“Catchments & Karst in the Southeast"

ANNUAL IAH FIELDTRIP

3rd & 4th October 2015

This year we will be heading to the southeast where we will visit catchments researched as part of the Teagasc Agricultural Catchments Programme (Castledockrell) and the EPA Strive Pathways Project (Nuenna). We will hear about pathways in the karst which dominates the Nuenna catchment and visit the spectacular karst feature of nearby Dunmore Caves.

The first day of the trip will take us to Co. Wexford where we will make a number of stops in the Castledockrell Catchment and hear about the research undertaken there into nutrient management and water quality. We will move on to Kilkenny in the afternoon where we will visit Dunmore Caves, one of the oldest caves in Ireland, followed by an overnight in Kilkenny City. The second day will focus on the Nuenna catchment and the research undertaken by EPA/TCD/QUB into contaminant movement and attenuation along pathways in this karst area. A brief summary of topics to be covered at each site is provided below.

We are intending to base ourselves in the Hotel Kilkenny (www.hotelkilkenny.ie) where we have been offered an IAH fieldtrip rate of (~ €110 pps / €140 single for dinner B&B). ****Please note you are responsible for booking of your own accommodation. The hotel is holding rooms for us until the 19th September only**.** Other accommodation (including hostels) is available nearby.

There will be a bus leaving from Dublin in the morning taking us around the sites. The estimated charge to attendees will be ~ €60 for those taking the bus and availing of lunch on the Saturday and Sunday. For unwaged members, there will be no charge for bus and lunch. Please contact fieldtrip secretary for more information.

If you are considering attending this year’s fieldtrip can you please notify the fieldtrip secretary as soon as possible. Fieldtrip Secretary: Aisling Whelan (fieldtrip@iah-ireland.org)

Indicating if you

(1) Are attending
(2) Wish to travel on bus from Dublin?
(3) Wish to stay in group hotel?
(4) Wish to attend group evening meal?

Saturday 3rd October

Castledockrell Catchment (Teagasc Agricultural Catchments Programme)

(led by Per-Erik Mellander, Teagasc)

- Overview of the ACP
- Nutrient sources
- Nutrient and hydrological pathways
- Nutrient delivery and ecology

Dunmore Caves

(led by David Drew)

- One of the most unusual and ancient caves in Ireland, distant from the 'main' karst areas
- A fragment of karst palaeohydrogeology in Co. Kilkenny

Please note participants will find a helmet and bright light useful for this part of the field trip

Sunday 4th October

Nuenna Catchment (EPA Strive Pathways Project)

(led by Jenny Deakin)

- Conceptual model and pathways
- Nitrate dynamics, modelling and attenuation
- Groundwater source protection and critical source areas

Please note that the programme of visits is preliminary and subject to change pending landowner permission to access sites.

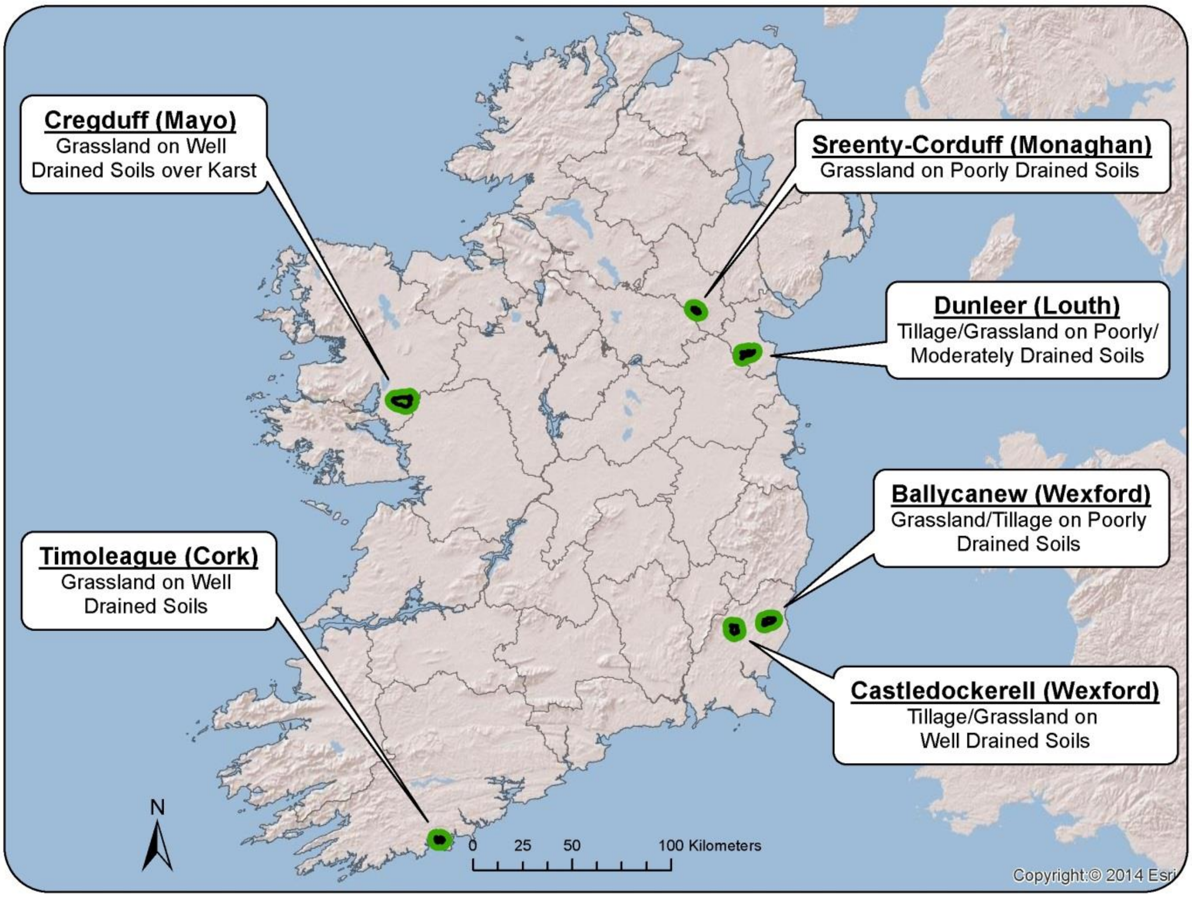
Also, please note that, for insurance reasons, the field trip is open to members of the IAH (Irish Group) and the following Irish Geoscience Network organisations only: Geothermal Association of Ireland (GAI) and Irish Quaternary Association (IQUA). Information on joining the IAH (Irish Group) can be found on our website: www.iah-ireland.org

IAH Fieldtrip 3rd October 2015

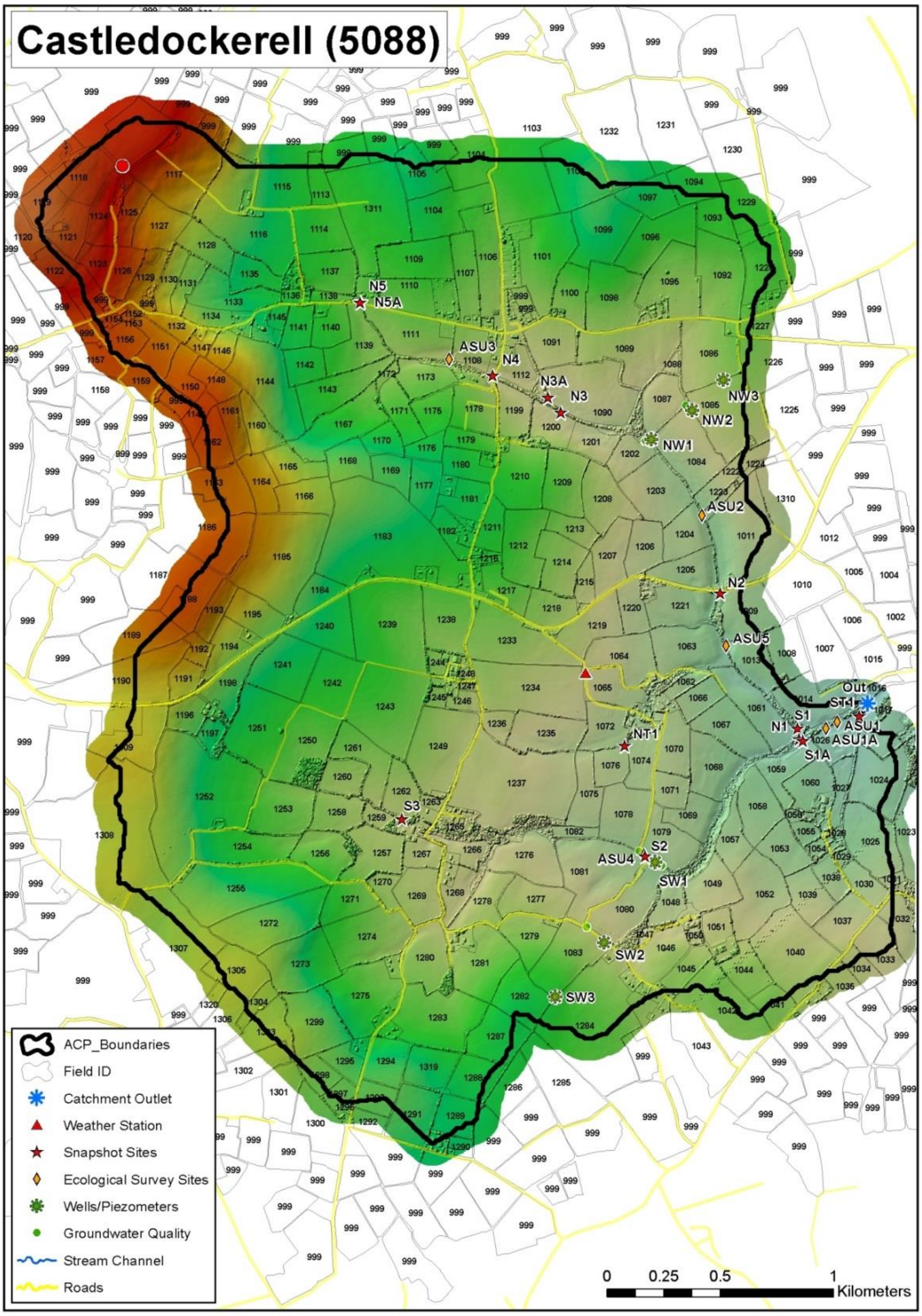
Agricultural Catchments Programme

The Agricultural Catchments Programme (ACP) is a national, partnership-based research/advisory project which aims to promote and maintain profitable, productive farming while protecting water quality. Its key objective is the monitoring and evaluation of Ireland's National Action Programme (NAP) and derogation to farm at organic nitrogen (N) rates of up to 250 kg ha^{-1}. The ACP is also working to provide the scientific evidence needed to support Irish agriculture in meeting the requirements of the Water Framework Directive (WFD) while achieving the ambitious production target set out in the Food Harvest 2020 report.

The ACP has 6 catchments; each was chosen to represent a specific combination of landscape, soils and farming.



Castledockerell catchment with its biophysical monitoring sites



- **First stop:** Upland rain gauge station – ACP and catchment overview
- **Second stop:** Focused study site for pathways (Southern well transect) – Background, Nutrient sources and transfer pathways
- **Third stop:** Catchment outlet – Nutrient delivery and impact on ecology

IAH Field Trip 3rd October 2015

DUNMORE CAVE

David Drew

Introduction

Dunmore Cave is located 11km north of Kilkenny at an altitude of 120m. It is the only cave of any size in the area though there is some (Holocene?) karstification along the shale–limestone contact to the west. The nearest caves of comparable size are those at Mitchelstown some 80km to the west. Although the cave contains only 300m of passages, its interest, both scientific and historical, is considerable and it may be that it is one of the oldest accessible caves in Ireland.

Geology and Geomorphology

- Dunmore Cave is located at the northern extremity of a long, narrow inlier of Carboniferous limestone oriented NNE-SSW. The limestone outcrop is 3km long but averages only 300m in width and is surrounded by Luggacurren Shales of Naumurian age and then the Killeshin Siltstone Formation. More than 2km separates the limestone from the main limestone outcrop to the west and southeast.
- This area is the southwestern extremity of the Castlecomer Plateau in which Coal Measure strata occupy the central part of the synclinal structure. The hydrogeology of the main Plateau has been investigated by Daly et al who remark upon the importance of the faulting in compartmentalising groundwater and regard the main aquifer rocks as being relatively thin sandstones recharged in their outcrops areas on the margins of the plateau. The relationship between groundwater in the Coal Measures and in the underlying limestone was not investigated.
- The valley of the Dinin River (tributary to the River Nore) lies c.1.5km west of Dunmore Cave and some 40m lower than the cave entrance. The Dinin valley in this reach is infilled to a depth of some tens of metres with outwash glacial gravels.
- Dunmore Cave is developed in the Clogrenan Formation *'clean to argillaceous calcarenite wackestones and packstones'* (GSI) with abundant

nodular chert that comprises the uppermost 90m of the Carboniferous limestone in this area.

- The inlier may lie, in part at least, along the axis of an anticline with dips of c.20^{o} to the east and 14^{o} to the west. In topographic terms the cave is located in a hillock
- The geology of the area surrounding the caves is shown in Figures 1 and 2.

Cave Description

- The plan and longitudinal section of Dunmore Cave are shown in Figure 3 and the main geological controls on the cave in Figure 4.
- The cave is formed largely along a joint system oriented at 160^{o} -170^{o} with subsidiary development in the east-west oriented joint set.
- The cave is developed at two levels – the upper level consisting of a passage 10m wide and 3m high with a flat bedding-plane roof. The lower level of the cave (Crystal Hall and Main Chamber) are lofty rifts oriented north-south.
- Little is visible of the original form of the cave when it was a groundwater conduit, apart from solution hollows and bevels in roof and ceiling – for example at the fairies' Floor. Collapse of the walls and roof of the original caverns has greatly modified the cave morphology, ultimately reaching the surface to form the entrance scree slope.
- Two types of secondary deposit are present in Dunmore Cave:
  - Extensive deposits of calcite, associated with water entering the cave via the major north-south joints – these are primarily floor and wall deposits.
  - Fluvial sediments of allogenic material – for example the sands and silts in the Rabbit burrow which were presumably transported into the cave by glacial meltwater.
- The cave is now almost hydrologically inactive except for a pool in Crystal Hall which rises and falls by some 20m seasonally and is possibly related to groundwater levels in the nearby Dinin valley.
- The manner of the evolution of the cave and its chronology is largely speculative. The only dating of the cave is from uranium- thorium dating

of calcite deposits but these relate only to the outermost layers of calcite and are of Holocene age. Clearly the cave initiation and development took place under very different topographic and hydrogeological conditions to those prevailing today. It may be that Dunmore Cave dates to early Pleistocene or even Tertiary times.

Questions

- Did the cave form beneath a cover of non-limestone (and presumably impermeable) rocks?
- When did the limestone inlier develop?
- Why has there been so little erosion of the limestone inlier as it is surrounded by rocks, which supply highly aggressive runoff?
- When, and under what groundwater conditions, did the cave develop and when did it become inactive?
- What degree of modification to the cave took place during the Pleistocene?
- When did the collapses that gave rise to the entrance take place?
- Are there more Dunmore Caves out there?

Figure 1. Geology

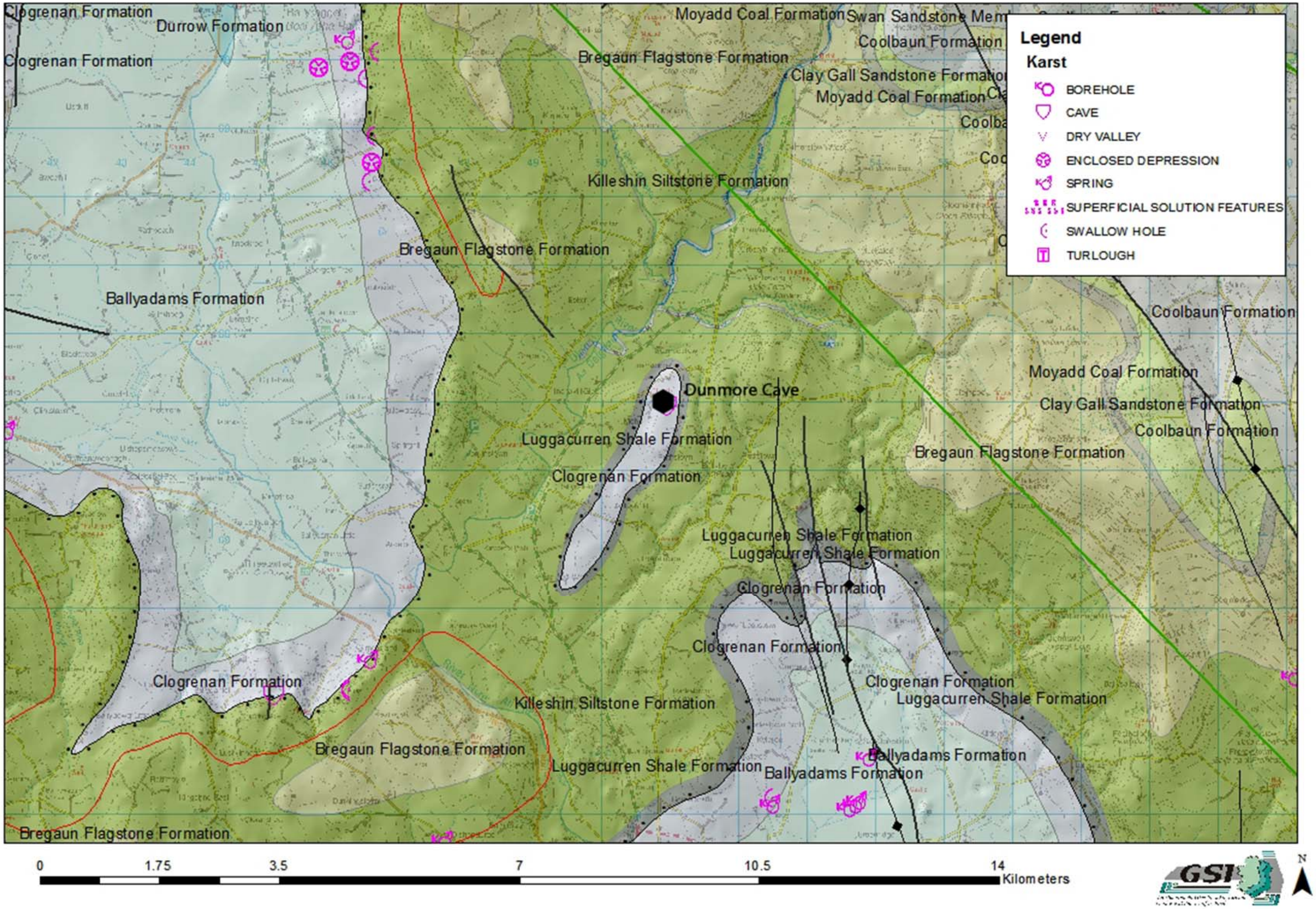


Figure 2. Geology (detail)

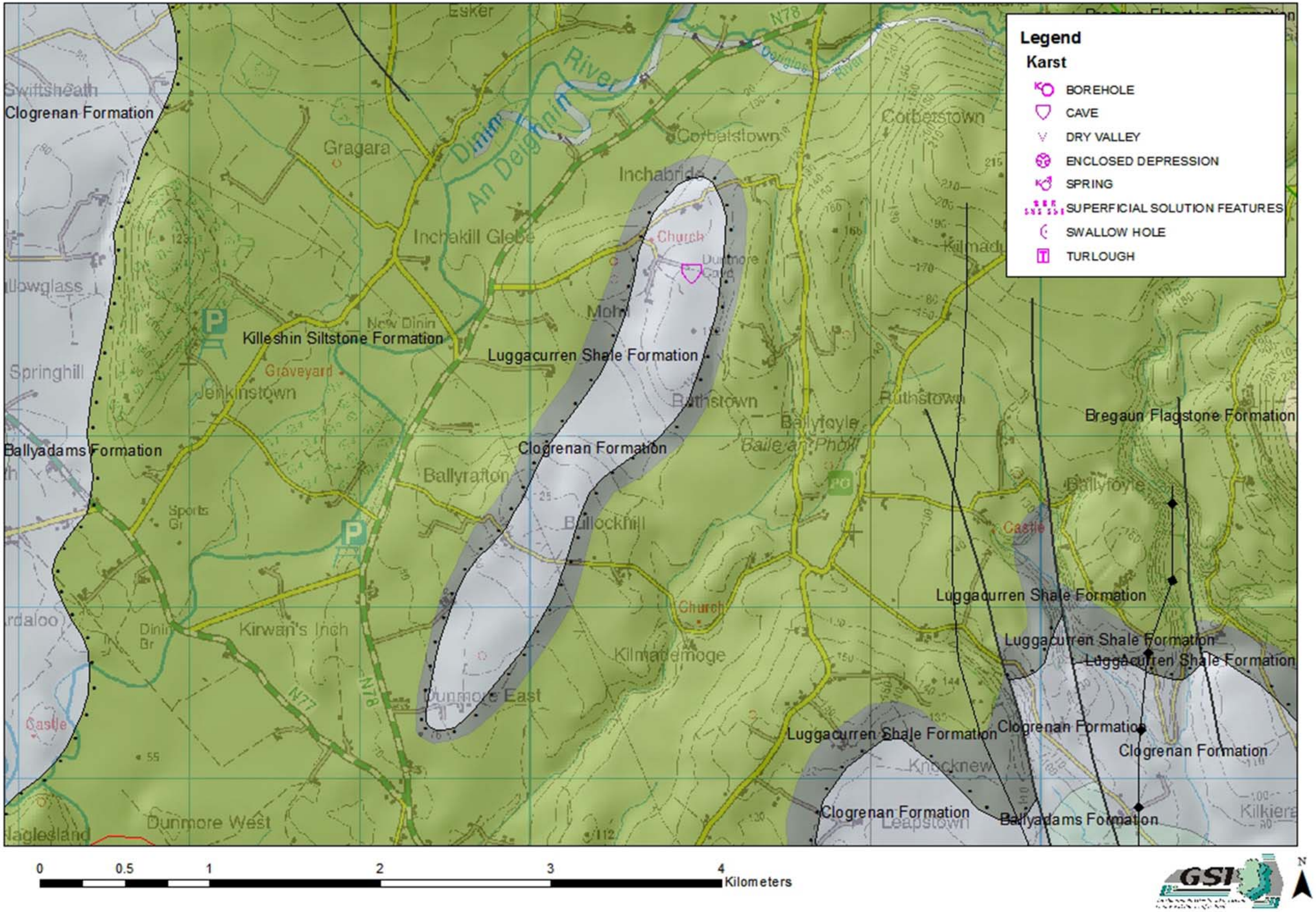


Figure 3. Plan Survey (showing tour pathways)

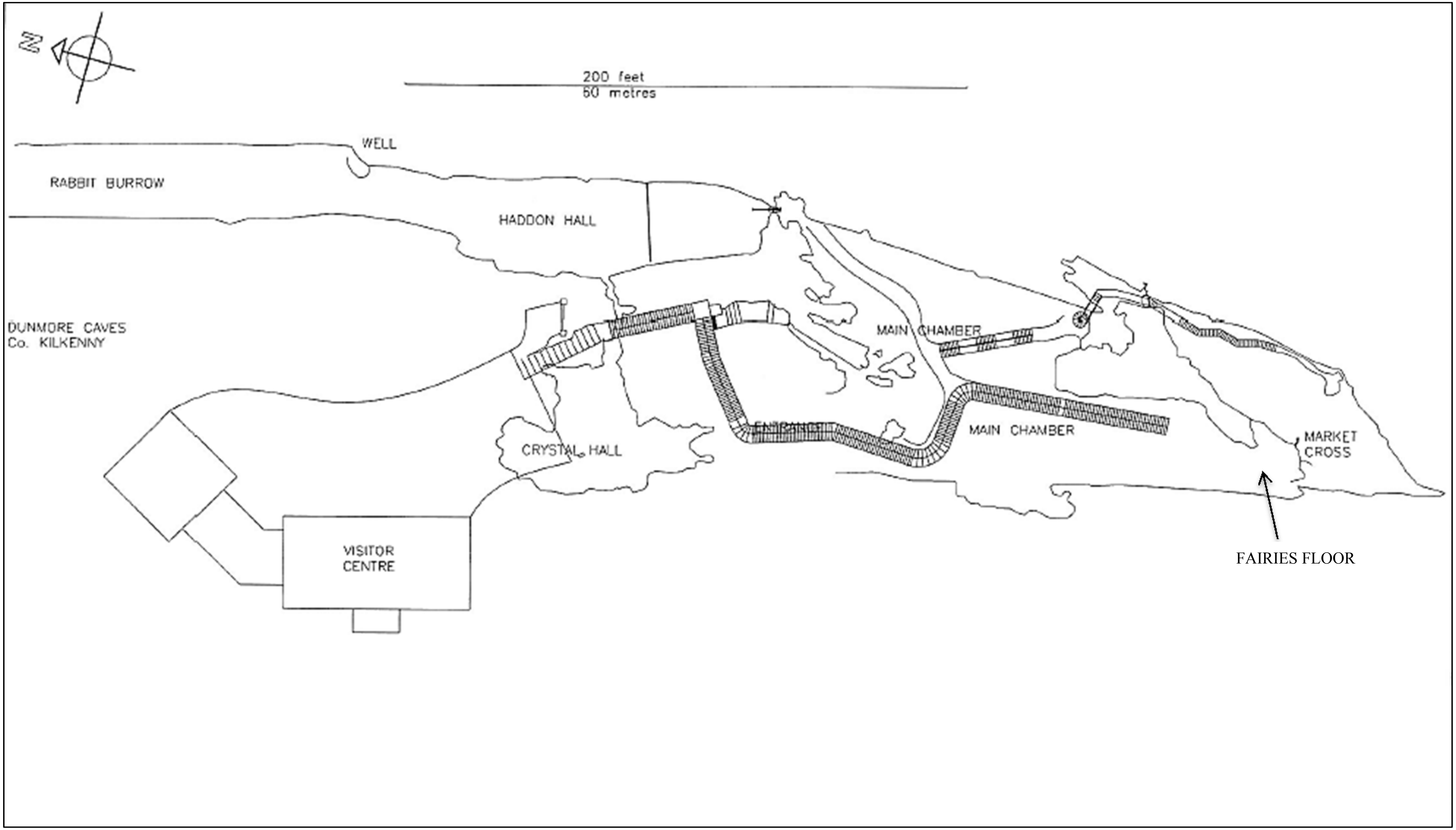
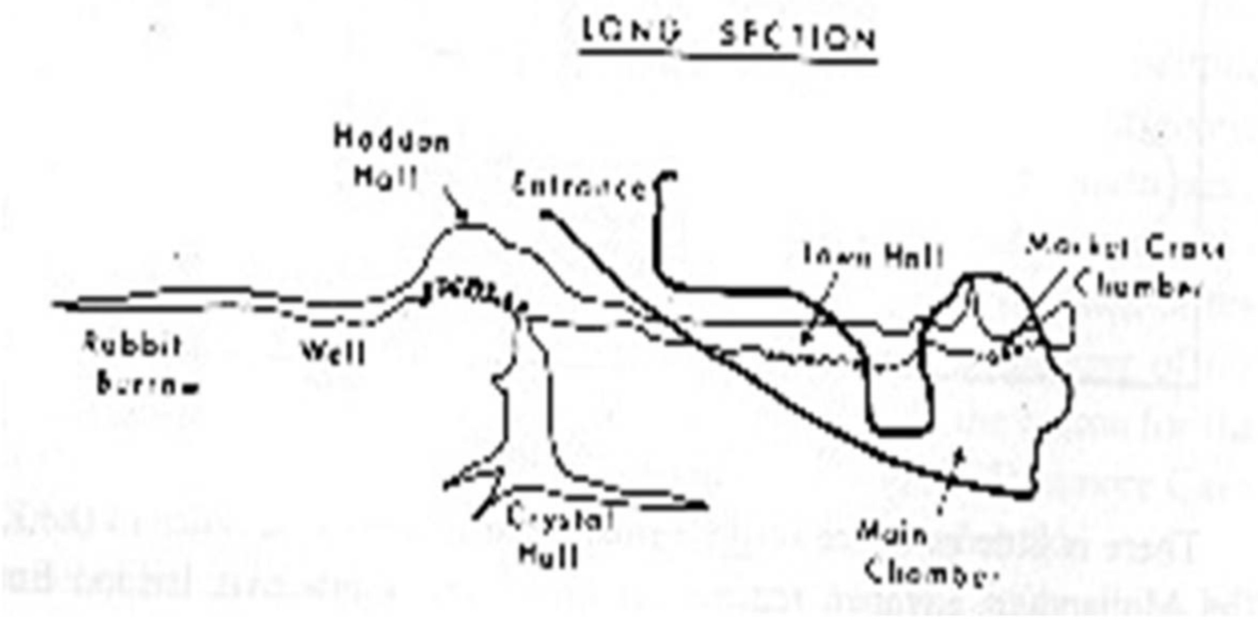
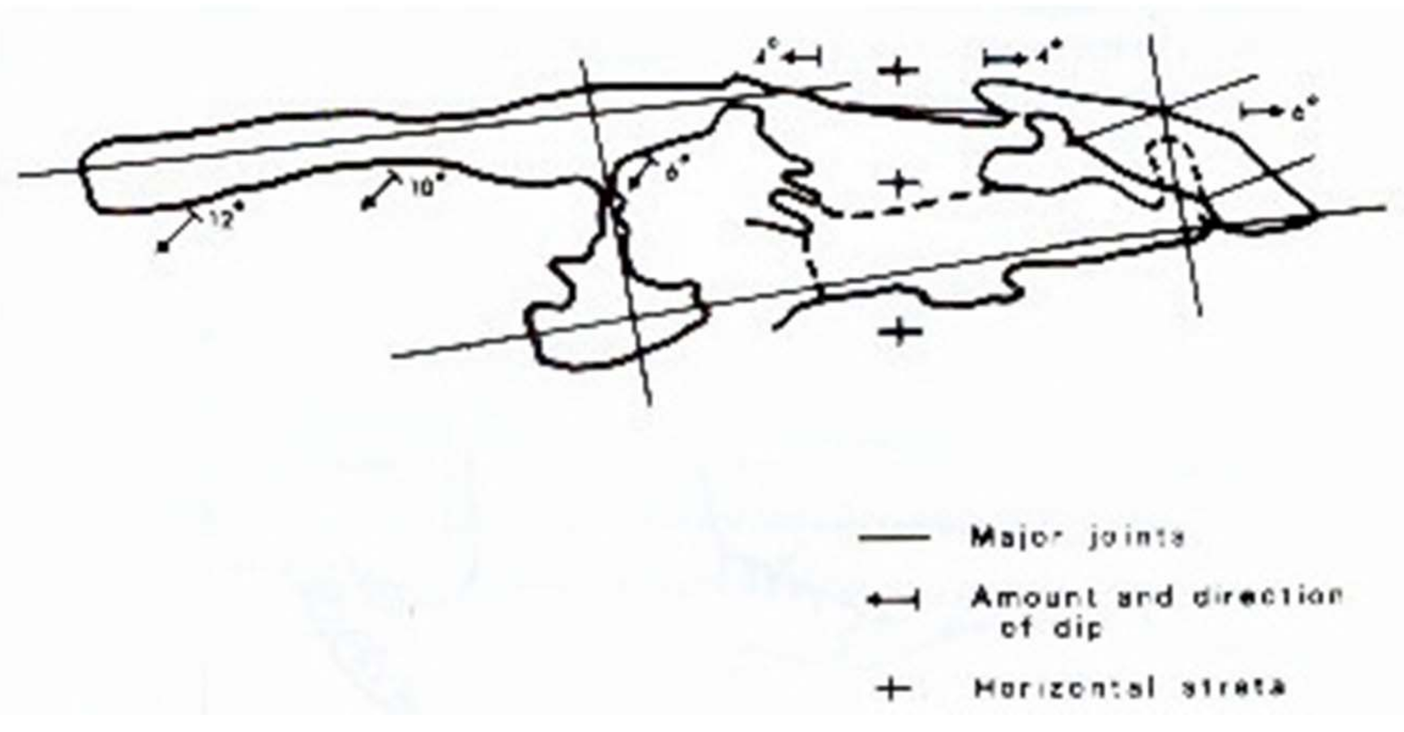


