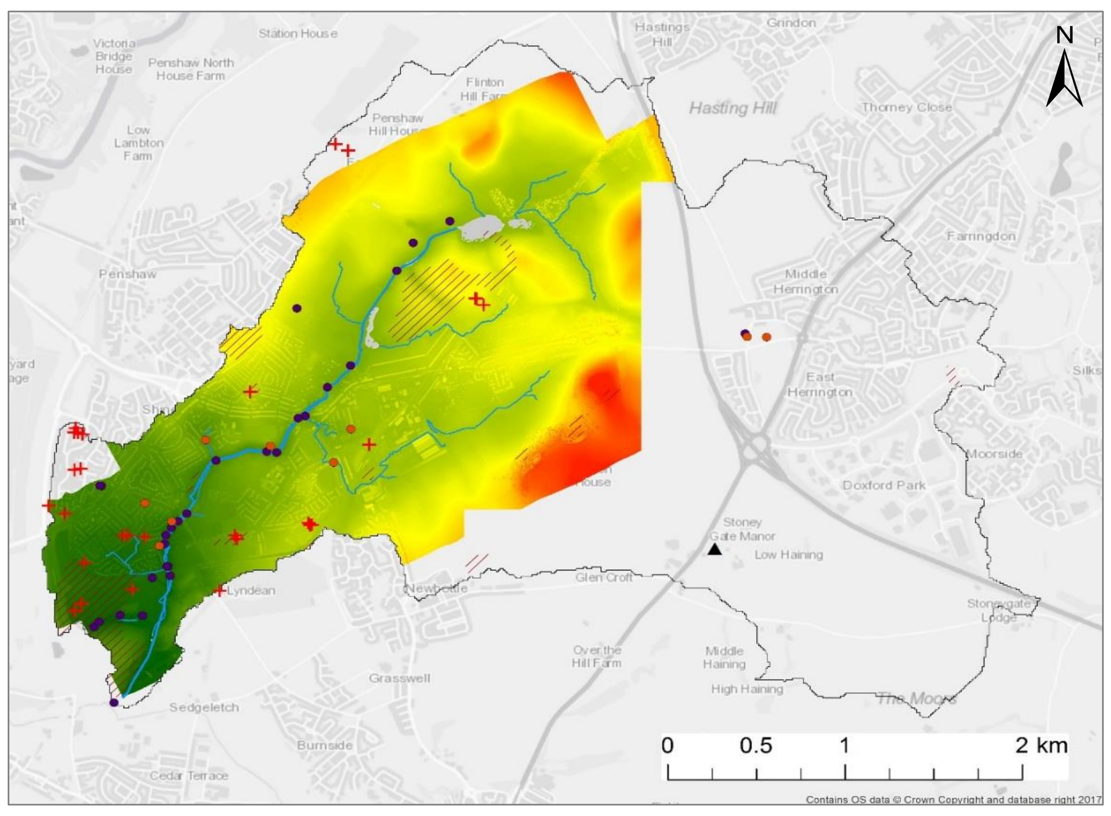


*Figure 2: SW network, showing mining and effluent threats, with elevation (Data sourced from: Northumbrian Water; LiDAR Digimap © Crown copyright).*

- The Herrington flows downstream through former open-cast coal mining workings towards redeveloped residential areas (Figure 2), coinciding with metal-rich and effluent-rich discharges respectively.
- However, nitrate concentrations were notably low relative to those of the GW abstractions (>80 mg/l). Thus, despite the agricultural and effluent releases, the source was unlikely pointing towards the channel inflows.

