Borehole Design: Ensuring Microbiological Security of Groundwater Abstraction

Presentation to the Hydrogeological Section of the Geological Society

10 September 2008

Focus of Talk

- Issues relating to provision of a microbiologically safe groundwater drinking water supply
- Drinking Water Microbiological Requirements
- Sampling Protocols
- Importance of Source-Pathway-Receptor
- Case Studies

Safe Water Supply

Drinking Water Directive 98/83/EC
Article 4

1. Member States shall take the measures necessary to ensure that water intended for human consumption is wholesome and clean…

(a) is free from any micro-organisms and parasites and from any substances which, in numbers or concentrations, constitute a potential danger to human health

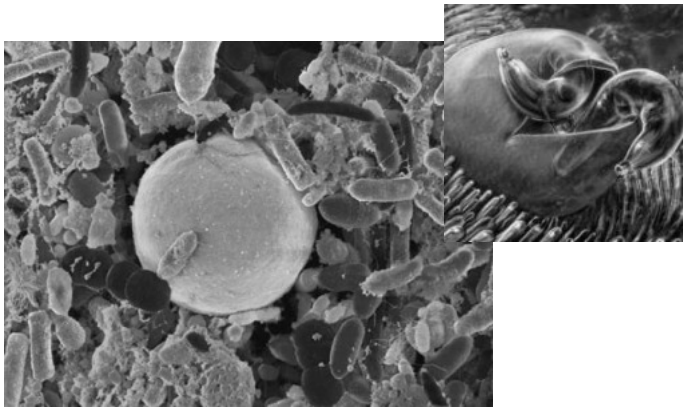
Drinking Water Microbiological Requirements

Parameter	Parametric value
Escherichia coli (E. coli)	0/100 ml
Enterococci	0/100 ml
Natural Mineral Water, Spring Water and Bottled Water	
Escherichia coli (E. coli)	0/250 ml
Enterococci	0/250 ml
Pseudomonas aeruginosa	0/250 ml
Total Viable Colony count @ 22 °C	100/ml
Total Viable Colony count @ 37 °C	20/ml

London Cholera Outbreak

- 1854 Outbreak
- Dr John Snow
- Traced to single pump on a borehole 9m deep in Broad Street
- Overlying section of sewer at 7m deep
- Led to significant advancement of London sanitation in 1880s

Cryptosporidium Outbreaks



- Galway – Lough Mask source
- Clonmel – Glenary spring/surface water source
- Carlow – River Barrow source

End of Pipe Treatment ?

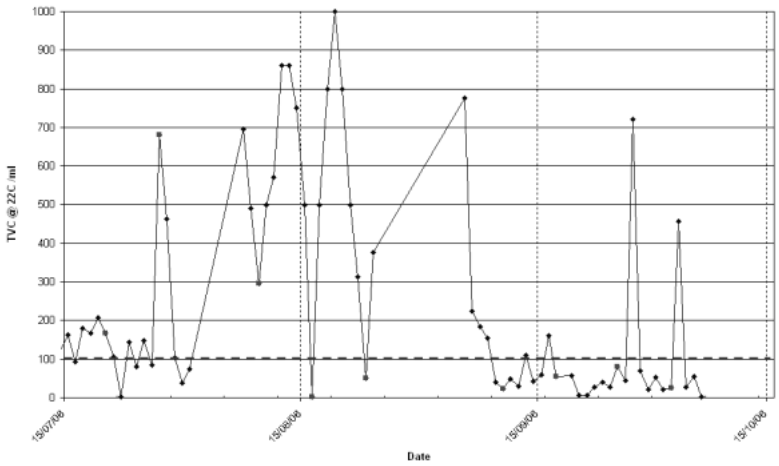
Microbiological Sampling

General Discussion on Microbiological Sampling Programmes

- Point sampling times that are linked to abstraction programmes **do not** necessarily coincide with high rainfall events.
- Historical data on waterborne diseases correlated with rainfall data for the same period showed that disease outbreaks thought to be related to drinking water were linked statistically to heavy rainfall occurring the preceding month. For groundwater the lag between illness and severe precipitation was two months

Micro Sampling Regimes

- Daily or Weekly Sampling Programmes ?