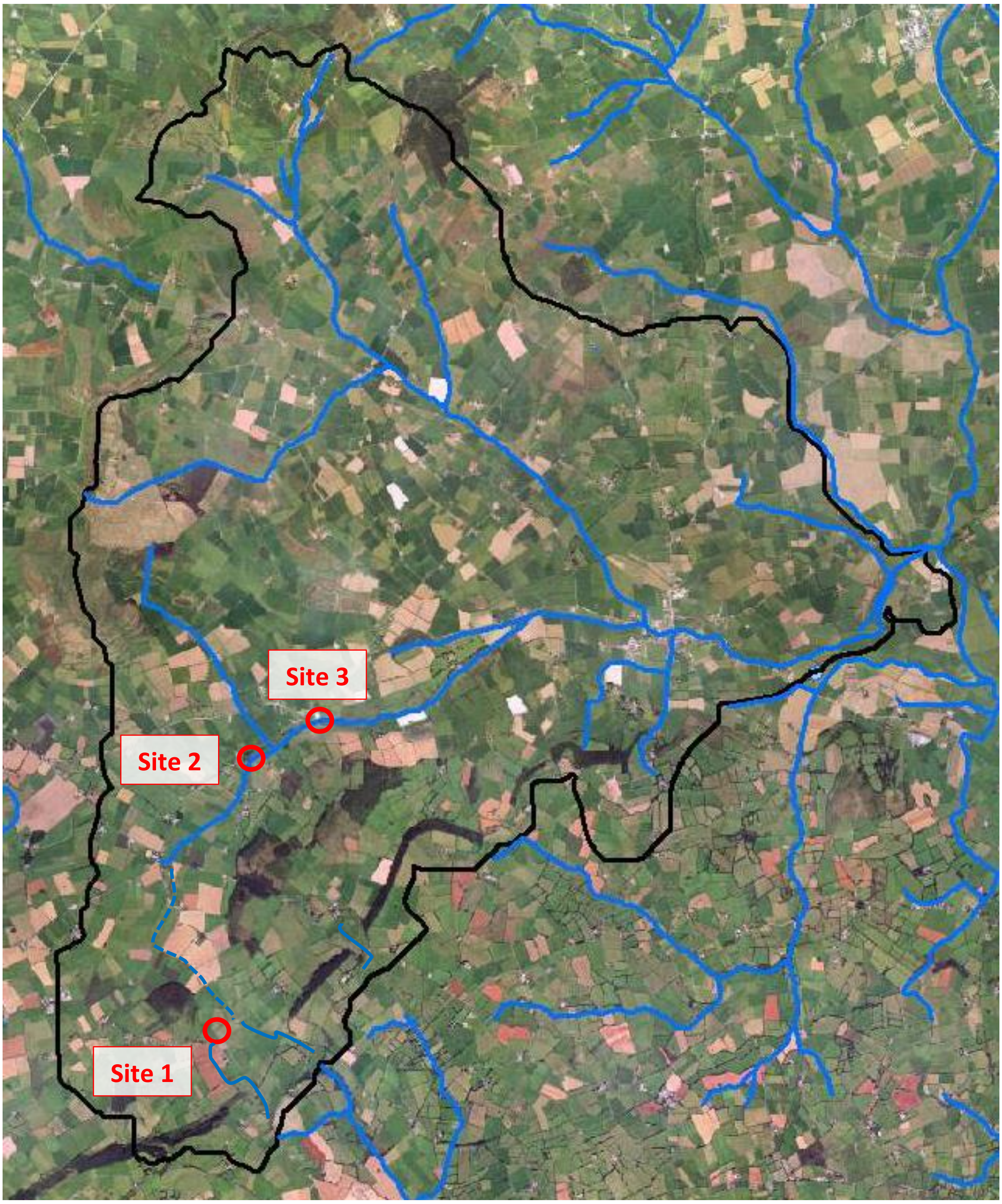
Figure 4. Longitudinal Section & Structural Geology





SUMMARY INFORMATION FOR THE NUENNA CATCHMENT VISIT

4th October 2015



Site 1: Killaghy swallow hole in upper catchment

Site 2: Boiling Spring/GWS Spring

Site 3: Nuenna @ Clomantagh Br

Itinerary for Field Visit

Stop 1 Killahy swallow hole

- Outline of the trip and the stops (Jenny)
- Hydrogeological context (Jenny)
- Challenges with water balances and modelling in karst areas (Bruce)

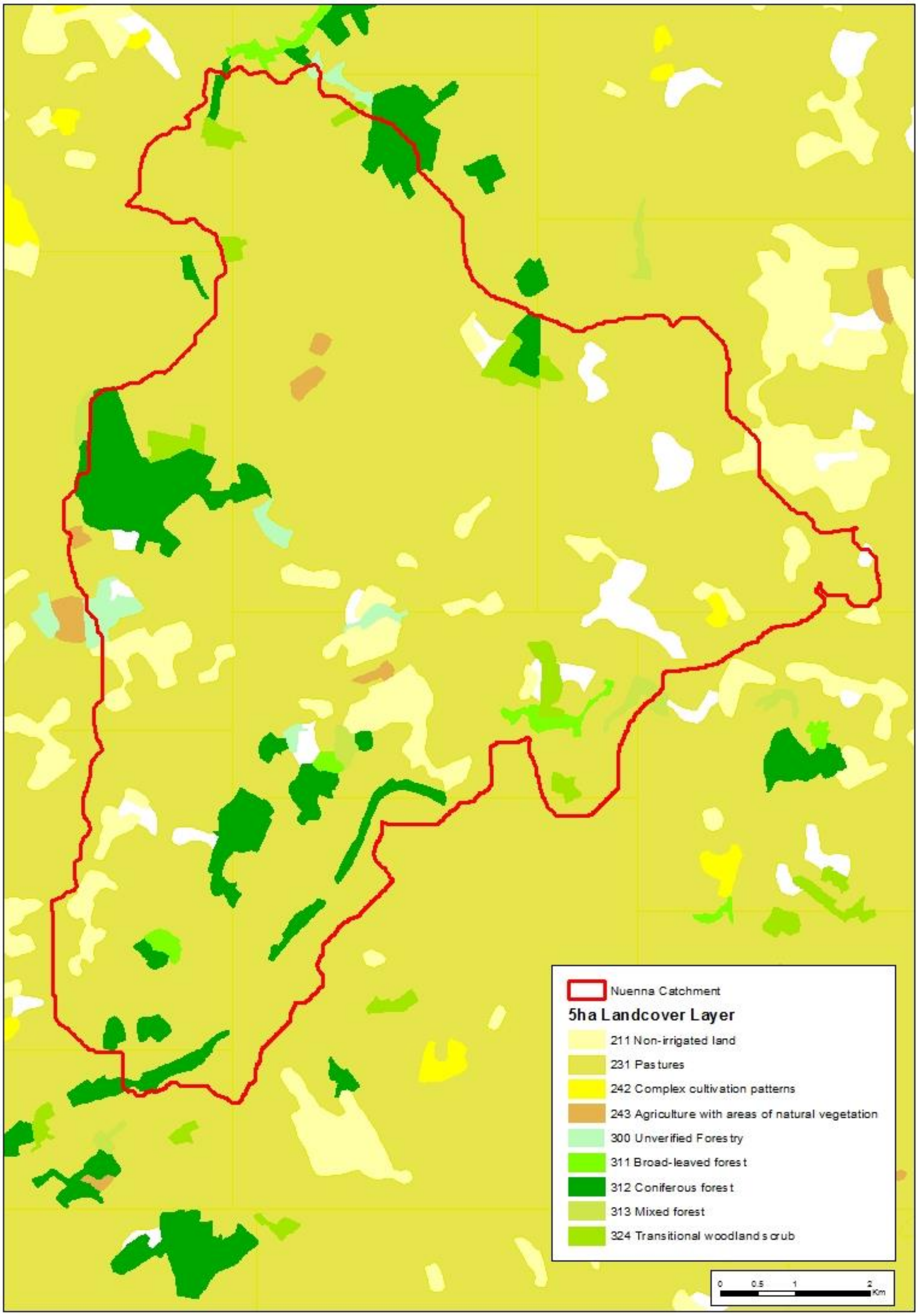
Stop 2 Boiling spring (Site 2)

- Characterising pathways – insights from chemistry (Jenny)

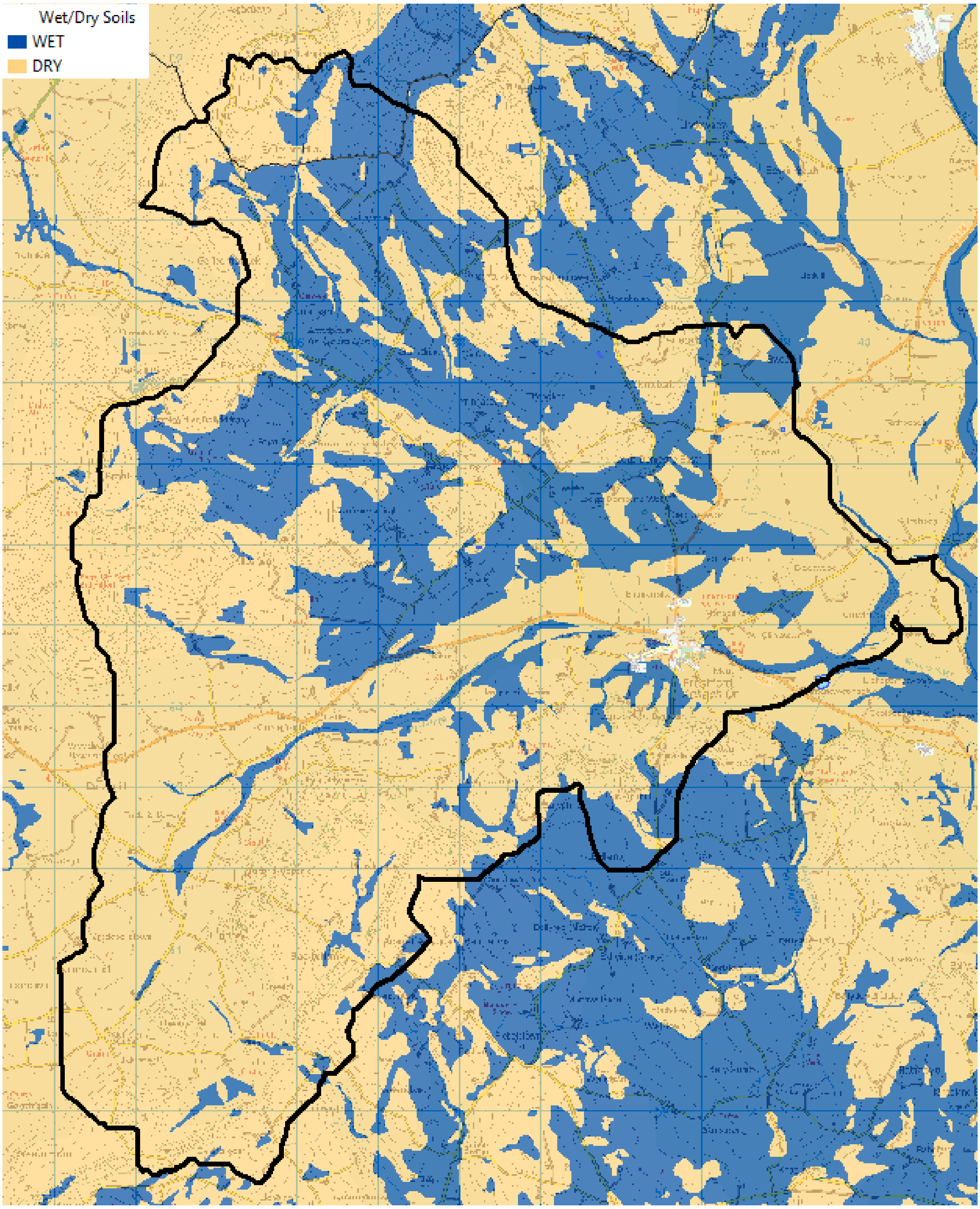
Stop 3 Clomantagh (Site 3)

- Nitrate dynamics in groundwater (Alison)
- Instream attenuation (Ray)
- Groundwater protection zones for drinking water sources (Coran)

CORINE Land Use

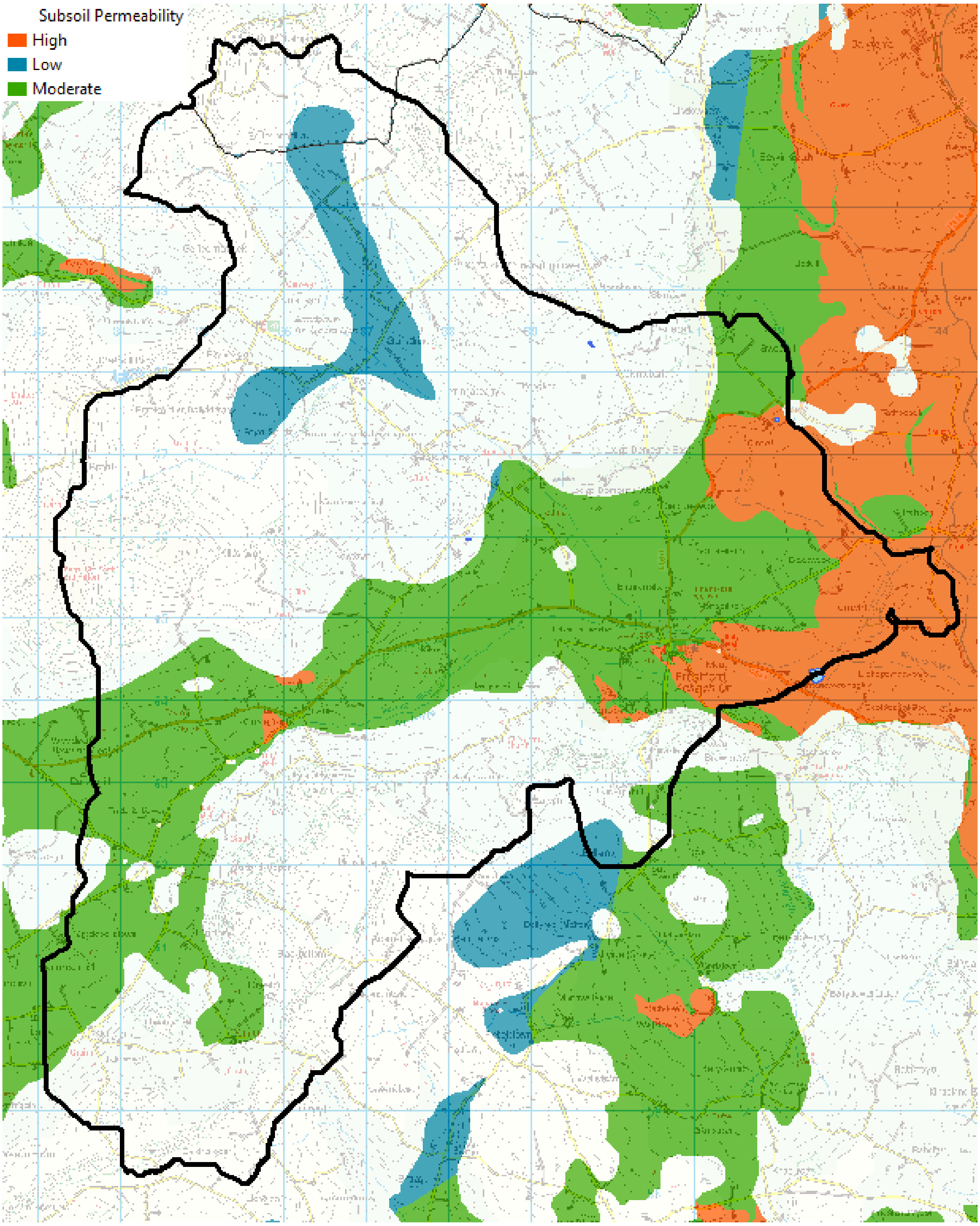


Wet/Dry Soils

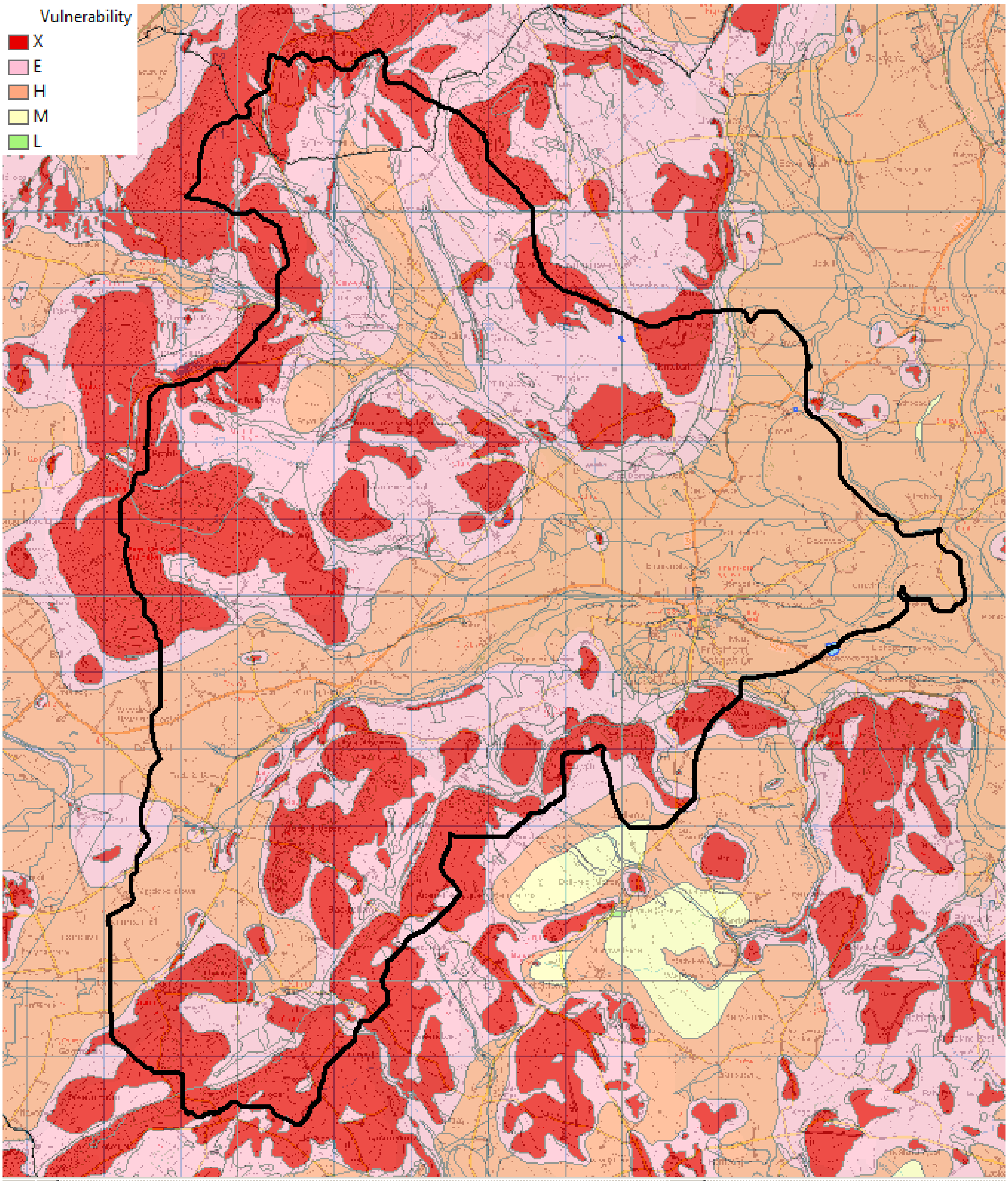


Subsoil Permeability

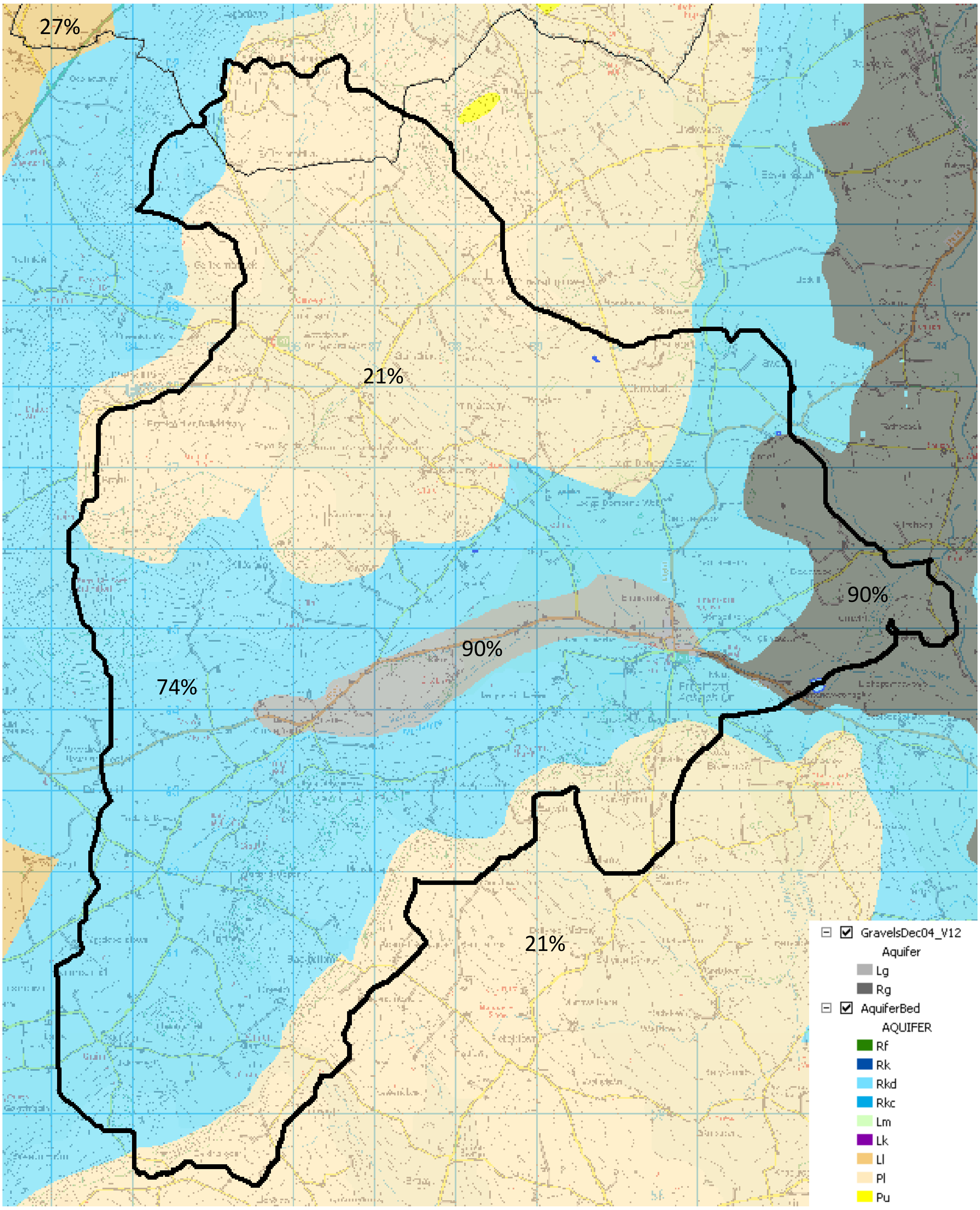
(blank areas have <3m subsoil over bedrock)



