Pathways and Poorly Productive Aquifers

ANNUAL IAH FIELDTRIP
28-29th September 2013

This year we will be heading north where we will be taken through some of the sites researched as part of the Poorly Productive Aquifer research and the Pathways Project.

The trip will take us to Co. Louth where we will visit the Mattock Catchment and Rockmarshall Wetland. We will move on to Newry before arriving in Belfast for our overnight. The second day will focus on the Mount Stewart Catchment site after a geophysical logging demonstration and a visit to Scrabo Quarry. A brief summary on each of the stops is provided below.

We are intending to base ourselves in the Malone Lodge Hotel, where we have been offered an excellent IAH fieldtrip rate of £55 dinner, B&B pps and £80 for single occupancy (~ €65 pps / €95 single). **Please note you are responsible for booking of your own accommodation. The hotel is holding rooms for us until the 23rd September. 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 ~ €55 for those taking the bus and availing of lunch on the Saturday. 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: Caoimhe Hickey (Caoimhe.hickey@gsi.ie)

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 28th September

Mattock catchment
- Detailed conceptual model: geology, groundwater, surface water, nutrient sources and transport
- Determining human v animal sources of microbiological contamination
- Lessons from geophysics
- GW public supply and interactions with surface water
- Role of deep gravel unit in discharging groundwater out of the catchment

Rockmarshall wetland
- Pressures on a coastal groundwater dependant terrestrial ecosystem.
- Ecological impacts
- Wetland instrumentation and monitoring
- Groundwater / surface water interactions and nutrient delivery

Newry Granite
- Outcrop observations of a poorly productive aquifer
- Newry Boreholes: Productive supplies in a poorly productive system

Sunday 29th September

Downhole geophysical logging demonstration
- General application of geophysical logging
- Case study in the Triassic Sandstone
- HiRAT: A valuable tool for obtaining supplemental information

Scrabo Quarry
- Overview of Geology of the North Down area
- Outcrop observations of Triassic Sandstone and Tertiary intrusives
- Petroleum Geologist's perspective.

Mt. Stewart
- Detailed conceptual model: geology, groundwater, surface water, nutrient transport
- Determining human v animal sources of contamination
- Fracture analysis: Outcrop observations vs results of downhole testing.
- Role of gravels in discharging water out of the catchment

Please note that the programme of visits is preliminary and subject to change pending landowner permission to access sites.
IAH Field Trip 2013
Site 1: Mattock Catchment
Stop 1: Drogheda Drinking Water Diversion

Stop 1: Upper catchment
• Pathways project intro
• Hydrogeological setting
• River water quality/issues
• Pressures and pathways

Stop 2: Mid catchment
• Drinking water supply and SW-GW interactions
• Microbial source tracking

Stop 3: Lower catchment
• Hard rock hydrogeology
• Geophysics
• Role of the gravels

P: EPA Strive
Pathways
G: Griffith Geoscience
Research

Figure 1.1
Contaminants of concern (COCs)
- Nitrogen
- Phosphorus
- FIOs
- Sediment
Mattock catchment

Catchment hydrology

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>17 km²</td>
</tr>
<tr>
<td>Rainfall</td>
<td>900 mm</td>
</tr>
<tr>
<td>Potential evapotranspiration</td>
<td>480 mm</td>
</tr>
<tr>
<td>Effective rainfall</td>
<td>444 mm</td>
</tr>
<tr>
<td>Median flow at catchment outlet</td>
<td>0.14 m³/s [0.002 – 15 m³/s] (Feb 2011-Feb 2013)</td>
</tr>
<tr>
<td>Runoff coefficient (Q/rainfall)</td>
<td>0.44</td>
</tr>
</tbody>
</table>

Geological setting

<table>
<thead>
<tr>
<th>Soils</th>
<th>Poorly drained gleys dominant, shallow well drained soils in upper catchment and on gravels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subsoils</td>
<td>Low permeability Iwr Palaeozoic till. Alluvium and gravels</td>
</tr>
<tr>
<td>Bedrock</td>
<td>Silurian and Ordovician sediments</td>
</tr>
<tr>
<td>Vulnerability</td>
<td>Extreme to Low</td>
</tr>
<tr>
<td>Aquifers</td>
<td>P↓, Pu</td>
</tr>
</tbody>
</table>

Water quality

| Land use | 83% Pasture 7% Tillage 1000 pe WWTP (modern) in the mid catchment |
| River    | NO₃: Moderate (15 mg/l as NO₃) MRP: High (0.064 mg/l as PO₄) |
| Groundwater | NO₃: Moderate in subsoil boreholes and MK2 Deep (10-20 mg/l as NO₃), otherwise low (<2 mg/l as NO₃) MRP: High in MK3 Gravel (0.050 mg/l P), Moderate in MK1 Subs (0.028 mg/l P), Low to moderate in bedrock boreholes (mostly <LoD, otherwise 0.020-0.030 mg/l P). |
| Q-Value  | Q3 to Q4/S |
| Status   | River: Moderate Groundwater: Good |

Figure 1.4

Mattock River flow and nitrate load, at low and moderate flows, with distance downstream