Cryptosporidium Sampling Programmes

- Cryptosporidium sampling within private water supply is often sporadic – grab samples are unrepresentative
- Cryptosporidium sampling through filtration following DWI guidelines ensures a continuous sample is taken over abstraction period. Guidelines require 24-72 hourly change of filter.
- Recommended best practice for bottled water industry is that the DWI guidelines on continuous cryptosporidium sampling are followed

Ensuring Microbiological Security in Groundwater

- **Source – Management of Land use and Surface Drainage**
- **Pathway – Understanding of Groundwater Hydraulics**
- **Receptor – Borehole Construction (and Treatment Processes)**

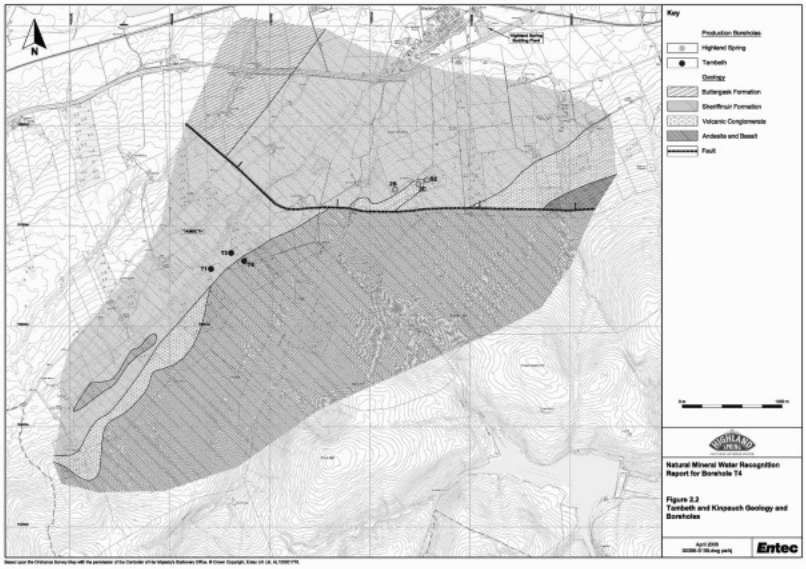
Pathway - Limestone or Hard Rock Aquifer

- Flow through discrete fractures
- Low storage, potential for rapid travel times with surface with sub-vertical fractures
- Potential for strong hydraulic connection over significant distances

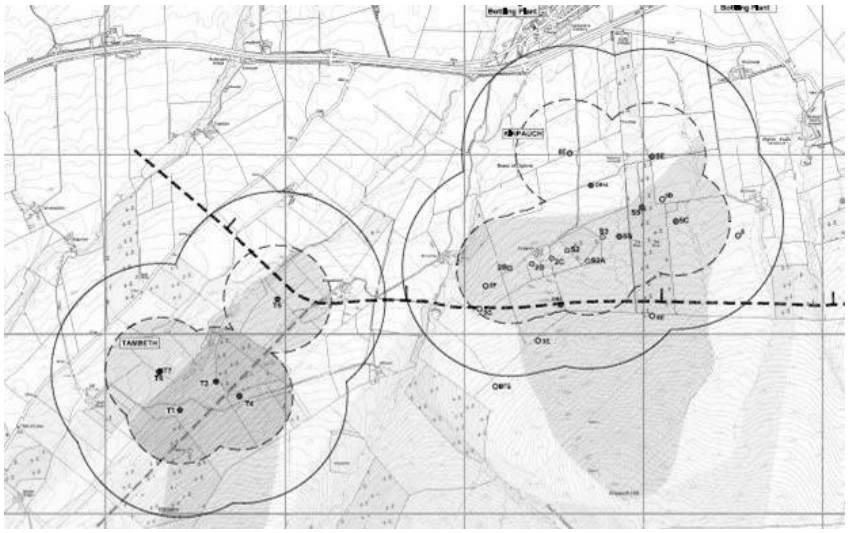
- UK's leading independent bottler of spring water
- Invested £50m since initiation of the source in 1979
- Soil Association Organic Status for their two catchments
- Bottles approximately 240 million litres per year from nine production boreholes

