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THE GSI GROUNDWATER NEWSLETTER

NUACHTÁN SCREAMHUISCE SGÉ

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In This Issue

Groundwater protection schemes serve as a practical and effective means for land-use planners and water resource managers to protect groundwater and prevent pollution. They provide **a framework to assist decision-making on the location, nature and control of development and potentially polluting activities**. They also can be used to assist in areas such as: **groundwater supply**; **groundwater quality assessment**; **site investigations**; **locating high risk areas for phosphorus leaching**; and as **a component of future integrated catchment plans**. Three publications were recently launched jointly by the DELG, EPA and GSI (see page 16). ***Groundwater Protection Schemes*** outlines a methodology for the development of such schemes by local authorities. The supplementary documents ***Groundwater Protection Responses for Landfills*** and ***Groundwater Protection Responses to the Landspreading of Organic Wastes*** outline the application of the principles of such schemes in relation to two specific activities/developments.

Groundwater protection schemes on their own will not prevent pollution. **Waste licensing** has a critical role. A comprehensive and important article by Margaret Keegan and Ted Nealon (page 3) outlines the **geological and hydrogeological information** required as part of a waste licence application. The article includes details on some of the failings with the geological and hydrogeological aspects of licence applications to-date.

Full groundwater protection schemes need many types of information, including hydrogeological and geological. Teagasc are undertaking a project to develop a **forest soils classification and productivity ranking (FSCP)** (described by Robbie Meehan on page 7), which will involve production of **soils parent material** and **soils maps** for the country. This work is of wide national significance as these maps will provide **basic subsoils information for vulnerability mapping**, and will also provide information that will be relevant to **assessing phosphorus runoff or leaching**, to **integrated catchment management plans** and to the **broad range of other activities that require soils and subsoils information**.

Delineation of **Source Protection Zones (SPZs)**, the highest priority component in the production of a groundwater protection scheme, requires **estimation of recharge**. Olga Aslibekian presents the results of some of her work on recharge on page 8. Kevin Cullen keeps us informed on changes in European legislation regarding **spring waters** and **natural mineral waters** on page 12; Nick Gray gives useful information on **corrosion prevention** on page 13; and Geoff Wright asks the question "**how many wells are there in Ireland?**" on page 2.

Editor

How Many Wells Are There in Ireland?

A recent press release by the newly-founded Institute of Geologists of Ireland quoted Eugene Daly to the effect that there were roughly 200,000 wells in Ireland, and that at least a quarter of these could be contaminated. This provoked some discussion. Are there really so many wells in the country, and could the number of polluted wells be so high?

The truth is that we don't know. There are no provisions for notifying any authority of the existence of a well, nor for registering a new well. So any such figures must necessarily be rough estimates. But we can look at a few different approaches to estimating the figure.

1. The GSI's basic well database contains records of about 25,000 wells. The majority of these were notified to GSI through a Department of Agriculture grant scheme in the 1960s and 1970s. The last records submitted under this scheme arrived in about 1977.

Field surveys carried out by GSI in the 1970s invariably found that the number of wells in any given area far exceeded the numbers in our records for the same area. Some examples from southeast Cork:

6" Sheet (Cork)	Well Records	Field Survey
65	31	50 (part sheet)
66	21	163 (part sheet)
67	24	111
75	18	122
76	18	86
77	22	342
78	16	306
88	17	63
89	3	142
Total	170	1385

Thus the well records for this area in 1977 included only 12% of the total of wells in the area (and some field surveys did not include whole sheets). Data for Co. Kilkenny and Co. Kerry tell a similar, if less extreme, story. Thus even in 1977, the total number of wells in Ireland was several times the number of our well records, so conservatively was likely to be in the range of 75,000 - 100,000.

2. As far as we know (and again there are no official statistics) there are some 50 well drilling companies in the Republic. In 1975 it was estimated that some 5000 new wells were drilled each year. This approximate rate of well drilling has probably persisted, with some fluctuations, for the past 20 to 25 years, which implies that some 100,000 to 125,000 new wells have been drilled over that period. This would represent two wells per week, or 100 per year, drilled by each firm.

3. The above figures, while based on limited samples, extrapolations and estimates, do suggest that the total number of wells in the country at present is likely to be at least 200,000, and could be considerably more. Many of these wells may no longer be in use, but since there are no regulations concerning the abandonment of wells, if polluted they could be actively contributing to the contamination of aquifers by allowing a ready pathway for contaminants.

4. Finally, how many wells are contaminated? A recent EPA report (The Quality of Drinking Water in Ireland for 1997) said that some 36% of Group Scheme sources were polluted. We could hardly expect that the percentage of private wells contaminated would be much lower.

We would welcome further contributions to this discussion, particularly from drilling companies.

Geoff Wright, Geological Survey of Ireland.

Waste Licensing - Background and Requirements

Background

The Waste Management Act 1996 requires that all significant waste activities be subject to licensing by the Environmental Protection Agency (EPA). The licensing system applies to disposal activities (landfill sites, transfer stations, storage facilities and certain types of treatment) and recovery activities. The system has been introduced on a phased basis and the specified dates are dependent on the type and size of the activity.

The EPA cannot grant a licence unless it is satisfied, among other things, that the activity, when operated in accordance with the conditions set by the Agency, will not cause environmental pollution. In order for the EPA to determine whether to grant or refuse a licence specified information must be supplied by the applicant.

To assist applicants in complying with the Waste Licensing Regulations the Agency has produced Application Forms for Waste Disposal Activities (Landfill) and for Waste Recovery/Disposal Activities (other than Landfill) and associated Guidance Notes.

The following is a summary of the geological and hydrogeological information which is required to be submitted as part of a waste licence application. The level of detail required is dependent on the type of facility and is based on the overall risk to groundwater. Consequently more detail is required for a landfill for non hazardous biodegradable waste than for a transfer station for similar wastes. Guidance is also provided in the EPA's Landfill Manual - *Investigations for Landfills*.