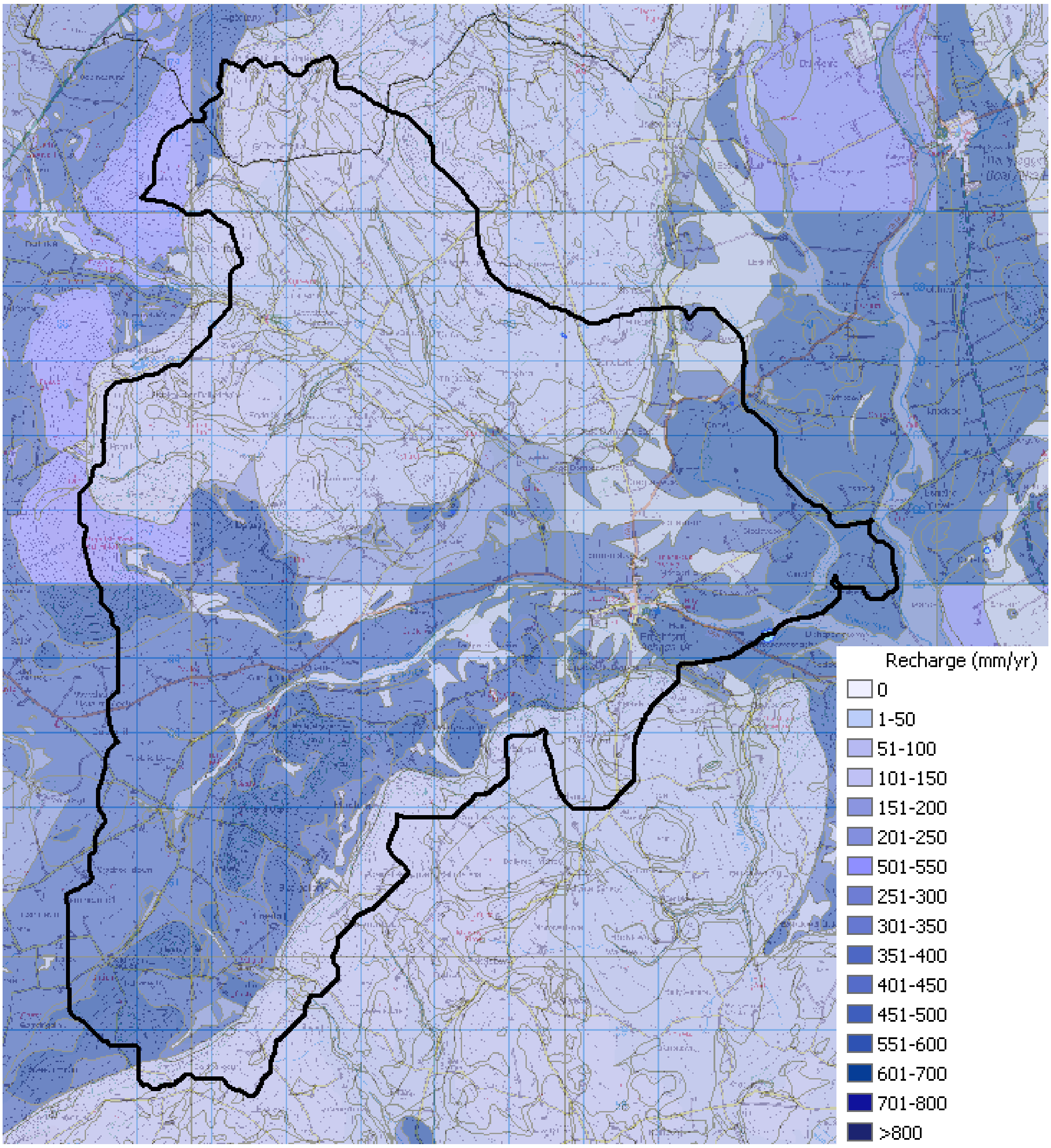
Groundwater Vulnerability



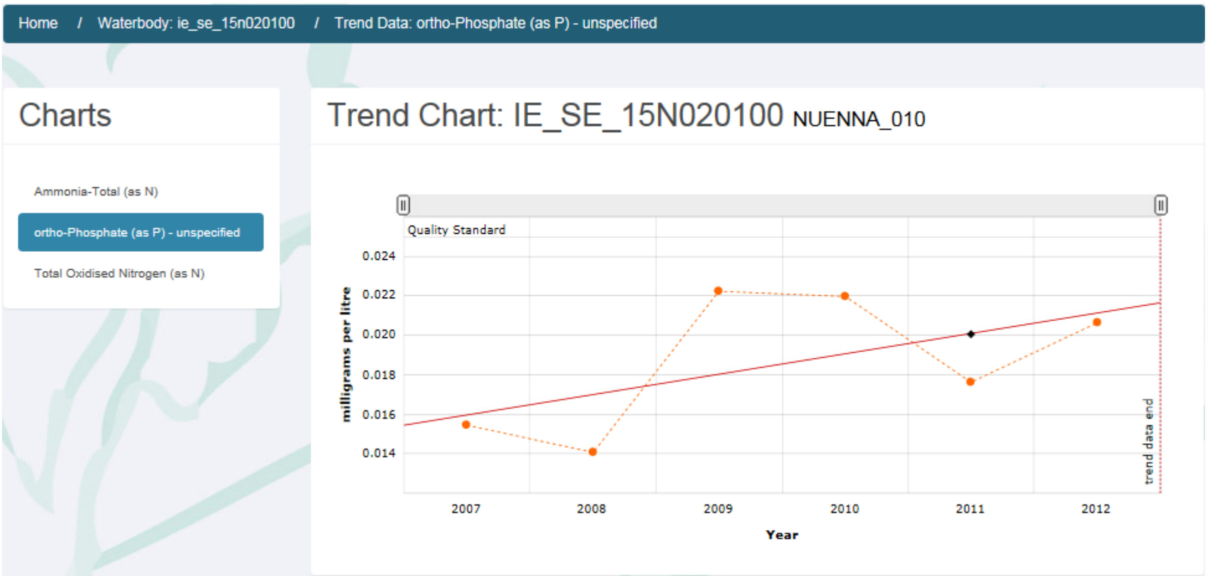
Aquifer Map

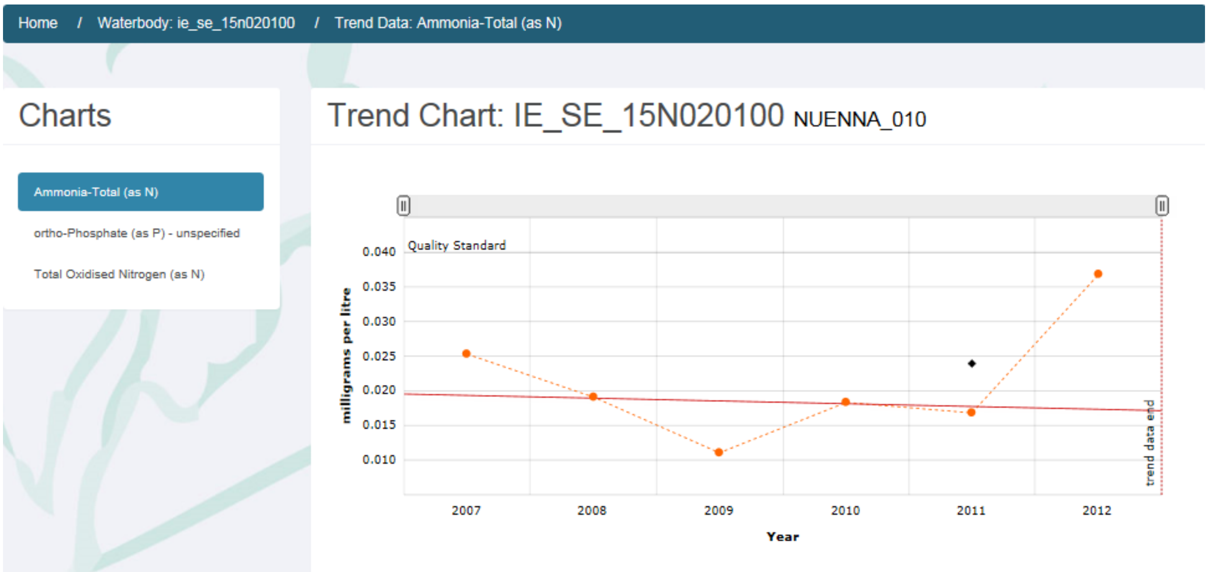

27%
21%
74%
90%
90%
21%
GravelsDec04_V12
Aquifer
Lg
Rg
AquiferBed
AQUIFER
Rf
Rk
Rkd
Rkc
Lm
Lk
Ll
Pl
Pu

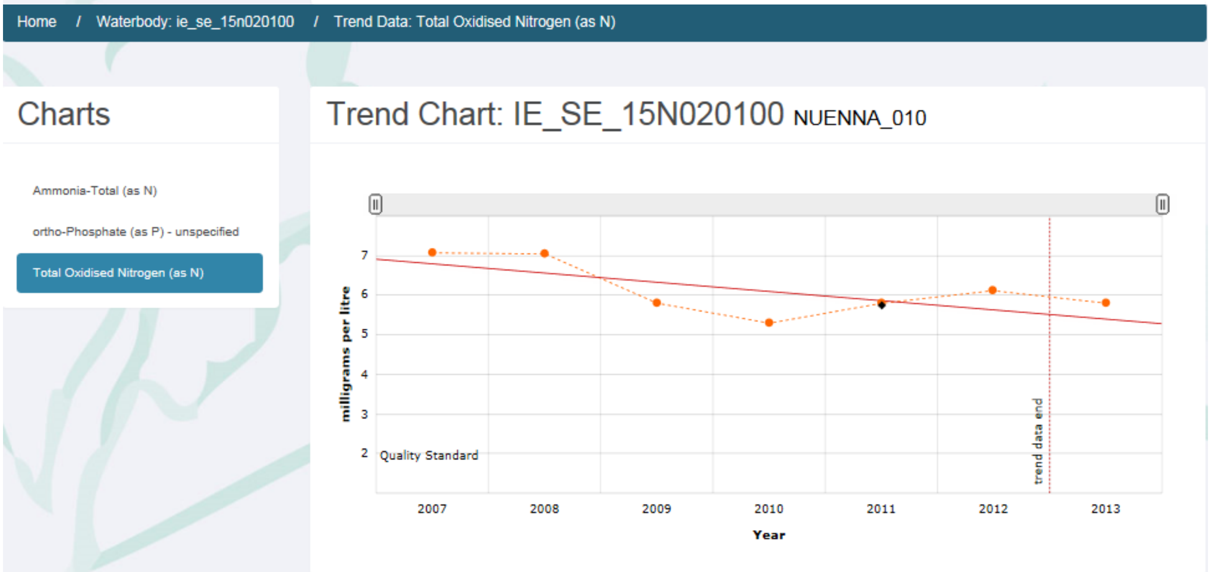
Groundwater Recharge

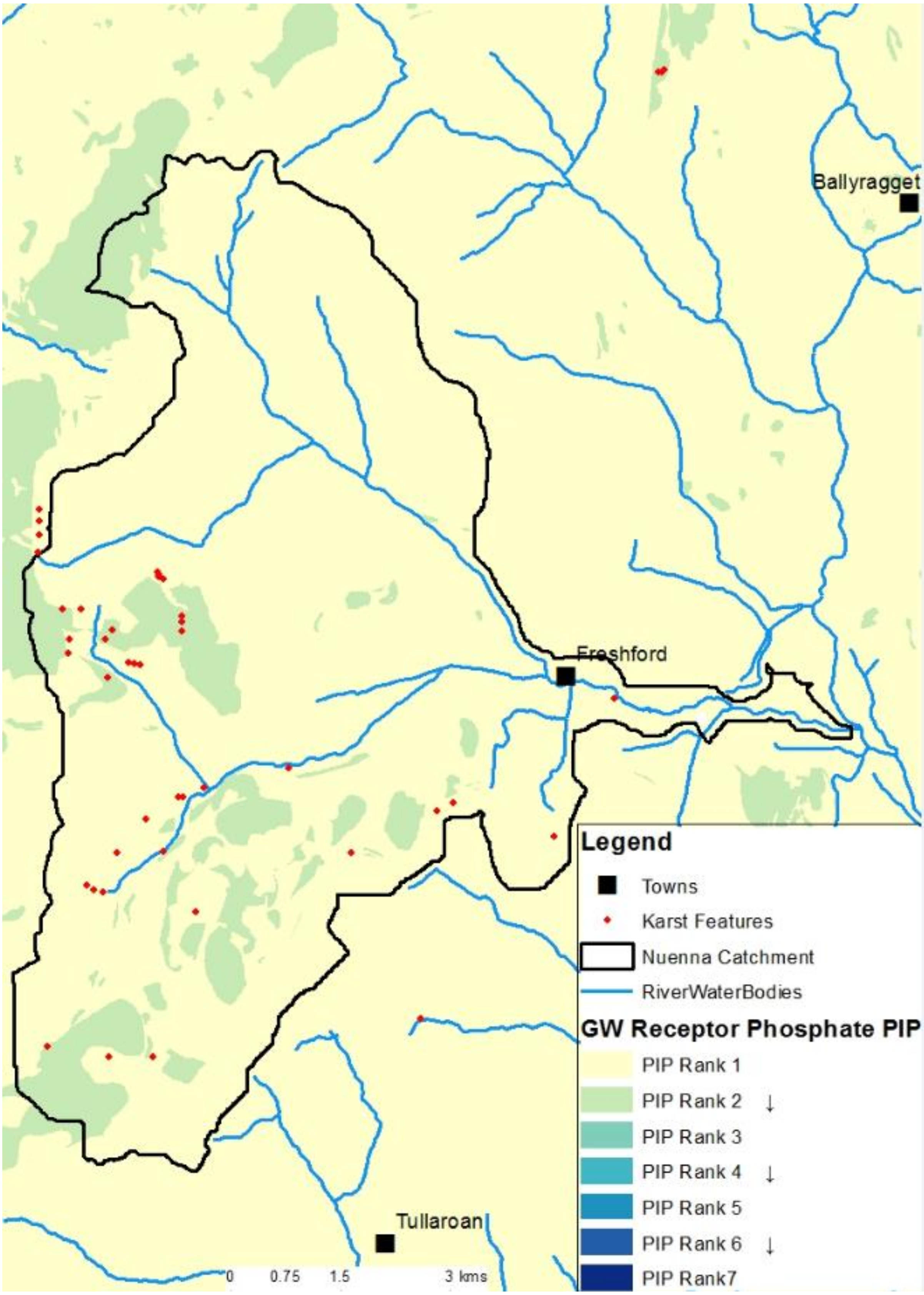


Site 3 Clonmantagh Bridge

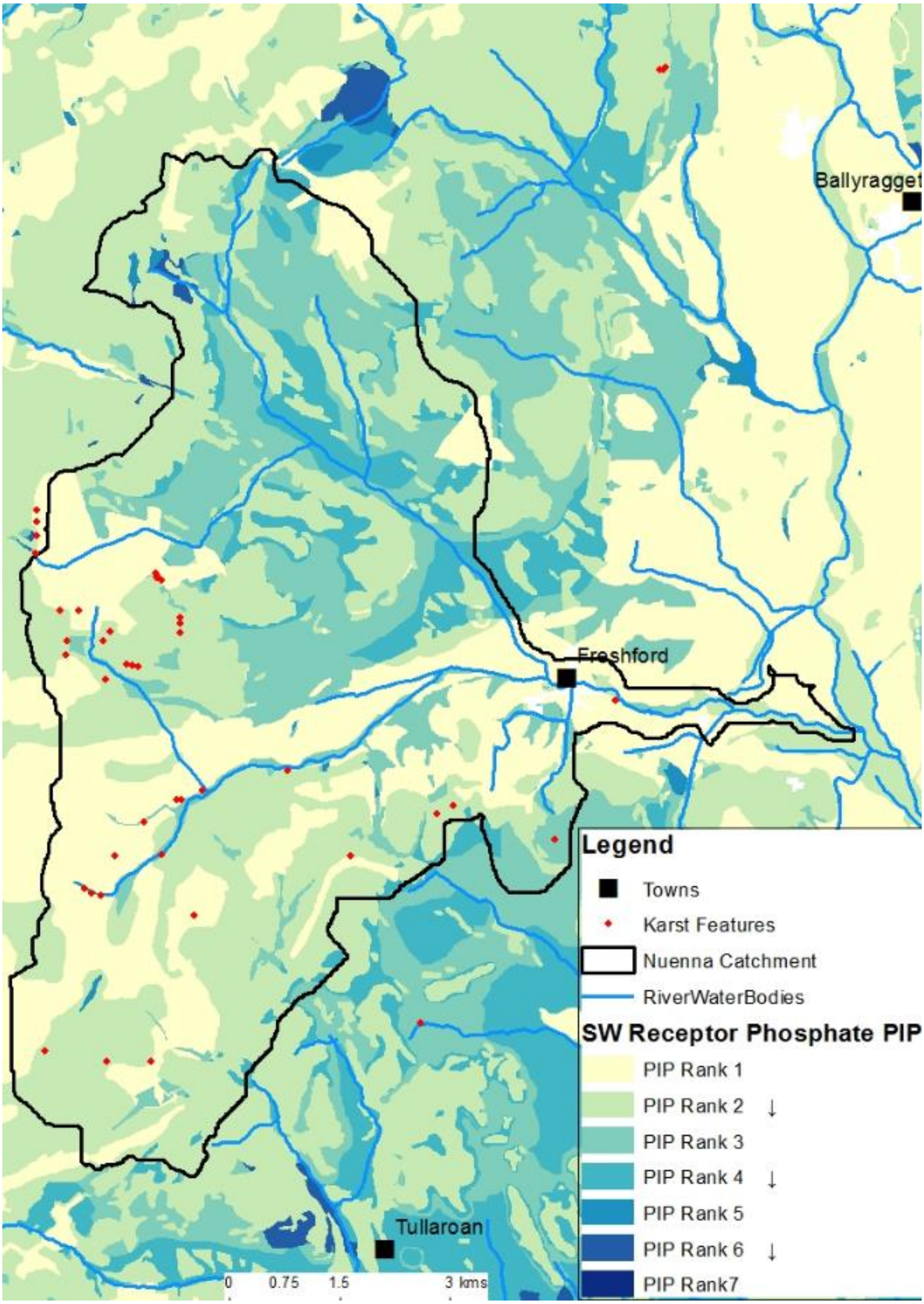




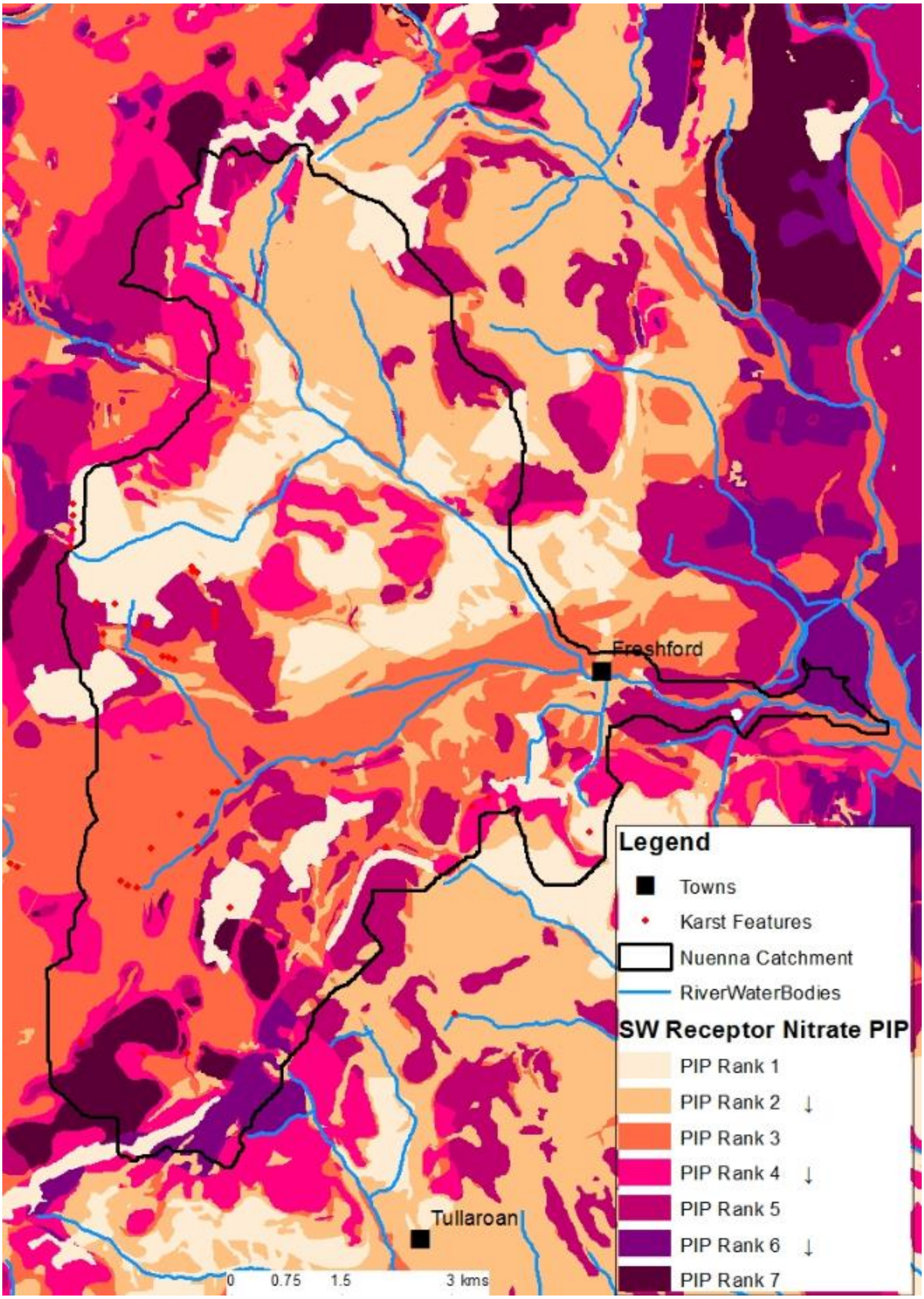




Ballyragget
Freshford
Tullaroan
0 0.75 1.5 3 kms
Legend
Towns
Karst Features
Nuenna Catchment
RiverWaterBodies
GW Receptor Phosphate PIP
PIP Rank 1
PIP Rank 2
PIP Rank 3
PIP Rank 4
PIP Rank 5
PIP Rank 6
PIP Rank7



Ballyragget
Freshford
Tullaroan
0 0.75 1.5 3 kms
Legend
Towns
Karst Features
Nuenna Catchment
RiverWaterBodies
SW Receptor Phosphate PIP
PIP Rank 1
PIP Rank 2
PIP Rank 3
PIP Rank 4
PIP Rank 5
PIP Rank 6
PIP Rank7


Freshford
Tullaroan
Legend
Towns
Karst Features
Nuenna Catchment
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SW Receptor Nitrate PIP
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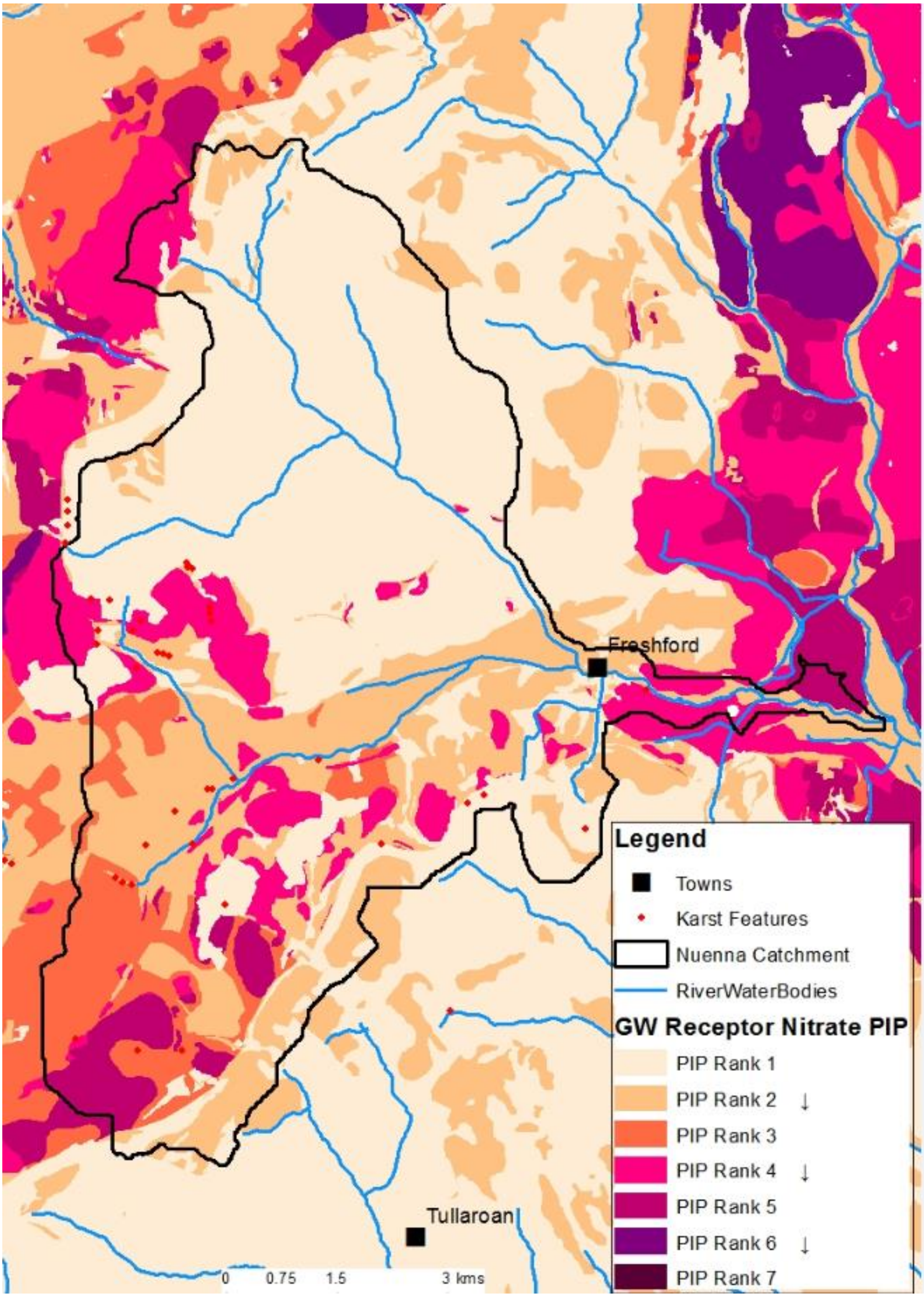
PIP Rank 7
0 0.75 1.5 3 kms

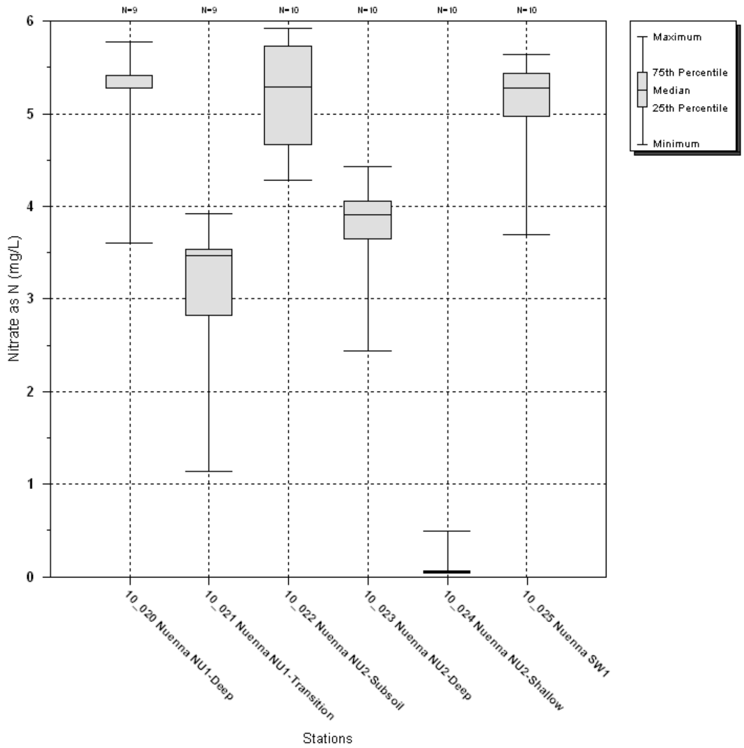

Freshford
Tullaroan
0 0.75 1.5 3 kms
Legend
Towns
Karst Features
Nuenna Catchment
RiverWaterBodies
GW Receptor Nitrate PIP
PIP Rank 1
PIP Rank 2 ↓
PIP Rank 3
PIP Rank 4 ↓
PIP Rank 5
PIP Rank 6 ↓
PIP Rank 7