Source - Land Use Management

Geological Setting



Source – Protection Zones



Source - Restrictions

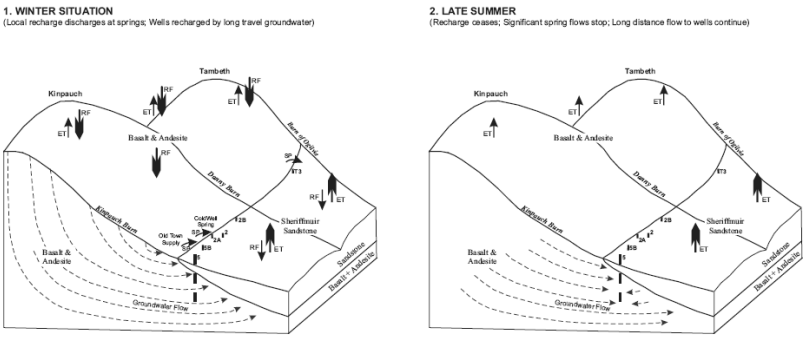
- **Permitted activities:**
  - Essential activities relating to management and maintenance of the existing boreholes.
  - Essential land management, including grass mowing, forestry operations – subject to specific restrictions regarding method of operation, materials (oils) used, etc.
  - The use of the farm tracks by essential vehicles.
  - Construction of new boreholes, subject to site specific restrictions (use of biodegradable oil when drilling).

All Zones

- **Prohibited activities:**
  - Grazing of livestock. Stray livestock entering from adjacent areas must be removed immediately
  - Breeding and keeping of animals, including game birds
  - Residential human activity
  - Spreading of slurry or farm waste
  - Use of wild animal traps as this may attract rodents
  - Septic tanks
  - Use of pesticides, herbicides or fertilisers
  - Sheep dipping within the area
  - Storage of chemicals, fuels, fertilisers, farmyard waste and animal foodstuffs

Permitted in Zones 2 & 3

Pathway - Aquifer Hydraulics

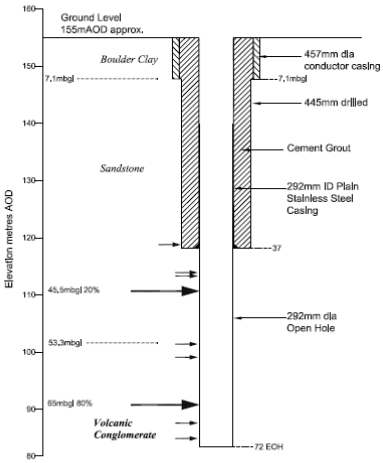


Receptor - Borehole Construction (1)

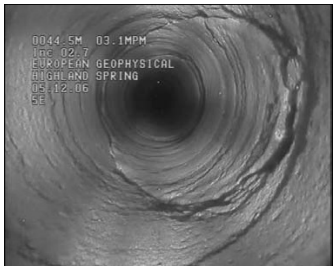
Receptor - Wellhead Protection

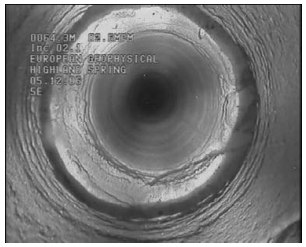
- Removal of the potential for local pathways close to borehole through
  - *Underlying Geomembrane*
  - *Concrete slab*
  - *Outer housing*
  - *Sealed flange plate*
  - *Fenced hard standing*