General Requirements

Existing Environment

Section C of the Application Form relates to the Existing Environment. Geological and hydrogeological information to assist the Agency in assessing the current state of the environment at the location of the activity must be provided. The information requirements are similar for existing and proposed facilities.

Geological information required includes:

- regional bedrock and subsoil geology, including soil and subsoil properties, and sediments in the case of estuaries;
- an interpretative report outlining the bedrock and subsoil types (local) incorporating details of thickness of the various layers, including lateral and vertical variations, and a three dimensional description of the subsurface;
- geophysical investigations and interpretations of the data;
- features of recognised geological or geomorphological interest;
- all investigation data, including all trial pit, borehole logs and borehole construction details;
- details of mining or quarrying activities in the vicinity; and
- copies of all QA/QC plans for the investigation methods.

The above information should be presented in a form which provides an overall geological picture of the site and its surroundings. Using the data obtained a clear interpretation of the geological nature of the site and its hydrogeology should be provided.

Hydrogeological information required includes:

- aquifer category and characteristics;
- permeability and porosity (effective) of bedrock and subsoils;
- direction of hydraulic gradient and relative groundwater movement both horizontal and vertical;
- groundwater recharge and discharge areas;
- groundwater quality and hydrochemistry;
- groundwater abstraction points, private and public wells, springs etc. within 500m of the facility; and
- vulnerability of the groundwater to pollution determined from the type and thickness of the subsoil with reference to the DoELG/EPA/GSI (1999b) guidelines.

Calculation Sheets should be submitted on the standard forms (where provided) including:

- aquifer tests (pumping and recovery);
- variable head tests;
- packer tests;
- throughput;

- time of travel and
- permeability/hydraulic conductivity,

for the different hydrostratigraphic units.

An interpretative report should also be submitted including a conceptual model of the hydrogeological regime which is based on the regional geology and hydrogeology and supported by the findings of the site investigations and testing. The groundwater/surface water interaction which includes any tidal affects should also be addressed. The hydraulic connection between different hydrostratigraphic units should be discussed. An assessment of the overall risk to groundwater should be presented.

Drawings and other data required include:

- 1:500 or 1:1000 scale drawings showing the location of investigation points. This should include an area of at least 500m from the site boundary and should show the geological features, location of trial pits, boreholes and other aspects of the investigation;
- water table/piezometric surface (taking into account seasonal variations) including direction of groundwater flow;
- geophysical survey data;
- geological cross-sections (minimum of two at right angles) showing the water table /piezometric level, depth to bedrock and formation level;
- pathways, for groundwater movement (faults and permeable zones) and zones that restrict movement, must be identified and characterised;
- thickness of unfractured clay, fine silt or siltstone/shale layers should be clearly identified;
- drainage details;
- locations of public and private groundwater abstraction points and springs;
- identification of vulnerable receptors such as karst features; and
- wetland sites of recognised and potential ecological value.

The above drawings should be clearly labelled and have unique drawing numbers. All drawings should be submitted at an appropriate scale. The drawings should provide a clear picture of what is happening at the site.

Environmental Impacts and Mitigation Measures

Section H of the application form requires information on emissions, the environmental impacts of the development and proposed mitigation measures. For new developments, predictions need to made of the potential impacts and for existing activities data obtained from investigations and monitoring should be used to asses the emissions from the facility and their impacts.

This attachment should contain a description of any impact on the bedrock, subsoils and soils, and any proposed mitigation measures.

If there is a significant risk to the groundwater then mitigation measures should be outlined to prevent or limit any potentially polluting discharge. Any mitigating works proposed or implemented should be described and the effect of such remedial works should be illustrated.

In the case of landfill where groundwater is at risk the following information should be provided in order to allow an assessment of the risk to groundwater to be made:

- the groundwater protection zone (as outlined in DoELG/EPA/GSI, 1999a)
- the type of discharge, i.e. indirect or direct, supported by investigation data;
- estimates of the volume of leachate that may leak from the landfill;
- modelling of the movement of the leachate within the landfill/sub-strata;
- the potential impact of the leakage in terms of
  - (i) the time of travel of the groundwater itself to the nearest receptor;
  - (ii) the time of travel for the leachate to pass through the lining system to the groundwater;
  - (iii) the time of travel within the unsaturated zone (subsoil and bedrock) for leachate to reach the groundwater;
  - (iv) the dilution it will receive in the underlying subsoil and groundwater; and

(v) an interpretation of the groundwater quality and the impact of leachate migration on groundwater quality.

Details of impacts from other emission sources such as septic tanks, underground storage tanks, drainage systems etc. located in the facility should be considered and included in this section.

Environmental Monitoring

Current and future monitoring proposals should be submitted in Section J. The programme for environmental monitoring should include the following information:

- the parameters to be monitored;
- monitoring intervals;
- location and specification of monitoring points. Twelve digit national grid references should be provided ;
- collection, sampling and transportation procedures;
- analytical procedures;
- equipment used;
- names of persons responsible for monitoring;
- chain of custody procedures;
- monitoring arrangements (such as the use of subcontractors);
- reporting procedures for the subcontractor to the client, (if relevant); and
- reporting procedures for the applicant to the Environmental Protection Agency, including proposed arrangements in the case of breaches of trigger levels or emission limit values.

Applicants should note that **minimum monitoring requirements** and good practices for landfills are set out in the Agency's Landfill Monitoring Manual. When a waste licence is issued site specific monitoring requirements are set out in the licence.

Results of any environmental monitoring undertaken by the applicant during the processing of the application should be forwarded to the Agency during the assessment of the application. The forms provided in Annex 1 of the Application Form should be used to record monitoring results as far as is practicable. Monitoring points should be clearly identified on an appropriately titled and referenced drawing. All monitoring results should be accompanied by an interpretation of their significance

Graphical or tabular presentations for groundwater and leachate data should be provided to allow trends in groundwater quality and leachate quality to be detected.