Drinking Water Supplies in the Nuenna Catchment

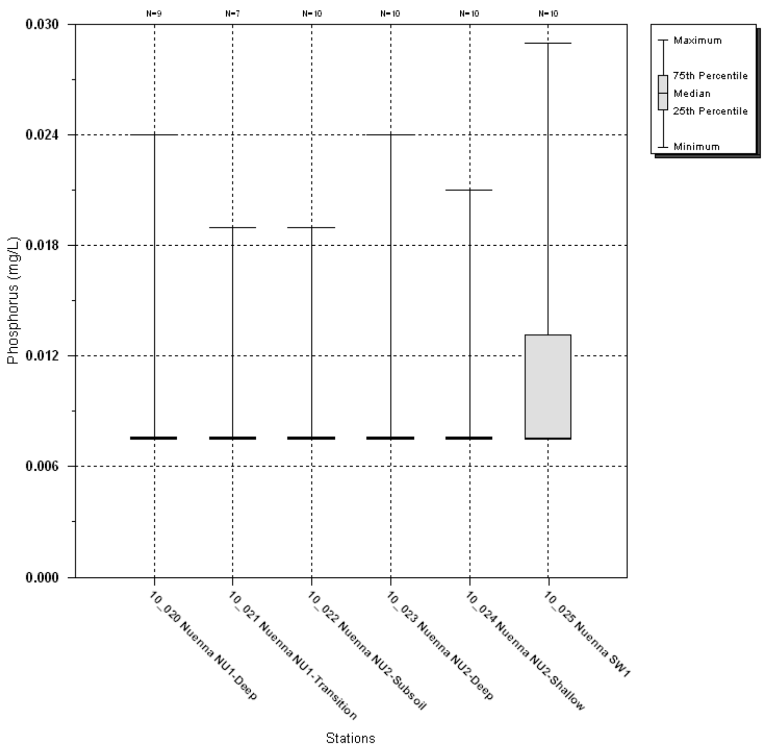
- Balief & Clomantagh GWS
- Barna/Kilrush GWS
- Clomantagh/Killashulan GWS
- Tubrid Lower GWS
- Tubrid Upper GWS
- Parks & Rathcolevin GWS
- Graine GWS

Groundwater Quality in EPA BHs near Clonmantagh Br

Nitrate



Orthophosphate



<u>**EPA STRIVE Pathways Project data**</u>

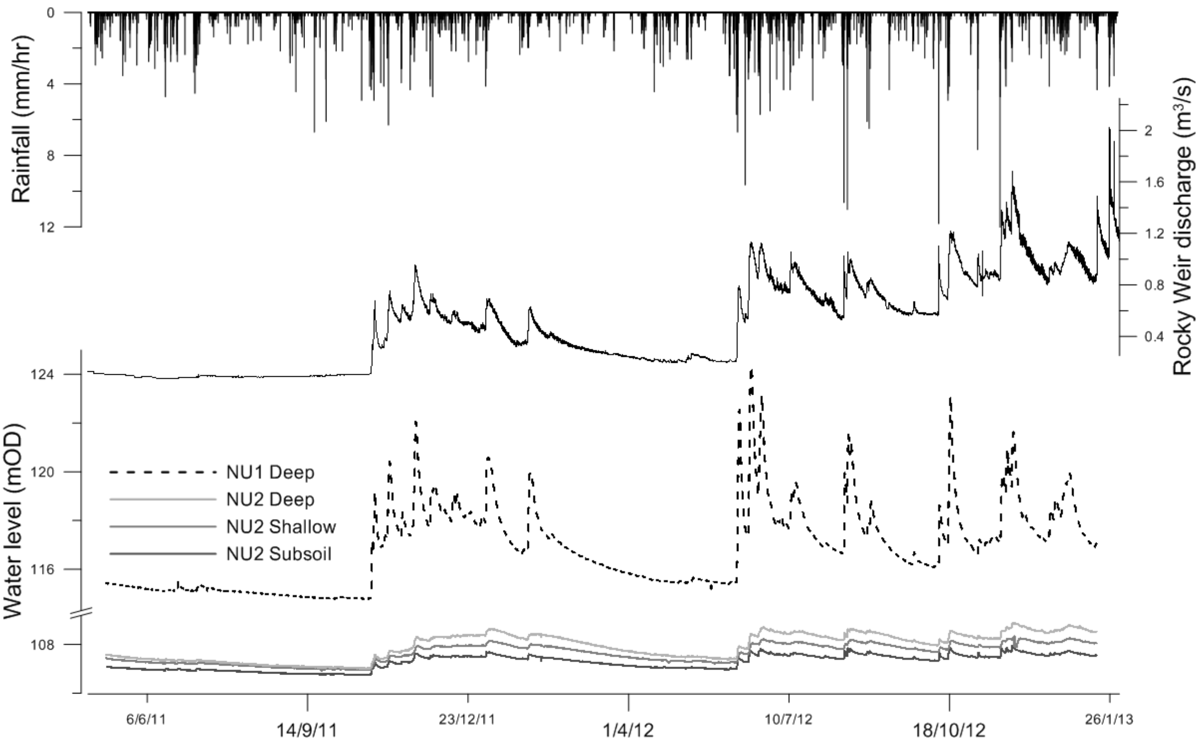


Fig. 1 Groundwater and surface responses to rainfall, Nuenna catchment. Note, the Rocky Weir is located at Clomantagh just above the biological monitoring point. The NU2 suite of boreholes is also located at Clomantagh close to the river, whilst the NU1 suite is higher up the catchment.

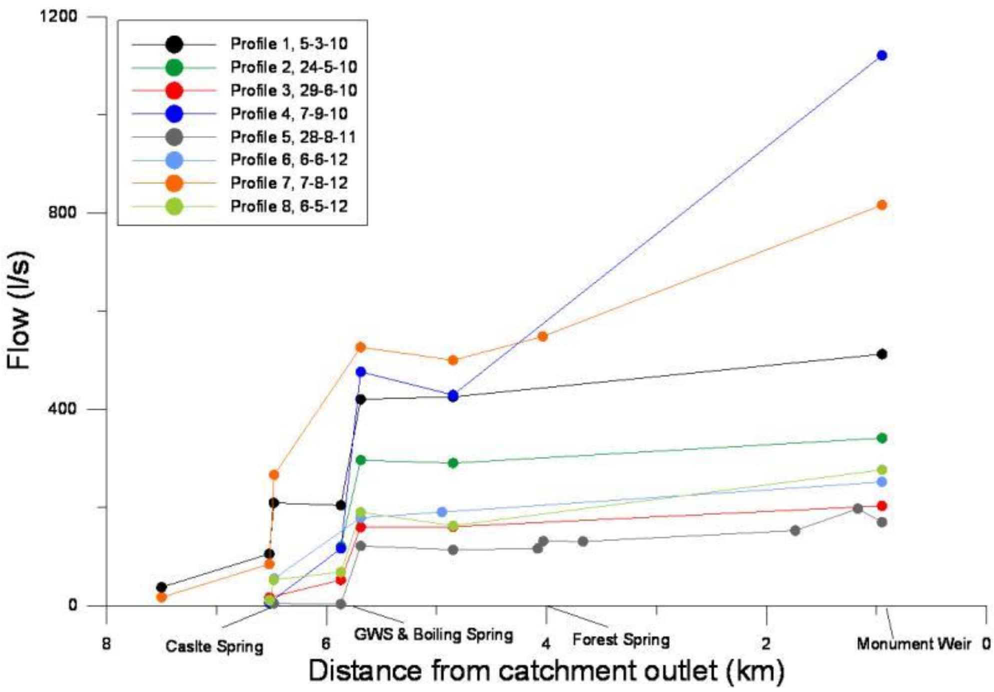


Fig. 2 Changes in flow in the Nuenna with distance from the Pathways project sub-catchment outlet which is above the Gorteehahilla confluence. The major flow increases are due to the presence of a number of large karst springs.

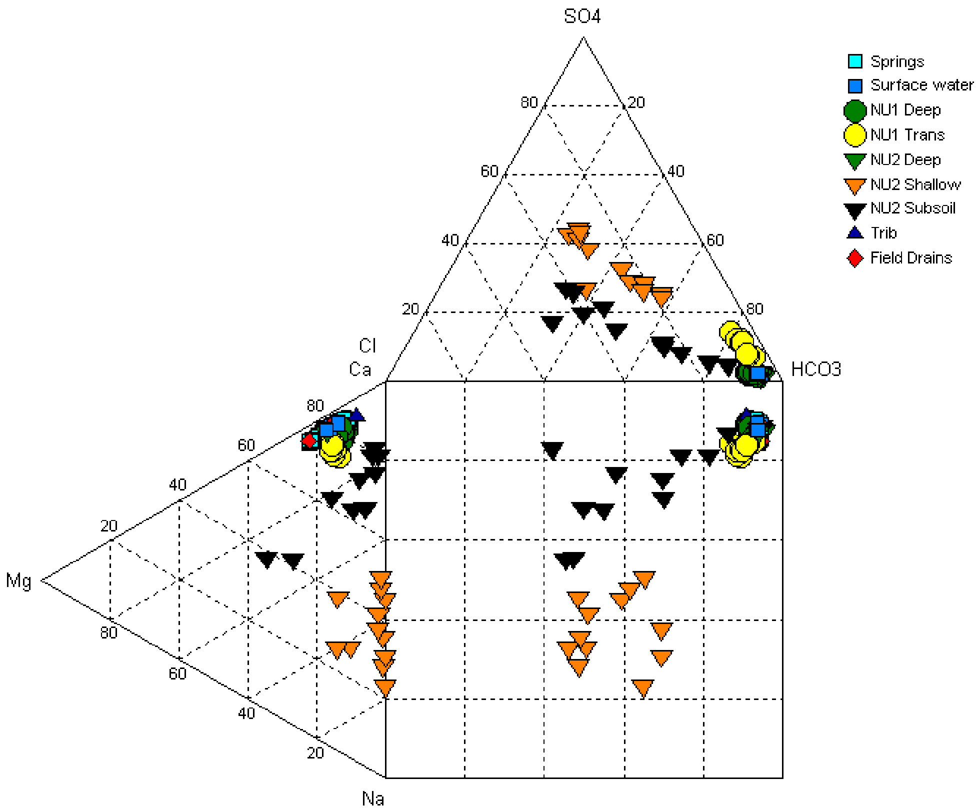


Fig. 3 Durov plot of groundwater and surface water in the Nuenna catchment. River chemistry and groundwater chemistry are very similar with the exception of the 2 shallow boreholes close to the stream where there is a known contamination issue. There is a large contribution of GW to the river.

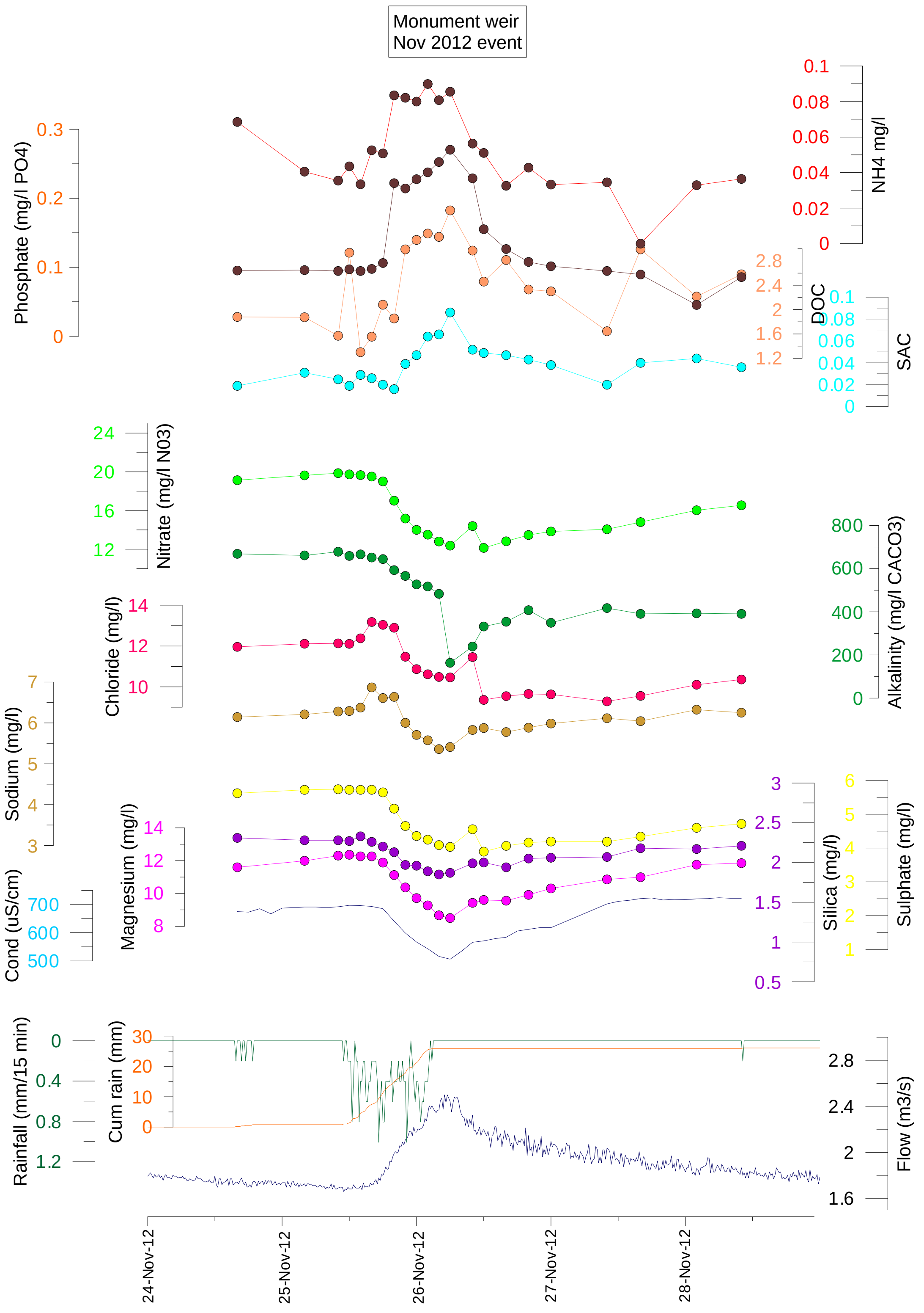


Fig. 4 Surface water flow, rainfall, and chemical parameters at Monument Weir during a rainfall event in November 2012. Data show that major ions and nitrate are delivered via groundwater pathways and are diluted with rain, while PO4 and ammonium are delivered via near surface pathways and increase with rain.

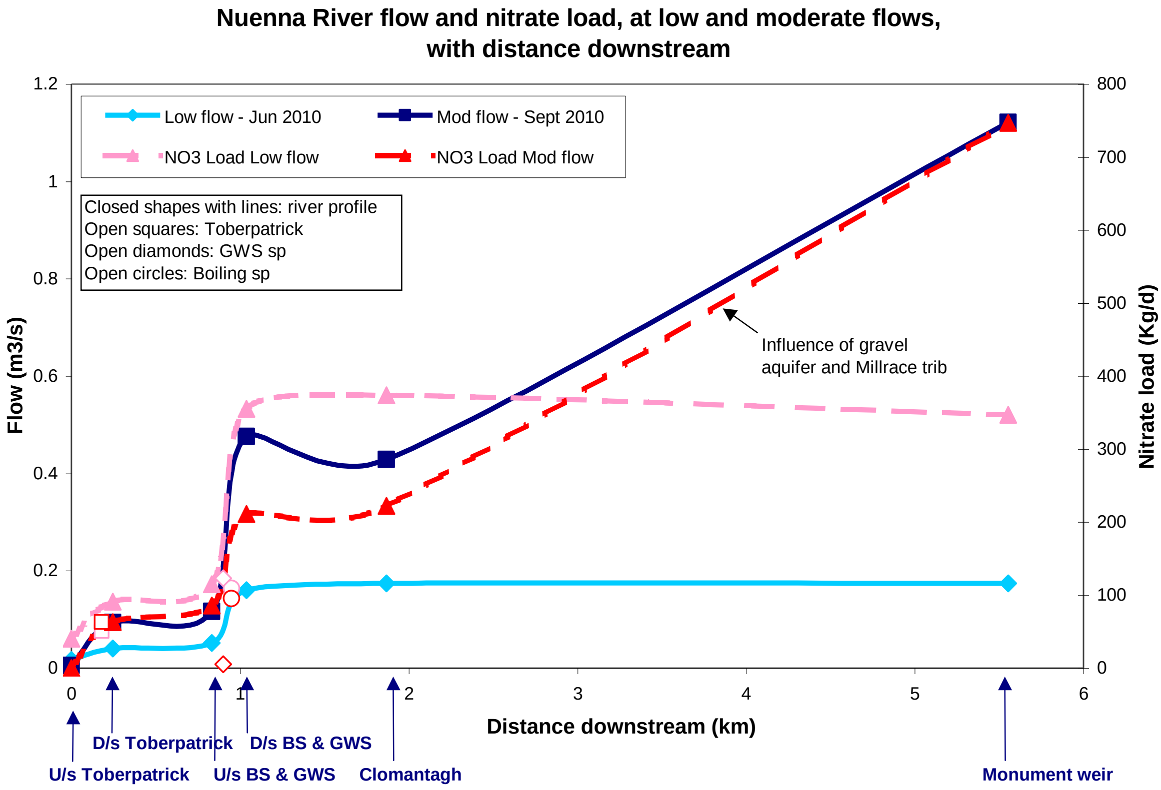


Fig. 5 Nitrate loads with distance downstream. Note increases in fluxes with major springs and higher loads with low flows in summer due to landuse.

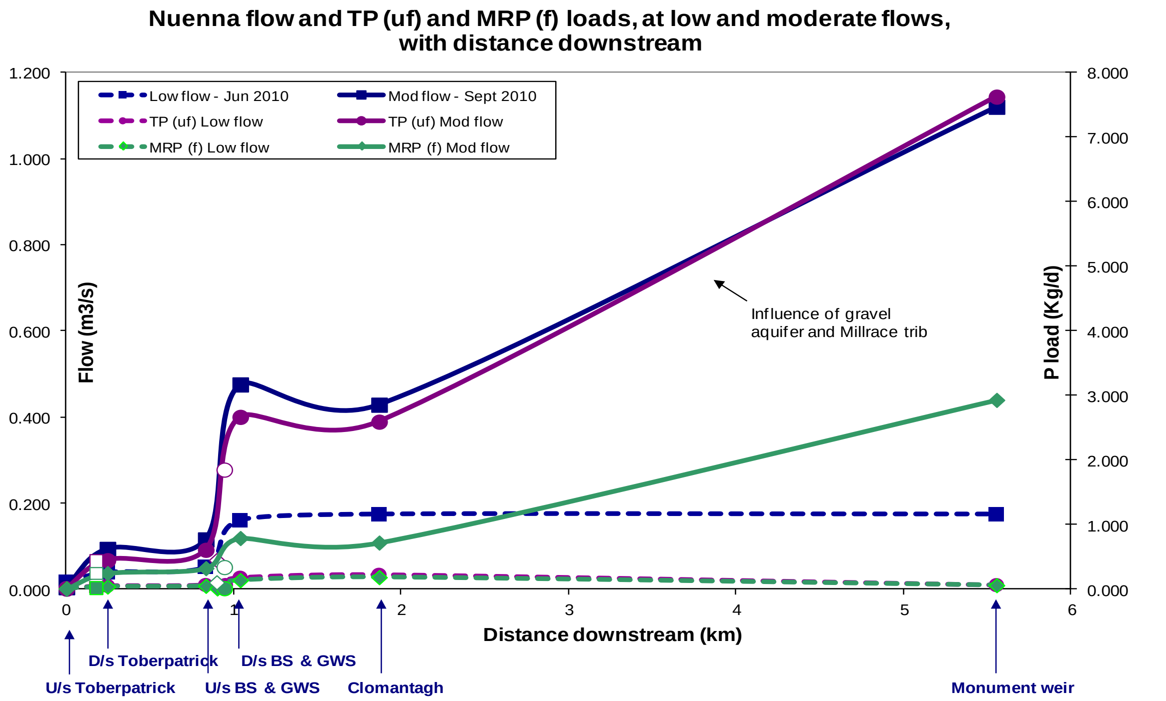
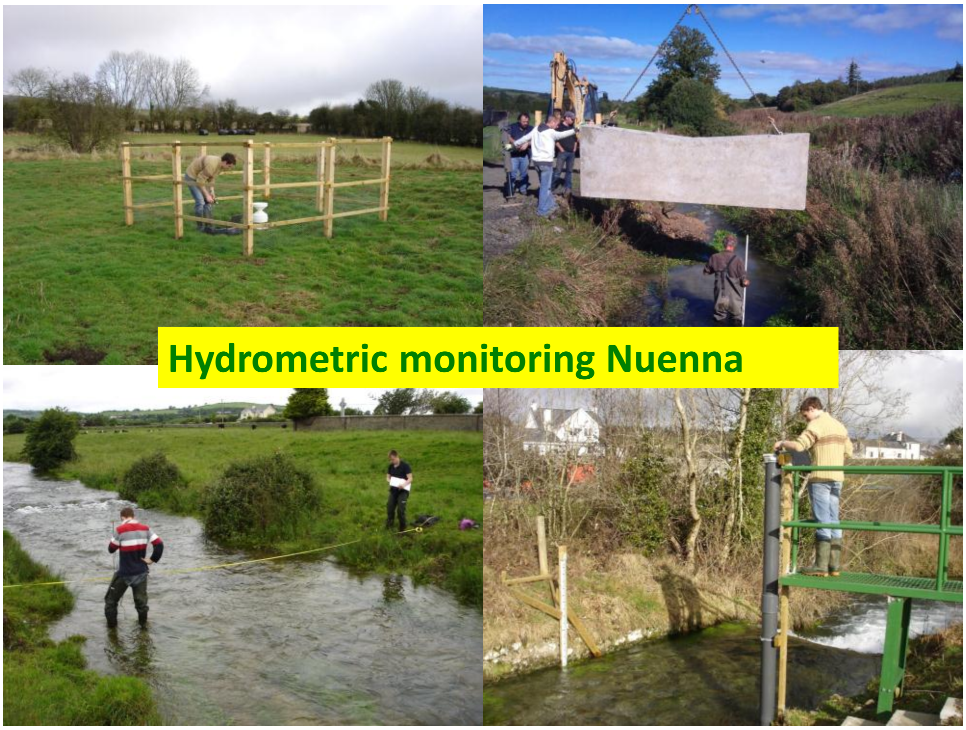


Fig. 6 P loads with distance downstream. Note higher TP than MRP in moderate flows, but low P overall



Hydrometric monitoring Nuenna

Checking rainfall data with double-mass analysis

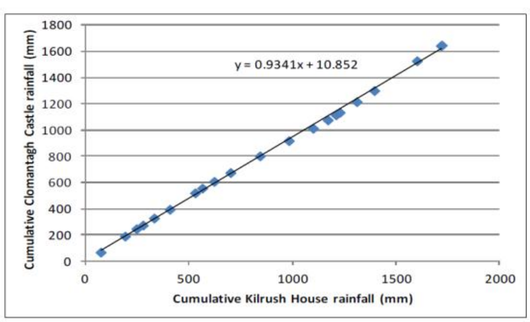


Figure 5-18. Nuenna double-mass curve for Kilrush House and Clomantagh Castle rain gauges (Nov 2010 – May 2012.

(O'Brien, 2013)

Rating curve for one of the stream gauges (Rocky Weir)

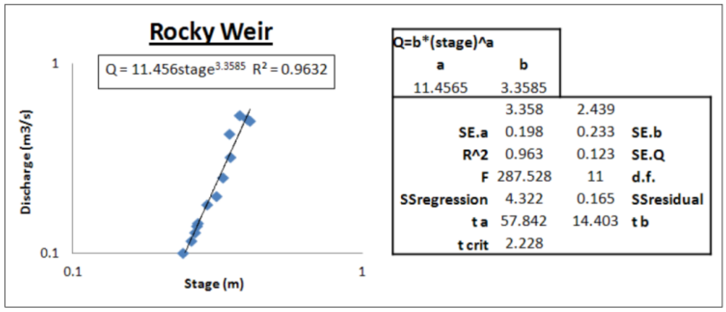


Figure 5-28. Rocky Weir rating Curve and associated power series fitting statistics.

(O'Brien, 2013)

Water balance

Nuenna								
Year	Rain	PE	AE	AE/PE	Effective rainfall	Monument	Rocky	Castle
2011	944.4	498.3	489.3	0.982	455.1		418.5	337.3
2011	966.2	498.3	492.3	0.988	473.9	475.1		
			Topographic area (km^2)			35	21.6	13.8
			Calculated Area (km^2)				19.9	10.2

(O'Brien et al., 2015)

Flow accretion profiles along the Nuenna

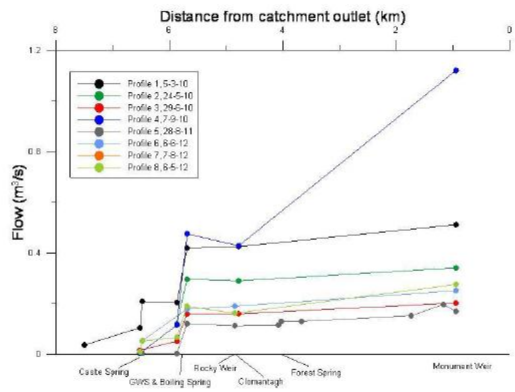


Figure 7.5: Flow along the Nuenna River during spatial sampling rounds

(Deakin et al., 2015)

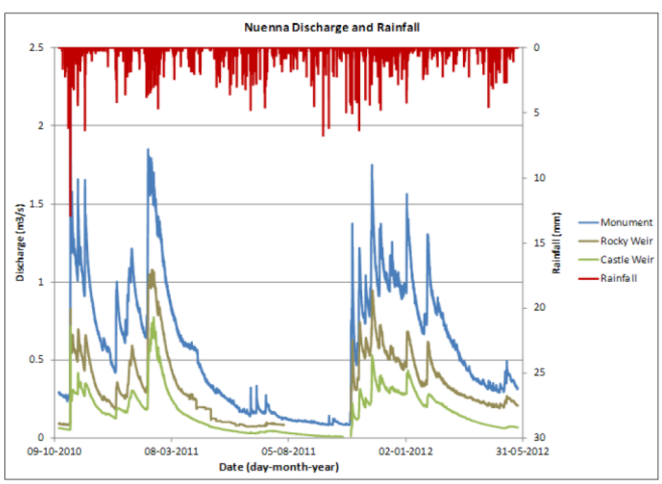


Figure 4-30. Nuenna discharges at the three catchment hydrometric stations with rainfall from Clomantagh Castle (October 2010 to May 2012).