Closed shapes with lines: river profile
Open shapes without lines: tributary inputs

Mattock flow and TP (uf) and MRP (f) loads, at low and moderate flows, with distance downstream
Figure 1.5

Flow m3/s

Event A Mattock Diversion

Outlet Jun 2012

% Pathway contribution
Low flow Peak flow Total

Overland flow:
Lane drain: 0 53 35
Groundwater:
GW Berrils 37 10 47
OF Berrils 59 29 40
Total flow

Overland flow: 1 54 34
Land drain: 59 29 40
Groundwater: 40 17 26

Matchup event hydrograph separation
(relative pathway contributions)

OF Berrils
LD Berrils
GW Berrils
Total flow
Stop 2: Pitch and Putt Course

Mattock Geophysical (ERT) Investigation
QUB Groundwater Group,
Griffiths Geoscience Research.

Figure 1.6
Figure 1.7
Microbiological Sampling

Figure 1.8

Mattock Catchment

- Green circles = Sample Locations
- Blue lines = River/Tributary Channel
- Red lines = Catchment Boundary

Base image: Google Earth
Figure 1.9

Microbiology Flux. Open vs Closed Season.

All Flow: Closed Season on left, Open Season on right

Low Flow: Closed Season on left, Open Season on right
Microbial Sources

Ternary Plot for Faecal Indicator Microorganisms Sampled in the Mattock River, Spring, Autumn & Winter 2012

Figure 1.10
Stop 3: EPA Groundwater Monitoring Transect

Figure 1.11

Piezometers set at different depths along a transect.
Mattock Catchment
Borehole Transmissivity

Theis and Theis Recovery
Drawdown Analysis

Hydraulic Conductivity?
Transmissivity/Saturated Length
For Fractured Rock???

Figure 1.12
Stereographic Projection

Planes and Poles to Planes


Figure 1.13
Mattock Fracture Data

Fracture orientations for all outcrop and borehole data in Mattock
a) rose diagram b) Schmidt net (poles to fracture planes) density
distribution plot

Hydraulically active fractures (HAF) and zones identified from
tracer tests . a) rose diagram b) Schmidt net (poles to fracture
planes) density distribution plot

<table>
<thead>
<tr>
<th>Hydraulic Zones thickness</th>
<th>Shallow boreholes</th>
<th>Deep boreholes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample size</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>Mean (mm)</td>
<td>15.1</td>
<td>118.6</td>
</tr>
<tr>
<td>Std dev (mm)</td>
<td>14.9</td>
<td>51.4</td>
</tr>
<tr>
<td>Range (mm)</td>
<td>59.9</td>
<td>449.9</td>
</tr>
</tbody>
</table>

N = 520

N = 12
Site 2: Rockmarshall Wetland, Co. Louth.
Nitrate Delivery

Notes:

Figure 2.2

Nitrate Levels at Rockmarshall Wetland (July 2013)

Key
- Stream Gauging Point with Flow (l/s)
- Nitrate at monitor Points (mg/l N)
- Up-gradient Point Source
- Groundwater Flow Direction

100m
Schematic Illustration of Hydrogeological Regime at Rockmarshall, Co. Louth,
Site 3: Newry Granite

Figure 3.1

Base image: OSNI
Site Topography

Figure 3.2

Base image: Google Earth
Bedrock Geology

Figure 3.3
Borehole Locations

Figure 3.4

Base image: Google Earth
Constant Rate Test

Semi-log Plot Response

Figure 3.5

Image: McLorinan Consultants
Site 4: David Keir Building, Belfast.
Geophysical Logging of Boreholes

Caliper (Borehole Diameter)

Temp and elect. Conductivity probe

Geologging Setup

Figure 4.1
Example of Suite of Geophysical Logs

Figure 4.2
Site 5: Scrabo Quarry, Sherwood Sandstone

Scrabo Quarry showing sandstone and igneous intrusions

Cross-bedding (GSNI)

Figure 5.1
Newtownards Geology (GSNI Sheet 37 1:50 000)
W. A. Ross & Co., The Royal Belfast Ginger Ale and Aerated Water Works, Belfast.—No city in the United Kingdom has gained a more eminent reputation in connection with the manufacture of ginger ale and aerated waters generally than Belfast, and the fact is largely due to the great purity and fine quality of the waters of the artesian wells which exist in this neighbourhood. The enterprise of manufacturers has accomplished the rest, and an illustration of what has been done in raising the aerated water trade of Belfast to the highest level of perfection, is afforded by the establishment of Messrs. W. A. Ross & Co., one of Ireland’s foremost firms in the important industry in question. This distinguished and ever-progressive house was founded in 1879 by Mr. W. A. Ross, who has been ably assisted from the first by his son. By energetic management and the exercise of untiring enterprise, the business has been developed to proportions of great magnitude and importance, and it is not too much to say that its fine productions are now known in almost all parts of the world. The Royal Belfast Ginger Ale and Aerated Water Works comprise a very extensive and substantial block of buildings, situated right over their artesian well, admirably arranged for the purposes of the immense and constantly increasing trade carried on. They are perfectly equipped in every respect, and in all our experience of well-organised and carefully conducted industrial establishments we have never seen a neater, cleaner, or more systematically appointed factory.