A minimum of three sets of analysis results should be submitted to the Agency, particularly if the results indicate elevated parameter values. Monitoring should include analysis for List I and II substances in order to comply with the Groundwater Directive and article 40(4)(a)of the Waste Management Act.

Contingency Arrangements

Section K requires information on unexpected events.

Information required includes:

- measures to prevent and/or prevent unauthorised or unexpected emissions;
- fire water storage and fire fighting procedures;
- contingency arrangements in case of breakdown or emergency situations;
- contingency arrangements in case of contamination of air, surface water, groundwater or other environmental media; and
- emergency contact numbers for staff with responsibility for the activity.

The provisions made for response to emergency situations outside of normal working hours, [i.e. night, weekends and holiday periods] should be detailed.

Assessment of Waste Licensing to-date

The Agency have received 96 waste licence applications to date (March 1999) which break down into the following categories of activities;

- Landfill (64);
- Transfer stations (19);
- Hazardous Waste Transfer Stations (3);
- Hazardous Waste Treatment and Transfer Stations (3);
- Healthcare Risk Waste Treatment (5), and
- Dredgings (2).

Seven licences have been granted; six are at proposed decision phase, one application has been abandoned and one withdrawn, leaving 81 applications being processed.

During the assessment process a number of common problems have arisen with the hydrogeological information contained in some applications thus requiring notices to be issued for further information. In order to minimise this requirement the more significant problems to be addressed are listed below:

- borehole logs - inaccurate and not correlating to cross sections;
- lack of interpretation of borehole logs and their hydrogeological significance;
- drilling of boreholes through the waste and penetrating into the aquifer - creating a direct pathway for potential movement of leachate;
- lack of information on construction details of monitoring wells and conflicts with borehole logs;
- poor description of borehole data;
- insufficient groundwater monitoring and lack of List I and II analysis;
- no additional groundwater monitoring where elevated parameter values occur;
- poor description of the hydraulic connection between units and/or surface waters especially in tidal areas;
- statements made without supporting data; and
- Non technical summaries - written in technical jargon.

These difficulties may be overcome by applying, the practices and procedures outlined in the EPA Manual *Investigations for Landfill* , a QA/QC system (preferably a certified system) and by applying standards such as BS 5930 - Code of Practice for Site Investigations. The quality and extent of hydrogeological investigations needs to be specifically addressed by applicants. The setting up of the "Institute of Geology of Ireland" and the introduction of professional accreditation should improve standards further.

Reference Materials

BS 5930: 1981. Code of practice for site investigations. British Standards Institution, London, 147p.

DoELG/EPA/GSI, 1999 (a). Groundwater Protection Schemes. Department of Environment and Local Government, Environment Protection Agency and Geological Survey of Ireland. 24pp.

DoELG/EPA/GSI, 1999 (b). Groundwater Protection Responses for Landfills. Department of Environment and Local Government, Environment Protection Agency and Geological Survey of Ireland. 4pp.

EPA Landfill Manual *Investigations for Landfills*

EPA Landfill Manual *Landfill Monitoring*

EPA Landfill Manual *Landfill Operational Practices*

EPA Landfill Manual *Landfill Site Design (in press)*

EPA Waste Management Licensing - Guide to Implementation and Enforcement in Ireland.

IEI Waste Management Course - Module 2 'Licensing and Permitting'

Waste Management Act 1996 and 1998 amendment

Waste Management (Licensing) Regulations 1997 and 1998 amendment

Waste Disposal Activities (Landfill) Application Form and Guidance Note

Waste Disposal/Recovery Activities (other than Landfill) Application Form and Guidance Note

Margaret Keegan and Ted Nealon, Environment Protection Agency

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Summary of Project to Develop a Forest Soils Classification and Productivity Coverage

Background

Forestry is now the fastest growing land use enterprise in Ireland, with Government plans to increase the national area under forestry from the current 8 percent to 17 percent (this would constitute planting 700,000 hectares over the next 30 years). As a result of this, the afforestation programme is changing to farmer-based planting. Historically forestry was regarded as the land use of last resort, resulting in the planting of only the most marginal of soils. With the move to farmer planting, there has been more incentive to afforest better soil.

With this in mind the idea of assessing the area, extent and location of soils suitable for farm forestry is now being realised with the inception of the project to develop a Forest Soils Classification and Productivity ranking (FSCP). Based at the Teagasc Research Centre at Kinsealy, the aim of the FSCP is to derive a soil classification and to provide a forest productivity classification on this. This will involve developing a composite soil coverage for the counties which have not already been mapped and refining the classification in those counties which have. The soil classification will be based on soil depth, drainage (good vs. poor), chemical reaction (acid vs. base) and composition (mineral vs. organic). This will aid in the assessment and planning of the national planting programme.

The National Soil Survey (An Foras Talúntais, 1963–1993) programme only covered part or all of only 15 counties. This focused on the counties with the greatest extent of valuable and productive agricultural land. The counties which are now the centres of the current farm forestry drive have little or no soils data available. The FSCP will therefore initially focus on counties where National Soil Survey maps are not available. However, the classification is required for all 26 counties. This will offer the best scientific basis to plan for the nature, extent, location and character of new afforestation at local county, regional and national levels.

Methods

In the areas where 6" mapping of soils has been carried out, a 'Known Soils Coverage' will be digitised from the existing soils maps (Teagasc archives). These include the published National Soils Survey County Series (Carlow, Clare, Kildare, Laois, Limerick, Leitrim, North Tipperary, Meath, Wexford and Westmeath), the part published counties (West Cork, West Mayo and West Donegal) and, where possible, the unpublished counties (Offaly and Waterford). Other large scale soils maps of small areas surveyed for specific research purposes will also be incorporated.