(O'Brien, 2013)

Schematic geological cross section across the Nuenna valley

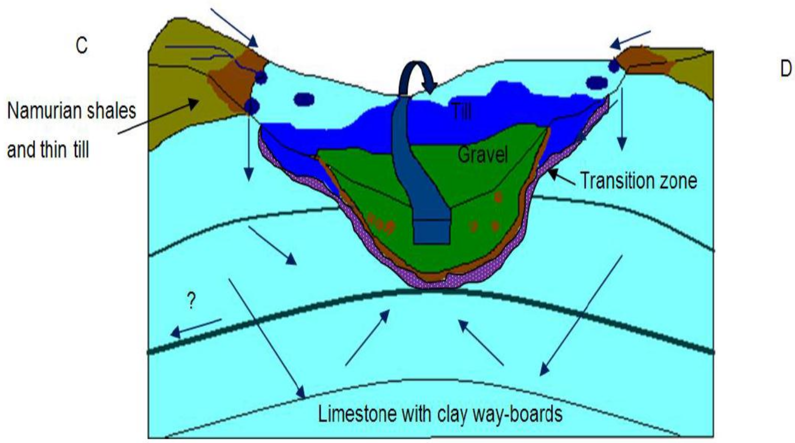
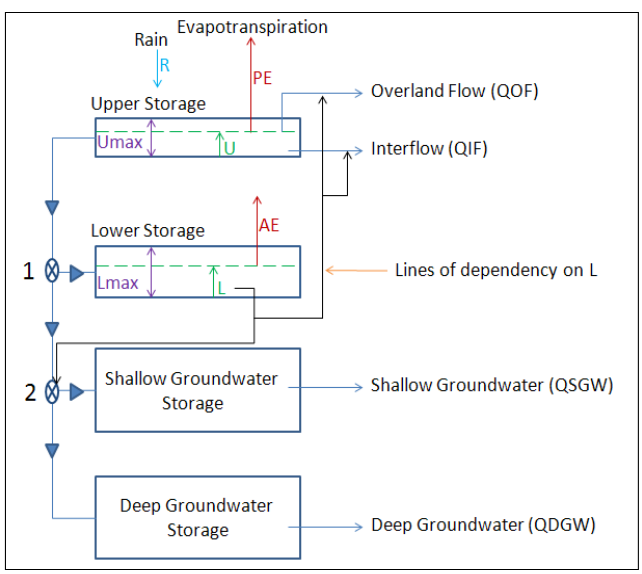


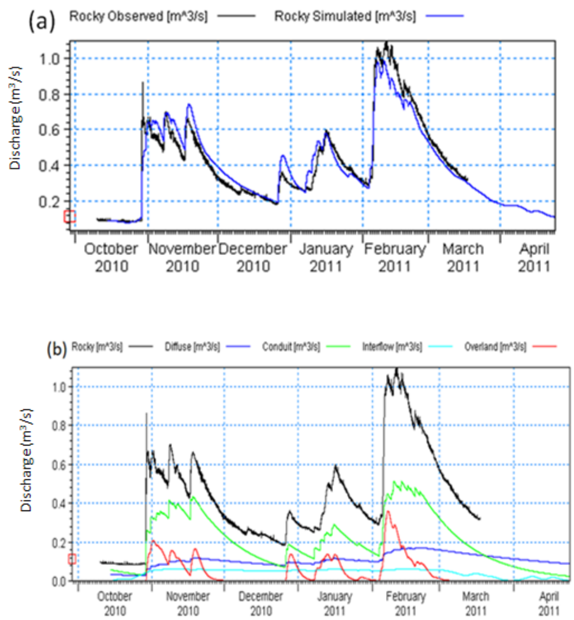
Figure 4-29. Schematic cross-section of the Nuenna, (Archbold and Deakin, 2011).

NAM model structure



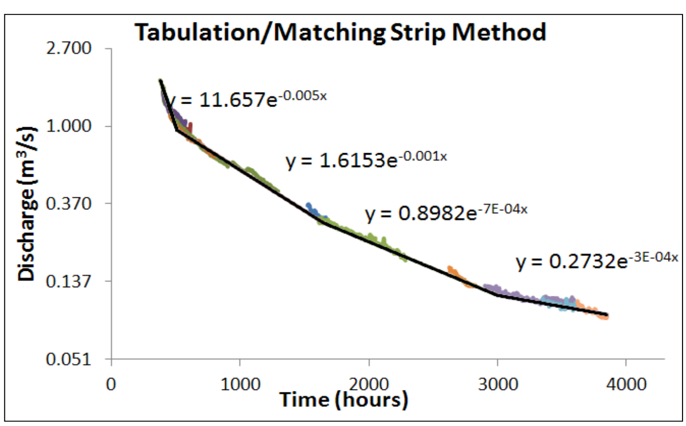
(O'Brien, 2013)

Modelling of Nuenna catchment

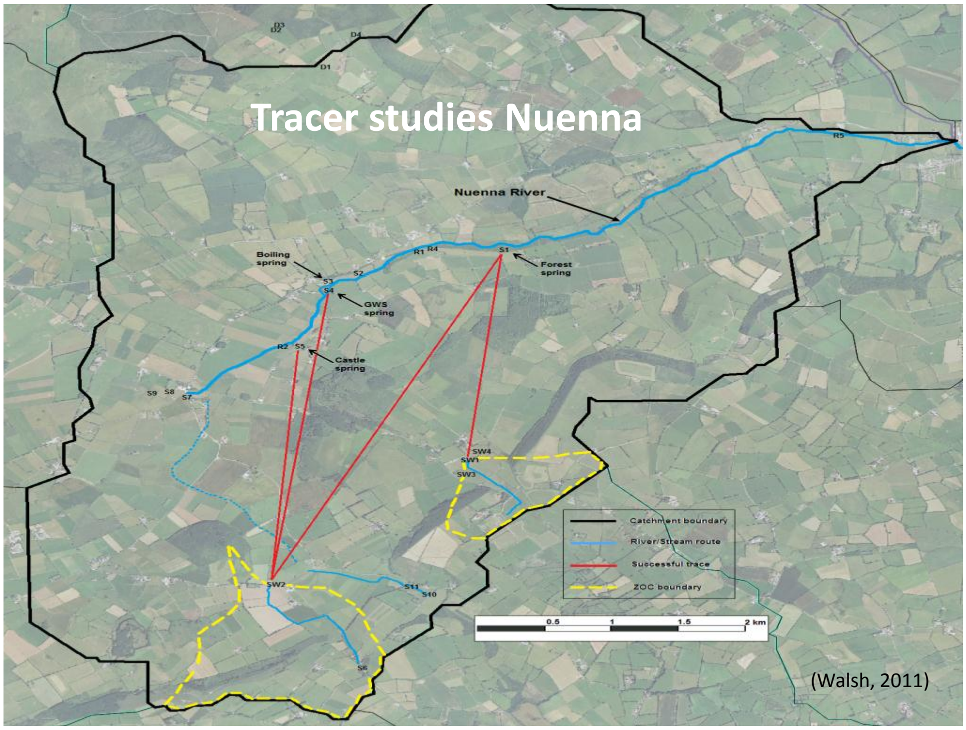


(O'Brien, 2013)

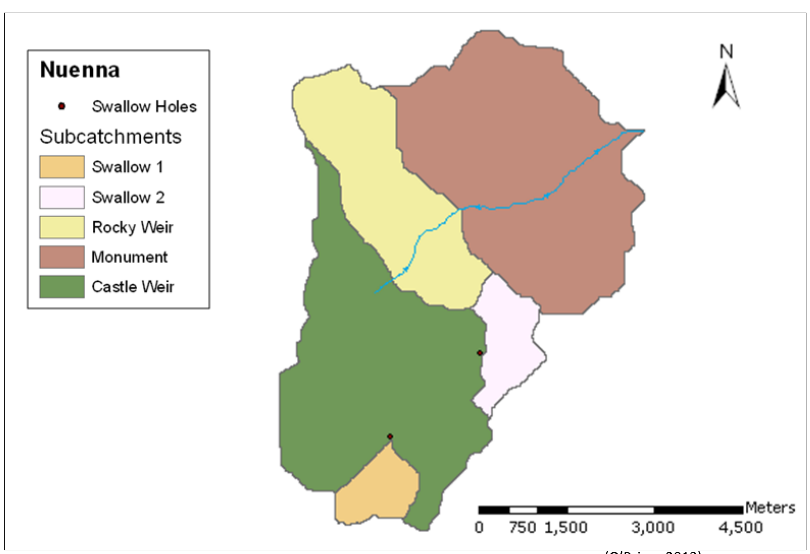
Master recession curve analysis, Nuenna (Monument)



(O'Brien, 2013)



Swallow hole sub-catchments Nuenna



(O'Brien, 2013)

Pathway separations

Catchment	Area (km^2)	Deep Groundwater			Shallow Groundwater			Groundwater	Interflow			Overland			Quick Flow
		MRC	Mod Lyne	NAM	MRC	Mod Lyne	NAM	Recharge Coeff[a]	MRC	Mod Lyne	NAM	MRC	Mod Lyne	NAM	Recharge Coeff[a]
		%	%	%	%	%	%	%	%	%	%	%	%	%	%
Gortinlieve	**0.94**	14.6	6	12.9	5.3	5.9	14.5	11.3	51.6	50	50.8	28.5	38.1	21.8	88.7
Glen Burn (Sub)	**4.79**	11.7	2.4	12.2	11.1	2.4	6.1	18.4	34.3	56.7	39.9	42.9	38.5	41.8	81.6
Glen Burn (Outlet)	**5**	11.7	3.4	4.9	10.4	3.5	7.8	18.9	43.8	62.8	43.6	34.2	30.3	43.7	81.1
Mattock (Div Weir)	**6.99**	8.5	8.8					23.1	49.6	52.2	51.2	41.9	39	32.7	76.9
Mattock (Collon)	**11.61**	12.9	7.4	6.2	15.8	7.6	11.8	23.1	33.7	45.8	48.3	37.7	39.2	33.7	76.9
Mattock (Berril's)	**16.88**	4.5	2.9	9.9	6.5	2.8	6.8	23	30.1	59.2	45.7	58.9	30.13	37.6	77
Nuenna (Castle)	**10.24**[b]	48.5		30.6	36		44.6	70.5	10.3		15.4	5.2		9.4	29.5
Nuenna (Rocky)	**19.89**[b]	51.4		31.9	40.3		47.8	82.2	6.5		13.2	1.8		12.1	17.8
Nuenna (Mon)	**34.99**	44.1		31.7	35.7		45.3	71.3	14.2		13.4	6		9.7	28.7

(O'Brien et al., 2015)

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Developing an integrated hydrograph separation and lumped modelling approach to quantifying hydrological pathways in Irish river catchments

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SUMMARY

An appreciation of the quantity of streamflow derived from the main hydrological pathways involved in transporting diffuse contaminants is critical when addressing a wide range of water resource management issues. In order to assess hydrological pathway contributions to streams, it is necessary to provide feasible upper and lower bounds for flows in each pathway. An important first step in this process is to provide reliable estimates of the slower responding groundwater pathways and subsequently the quicker overland and interflow pathways. This paper investigates the effectiveness of a multi-faceted approach applying different hydrograph separation techniques, supplemented by lumped hydrological modelling, for calculating the Baseflow Index (BFI), for the development of an integrated approach to hydrograph separation. A semi-distributed, lumped and deterministic rainfall runoff model known as NAM has been applied to ten catchments (ranging from 5 to 699 km^2). While this modelling approach is useful as a validation method, NAM itself is also an important tool for investigation. These separation techniques provide a large variation in BFI, a difference of 0.741 predicted for BFI in a catchment with the less reliable fixed and sliding interval methods and local minima turning point methods included. This variation is reduced to 0.167 with these methods omitted. The Boughton and Eckhardt algorithms, while quite subjective in their use, provide quick and easily implemented approaches for obtaining physically realistic hydrograph separations. It is observed that while the different separation techniques give varying BFI values for each of the catchments, a recharge coefficient approach developed in Ireland, when applied in conjunction with the Master Recession Curve tabulation method, predict estimates in agreement with those obtained using the NAM model, and these estimates are also consistent with the study catchments' geology. These two separation methods, in conjunction with the NAM model, were selected to form an integrated approach to assessing BFI in catchments.

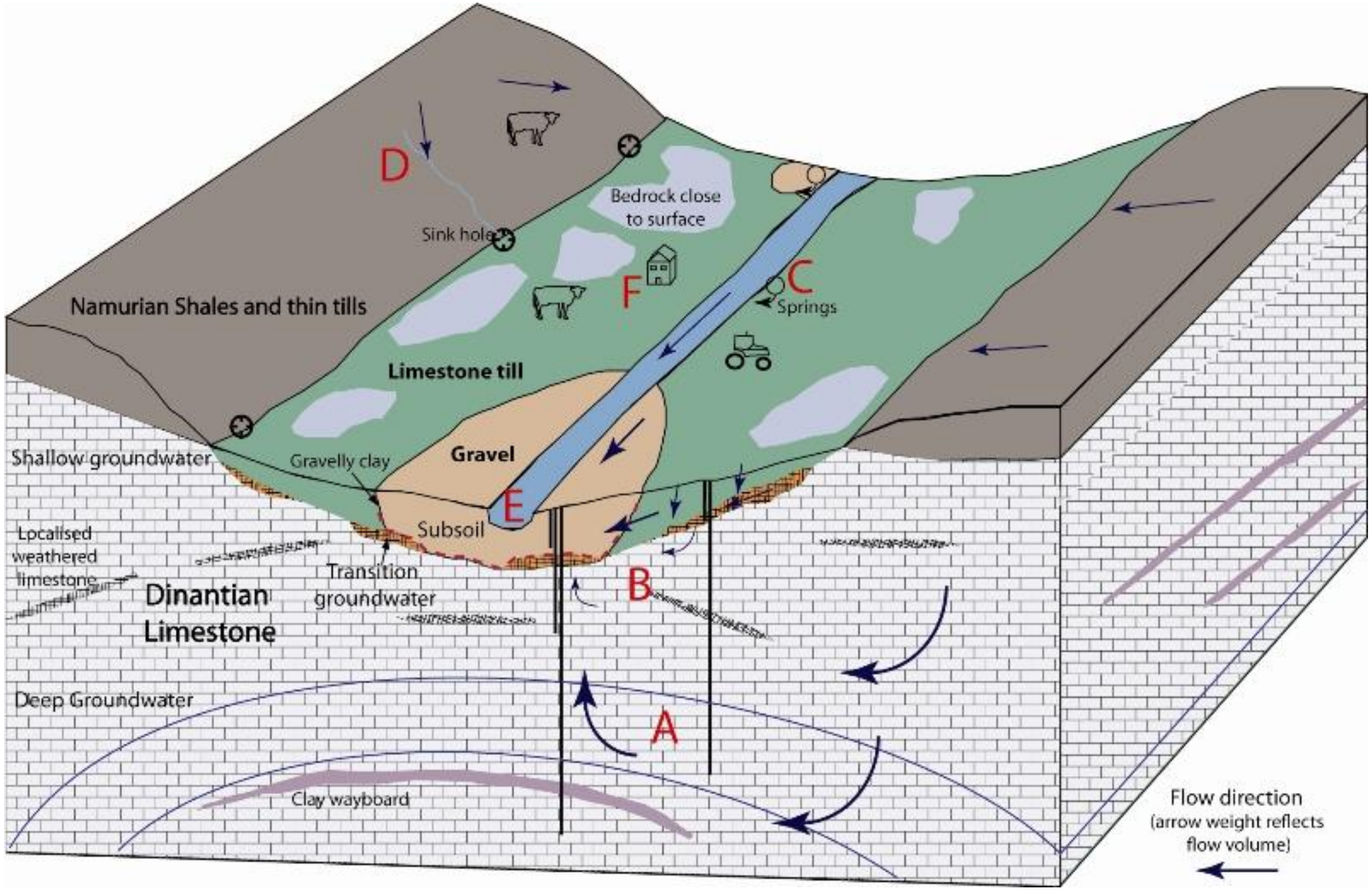


Figure 1 Conceptual model of the Nuenna catchment

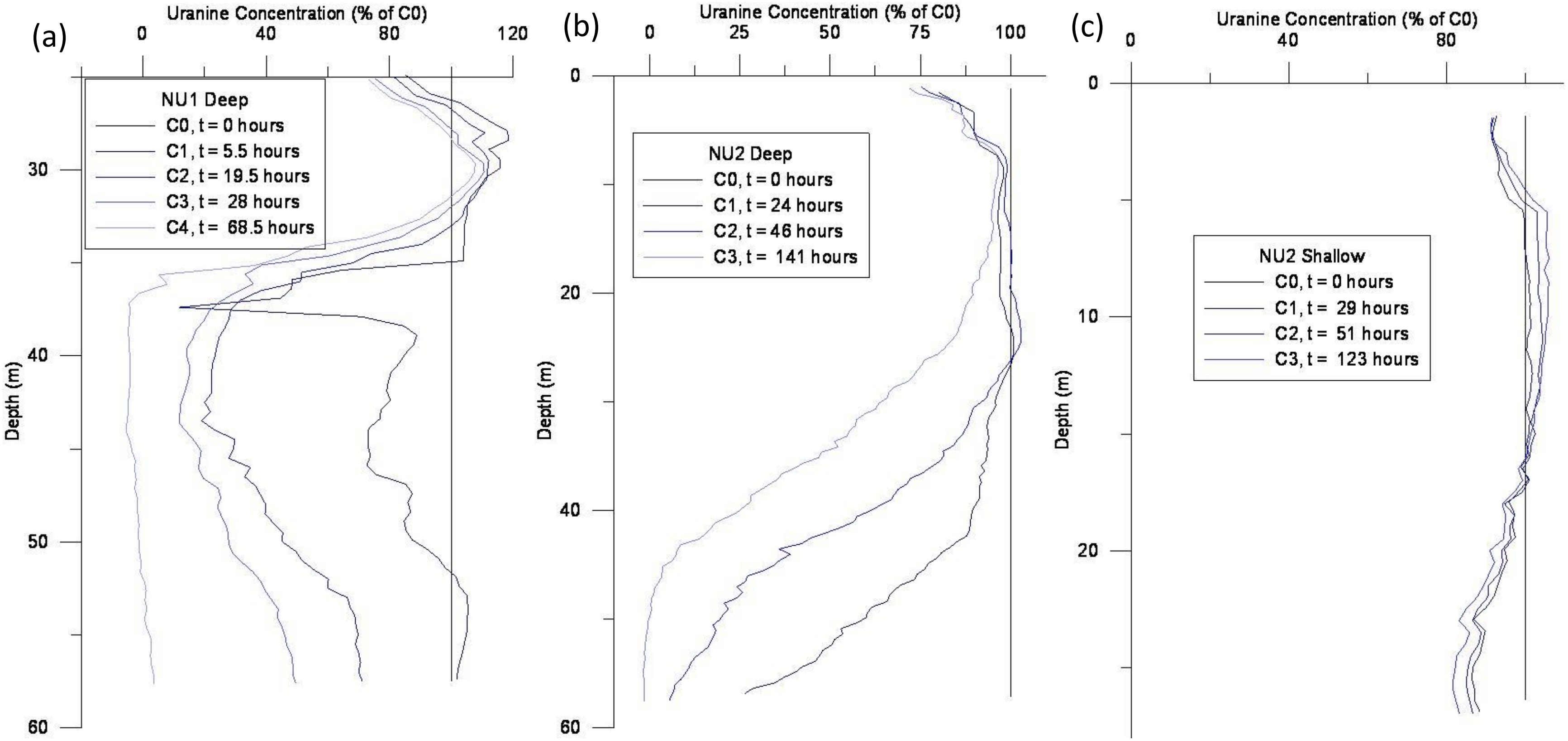


Figure 2 Hydraulically active fracture tracer tests in NU1 Deep (a), NU2 Deep (b) and NU2 Shallow (c) showing the percentage uranine dilution over time relative to the initial concentration (C0, t = 0 hours)

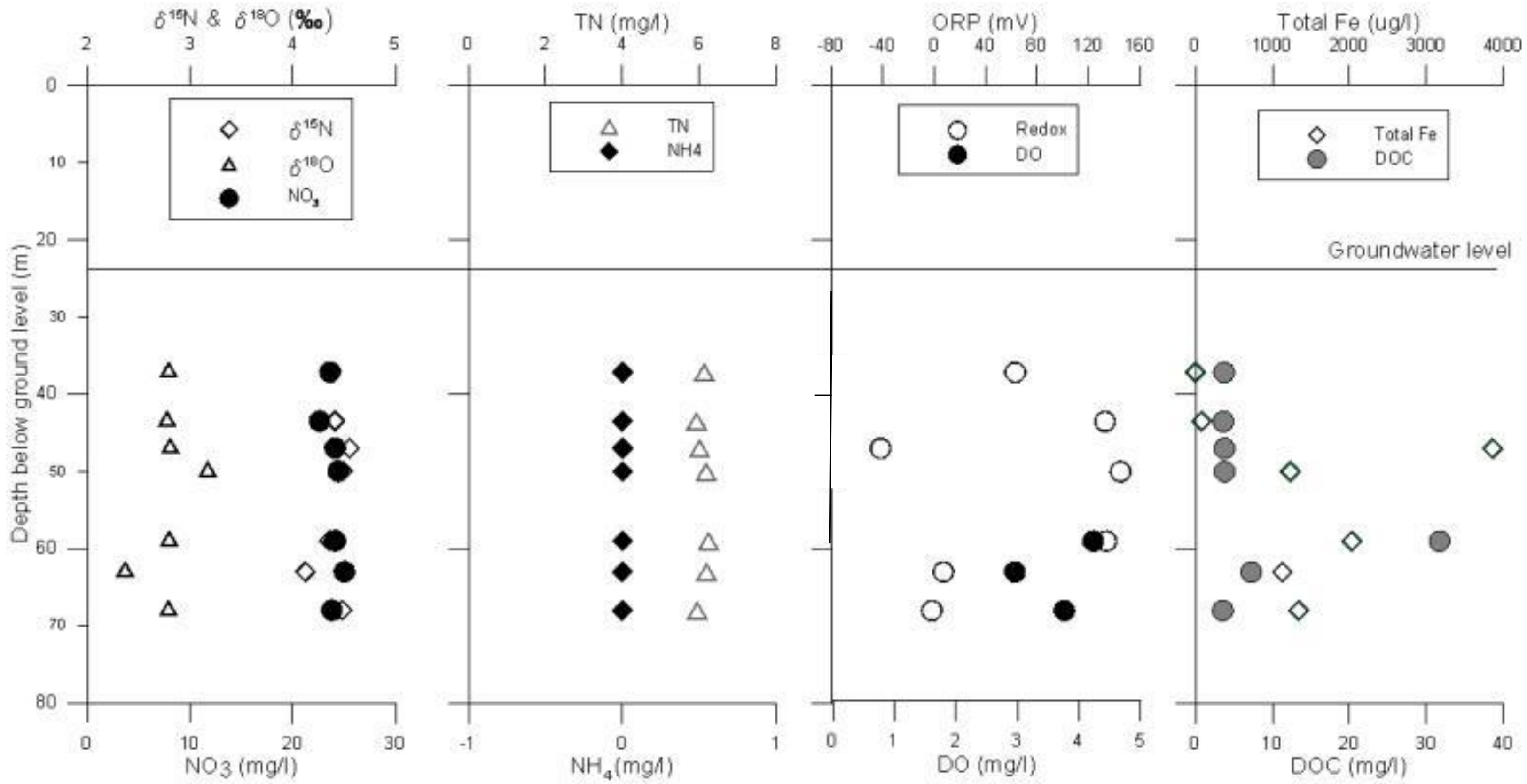


Figure 3 Stratification of NO_3, TN, NH_4, ORP, DO*, total Fe and DOC concentrations and NO_3 isotope ($\delta^{15}N$ and $\delta^{18}O$) values with depth in NU1 Deep

*missing DO results are due to instrument failure.

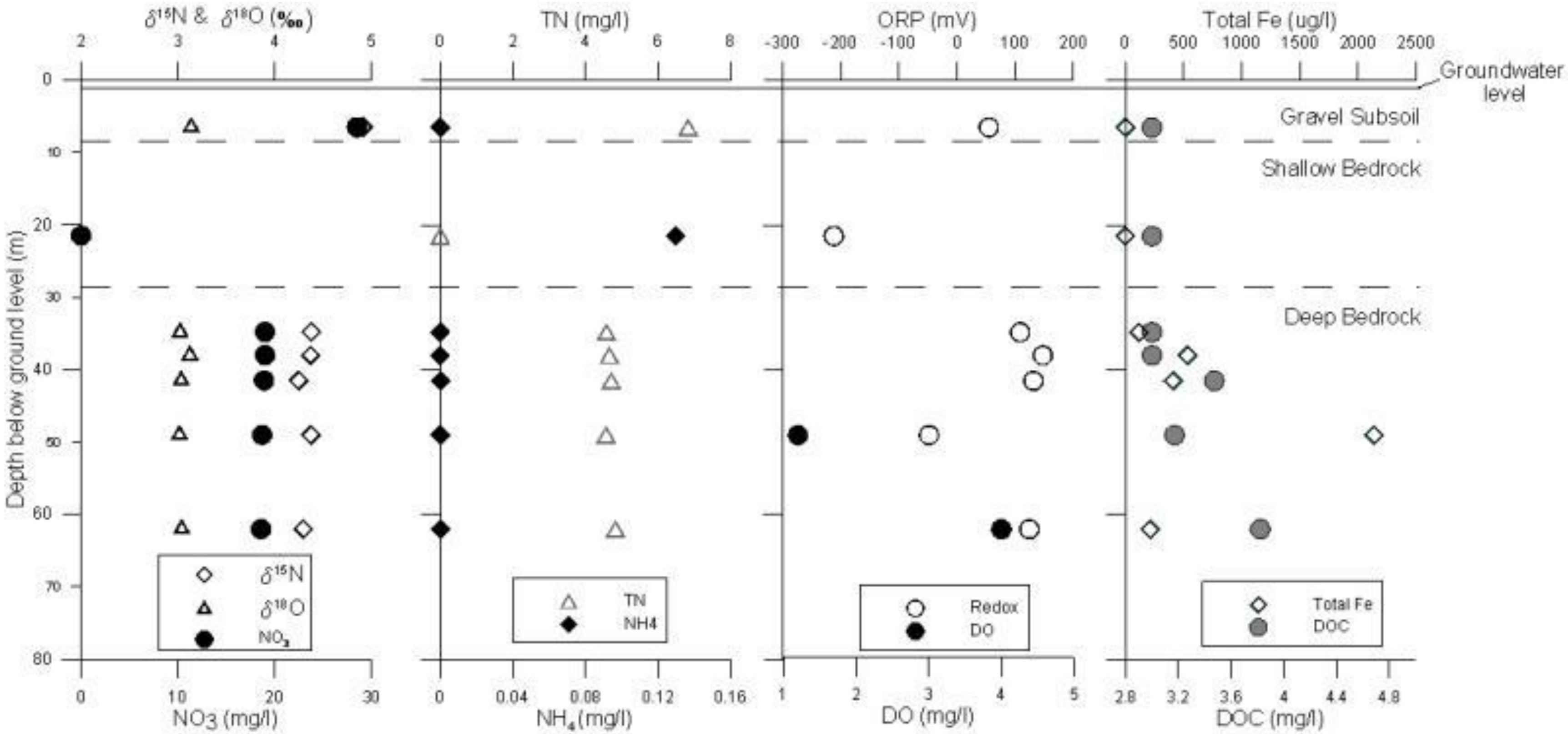


Figure 4 Stratification of NO_3, TN, NH_4, ORP, DO*, total Fe and DOC concentrations and NO_3 isotope ($\delta^{15}N$ and $\delta^{18}O$) values with depth in the NU2 borehole cluster

*missing DO results are due to instrument failure.