Figure 5.4
Site 6: Mount Stewart, Co. Down
Stop 1: (Temple of the Winds)

**Catchment hydrology**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Area</td>
<td>4.8 km²</td>
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<tr>
<td>Rainfall</td>
<td>800 mm</td>
</tr>
<tr>
<td>Potential evapotranspiration</td>
<td>500 mm</td>
</tr>
<tr>
<td>Effective rainfall</td>
<td>325 mm</td>
</tr>
<tr>
<td>Median flow at catchment outlet</td>
<td>0.037 m³/s [0.001 – 1.11 m³/s] (Jan 2011-Jan 2013)</td>
</tr>
<tr>
<td>Runoff coefficient (Q/rainfall)</td>
<td>0.39* (*But some water escaping out of catchment)</td>
</tr>
</tbody>
</table>

**Geological setting**

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soils</td>
<td>Poorly drained gleyes dominant, shallow well drained soils and brown earths between drumlins</td>
</tr>
<tr>
<td>Subsoils</td>
<td>Low permeability Iwr Palaeozoic till in drumlins with numerous rocky outcrops in between. Peat in upper catchment. Sand/gravel alluvium in lower catchment</td>
</tr>
<tr>
<td>Bedrock</td>
<td>Silurian sediments</td>
</tr>
<tr>
<td>Vulnerability</td>
<td>Extreme to Low</td>
</tr>
<tr>
<td>Aquifers</td>
<td>Not classified. However likely to be PI as per Mattock</td>
</tr>
</tbody>
</table>

**Water Quality**

| Land use                        | 82% intensive pasture 10% tillage                                           |
| River                           | \( \text{NO}_3^- \): Low (8 mg/l as \text{NO}_3^-) \ |
|                                | \( \text{MRP}: \) Very high MRP (0.34 mg/l as \text{PO}_4^3^-) \ |
| Groundwater                    | \( \text{NO}_3^- \): Generally low at <2 mg/l \text{NO}_3^- in bedrock, <12 mg/l as \text{NO}_3^- in alluvium and shallow bedrock. Up to 34 mg/l as \text{NO}_3^- where borehole construction a possible issue. \ |
|                                | \( \text{MRP}: \) Low to high, often <LoD, average 0.04 \ |

**Q-Value**

| Q2-03                           |  |

**WFD Status**

| Poor to Moderate |

*Figure 6.1 From Meredith, MSc, 2010*
Mountstewart field site with Geophysical Profiles and Monitoring locations (wells and surface water) indicated.
Greywacke exposure, Carrodore Quarry to NE of site
Seismic Refraction – Delineation of Drumlins

Figure 6.4
Figure 6.5


3D inversion of ERT profiles
Event sampling is very informative. Spikes in some indicators prior to the rain = point source; first increase in NO3 and PO4 (and NH4) = quickflow with point source contaminants e.g. cattle access points; last peak increased interflow and shallow groundwater contribution.

The catchment operates differently above and below a threshold that is related to groundwater levels.

Figure 6.6
Pathways

Figure 6.7
Figure 6.8
Event Microbiology

Figure 6.9

Ternary Plot of Relative Concentrations of Fecal Indicator Organisms in Glen Burn, Co. Down, Hydrological Event 19 Nov 2012 to 22 Nov 2012
Flow at catchment outlet often less than flow up-gradient

Figure 6.10
Theis and Theis Recovery Drawdown Analysis

Figure 6.11

Mt Stewart BHs Transmissivity

Transmissivity

Hydraulic Conductivity

- Shallow Greywacke
- Deep Greywacke
- Glacial till
- River Alluvium
- Shallow bedrock
- Deep bedrock
- Geomean
- Sandstone

0.001 0.01 0.1 1 10 100
T (m²/d)
0.0001 0.001 0.01 0.1 1
(m/d)
Mount Stewart Fracture Data

Fracture orientations for all local scale data in Mount Stewart
- a) rose diagram
- b) Schmidt net (poles to fracture planes)
  density distribution plot

Hydraulically active fractures identified from tracer tests
- a) rose diagram
- b) Schmidt net (poles to fracture planes)
  density distribution plot

<table>
<thead>
<tr>
<th>HAF Apertures</th>
<th>Shallow boreholes</th>
<th>Deep boreholes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample size</td>
<td>13</td>
<td>8</td>
</tr>
<tr>
<td>Mean (mm)</td>
<td>2.9</td>
<td>5.4</td>
</tr>
<tr>
<td>Std dev (mm)</td>
<td>1.2</td>
<td>2.0</td>
</tr>
<tr>
<td>Range (mm)</td>
<td>10.4</td>
<td>16.3</td>
</tr>
</tbody>
</table>

Figure 6.12

Fracture orientation data for Mount Stewart boreholes:
- Shallow boreholes: Sample size 13, Mean 2.9 mm, Std dev 1.2 mm, Range 10.4 mm
- Deep boreholes: Sample size 8, Mean 5.4 mm, Std dev 2.0 mm, Range 16.3 mm