To compliment this, for these and all other areas, the factors influencing soil formation will be identified and mapped countrywide and overlain in a GIS to arrive at an empirical and areally uniform soil classification. These factors will include parent material (outcropping rock or, more commonly, Quaternary sediments), slope, climatic data (rainfall, aspect and sunshine days) and drainage. The parent material will include data from the GSI where this is available. For the remaining areas, the relevant properties of the parent material will be mapped using digital photogrammetry and field verification. The GIS analysis will use a Digital Elevation Model (DEM) for the country and will subdivide large areas into recognisable topographic units (Topographic Unit Coverage, TUC) which will be combined with the parent material to give a soil landscape unit classification. Therefore, the soil landscape unit classification will highlight areas of similar topography and parent material which will give rise to a predictable sequence of soils. For example, a Lower Palaeozoic ridge landscape unit in north Meath will include three polygons of varying soils, as soil development comprises a ridgetop soil, a ridge flank soil and a valley bottom soil. This then forms the basic building block for further subdivision using climatic and drainage data. Precipitation levels and sunshine days (as well as aspect data derived from DEM analysis) are added as a layer in the GIS, along with drainage characteristics (derived from vegetation analysis using satellite imagery). These add further data to the TUC and help to further define the soils classification.

Each of the soils classifications derived from this method will be analysed statistically using information from Coillte's Forest Inventory and Planning System (FIPS) database. A productivity ranking will therefore be assigned to every polygon in the Forest Soils Classification thus allowing an assessment of total potential forest productivity at local, regional and national levels. As this project will initially only provide a general classification, a reliability index will accompany each polygon in both the soils classification and productivity rankings, indicating the quality of information.

The project is funded by the Forest Service and forms a vital part of the Forest Inventory and Planning System (FIPS). The results from this project will inform the major part of the Indicative Forest Strategy document which is now required by the Department of the Environment. The IFS will act as a decision support system for the Forest Service in guiding the location and character of new afforestation at county, regional or national level.

Robbie Meehan, Irish Forest Soils Project, Teagasc

Regional Assessment of Groundwater Recharge

1. Introduction

Groundwater recharge (GWR) is one of the hydrogeological parameters which is most important for the assessment of water resources, flooding potential, and groundwater vulnerability.

In general GWR determines the amount of water annually refilling an aquifer and is in balance with groundwater discharge.

Within Irish hydrogeological conditions a majority of aquifers are unconfined. For them GWR is mainly considered as a proportion of precipitation, which infiltrates through the ground surface and reaches the groundwater table, refilling aquifers. Being a proportion of precipitation, GWR may be measured in mm/a, or alternatively in $m^3/sec/km^2$ as the discharge unit. GWR values are determined by climatic conditions, relief, subsoil permeability, types of vegetation, and aquifer properties.

Data on GWR in Ireland are not widely available and those which are discussed in various sources differ significantly: 25-30 mm/a (1), 150-290 mm/a (2,3), 400-500 mm/a (4).

However, an attempt to apply some of these data to groundwater modelling in the Silvermines and Galmoy areas resulted in an unrealistic groundwater hydraulic surface. In particular this applied in the Galmoy case, where the aquifer transmissivity within the modelling field was efficiently assessed. For this reason some research was undertaken to evaluate GWR.

There are various methods allowing estimation of GWR with various degrees of accuracy (simulational modelling, calculations based on relevant equations, analysis of well or river hydrographs, lysimetric methods). The method of river hydrograph separation is believed to be efficient for regional GWR assessment.

The GWR calculation was based on an analysis of daily river discharge data for a few years, depending on data availability. The method provides regionally averaged GWR values within the considered river catchment areas.

River discharge data were provided by EPA and OPW. Results of the GWR calculation together with other elements of the water balance within the considered regions are shown in Table 1.

2. Discussion

For 15 river catchment areas GWR varies within a range from 31 to 169 mm/a with an average of 94 mm/a. The long-term average precipitation is 900-1300 mm/a, while estimated losses (long-term average evapotranspiration) are 455 - 490 mm/a

(5). On average GWR and surface runoff (RO) represent respectively 9% (3-19%) and 45% (38-53%) of total precipitation. The result of GWR calculation in some cases was confirmed by groundwater modelling.

The studied rivers are located in various geomorphologic zones, including a plateau (Feale); slightly rolling lowland mainly below 100 mOD (Deel and Maigue); and mountains, with elevation in some areas more than 300 mOD (Mulkear, Anner and Kilmastulla).

Geomorphologic features generally reflect geological structures within the catchments. The plateau is formed by Namurian rocks. Silurian and Devonian formations occur in the mountains, while the lowlands are mainly formed by Carboniferous limestones.

In order to assess the influence of relief on GWR, the Feale catchment area was examined. There are 5 gauging stations within this catchment: four of them monitor the discharge of R. Feale tributaries, which catchments have generally higher surface elevations than the main river valley downstream. This allows differentiation of GWR within the river catchment and assessment of GWR in the river valley zone itself, using a weighted average of GWR in the area:

$$GWR_{valley} = (GWR_{Feale} \times A_{Feale} - GWR_1 \times A_1 - \ldots\ldots - GWR_4 \times A_4) / (A_{Feale} - A_1 - \ldots\ldots - A_4)$$

where GWR_i is average groundwater recharge within a relevant catchment of area A_i. The resulting GWR_{valley} = 219mm/a, at least twice as high as the average GWR within the whole Feale catchment area. (Fig.1). Such information may become important for GW modeling. If a small scale model is related to an object within a river valley, then the greater GWR value should be applied. Groundwater modeling within a whole river catchment should be based on the average GWR within such an area.

RO varies within the range 321 - 629mm/a with greater values for uplands (>500mm/a). To assess the effect of surface elevation and its gradient on RO, the relationship between RO and an elevation coefficient A (percentage of a catchment area higher than 500 feet (~170m OD)) was considered (Fig.2). The boundary value of 500 feet identifies significantly steeper surface slopes within higher areas (Fig.3). For the main river catchment there is a strong correlation between RO and A (R^2=0.99), and their relationship is described by a logarithmic function.