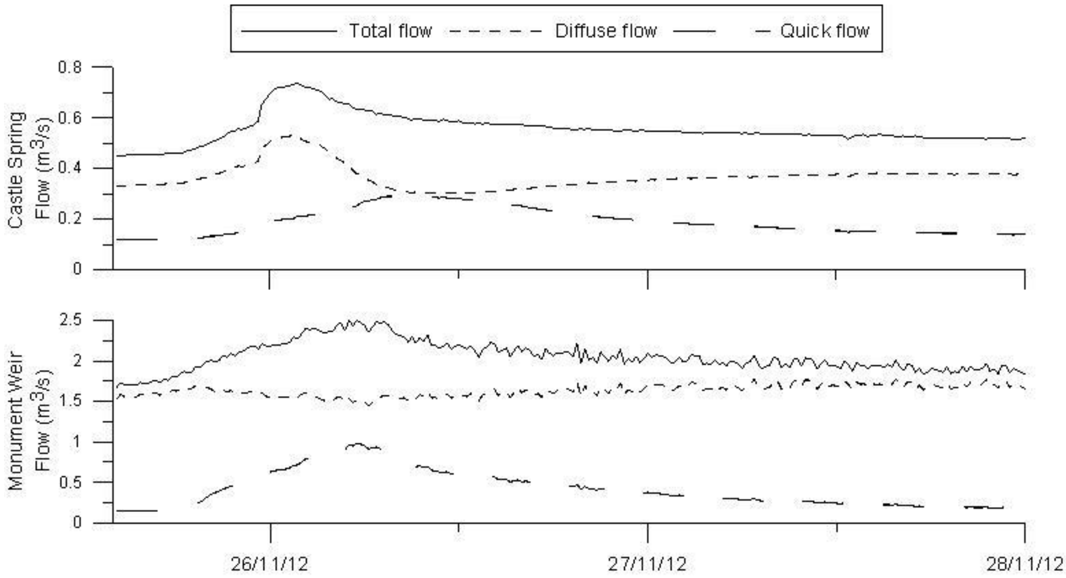


Figure 5 Simulated discharge of diffuse and quick flow pathways from chemical hydrograph separation at Castle Spring (bottom) and Monument Weir (top), November 2012

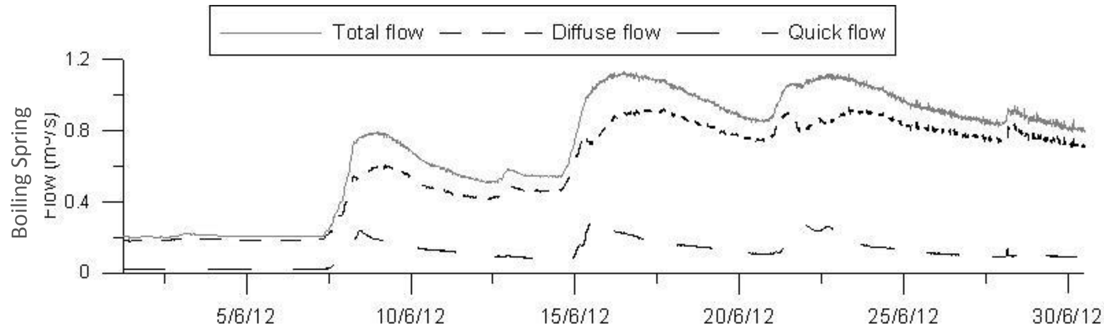


Figure 6 Simulated discharge of diffuse and quick flow pathways from chemical hydrograph separation at Monument Weir, June 2012

		Diffuse GW flow (%)	Quick flow (%)	Diffuse GW N flux (%)	Quick flow N flux (%)
Castle Spring	Pre event baseflow	74	26	89	11
	Event peak	71	29	94	6
	Quick flow peak	51	49	79	21
	Post event baseflow	74	26	89	11
Boiling Spring	Pre event baseflow	90	10		
	Peak of Event 1	69	31		
	Peak of Event 2	71	29		
	Peak of Event 3	75	25		
Monument Weir	Pre event baseflow	92	8	96	4
	Event peak	61	39	87	13
	Post event baseflow	92	8	95	5

Table 1 Proportion of diffuse groundwater (GW) and quick flow into Boiling Spring in June 2012, and flow and N flux into Castle Spring and Monument Weir in November 2012

Groundwater / surface water interactions –Are our assumptions right?

Looking through some hydrogeology text books one might be forgiven for thinking that the sole purpose of rivers is to receive groundwater discharging from aquifers. Although this is undoubtedly correct in many cases, the relationship can be more complex. Concepts such as bank storage remind us that hydraulic gradients acting between rivers and aquifers can reverse, resulting in groundwater being recharged by surface water. Similarly, natural gradients may be artificially reversed through induced recharge programmes to treat poorer-quality river water by passing it through adjacent aquifer materials to provide purer (ground)water that is more suited to human consumption. In this way, the purifying processes operating at the interface between groundwater and surface water can provide important geo-ecosystem services. Failure to consider these processes may have significant implications for understanding natural processes not in terms of drinking water quality, but for hydrological flow balances across entire catchments.

Despite proven benefits, the interaction of groundwater with rivers has been relatively neglected. Recognition of this knowledge gap by hydrological and hydrogeological communities in recent years has resulted in a significant improvement in our understanding of processes generating exchanges between groundwater-surface water. Nonetheless the role of these processes in heterogeneous catchments, such as those typically encountered in many parts of Ireland, remains poorly understood. The EPA STRIVE Pathways project aimed to better define hydrological processes in geologically heterogeneous catchments, such as that of the Nuenna River, Co. Kilkenny. Physical and chemical hydrogeological investigations completed in the framework of the project pointed to complex processes operating in the groundwater flowing through the diffusely karstified Lower Carboniferous limestone bedrock that underlies much of the area. Water discharged from the aquifer in a series of springs downstream of the river’s headwaters, with river discharge increasing downstream (as the catchment size increased). By contrast contributions to flow even further downstream, where the river passed onto a plain of deep alluvium, proved more ambiguous.

A programme of in-channel artificial tracer testing, employing non-reactive fluorescent tracers and mobile field fluorometers, coupled with point discharge measurements, aimed to characterise this process in greater detail (Figure 1). Three successive tests involved injecting pulses of tracer at increasing distance from the headwaters, while monitoring concentrations at three fixed downstream points. Simultaneous measurement of river discharge at monitoring points permitted comparison of flow rates determined from integration of tracer breakthrough curves, while continuous discharge monitoring confirmed no significant changes in flow rate over the duration of the studies.

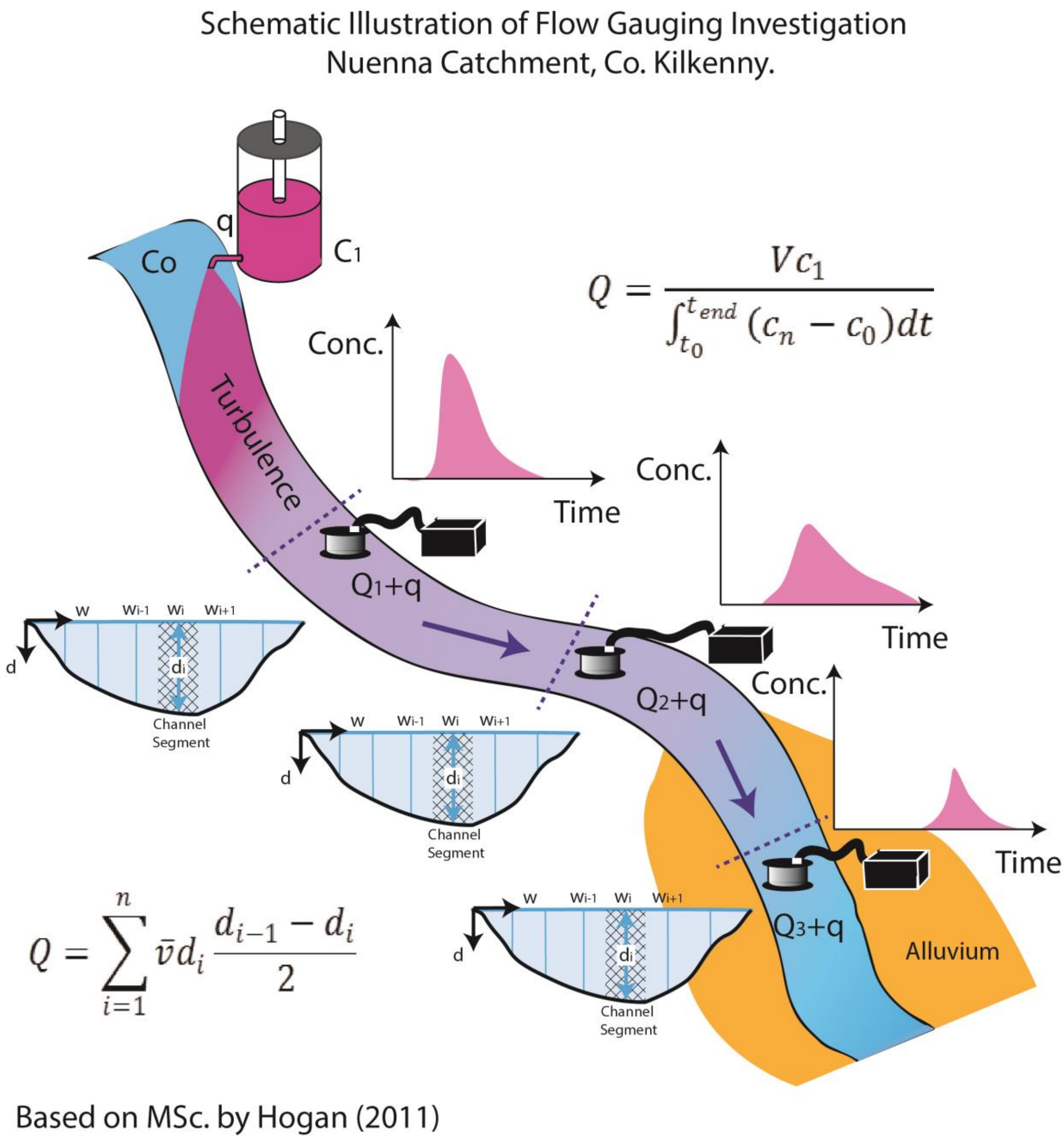
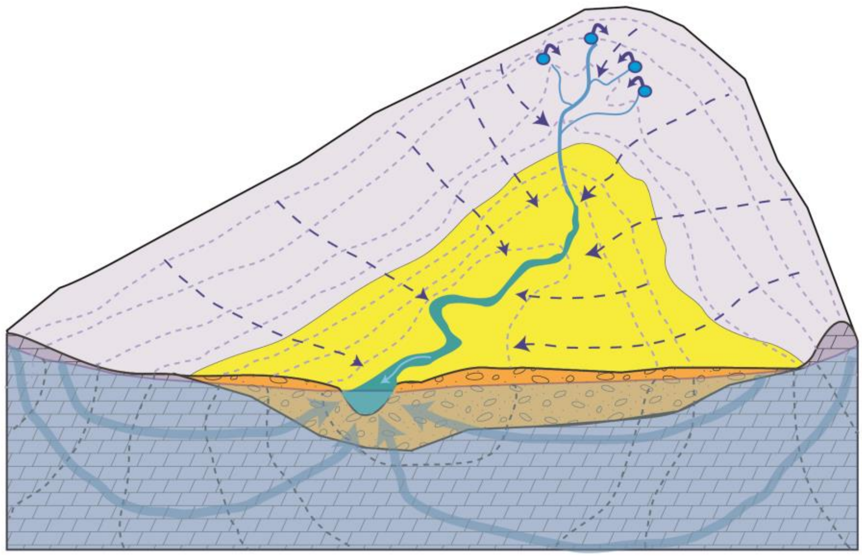


Figure 1

Analysis of tracer test results confirmed that flow rates increased from the headwaters to a point where an extensive sequence of deeper alluvium was encountered. However, in contrast to monitoring locations upstream, where rates determined from solute responses and classical flow gauging corresponded, a comparable relationship was not observed as the river flowed across the deep alluvium, nor was a the progressive increase in discharge rate observed as the river's catchment increased. Instead, flow measurements indicated that river discharge plateaued as Nuenna River passed onto the deeper alluvium. At the same time the mass of tracer observed at downstream monitoring points declined progressively, to a point 4.1 km downstream where no tracer was observed, even though the monitoring period exceeded calculated travel times in the river by a factor of three

Investigation findings suggest that groundwater-surface water interactions in the Nuenna Catchment are more complex than simple hydrological models suggest (See Figure 2a). The loss of tracer and near-constant flow rates along the course of the river, once it crosses the area of deeper alluvium, suggest that not all water discharging to the river remains as surface water. Indeed, the disappearance of the tracer points to river water discharging to alluvium, while groundwater discharges from it to the river channel in a dynamic process of surface water/alluvial groundwater exchange (Figure 2b).

A. Conventional View of Groundwater /Surface Water Interactions. All groundwater discharges to river.



B. Modified View of Groundwater /Surface Water Interactions. Alluvial plain acts as zone of diffuse discharge.
Active exchange of water between river and groundwater in alluvium.

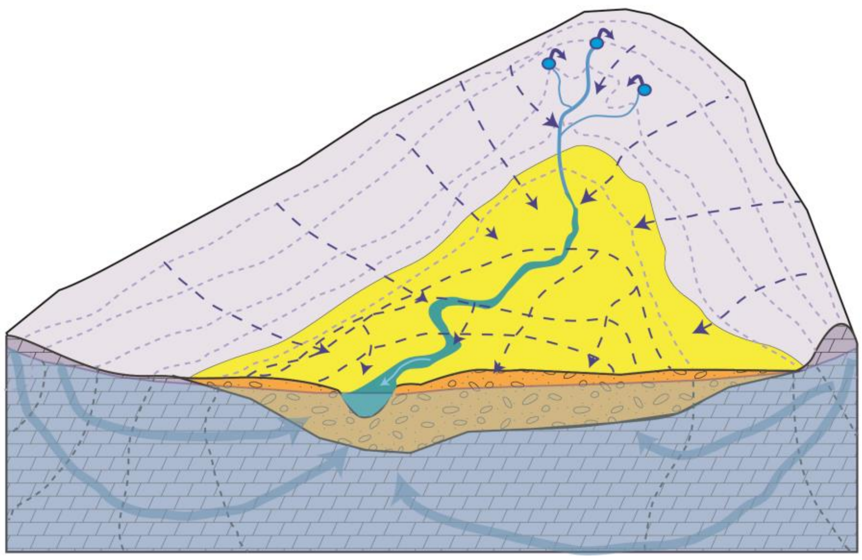


Figure 2: Groundwater surface water exchange (a) Classical model. (b) Proposed modified model based on tracer test results.

The study's outcomes hint at the complexity of groundwater-surface water interactions that may occur in other Irish catchments. Combined flow gauging and tracer testing provides a useful and inexpensive means of investigating these processes. In the case of the Nuenna River, results have indicated that groundwater can flow parallel to a river's overall course in alluvial plains. Failure to consider this process may result in misleading conclusions using flow gauging data derived from fixed discharge monitoring features, as ungauged groundwater can by-passes hydrometric monitoring points at catchment outlets. This in turn can have important implications for catchment flow balances and recharge calculations based upon them, should the quantity of by-passing water be a significant proportion of total flow. As a corollary to this point, results suggest that discharge data from weirs located on permeable deposits should be considered with caution; tracer testing can prove of assistance in investigating this issue.

Raymond Flynn (School of Planning, Architecture and Civil Engineering, QUB) and Daniel Hogan (RPS Consulting Engineers Belfast).

Establishment of Groundwater Zones of Contribution

Balief Clomantagh
Clomantagh Killashulan
Graine
Parks Rathclevin
Tubbrid Lower/Upper
Group Water Schemes, Co. Kilkenny

Coran Kelly

27 January 2014

National Federation of Group Water Schemes

Comhshaol, Pobal agus Rialtas Áitiúil
Environment, Community and Local Government

TOBIN
Patrick J. Tobin & Co. Ltd.

GSI

Why Need Protection?

1. Make sense to know where our water coming from
   – Zone of Contribution (ZOC)
2. Drinking Water Safety Plans
3. Water Framework Directive
4. Cryptosporidium Guidance
5. Good Agricultural Practices

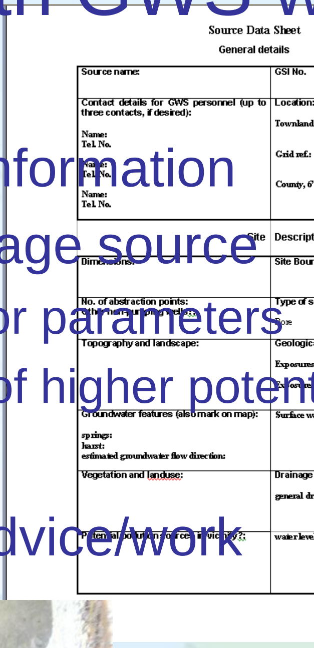
Background

- Groundwater source protection work continually on-going …
- >250 GWS ***Groundwater*** supplied schemes (>40 people)
- NFGWS – promoting general good management practice + advice on financing
  - grants requiring source protection work
- NFGWS, EPA, GSI met 2010 re water quality monitoring
  - Opportunity to progress source protection
  - GSI experience with source protection for Public Water Supplies
  - Looking at a national, multi-annual programme
  - Tailor work to suit requirement of the GWSs
  - Initiated the Pilot Project

Pilot Project: Interaction with GWS

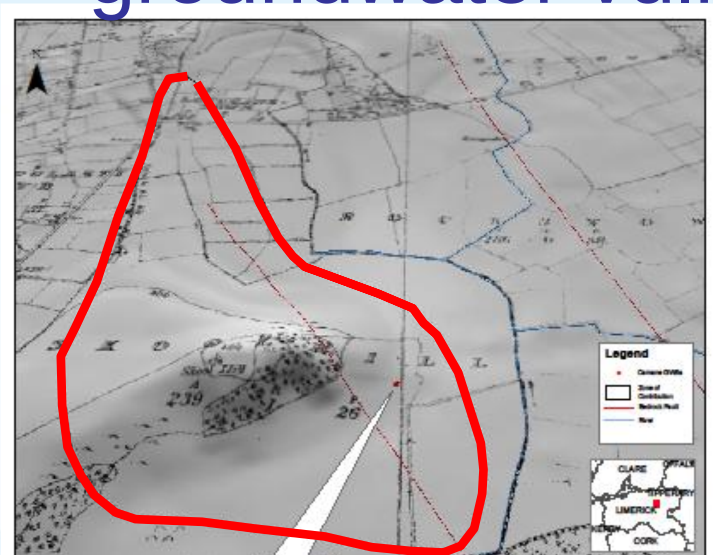
Forefront – relationship with GWS who are managing source:

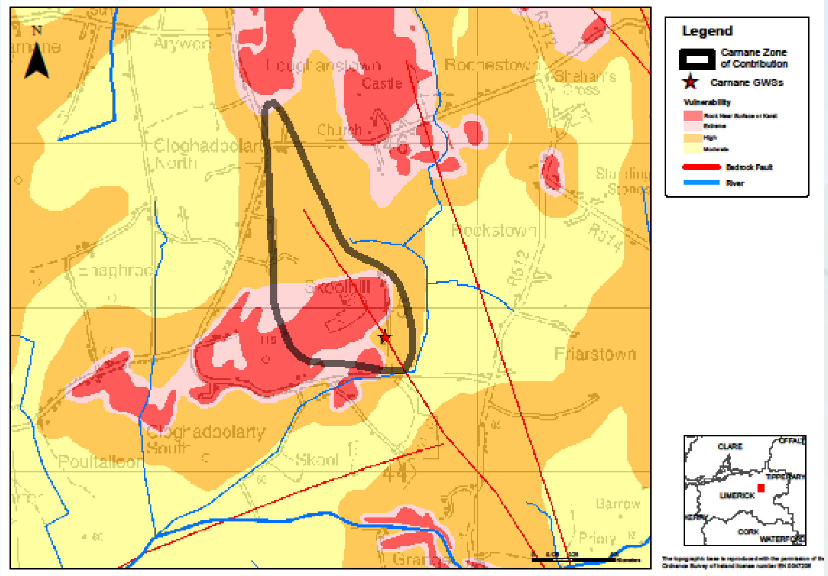
- Hydrogeologist gets available information
- GWS can more effectively manage source
  - GWS to understand and monitor parameters
  - GWS to identify land activities of higher potential risks
- Short term - Feedback
- Longer term - Links for future advice/work



Pilot Project: Product for GWS

- Maps of Zone of Contribution (ZOC) AND groundwater vulnerability





  – Most likely place where water supply is coming from

  – Likely groundwater vulnerability within the ZOC

    - Manage land activities to minimise risk of contaminating groundwater.

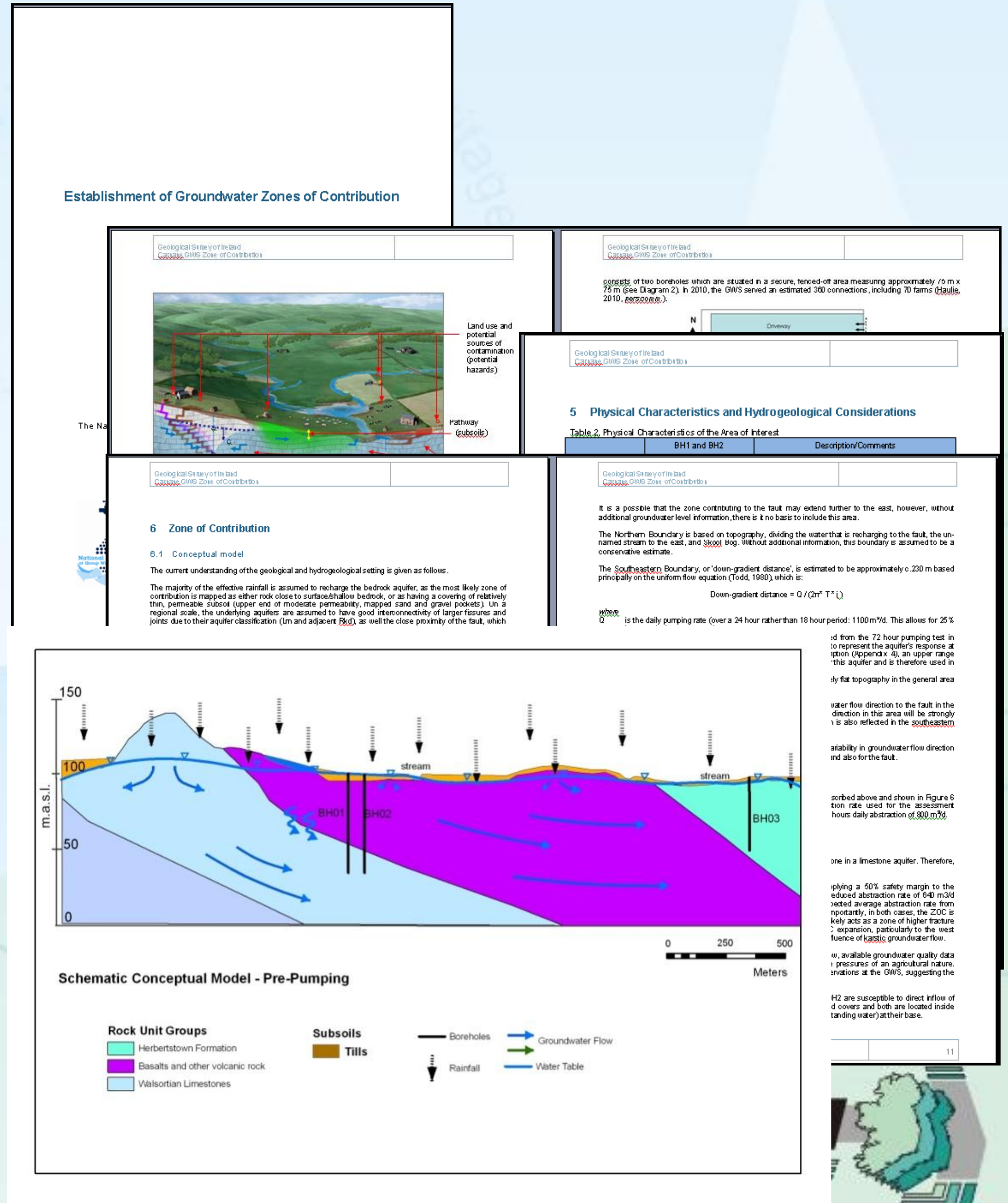
    - Enable GWS to identify most likely risks/hazards.

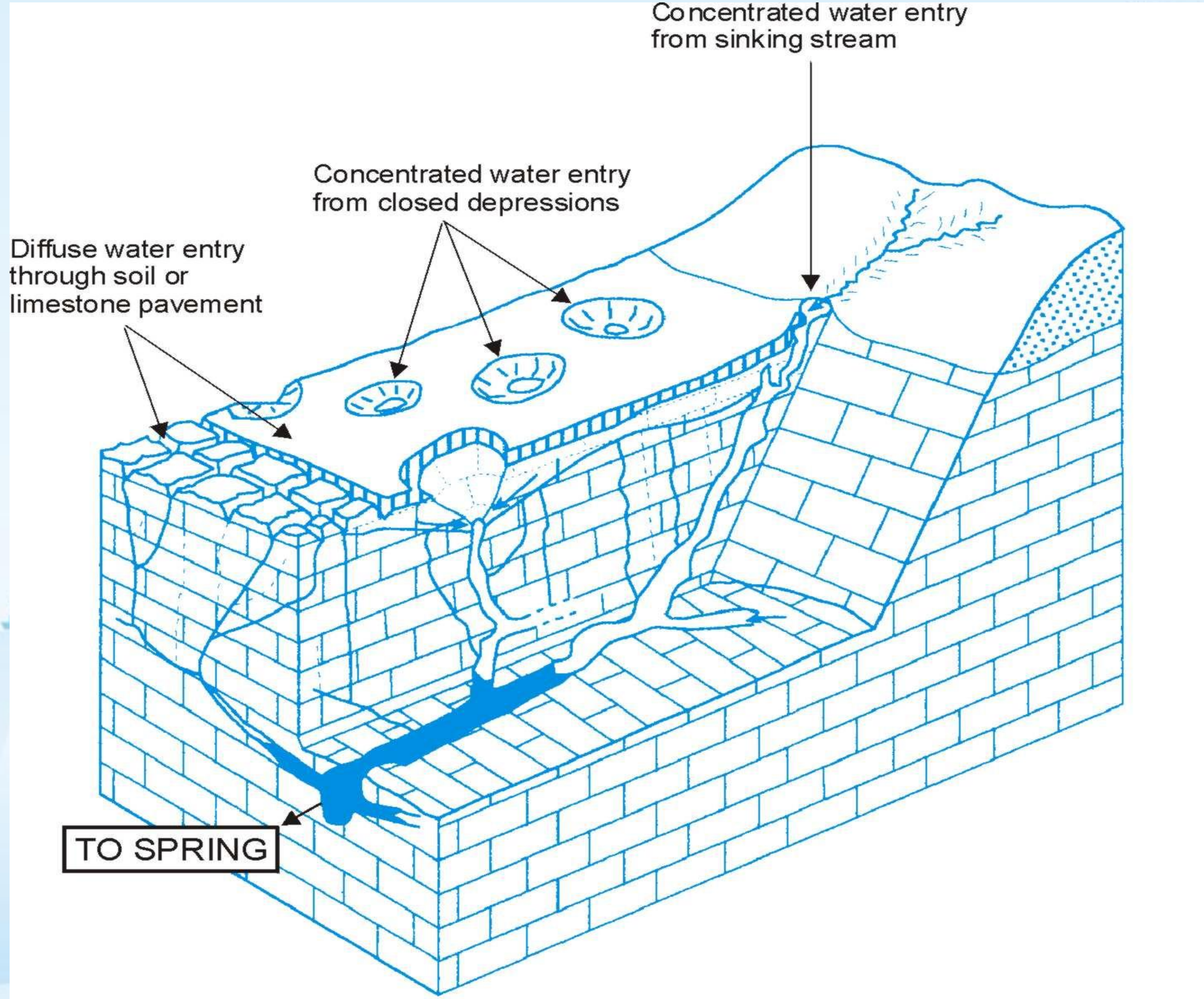
Pilot Project: Product for GWS

- Reports
  - Useful explanations, diagrams and images
  - Basic information in simple (table) format.
    - User friendly – minimise length and jargon.
  - Fully explained conceptual model:

    'Sky to Source'

    - Based on available data, the hydrogeologist's understanding of pathways that the rainfall takes to replenish the groundwater system
    - Including cross sections where possible





Possible entry routes for contaminants to enter karst groundwater

Nuenna Catchment

- Not normal ZOCs –
  - A large groundwater/underground interconnected catchment
  - disproportionately large wrt to abstractions
  - susceptible to contamination
- Great deal of investigation / monitoring
- But yet, boundaries difficult to delineate, uncertain and fluid
- A whole-catchment management approach required

Work programme

- Desk study (data collation)
- Water sampling (GWS)
- Site visits (July, November 2013)
- Reporting (November)
- Presentation (January 2014)