Receptor – Testing Programme

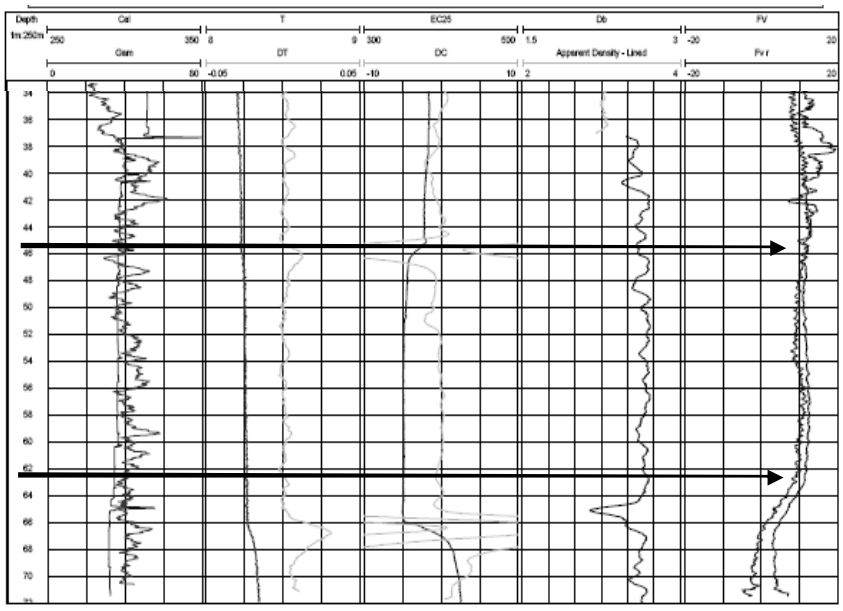


Downhole Camera





Flow Logging



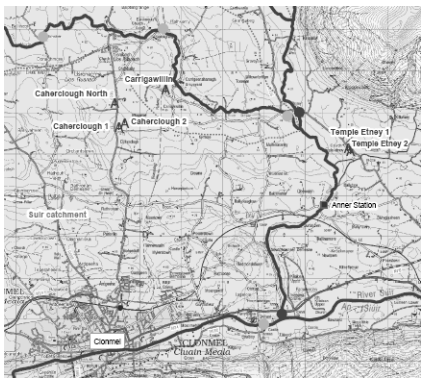
Packer Testing

- **Testing programme – isolate different fracture zones using packers**

Pumping Test Programmes

- Long pumping testing period required
- Sampling at a range of discharge rates
- Seasonal variability at low and high groundwater levels
- Sampling through several recharge events
- Use of multiple indicator parameters

Clonmel (South Tipperary) Public Water Supply

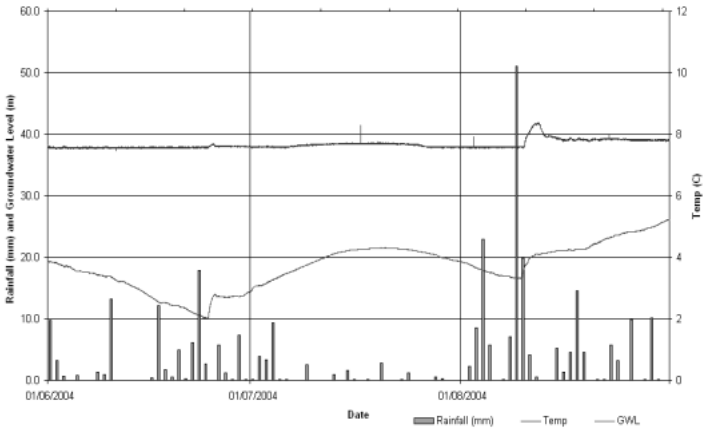


- **Existing upland surface water run-off sources**
- **Requirement for groundwater as short term solution prior to development of River Suir**
- **Following detailed assessment developed two well fields**

Receptor - Grouting

- ***"Typically, all public water supply wells must be grouted from the surface to a depth of at least 50 ft (15.2m) to prevent leakage of contaminants from the surface."*** **Driscoll, 1986**

Pumping Test - Non-Biological Indicators



Summary

- **Ensuring microbiological protection requires:**
  - Detailed Conceptual Understanding
  - Local wellhead protection
  - Catchment protection measures