The function RO = F(A) may apply to the approximate GWR estimation as GWR=AR-RO=AR-f(A), where AR stands for active rainfall. This may be demonstrated in the example of the Glyde (Co. Louth) catchment. Using the method of river hydrograph separation GWR for this area was estimated as 72mm/a.

On the other hand, the Glyde catchment has an elevation coefficient of 19. From Fig.2, RO in the area is about 400-410 mm/a. If precipitation and estimated losses are 942 and 460mm/a respectively (5), then GWR is 70-80 mm/a.

However, there are some exceptions from the described relationship: (1) catchment areas of highland rivers (A>85%); (2) catchments where highly permeable rocks are close to the surface (such as a karstic aquifer within the Anner catchment).

3. Main conclusions

1. Within the considered climatic, geomorphologic and geological conditions GWR may vary within the range 30-170mm/a. Such environments are typical for many areas of Ireland.

2. Average values of GWR vary between river catchments, and are influenced by precipitation and surface elevation. GWR may significantly vary within a single river catchment. This factor should be considered during hydrogeological investigations.

3. The correlation between RO and the elevation coefficient (A) may be used for an approximate estimation of GWR, except for areas where highly permeable strata become exposed or occur close to the surface, increasing the portion of GWR within the water balance. The latter strongly corresponds with zones of highly vulnerable aquifers, delineated within Ground Water Protection Schemes developed by GSI. Other exceptions may include highlands.

4. Acknowledgement

I express my sincere appreciation to Mr. Micheal MacCarthaigh for providing data and personal communications.

5. References

1. Wright, G.R. (ed.) 1982. Groundwater Resources of the Republic of Ireland. Commission of the European Communities.
2. Ground water resources in the NE (RDO) Region, 1981. Main Report. An Foras Forbartha & GSI.
3. Environmental Impact Statement. Galmoy Mine Project. 1995.
4. Daly, E.P. (1995) The principal characteristics of the flow regime in Irish aquifers. *In* The role of ground water in sustainable development. Proceedings of IAH Seminar, Portlaoise, p.1-8.
5. Ireland: River Quality 1991-94. EPA, 1996.

Table 1 Groundwater recharge and other parameters used in discussion.

Station No.	River	Geology/ Landform mainly	Rainfall	Evapotranspiration		Groundwater recharge			Surface runoff		A
			mm/a	mm/a	%	mm/a	Av/STDEV	%	mm/a	%	%
23002	***Feale***	Namurian	***1100***	***490***	***44.5***	***102***		***9***	***508***	***46***	71
23017	Smearlag	plateau	1190	490	41.2	93		8	607	51	
23006	Feale		1163	489	42.0	89		8	585	50	
23007	Oolagh		1179	489	41.5	92		8	598	51	
23005	Allaghaun		1179	489	41.5	61		5	629	53	
24001	***Maigue***	Carb. Lst	***900***	***489***	***54.3***	***90***		***10***	***321***	***36***	6
24022	Mahore	Low hills <100m	927	489	52.8	31		3	407	44	
24011	***Deel***	Carbon. Lst	***950***	***489***	***51.5***	***59***		***6***	***402***	***42***	15
24030	Deel	Low hills <100m	1060	489	46.1	65		6	506	48	
25001	***Mulkear***	Carb, Dev, Sil	***1109***	***464***	***41.8***	***169***		***15***	***476***	***43***	44
25005	Dead	Mountain	1033	469	45.4	152		15	412	40	
25044	***Kilmastul***	Carb, Dev, Sil Mountain	***1157***	***467***	***40.4***	***150***		***13***	***445***	***38***	25
	Anner	Carb, Dev Mountain	***984***	***455***	***46.2***	***155***		***16***	***374***	***38***	27

Olga Aslibekian, University of Limerick

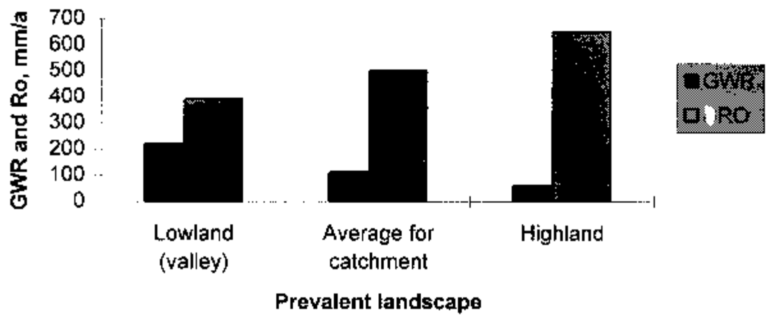

Fig.1. Relationship between surface elevation and the water balance elements within R. Feale catchment

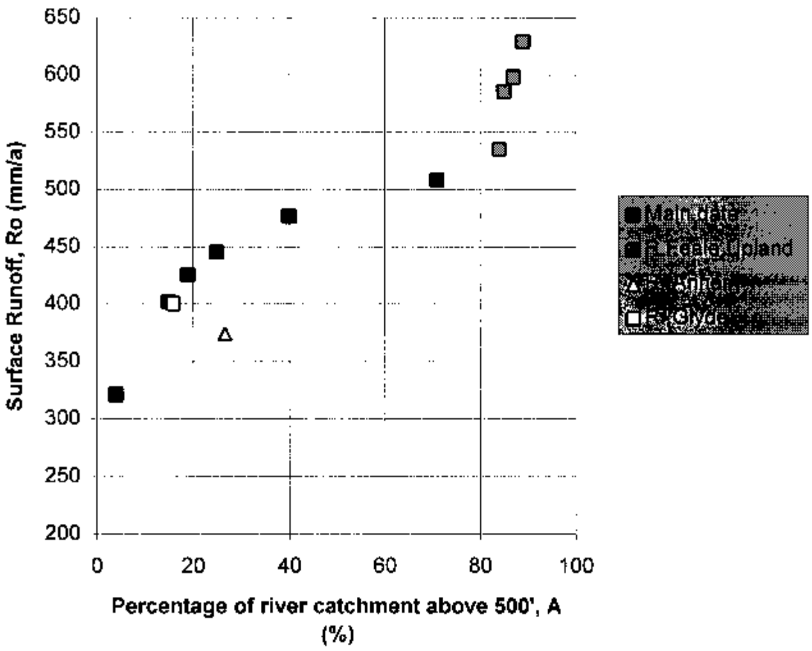

Fig. 2. Relationship between Ro and the parameter of land elevation (A).