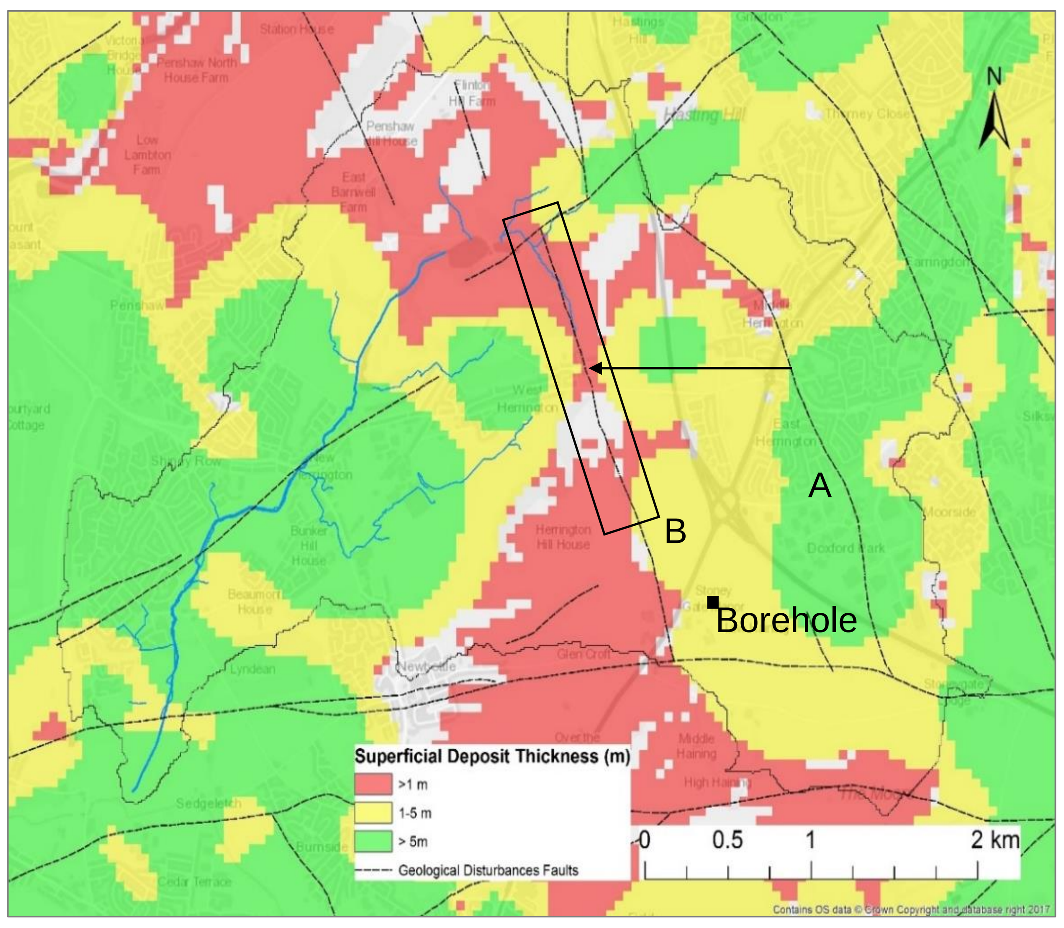


*Figure 3: Superficial deposit thickness with inferred geological faults (Geological Map Data BGS © NERC 2018) and SW connection (A to B). Rectangle shows the hypothesised SW nitrate source zone.*

Stream-subsurface connections are likely on the basis of the shallow thickness of superficial deposits (Figure 3). Nitrate sourcing from the area marked A was thought to be flowing towards fault B, from which it was thought that the SW was downwelling and flowing towards the borehole (Figure 3).

The A-B SW connection was found to be a historical path of the Herrington (Figure 4). Now culverted, water drains from agricultural fields into the drainage system. Thus, a possible nitrate source. Subsequent surveying of the drains suggested that no leaks were likely, thus leading to question GW sources.

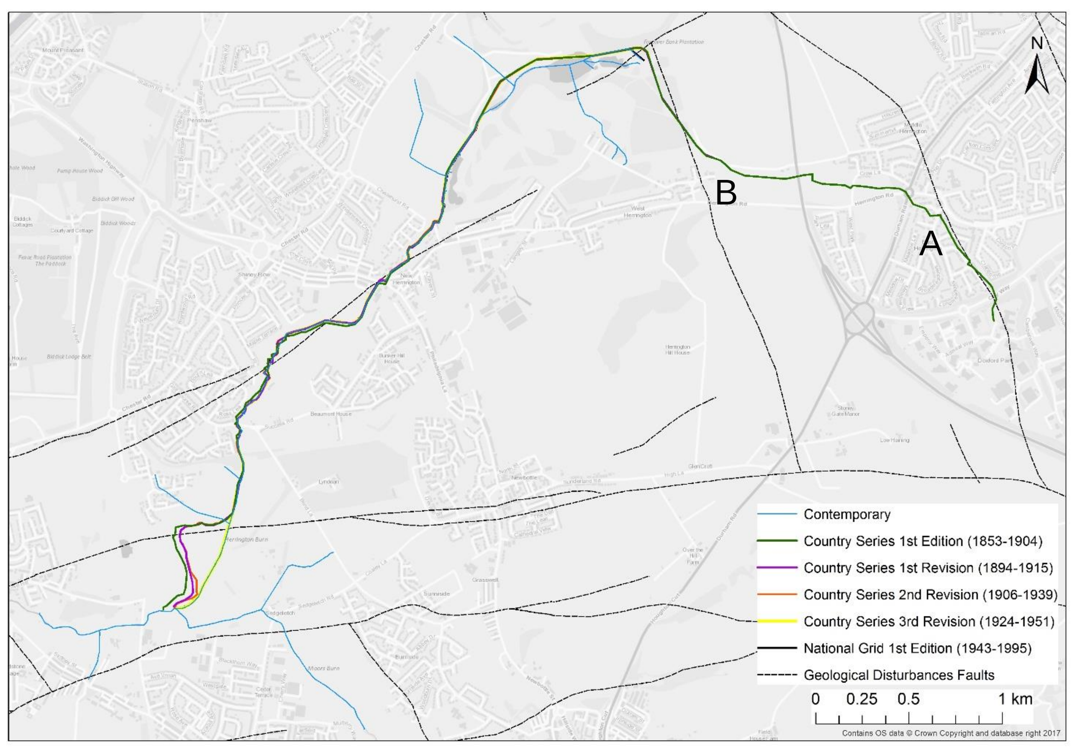


*Figure 4: Historical Vs. contemporary path of the Herrington Burn (© Crown Copyright and Landmark Information Group Limited 2018. All rights reserved. [1853-1995].).*

## What does this mean for management?

- IREM has proven an insightful and useful tool to link evidence to the management interventions of practitioners, considering the pathways and links, within, and between the GW and SW systems, bringing freely available data together using GIS.
- Composite mapping has facilitated a first-order approximation of the role of the surface and subsurface connections and interactions, allowing for the elevation of nitrates. Using IREM, likely contributions from the SW and shallow subsurface (including the drainage network) have been assessed, shifting the focus of investigation towards the deeper GW.

## Future work

IREM is to be applied in other streams of the Wear catchment impacted by multi-threats, with efforts to scale-up the application of IREM beyond the Herrington pilot test.

**References:** Brunner, P., Therrian, R., Renard, P., Simmons, C.T. and Franssen, H-J. H. (2017). Advances in understanding river-groundwater interactions. *River-Groundwater Interactions*. 55: 818-854.
Environment Agency (2018). *Catchment Data Explorer*. Available at: http://environment.data.gov.uk/catchment-planning/OperationalCatchment/3520 (Accessed on: 15th March 2018).

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