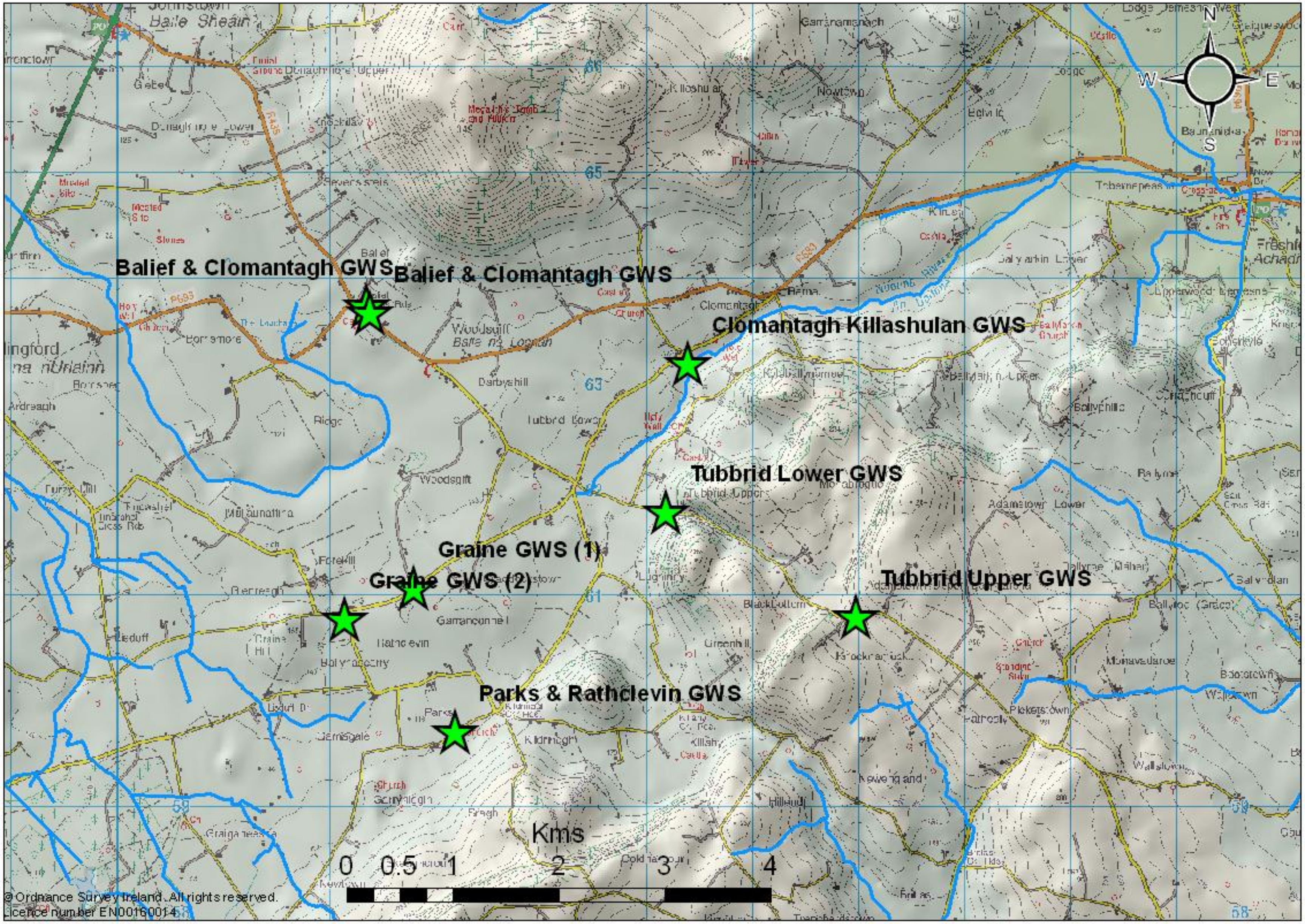
Water Use

- – Balief Clomantagh 150 m^3/d
- – Parks Rathclevin 15 m^3/d
- – Tubbrid Lower 40 m^3/d
- – Clomantagh Killashulan 70 m^3/d
- – Graine 84 m^3/d
- – Total (not including other wells) ~350m^3/d

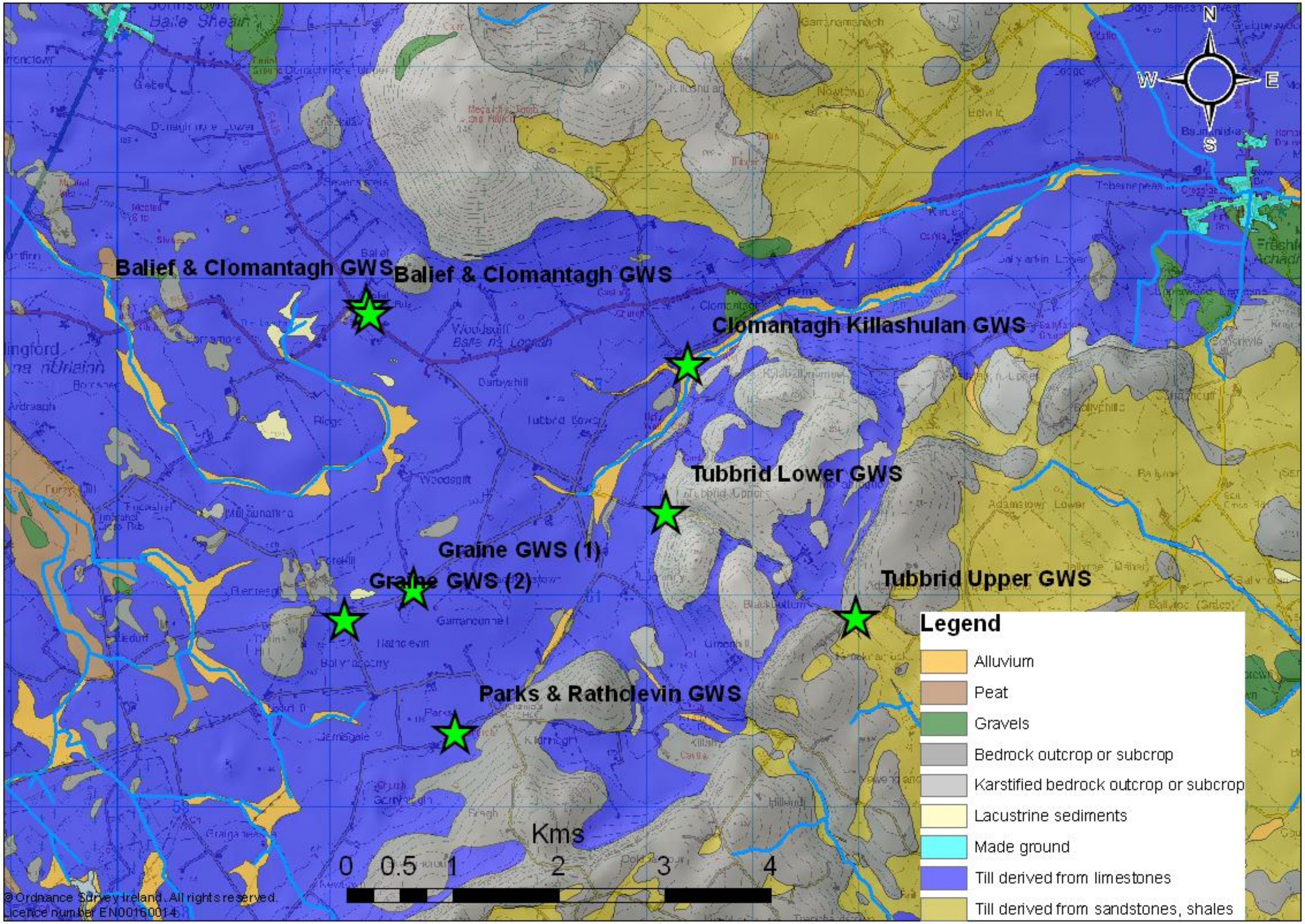
Land use

- Land use is dominated by tillage (13–19%) & pasture (70%) – mostly grazing
- Forestry (9%) occupies portions of the uppermost slopes
- Since 2006 there has been an increase in pasture.
- There are one-off houses, farmyards and a piggery in the catchment.

Location,Topography,Drainage



Subsoils


Balief & Clomantagh GWS
Balief & Clomantagh GWS
Clomantagh Killashulan GWS
Tubbrid Lower GWS
Graine GWS (1)
Graine GWS (2)
Tubbrid Upper GWS
Parks & Rathclevin GWS
N
W
E
S
Kms
0 0.5 1 2 3 4
Legend
Alluvium
Peat
Gravels
Bedrock outcrop or subcrop
Karstified bedrock outcrop or subcrop
Lacustrine sediments
Made ground
Till derived from limestones
Till derived from sandstones, shales
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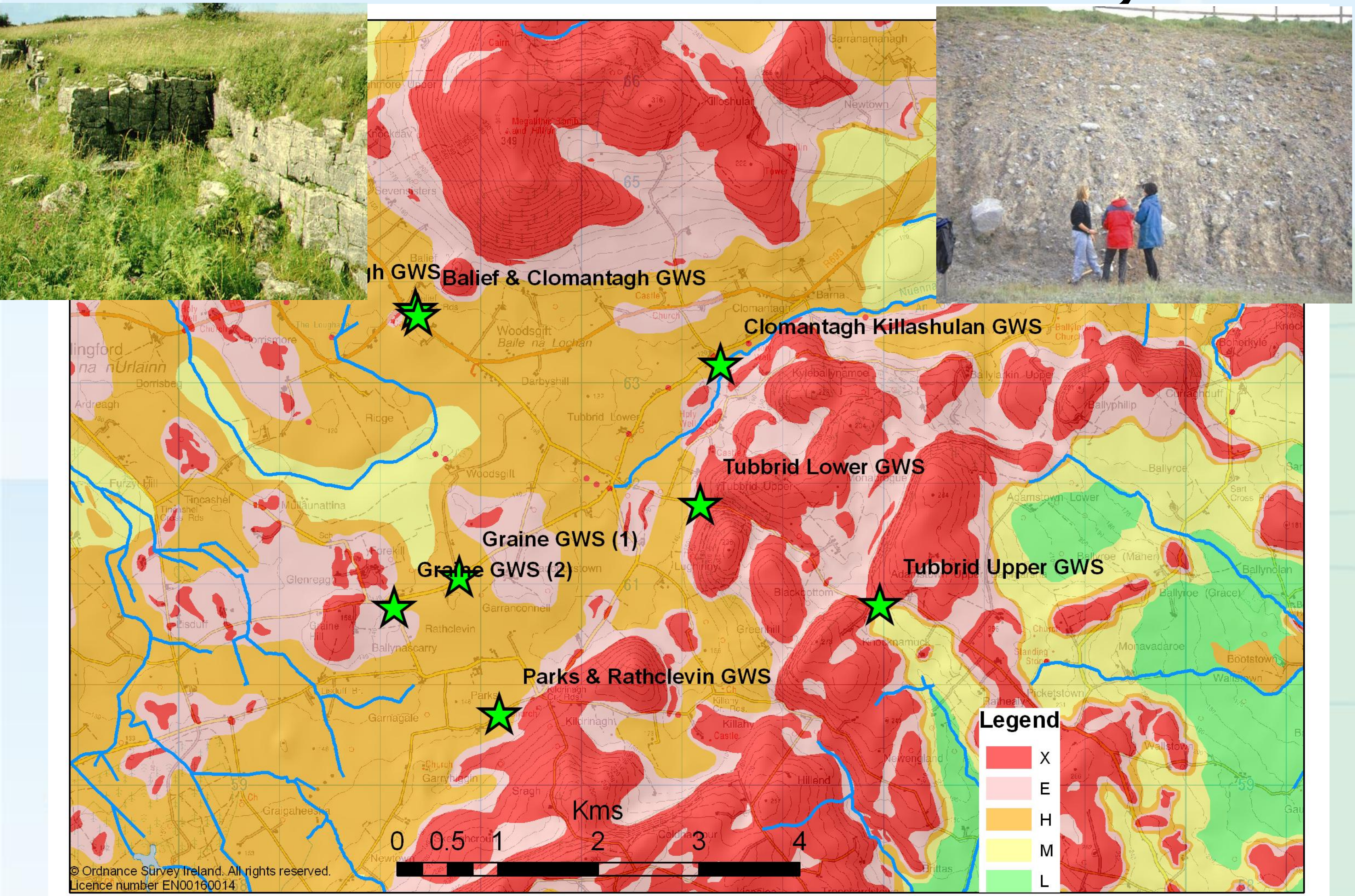
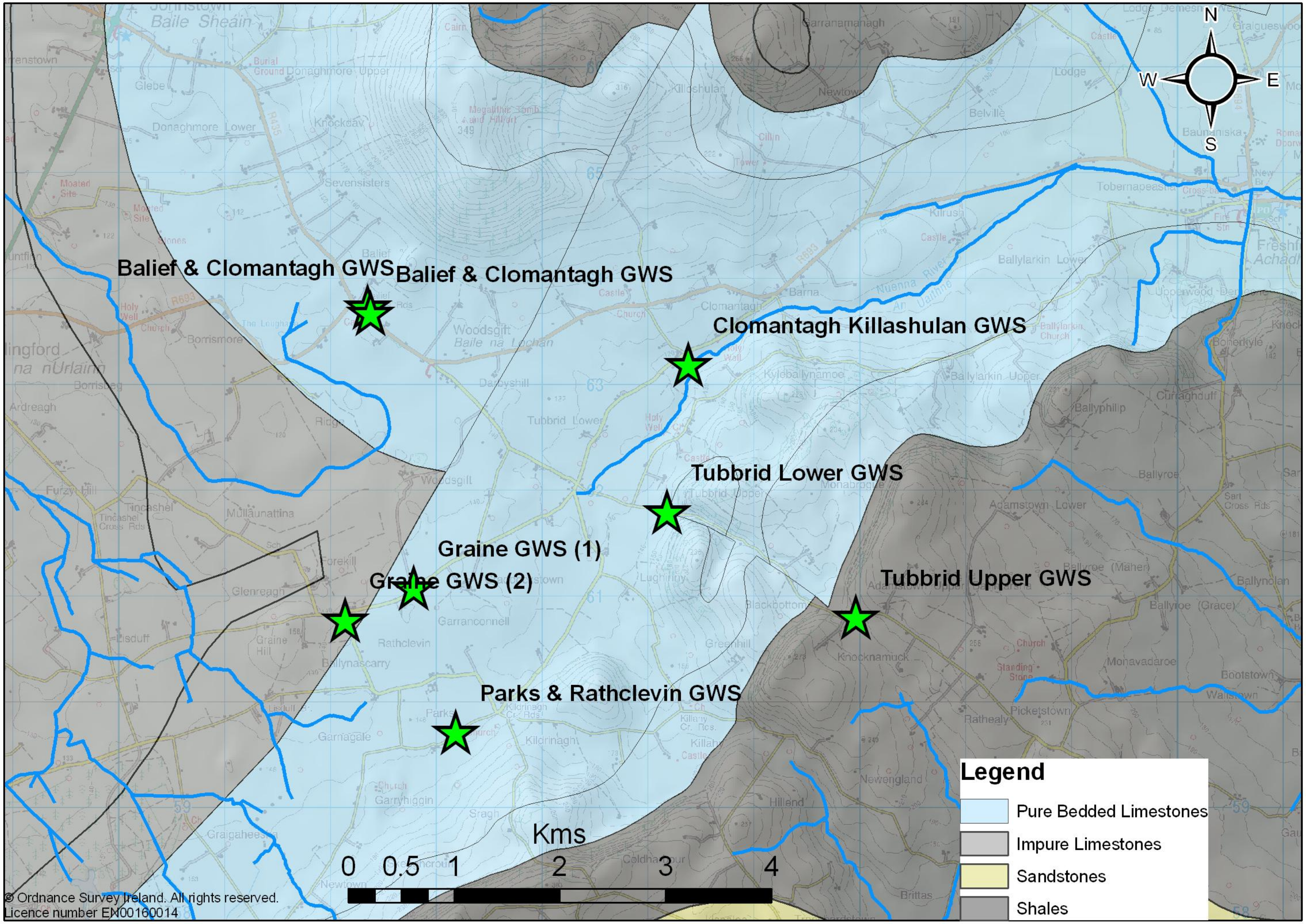
Groundwater vulnerability

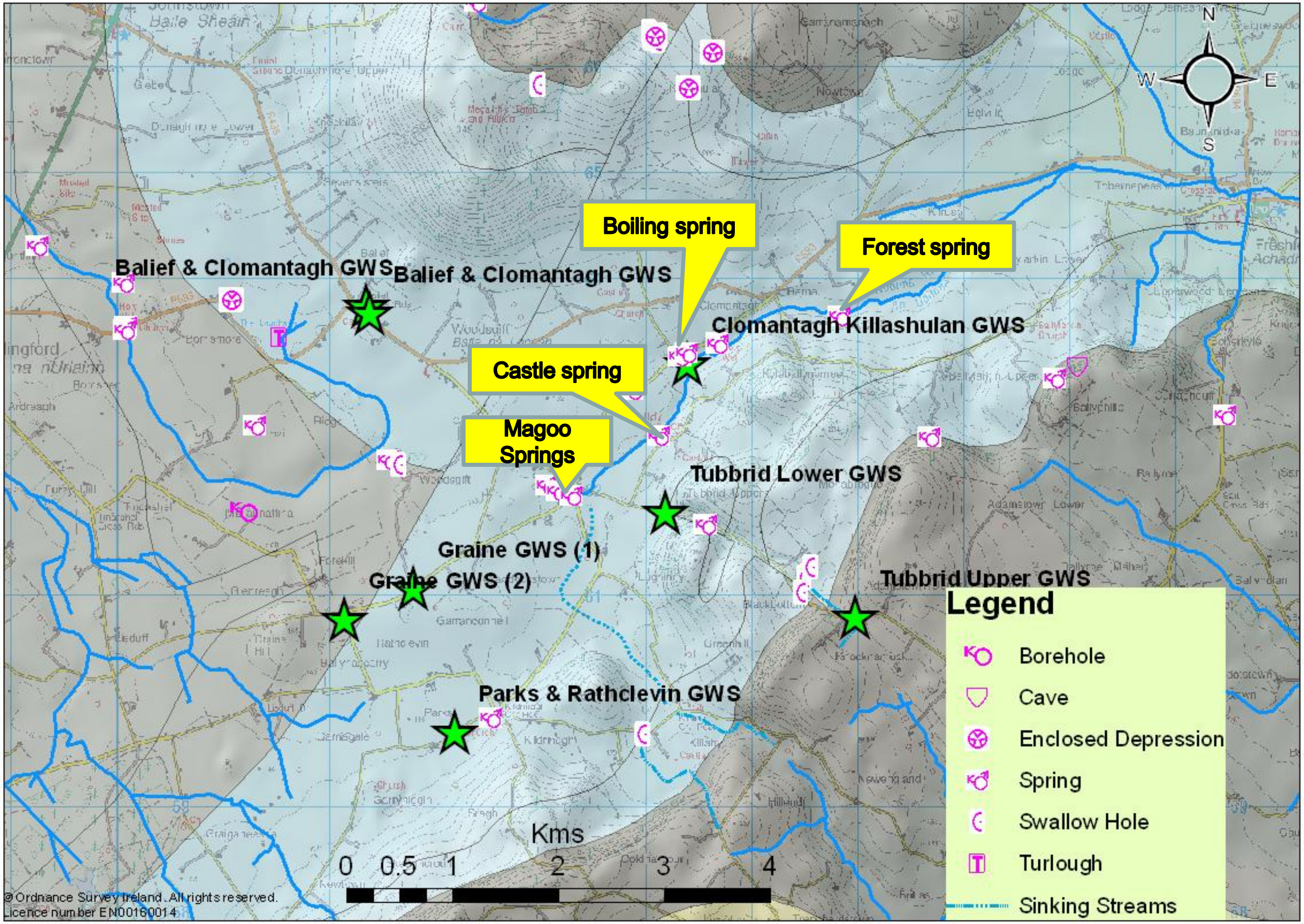


Bedrock



Balief & Clomantagh GWS
Balief & Clomantagh GWS
Clomantagh Killashulan GWS
Tubbrid Lower GWS
Graine GWS (1)
Graine GWS (2)
Tubbrid Upper GWS
Parks & Rathclevin GWS
N
W
E
S
Kms
0 0.5 1 2 3 4
Legend
Pure Bedded Limestones
Impure Limestones
Sandstones
Shales

Features



Boiling spring
Forest spring
Castle spring
Magoo Springs
Balief & Clomantagh GWS
Balief & Clomantagh GWS
Clomantagh Killashulan GWS
Tubbrid Lower GWS
Graine GWS (1)
Graine GWS (2)
Tubbrid Upper GWS
Parks & Rathclevin GWS
Kms
0 0.5 1 2 3 4
N
E
S
W
Legend
Borehole
Cave
Enclosed Depression
Spring
Swallow Hole
Turlough
Sinking Streams
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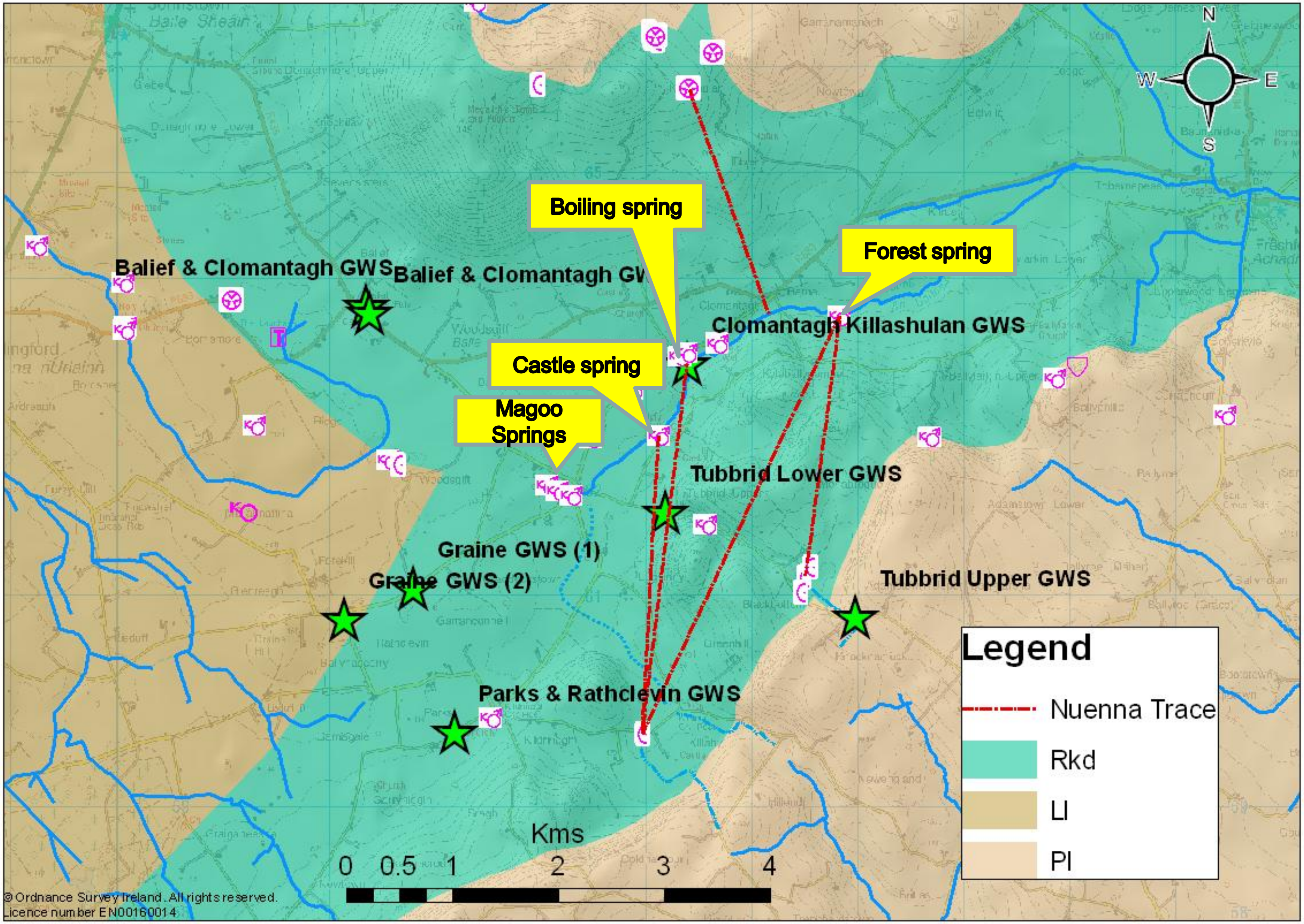
Aquifer