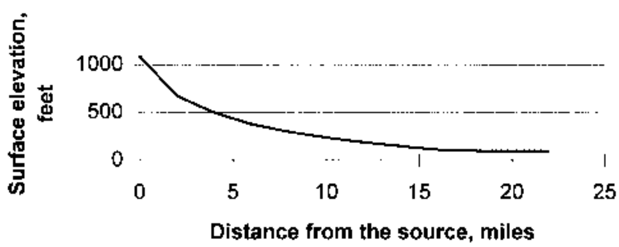

Fig. 3. Profile of R. Feale

Spring Waters Are Brought Partly Into The Net

Legislation

Recent changes in European legislation will partly regularise the position regarding the exploitation and marketing of natural mineral waters and spring waters. The old legislation imposed stringent environmental constraints on the location and quality of groundwaters that could be exploited and marketed as Natural Mineral Waters. These restrictions did not apply to those sources marketed as Spring Waters which were governed by standards applying to any bottled water product. The new regulations extend the microbiological quality standards applying to Natural Mineral Water sources to those sources marketed as Spring Waters with some additional changes to the level of treatment that can be carried out prior to bottling of both products. The new regulations are an improvement on the situation existing since 1980 and retain the natural purity of the groundwater sources as the basis for the consumers' confidence in the quality of European bottled waters.

The 1980 Directive 80/777/EEC together with Irish enacting Regulations SI No. 11 of 1986 provide the basis for the exploitation and marketing of natural mineral waters in the Republic of Ireland. Annex I of the Directive defines Natural Mineral Water as "microbiological wholesome water", "originating in an underground water table or deposit and emerging from a spring tapped at one or more natural or bore exits". The 1980 Directive required each Member State to verify the quality and catchment of sources exploited as Natural Mineral Waters and laid down strict microbiological standards that every source had to comply with in it's natural or un-treated state. The European and Irish regulations outlawed any treatment of the water that might effect its natural microbiological quality but did allow the addition of carbon dioxide to provide the carbonated natural mineral waters now known as the "Sparkling" category.

The 1986 Regulations identified the IIRS as the responsible authority in the Irish Republic for Natural Mineral Waters. This responsibility is now carried out by the National Standards Authority of Ireland (NSAI) and four sources now have the prestigious certification as Natural Mineral Water Sources and they are; Kerry Spring Water, Tipperary, Ballygowan and Glenpatrick Spring Water.

Marketing

The marketing of bottled water under the term Spring Water was not covered by the quality requirements set out in 80/777/EEC. This omission allowed a range of groundwater sources, i.e. wells or springs, to be exploited and marketed as Spring Water where the bottled product met basic quality requirements. The voluntary standard produced by the NSAI in 1992 and referenced as IS 432:1992 partly addressed this situation locally by setting a general specification for bottled waters originating in the Irish Republic.

The exclusion of Spring Waters from the European legislation covering bottled waters sold as Natural Mineral Waters was a difficulty for some Member States and was seen to provide economic benefits to Spring Waters – especially in reduced monitoring and analytical costs. This put some sources at an economic disadvantage as the added costs of Natural Mineral Water certification were not readily recouped by higher sales as the public paid little notice to the high quality guaranteed by Natural Mineral Water status.

The large amount of advertising directed at trying to educate the consumer in this matter is a reflection of the need to promote the concept that Natural Mineral Waters were of a higher quality than Spring Waters. While succeeding to some degree, the fact that some bottled waters are still sold as Spring Waters despite having Natural Mineral Water status is an indication of the lack of consumer appreciation of the quality assurance afforded by the Natural Mineral Water certificate.

Kevin Cullen, K.T. Cullen & Co.

Corrosion Prevention

I read Colette Cronin's article on corrosion (No 34, December 1998) with much interest. While groundwater for supply purposes must consistently yield a quantity of water sufficient to satisfy the requirements of the user; the physico-chemical quality of the water is often a *fait accompli,* with the microbial quality most often seen as the limiting factor for use. The corrosivity of the water is rarely taken into account by the architect, builder or plumber, with problems only emerging several years after completion of the building. So this raises the issue of the role of the hydrologist in corrosion control.

There are many areas in Ireland where the groundwaters are aggressive with little chance of finding an alternative non-corrosive water supply. Which means that in practice corrosion control requires either a water treatment and or plumbing solution. As Colette points out, the integrity of the well and pump is vitally important if water quality is to be maintained. Also analysis is also needed to identify corrosivity. At this stage the hydrologist should make it clear to the owner if there is a potential risk of corrosion and recommend that appropriate treatment and pluming options are selected.

Treatment

Treatment is only a practical option for group schemes or large individual systems (e.g. hotels). Corrosion control is mainly achieved by raising the pH of the water by: (i) dosing with sodium hydroxide, calcium hydroxide or sodium carbonate; (ii) passing the water through a bed of alkaline material; or (iii) removing excess carbon dioxide by aeration. Acid neutralization will invariably require coagulation and or filtration to remove particulate iron and manganese. Aeration is a very important treatment step for anoxic and anaerobic groundwaters, not only for raising the pH, but also for iron precipitation, and radon removal. Manganese is more difficult to remove as it requires a pH of between 8.5 and 9.0, with aeration playing a minor role. All these operations require professional support as significant quality problems can arise if systems are not operated correctly.

For individual dwellings there are no suitable *point of use* treatment systems readily available. So in practice corrosion control is usually achieved by correct plumbing. There are however a number of *point of entry* systems that treat the entire flow into the house. Acid water neutralizers reduce corrosivity of water by passing it through a special media pack which raises the pH. The water supply flows upwards through the unit and does not require any electricity, back washing or drainage. Other systems add soda ash or lime to the water. Iron removal systems can also increase the pH of the water which is aerated to bring the iron from its soluble ferrous state into the insoluble ferric state, which is then filtered out. Alternatively where the water is anaerobic it should all be pumped into the attic storage tank. The water should fall as far as possible into the tank, which must be vented, to ensure adequate reaeration. This can be enhanced by the use of a splash plate or fish tail nozzle on the inlet pipe. Sediment will be formed which will require periodic cleaning. The use of a second storage tank in series will act as a sediment trap. As all the water will be now supplied from the main attic storage tank the drinking water supply to the kitchen will require a 1μm pore cartridge filter attached and also a UV sterilizer (DWI, 1993). This will not affect the natural taste of the water and is needed solely to remove any residual iron solids and to ensure that there is no possibility of viable heterotrophic bacteria, which readily develop on the surface of the storage tanks, being ingested. Attic storage tanks are particularly vulnerable to bacterial and viral contamination from vermin and birds. Some household appliances have pressure operated values, so ensure there is still sufficient hydraulic head for their operation. Most laundry detergents contain anti-corrosion and neutralizing additives, so washing machines can be connected directly to the pressure tank, this is not the case with dishwashers which may suffer corrosion if the water is aggressive.

Water should be considered as a food and as such great care should be taken to ensure its safety to the consumer. So advice should be sought from the Public Health Officer especially if using home made treatment systems. While private supplies currently fall outside the legislation, supplying such water to a third party does not.

Plumbing

Corrosion can be significantly controlled by good plumbing practice. In the UK, Water Bylaws are used to ensure that correct materials and practices are followed, with all plumbing work inspected. For example it is illegal in the UK to install a new water storage tank without a cover, and all British Standard approved tanks are sold with covers. Yet in Ireland the very same tanks are sold but the lids are generally not available.

From my own experience the important factors in plumbing are: (i) the quality of copper pipes, cylinders and metal fittings used; (ii) the handling and installation of metal pipes, (iii) the use of sacrificial anodes, and finally (iv) good work practice (i.e. not coupling dissimilar metals).

Corrosion can result in a number of metals or alloys, from which pipework or plumbing fittings are made, contaminating drinking water. The most important of these are lead, copper, zinc and iron. Most types of corrosion involves electro-chemistry. So for corrosion to occur the components of an electrochemical cell need to be present, i.e. an anode, a cathode, a connection between the anode and cathode (external circuit) and finally a conducting solution (internal circuit), in this case the water. The anode and cathode are sites on the metal pipework (it may be the same metal or different metals), that have a difference in potential between them. When this occurs then oxidation (the removal of electrons) occurs at the cathode which is negatively charged and dissolution occurs at the anode releasing metal into solution.

The formation of corrosion cells on the same piece of metal occurs where adjacent anodes and cathodes are formed. This is due to non-uniformity of the surface and can be caused by minute differences in the pipe surface caused during manufacture, or by stress imposed by its installation, especially bending pipes. Any imperfections in the pipe will create tiny areas of metal with different potentials. Copper pipes are available in a variety of thicknesses and qualities each with difference resistance to corrosion. Only the highest grade of pipes and cylinders should be used where the water is potentially cuprosolvent.

Corrosion is much more rapid where two different metals are coupled together. The most serious situation is where a copper pipe is used to replace a section of lead pipe, often the supply pipe. The conducting solution (electrolyte) is the water, the copper pipe is the cathode, and the lead pipe the anode. So the lead pipe slowly corrodes releasing the metal into solution. The metals and alloys most commonly used in water supply can be placed in their electrochemical order, which is in the decreasing order in which they tend to corrode when connected under ordinary environmental conditions. These are manganese, zinc, aluminium, steel or iron, lead, tin, brass, copper and bronze. The further apart the two metals are on this scale, then the greater the potential difference between them and so the greater the rate of corrosion will be. So iron pipes will corrode if connected by brass fittings, and of course lead pipes will corrode if connected to copper fittings. So in household plumbing it is best to use all the same metal, e.g. copper pipes and copper fittings, or metals very close on the electrochemical scale e.g. copper pipes and brass or bronze fittings. Metals can only be safely mixed if the sequence of metals is kept as follows: downstream order of use, galvanized steel, uncoated iron, lead, and copper. Plastic pipes can be used in conjunction with any materials quite safely, and if corrosion is suspected then the new flexible plastic piping should be used where ever possible.

The corrosion of galvanized steel is slightly different. The zinc layer is there to protect the steel underneath by corroding preferentially, ensuring that any exposed steel becomes the cathode rather than the anode. As the zinc corrodes it forms zinc hydroxycarbonate which then forms a protective layer on the steel. However, in soft waters where the alkalinity is low (<50 mgL-1 as CaCO3), or in water with a high carbon dioxide concentration, the corrosion product tends to be zinc carbonate. This does not adhere to the metal surface and so is lost in the water, giving the appearance of sand in the water. It is advisable not to use galvanized tanks or pipework for such aggressive waters. Corrosion of galvanized steel is increased significantly if coupled with copper tubing, especially if used upstream of the galvanized tank and the water is cuprosolvent. Even a small amount of copper can significantly increase the rate of corrosion. So for domestic purposes, stay clear of galvanized steel.

The rate of corrosion is rapidly increased at higher temperatures and more acidic pH. Corrosion of metals is therefore more pronounced in softer water and in the hot water circuit. The hot water cylinder is usually made from copper which is a particular target for corrosion. Differences in dissolved oxygen or hydrogen ion concentration (pH) can also set up a difference in potential within a pipe. This occurs most often under rivets, washers or in crevices where the dissolved oxygen may be lower. The area of the metal in contact with the higher dissolved oxygen concentration will become the cathode and the area with the lower dissolved oxygen concentration becomes the anode and so corrodes. The same occurs with differences in hydrogen ion concentration.