Boiling spring
Forest spring
Castle spring
Magoo Springs
Balief & Clomantagh GWS
Balief & Clomantagh GW
Clomantagh Killashulan GWS
Tubbrid Lower GWS
Graine GWS (1)
Graine GWS (2)
Tubbrid Upper GWS
Parks & Rathclevin GWS
N
W
E
S
Kms
0 0.5 1 2 3 4
Legend
Nuenna Trace
Rkd
Ll
Pl
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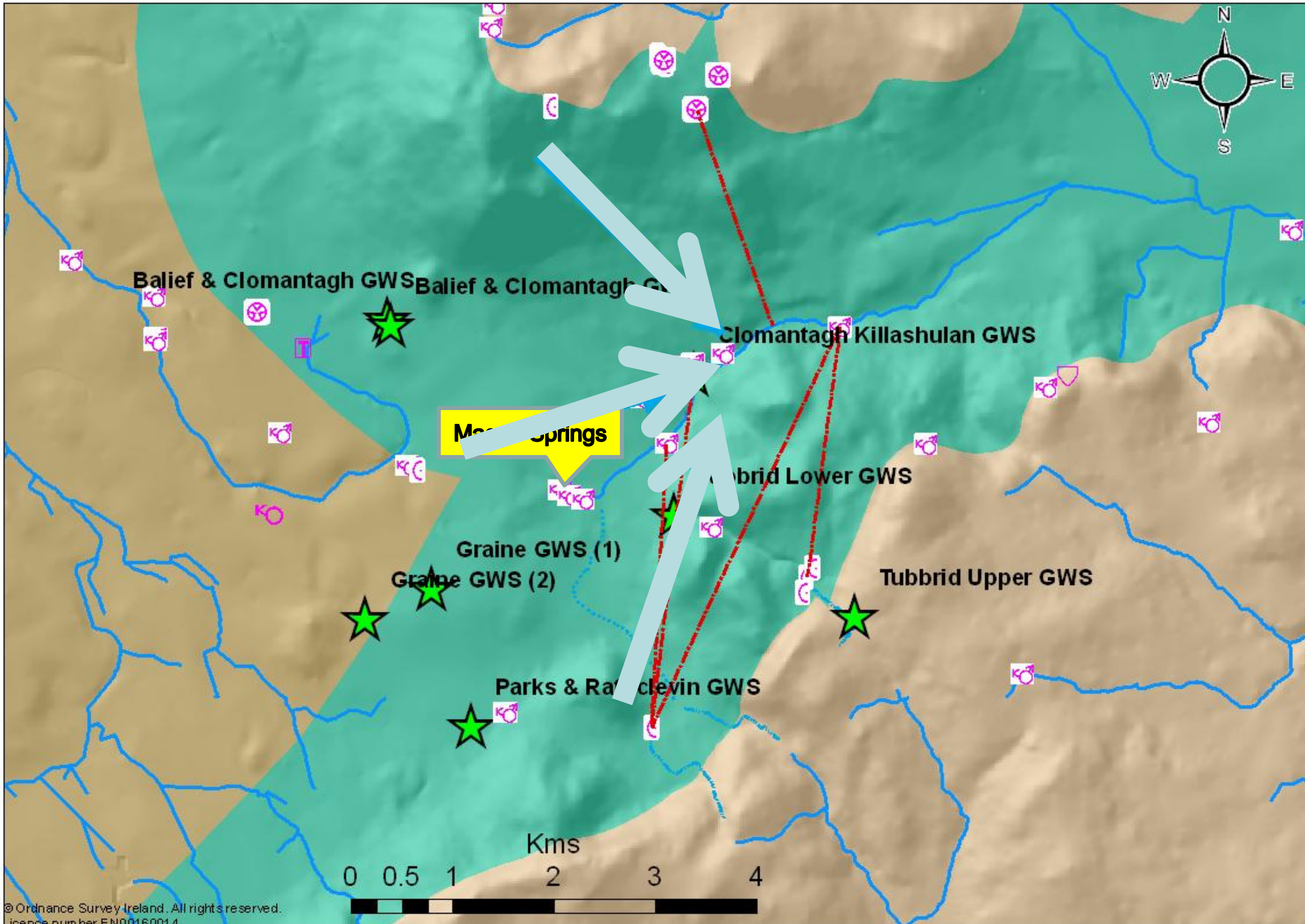
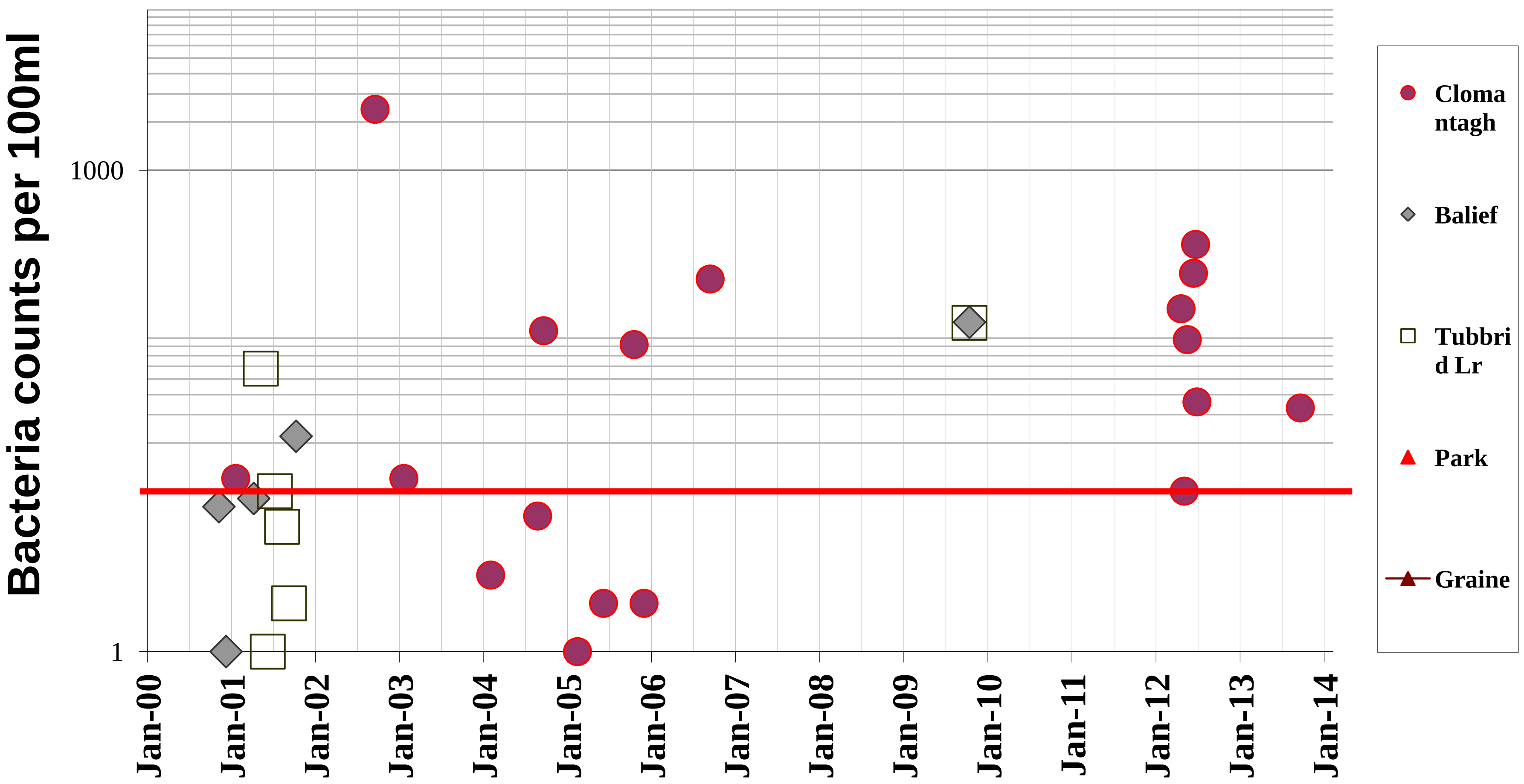
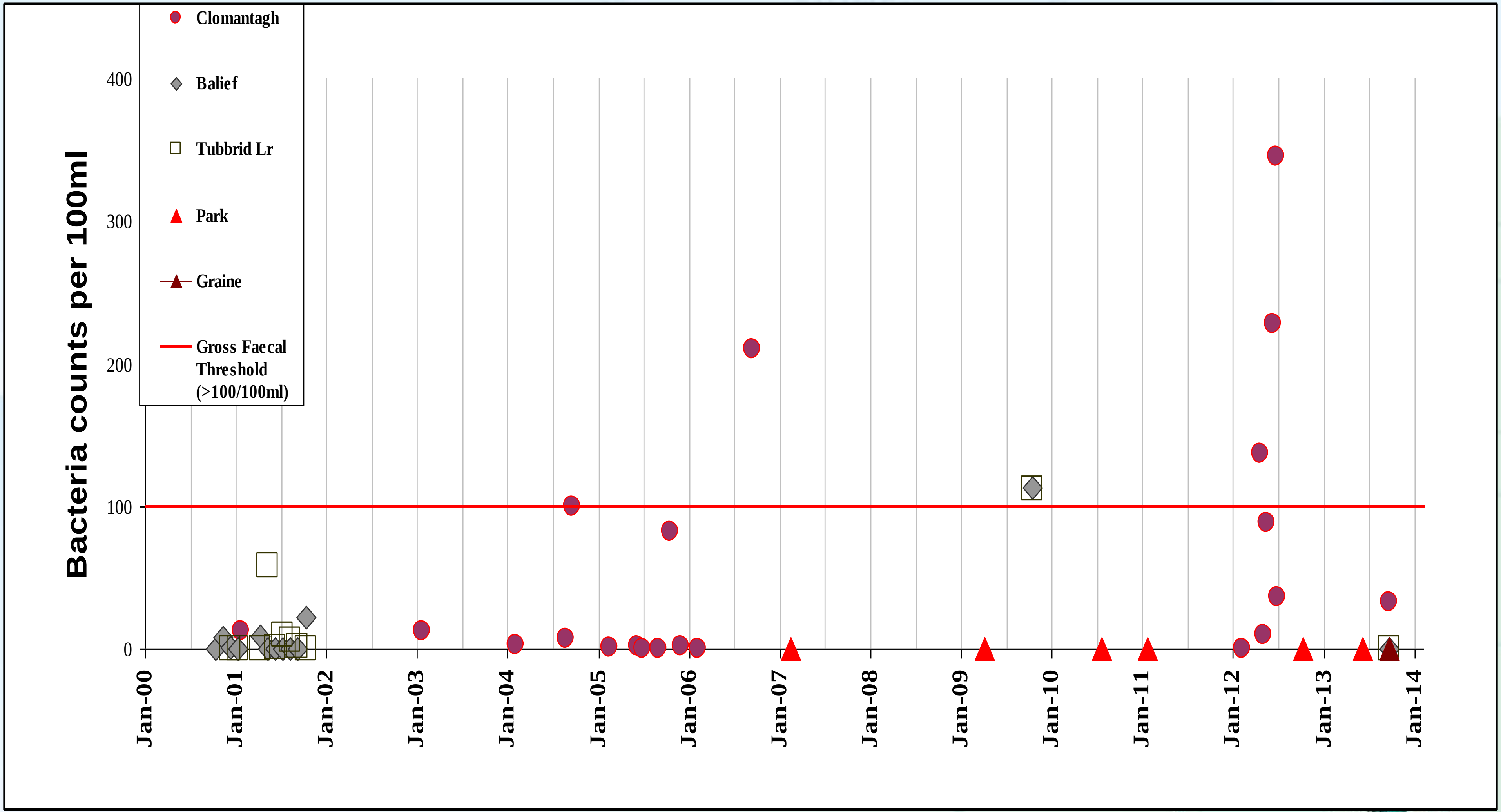
Flow direction/model



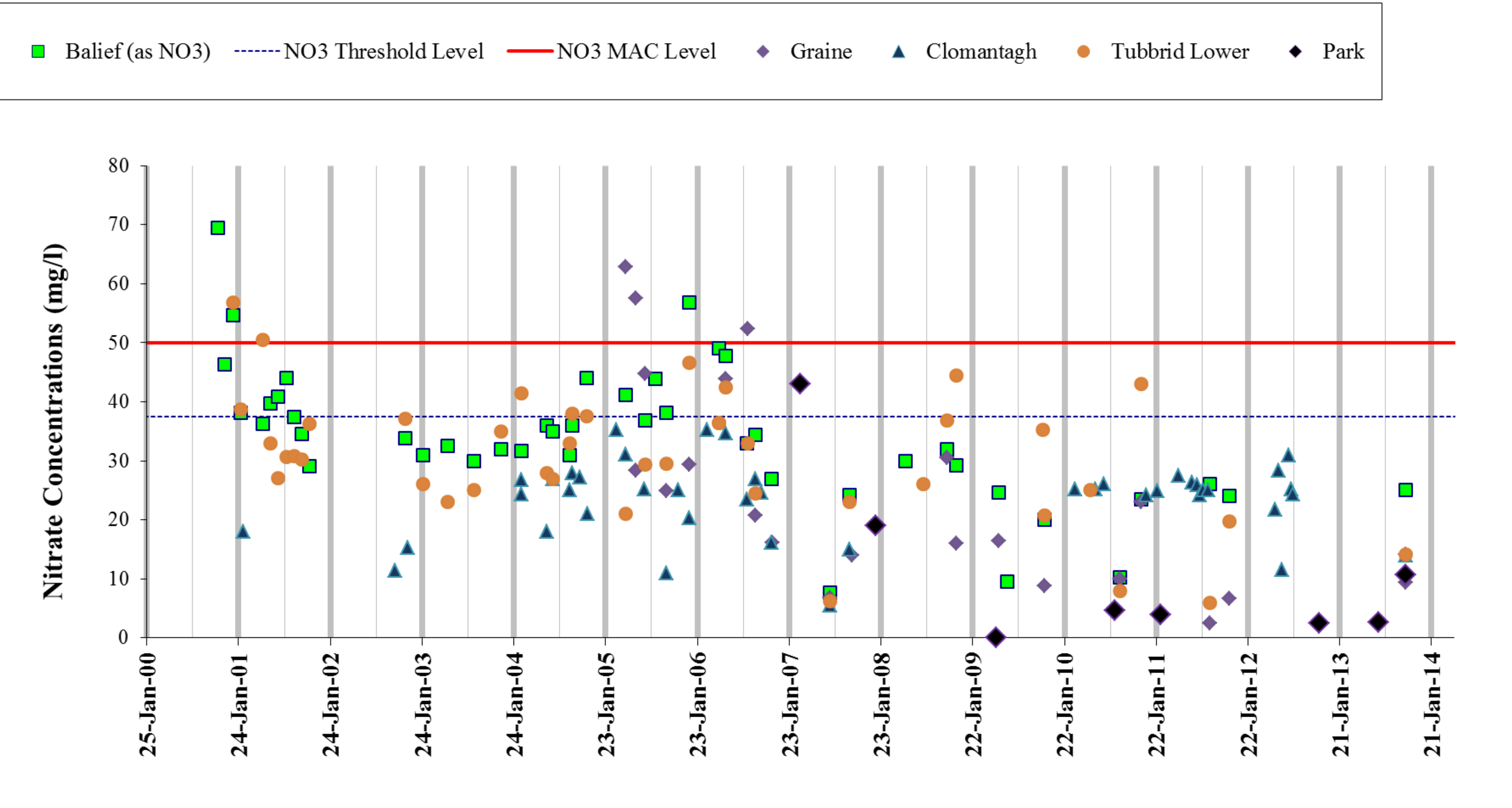
Water Quality



Water Quality

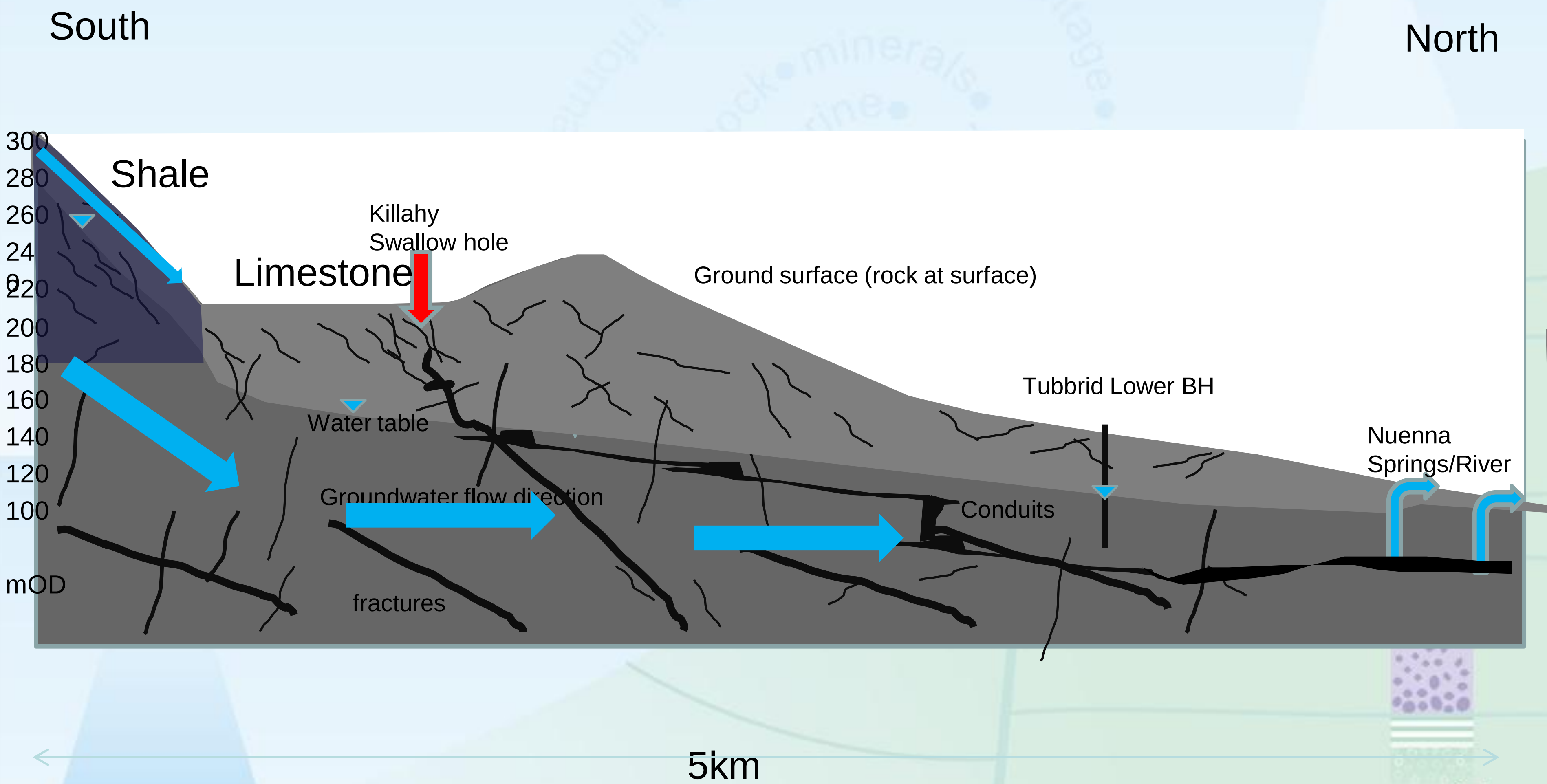


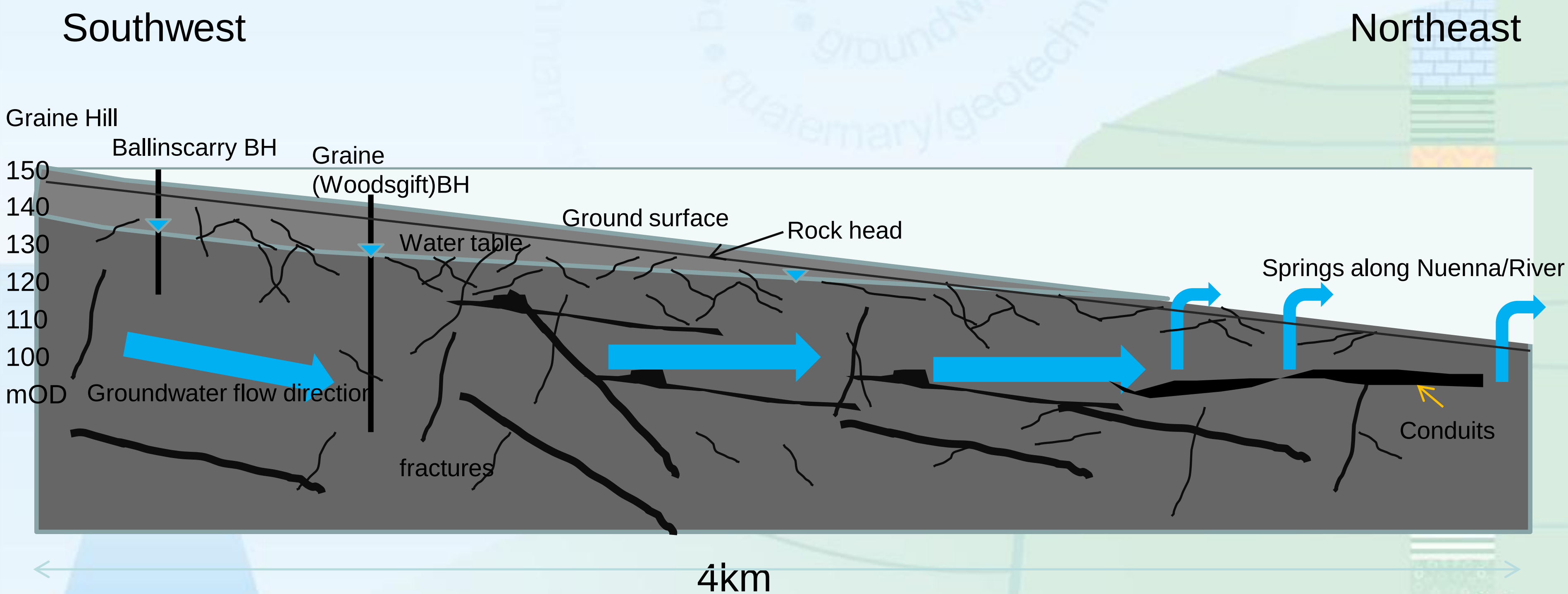
Water Quality



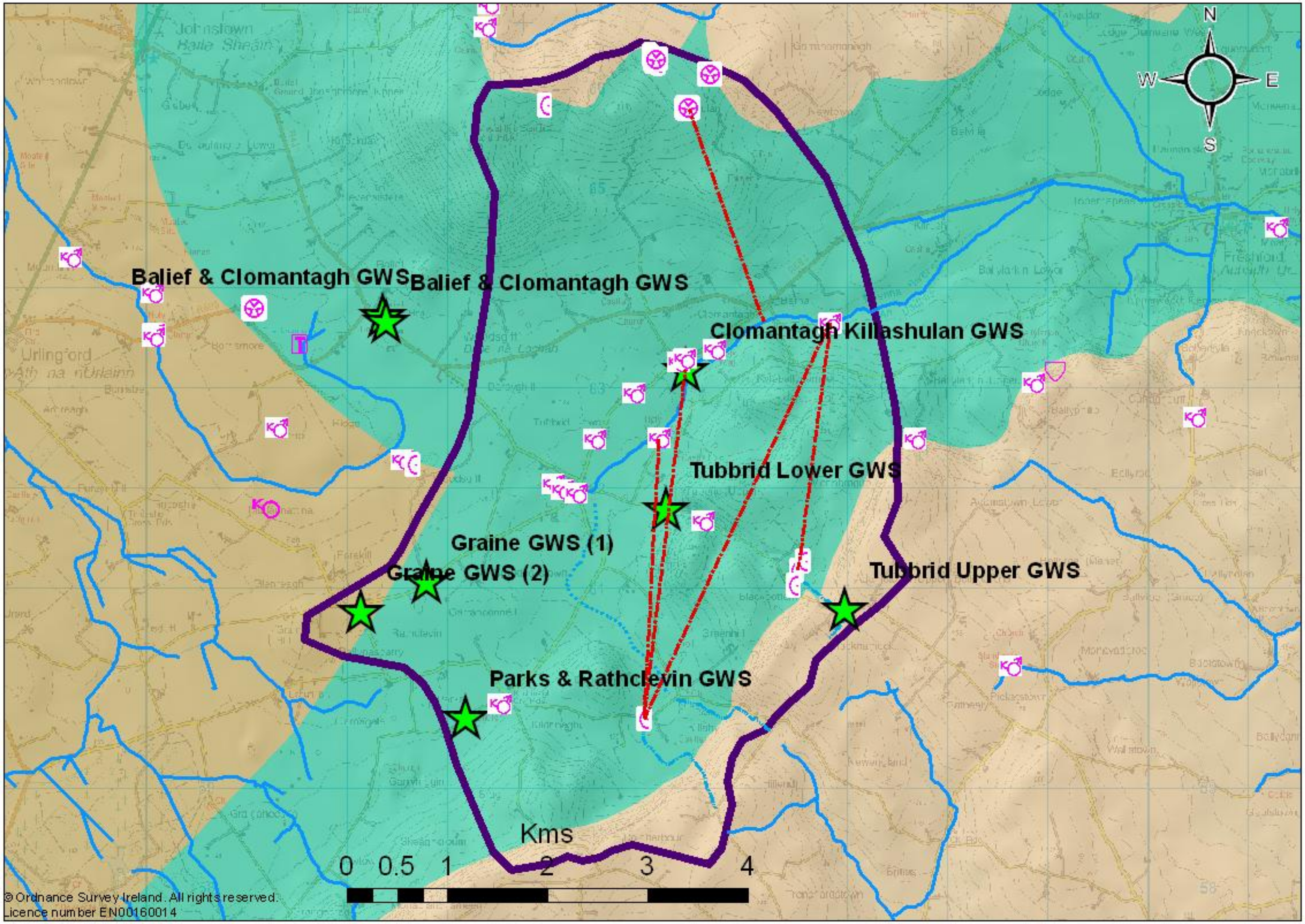
Water Quality

- Key points
  - Bacteria
  - Nitrate
    - Decline
    - Average (below threshold value but above background signal
    - Upper catchment lower concentration
    - Seasonal variations
  - P in Forest spring (trace)
- Sources
  - Agriculture / Septic tanks

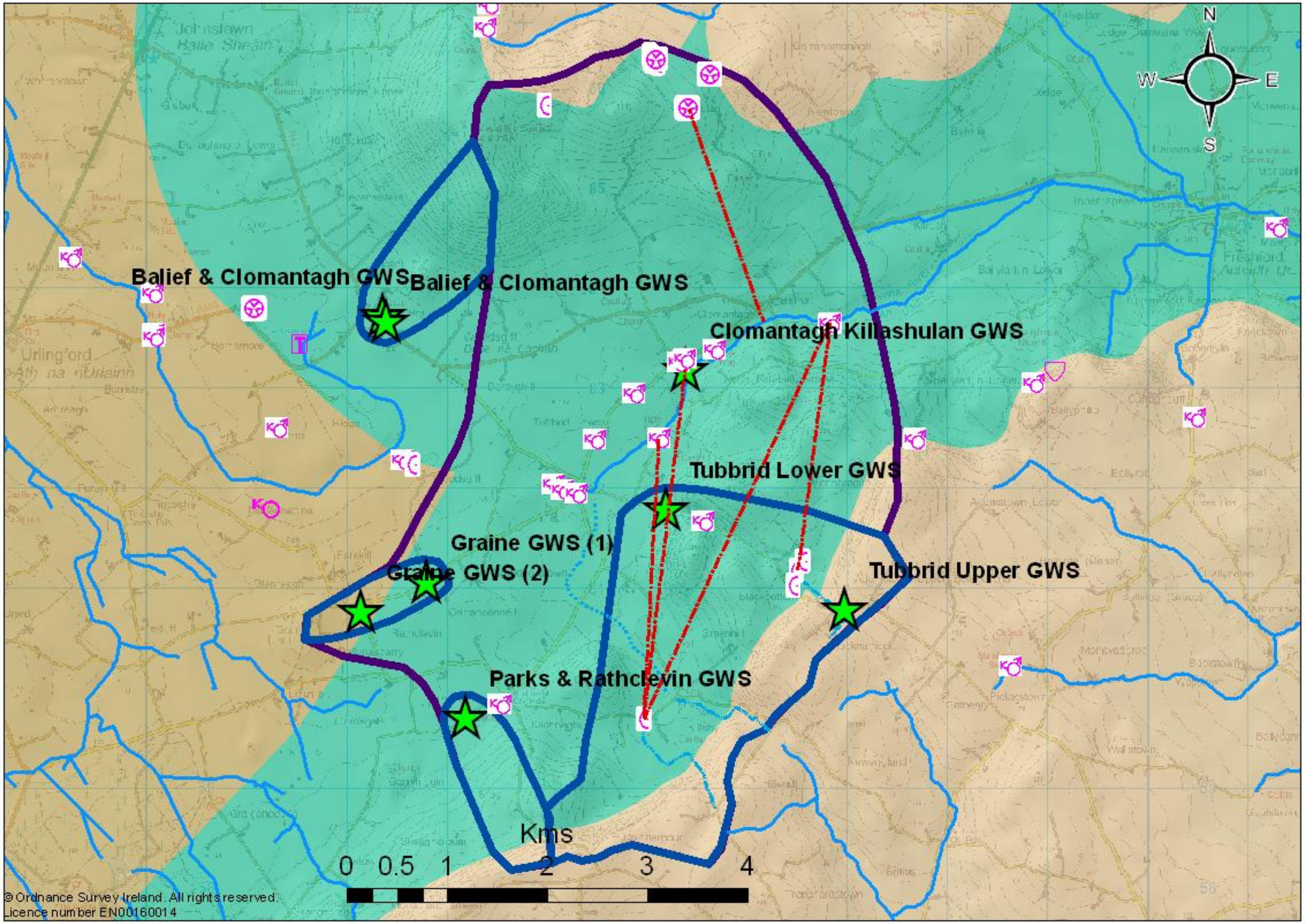

South
North
300
280
260
240
220
200
180
160
140
120
100
mOD
Shale
Limestone
Killahy
Swallow hole
Ground surface (rock at surface)
Water table
Groundwater flow direction
fractures
Tubbrid Lower BH
Conduits
Nuenna
Springs/River
5km


Southwest
Northeast
Graine Hill
Ballinscarry BH
Graine
(Woodsgift)BH
150
140
130
120
110
100
mOD
Ground surface
Rock head
Water table
Springs along Nuenna/River
Groundwater flow direction
fractures
Conduits
4km

Zone of Contribution



Zone of Contribution




CAMPION

Recommendations

- Improve ‘raw’ water quality
- One of the main issues is in relation to farming activities on the ‘rock close’ areas
- Cryptosporidium treatment barrier
- Regular inspection and maintenance checks could be carried out on the septic tanks
- It may be appropriate for the GWSs and/or WSA to consider preparing a land-spreading exclusion zone report (EPA guidance notes)
- A regular survey of water quality parameters
- In conjunction with the NFGWSs and the other GWSs it could be considered to set up a catchment stakeholders group and other relevant stakeholders
- A well audit for water levels could be done to improve the uncertainty on the western boundaries and the groundwater flow directions
- Further tracing work could be done in conjunction with GSI using different flow conditions and other input sites