Corrosion can be controlled by choosing the correct metal and alloys, or by using special corrosion resistant ones. Surfaces can be coated or lined with special protective films. Lining is more commonly carried out in water mains to protect iron pipes, but is also possible in smaller pipes. Corrosion can also be prevented by connecting pipework to another piece of metal which will act as an anode and so will be deliberately corroded instead of existing pipework. This is known as cathode protection and the metal insert a sacrificial anode, should be installed in metal storage tanks to protect them from aggressive water, and also in the hot water cylinder which is particularly at risk. Sacrificial anodes are generally made out of magnesium alloy fitted onto a steel rod for use with galvanized steel tanks, while copper cylinders are protected by using aluminium rods. Although there are many other ways of protecting metal pipework from electro-chemical corrosion, selection of the correct materials and fitting a sacrificial anode is all that is normally required.

Conclusion

So the role of the hydrologist is to identify and alert owners to corrosivity problems. To protect borehole and pumping equipment and to recommend the type of action that could be taken to prevent plumbo- and cuprosolvency occurring within the household plumbing system. Obviously water treatment installation and plumbing must be done by qualified persons. But if the UK Model Water Bylaws are carefully followed then corrosion will be minimal (White and Mays, 1989). A test method to assess the potential of metallic products to contaminate water supplies has been published by the British Standards Institution (BSI, 1992).

References

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"Groundwater Protection Schemes" Launched

On 4th May, three publications:

- ***Groundwater Protection Schemes;***
- ***Groundwater Protection Responses for Landfills;*** and
- ***Groundwater Protection Responses to the Landspreading of Organic Wastes***;

which were prepared jointly by DELG, EPA and GSI, were launched by Mr. Joe Jacob T.D., Minister of State at the Department of Public Enterprise.

Copies of these publications (total price £5) can be purchased from: the GSI public office, the EPA and Government Publications office.

Extract for Minister's Speech Given at Launch

Many of us would associate well and spring water with a cool, pure, sparkling, wholesome liquid. In many instances this is still an accurate perception. However, increasingly pollution of groundwater sources is becoming a matter of concern. The recently published report by the Environmental Protection Agency on the quality of drinking water shows an increase in bacterial contamination. Also, there is a worrying trend of rising nitrate levels in some areas. So, I would like to talk to you here today about the Government's concerns about groundwater, and in particular about the publications that are being launched here today.

Groundwater is an important source of water in Ireland. While it might not be important in my home county of Wicklow, it supplies 20-25% of Ireland's drinking water overall, and a much higher proportion in some counties, such as Roscommon, Offaly and many of the other midland counties. Private wells are used by thousands of people, and it is the source of water for many industries, including our well known bottled water industry. Springs are not only a source of water, but are part of our rural mythology and tradition. So, it is vital that we prevent groundwater pollution, particularly as groundwater 'is out of sight, out of mind' for many people.

The launch of these publications today is another important step in a continuing series of measures being taken at national level to protect and improve our groundwater resources. For example, the Department of Agriculture and Food operates the REPS scheme, which imposes conditions in relation *to the prevention of water pollution. Guidelines issued by the Department of the Environment and Local Government last August will assist local authorities in relation to nutrient management planning. A new system of licensing by the EPA was established in February to regulate discharges to groundwater by sanitary authorities. And the powers of local authorities to make by-laws to regulate agricultural activities were extended and strengthened by Regulations made in April.*

Several river catchment projects, led by local authorities, are underway to establish water quality monitoring and management throughout the country. These projects provide an excellent means to engage the support of all relevant players in the implementation of water-quality strategies. The monitoring and management systems to be established by these projects will be of immense value for the implementation in due course of the proposed EU Framework Directive on Water Policy. This requires the co-ordination of measures in relation to surface water and groundwater. In many rivers, for example, more than 60% of the annual flow is derived from groundwater. In low-flow periods in Summer, more than 90% can be groundwater. Groundwater protection schemes are doubly beneficial in these cases because they protect not only the groundwater but also the surface waters which are fed by them.

The objectives of the Protection Scheme that I am launching today is to set out a methodology for the protection of groundwater and the prevention of pollution through the use of land surface zoning and groundwater protection responses for potentially polluting activities.

The Scheme aims to maintain the quality of groundwater by applying risk assessment to groundwater protection and sustainable development. This is in keeping with the spirit of existing legislation and the proposed EU Framework Directive on Water Policy.

One of the components of a protection scheme is a land surface zoning map, which is based on the geological and groundwater conditions in any area or county. These zones indicate the degree of risk or threat to groundwater from human activities, and therefore provide a powerful tool for environmental protection.

The second component is groundwater protection responses for the various zones. These indicate the acceptability of a particular activity in each zone and the planning or licensing conditions that are required to prevent pollution. The groundwater protection responses to the "Landspreading of Organic Wastes" and "the Siting of Landfills" are being published today. Further responses for other activities will be published in the future. The availability and use of a protection scheme by a planning or licensing authority has many benefits:

- *The Scheme provides the authorities with guidelines in carrying out their functions;*
- *It provides a framework to assist decision making which will protect groundwater.*
- *Good decisions require accessible, reliable information on groundwater. These Schemes provide this information and help ensure that groundwater is no longer 'out of sight, out of mind'.*

CONTRIBUTIONS FOR THE NEXT ISSUE OF THE NEWSLETTER

The GSI Groundwater Newsletter aims to improve communication among scientists and engineers involved in groundwater. It includes news, developments, reviews and opinions on all aspects of groundwater - exploration, development, management, water quality, pollution and energy. It is published 2-3 times each year.

Your contribution to the dialogue would be welcome. **Contributions for the next issue should arrive before 1st October 1999** to:

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GSI Groundwater Newsletter,
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